General Introduction: •

INTRODUCTION Medical parasitology deals with the parasites, which cause human infections and the diseases they produce.

• It is broadly divided into two parts: 1. Protozoology 2. Helminthology.

• The pioneer Du tch microscopist, Antonie 11an Leeuwenhoek of Holland in 1681, first introduced single lens microscope and observed Giardia in his own stools.

• Louis Pastuer in 1870, first published scientific study on a protozoa(disease leading to its control and prevention during investigation of an epidemic silk worm disease in South Europe.

• A seminal discovery was made in 1878 by Patrick Manson about the role of mosquitoes in filariasis. This was the first evidence of vector transmission.

• Afterwards, Laveran in Algeria discovered the malarial parasite (1880), and Ronald Ross in Secunderabad and Calcuna in India, showed its transmission by mosquitoes (1897). A large nwnber of vector-borne disease have since then been identified.

• By mid 20th century, with dramatic advances in antibiotics and chemotherapy, insecticides and antiparasitic drugs, and improved lifestyles, all infectious diseases seemed amenable to control.

• PARASITES Parasites are living organisms, which depend on a living host for their nourishment and survival. They mulriply or undergo development in the host.

• The term "parasite" is usually applied to Protozoa (unicellular organisms) and Helminths (multicellular organisms) (Flow chart 1).

• Parasites can also be classified as: - Ectoparasite: Ectoparasites inhabit only the body surface of the host without penetrating the tissue. Lice, ticks and mites are examples of ectoparasites. lhe Parasitology term infestation is often employed for parasitization with ectoparasites. - Endoparasite: A parasite, which lives within the body of the host and is said to cause an infection is called an endoparasite. Most of the protozoan and helminthic parasites causing human disease are endoparasites. - Free-living parasite: It refe rs to nonparasitic stages of active existence, which live independent of the host, e.g. cystic stage of Naegleriafowleri. Endoparasites can further be classified as: Obligate parasite: The parasite, wh ich cannot exist without a host, e.g. Toxoplasma gondii and Plasmodium. - Facultative para.site: Organism which may either live as parasitic form or as fre e-living form, e.g. Naegleriafowleri. - Accidental parasites: Parasites, which infect an unusual host are known as accidental parasites. Echinococcus granulosus infects man accidentally, giving rise to hydatid cysts. - Aberrant parasites: Parasites, which infect a host where they cannot develop further are known as aberrant or

wandering parasites, e.g. Toxocara canis (dog roundworm) infecting lhwnans.

- HOST :Host is defined as an organism, which harbors the parasite and provides nourishment and shelter to latter and is relatively larger than the parasite.

- The host may be of the following types:

 - Definitive host: The host, in which the adult parasite lives and undergoes sexual reproduction is called the definitive host, e.g. mosquito acts as definitive host in malaria. The definitive host may be a human or any other living being. However, in majority of human parasitic infections, man is the definitive host (e.g. fil aria, roundworm, hookworm).

Intermediate host: The host, in which the larval stage of the parasite lives or asexual multiplication takes place is called the intermediate host. In some parasites, two different intermediate hosts may be required to complete different larval stages. These are known as first and second intermediate hosts, respectively (Box 1). –

Paratenic host : A host, in which larval stage of the parasite rema ins viable without furth er development is referred as a paratenic host. Such host transmits the infection to another host, e.g. fish for plerocercoid larva of D. lalum.

Reservoir host: In an endemic area, a parasitic infection is continuously kept up by the presence of a host, which harbors the parasite and acts as an important source of infection to other susceptible hosts, e.g. dog is the reservoir host of hydatid disease.

- Accidental host: The host, in which the parasite is not usually found, e.g. man is an accidental host for cystic echinococcosis.

SOURCES OF INFECTION

Contaminated soil and water: Soil polluted with embryonated eggs (roundworm, whipworm) may be ingested or infected larvae in soil, may penetrate exposed skin (hookworm).

Infeclive forms of parasites present in water may be ingested (cyst of ameba and Giardia). Water containing the intermediate host may be swallowed (cyclops containing guinea worm larva).

Infected larvae in water may enter by penetrating exposed skin (cercariae of schisotosomes). - Free-living parasites in water may directly enter through vulnerable sites (Naegleria may enter through nasopharynx). Food: Ingestion of contami nated food or vegetables conraining infeclive stage of parasite (amebic cysts, Toxoplasma oocysts, Echinococcus eggs).

Ingestion of raw or undercooked meat harboring infeclive larvae (measly pork containing cysticercus cellulosae, the larval stage of Taenia solium).

Giardia Lamblia

- History and Distribution It is one of the earliest protozoan parasites to have been recorded.

• The flagellate was first observed by Dutch scientist Antonie van Leeuwenhoek (1681) in his own stools. • It is named Giardia after Professor Giard of Paris and lamblia after Professor Lambie of Prague, who gave a detailed description of the parasite.

• It is the most common protozoan pathogen and is worldwide in distribution. Endemicity is very high in areas with low sanitation, especially tropics and subtropics. Visitors to such places frequently develop traveler's diarrhea caused by giardiasis through contaminated water.

Habitat G. lamblia lives in the duodenum and upper jejunum and is the only protozoan parasite found in the lumen of the human small intestine .

Morphology It exists in two forms: 1. Trophozoite (or vegetative form) 2. Cyst (or cystic form)

Trophozoite The trophozoite is in the shape of a tennis racket (heartshaped or pyriform-shaped) and is rounded anteriorly and pointed posteriorly . It measures 15 pm x 9 m wide and 4 thick . Dorsally, it is convex; and ventrally, it has a concave sucking disk, which helps in its attachmem to the intestinal mucosa. It is bilaterally symmetrical and possesses: - One pair of nuclei - Four pairs of flagella Blepharoplast, from which the flagella arise (four pairs) - One pair of axostyles, running along the mid line - Two sausage-shaped parabasal or median bodies, lying transversely posterior to the sucking disk. 'The trophozoite is motile, with a slow oscillation about its long ax.is, often resemblingfalling leaf Ventral aspect 0~ Lateral 5 aspect 0 Fig. 1: Giardia lamblia in duodenal fluid wet preparation. Magnification 1500X Sucking—

- disc Basal bodies of flagella Nucleus Para basal body m Flagella (4 pairs) Sucking disc Nucleus Flagella (4 pairs) m Intestinal, Oral and Genital Flagellates Cyst It is the infective form of the parasite (Fig. 2C).

- The cyst is small and oval, measuring 12 mcgx 8 mcgand is surrounded by a hyaline cyst wall.

- Its internal structure includes two pairs of nuclei grouped at one end. A young cyst contains one pair of nuclei.

- The axostyle lies diagona lly, forming a dividing line within cyst wall. Remnants of the flagella and the sucking disc may be seen in

the young cyst. Life Cycle Giardia passes its life cycle in one host. Infective Form Mature cyst. Mode of Transmission

- Man acquires infection by ingestion of cysts in contaminated water and food.

- Ingestion of as far as 10 cysts is sufficient to cause infection in a man. Children are commonly affected.

- Direct person-to-person transmission may also occur in children, male homosexuals and mentally ill persons. Enhanced susceptibility to giardiasis is associated with blood group A, achlorhydria, use of Cannabis, chronic pancreatitis, malnutrition, and immune defects such as 19A deficiency and hypogammaglobulinemia.

- Within half an hour of ingestion, the cyst hatches out into two trophozoites, which multiply successively by binary fission and colonize in the duodenum (Fig. 3).

- The trophozoites live in the duodenum and upper part of jejunum, feeding by pinocytosis.

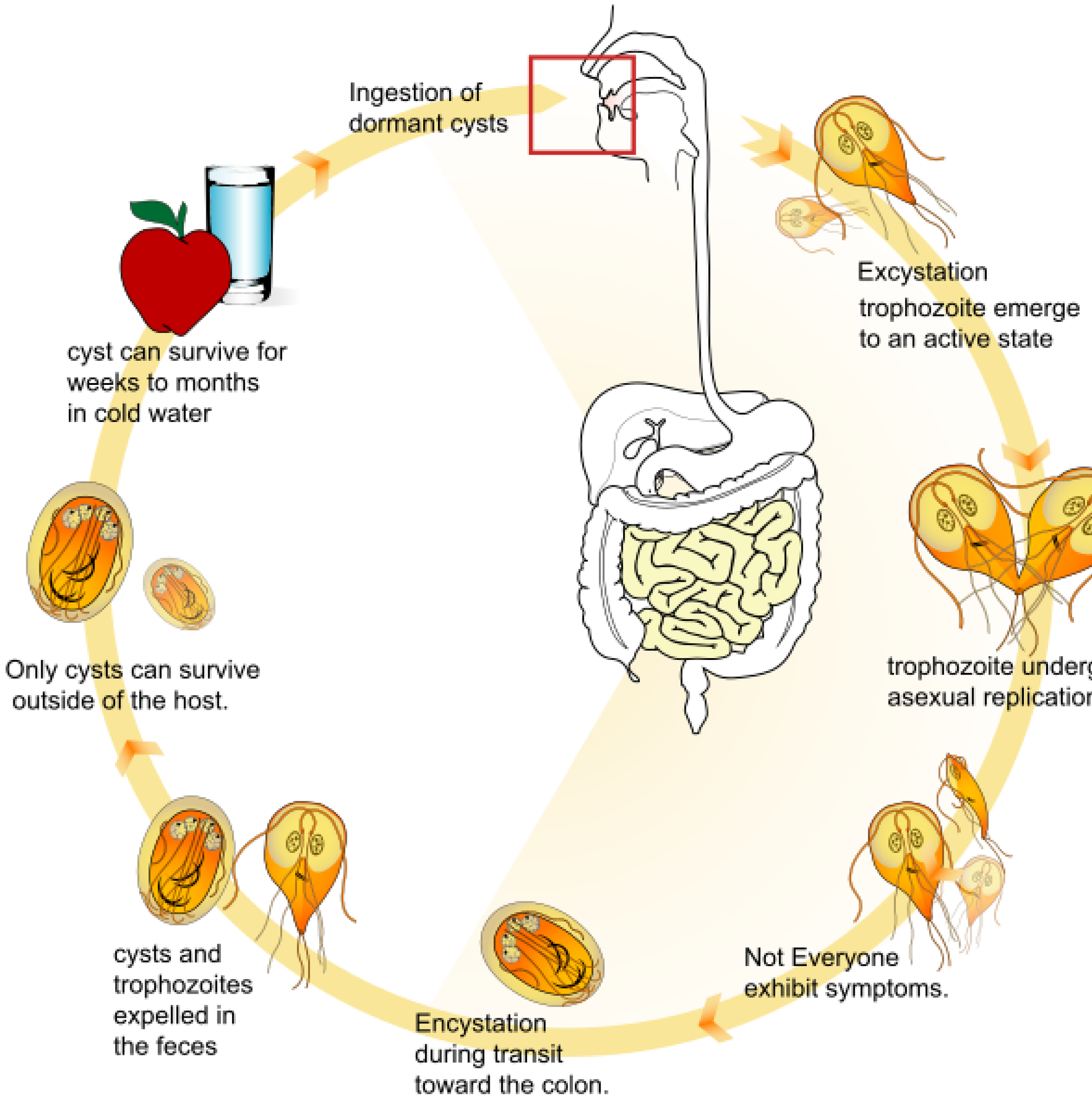


Fig: Life cycle of Giardia Lamblia

Entamoeba histolytica

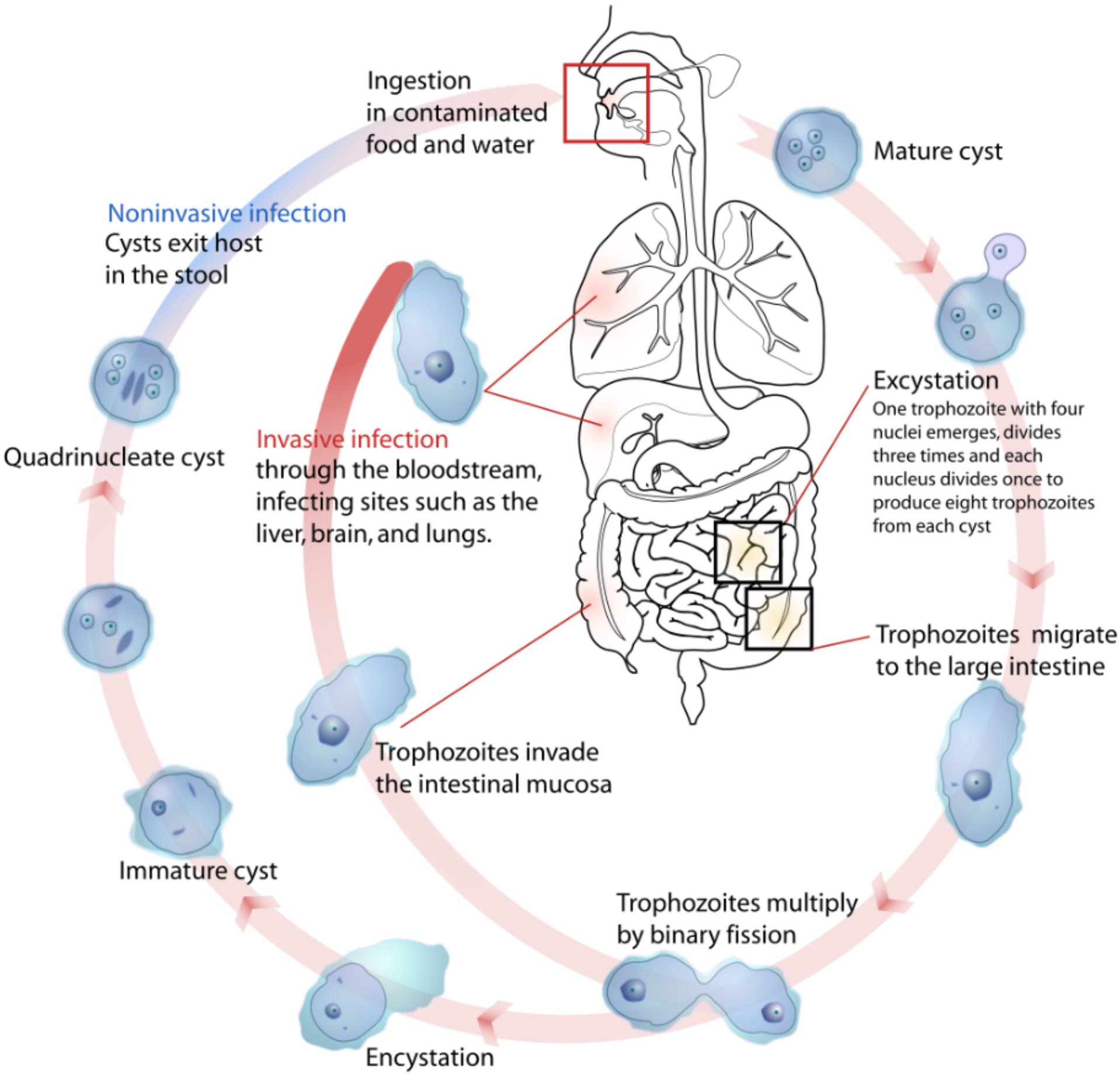
Entamoeba histolytica is an anaerobic parasitic amoebozoan, part of the genus *Entamoeba*.[1] Predominantly infecting humans and other primates causing amoebiasis, *E. histolytica* is estimated to infect about 35-50 million people worldwide.[1] *E. histolytica* infection is estimated to kill more than 55,000 people each year.[2] Previously, it was thought that 10% of the world population was infected, but these figures predate the recognition that at least 90% of these infections were due to a second species, *E. dispar*.[3] Mammals such as dogs and cats can become infected transiently, but are not thought to contribute significantly to transmission.

Transmission

The active (trophozoite) stage exists only in the host and in fresh loose feces; cysts survive outside the host in water, in soils, and on foods, especially under moist conditions on the latter. The infection can occur when a person puts anything into their mouth that has touched the feces of a person who is infected with *E. histolytica*, swallows something, such as water or food, that is contaminated with *E. histolytica*, or swallows *E. histolytica* cysts (eggs) picked up from contaminated surfaces or fingers.[4] The cysts are readily killed by heat and by freezing temperatures; they survive for only a few months outside of the host.[5] When cysts are swallowed, they cause infections by excysting (releasing the trophozoite stage) in the digestive tract. The pathogenic nature of *E. histolytica* was first reported by Fedor A. Lösch in 1875, but it was not given its Latin

name until Fritz Schaudinn described it in 1903. *E. histolytica*, as its name suggests (*histo*– *lytic* = tissue destroying), is pathogenic; infection can be asymptomatic, or it can lead to amoebic dysentery or amoebic liver abscess. Symptoms can include fulminating dysentery, bloody diarrhea, weight loss, fatigue, abdominal pain, and amoeboma. The amoeba can 'bore' into the intestinal wall, causing lesions and intestinal symptoms, and it may reach the blood stream or peritoneal cavity. From there, it can reach vital organs of the human body, usually the liver, but sometimes the lungs, brain, and spleen. A common outcome of this invasion of tissues is a liver abscess, which can be fatal if untreated. Ingested red blood cells are sometimes seen in the amoeba cell cytoplasm.

Life cycle of Entamoeba Histolytica:


Ingestion
in contaminated
food and water
Mature cyst
Noninvasive infection
Cysts exit host
in the stool
Excystation
One trophozoite with four nuclei emerges, divides three times and each nucleus divides once to produce eight trophozoites from each cyst
Quadrinucleate cyst
Invasive infection
through the bloodstream, infecting sites such as the liver, brain, and lungs.
Trophozoites migrate to the large intestine
Trophozoites invade the intestinal mucosa
Immature cyst
Trophozoites multiply by binary fission
Encystation

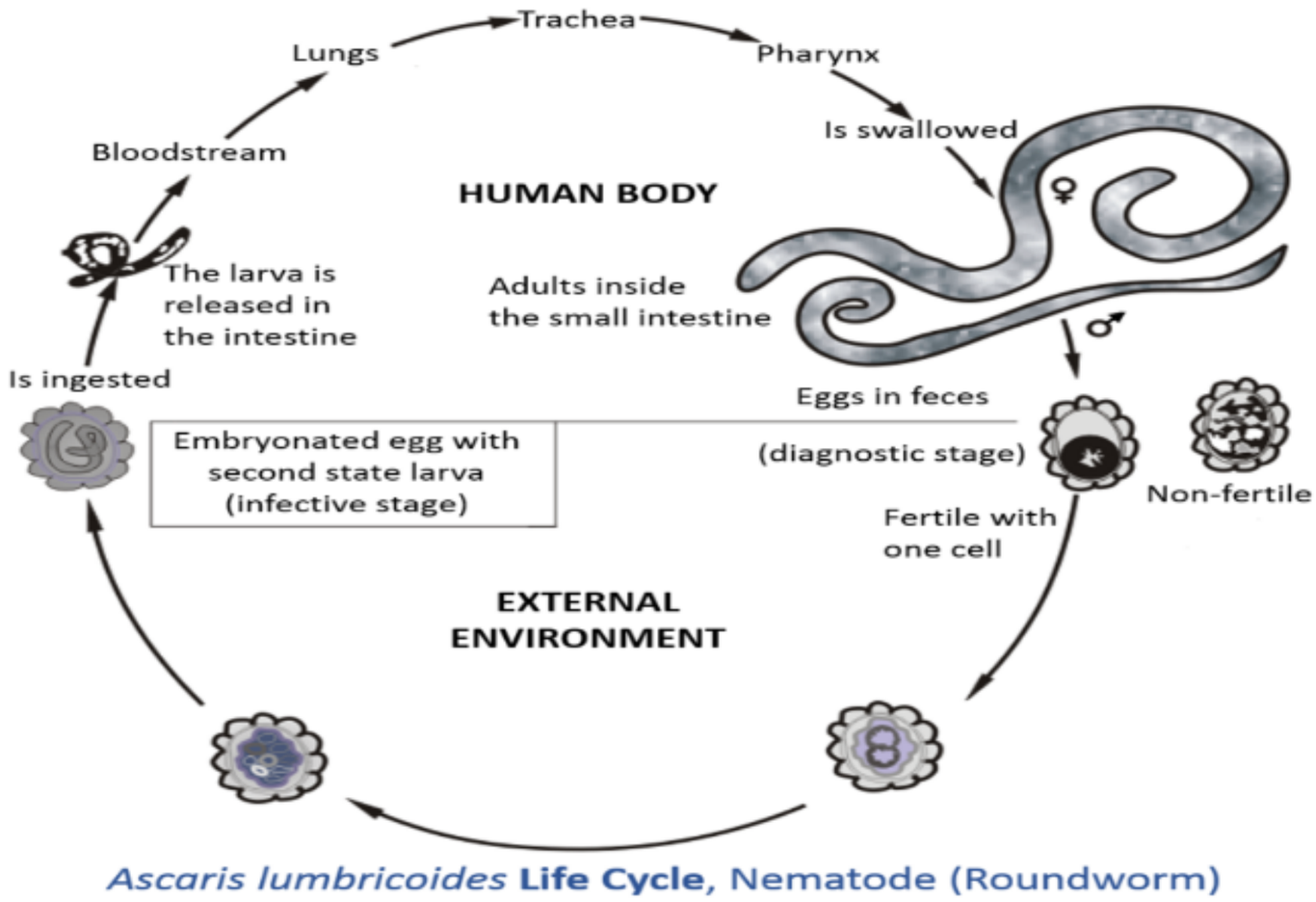
Ascaris Lumbricoides

Ascaris lumbricoides is a large parasitic roundworm of the genus *Ascaris*. It is the most common parasitic worm in humans. An estimated 807 million– 1.2 billion people are infected with *A. lumbricoides* worldwide.

People living in tropical and subtropical countries are at greater risk of infection. Infection by Ascaris lumbricoides infection is known as Ascariasis.

Morphology

Ascaris lumbricoides is characterized by its great size. Males are 2– 4 mm (0.08– 0.2 in) in diameter and 15– 31 cm (5.9– 12 in) long. The male's posterior end is curved ventrally and has a bluntly pointed tail. Females are 3– 6 mm (0.1– 0.2 in) wide and 20– 49 cm (7.9– 19 in) long. The vulva is located in the anterior end and accounts for about one-third of its body length. Uteri may contain up to 27 million eggs at a time, with 200,000 being laid per day. Fertilized eggs are oval to round in shape and are 45– 75 µm (0.0018– 0.0030 in) long and 35– 50 µm (0.0014– 0.0020 in) wide with a thick outer shell. Unfertilized eggs measure 88– 94 µm (0.0035– 0.0037 in) long and 44 µm (0.0017 in) wide.

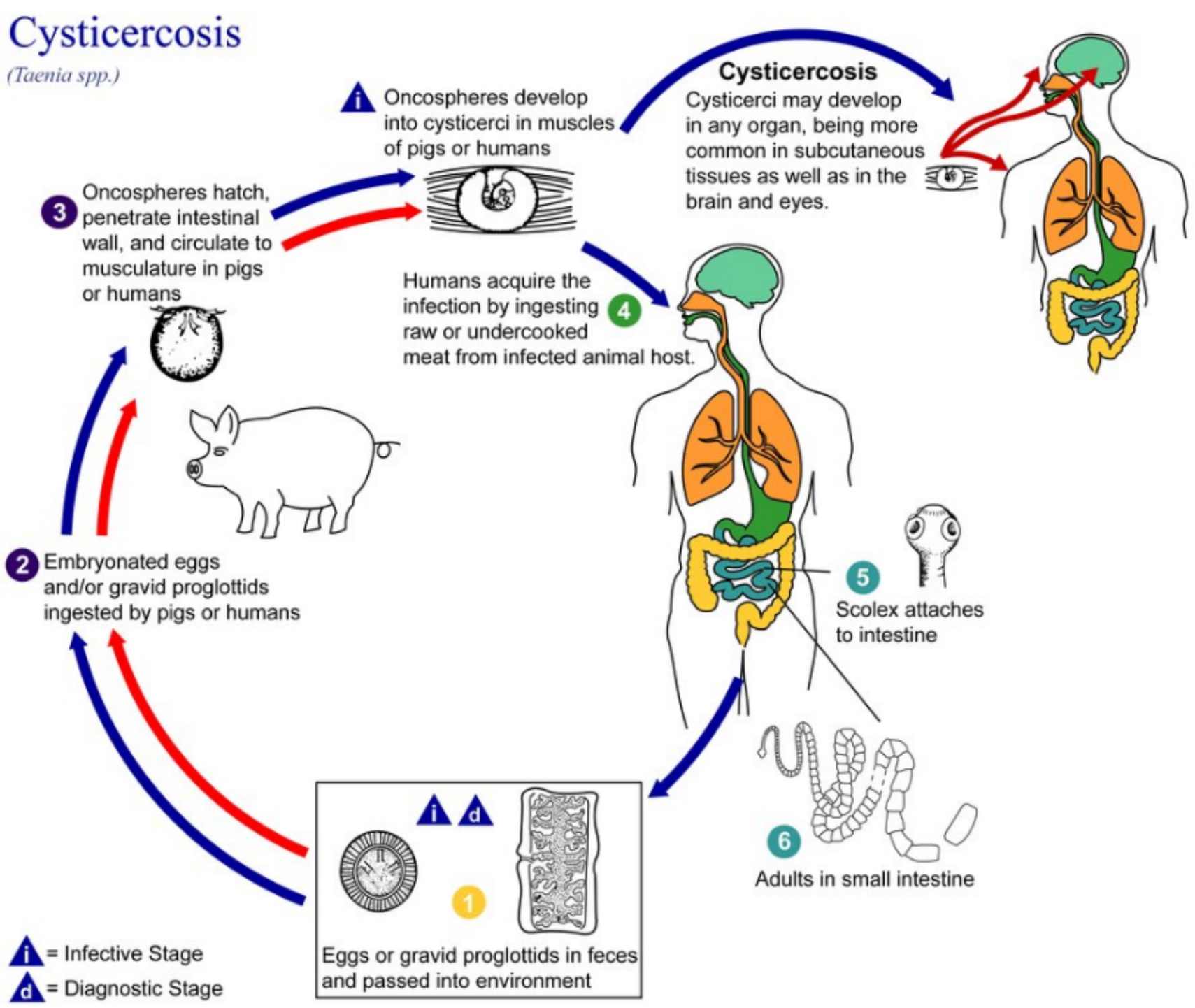


Ascaris lumbricoides **Life Cycle**, Nematode (Roundworm)

Taenia solium

Taenia solium, the **pork tapeworm**, belongs to the cyclophyllid cestode family Taeniidae. It is found throughout the world and is most common in countries where pork is eaten. It is a tapeworm that uses humans as its definitive host and pigs as the intermediate or secondary hosts. It is transmitted to pigs through human feces that contain the parasite eggs and contaminate their fodder. Pigs ingest the eggs, which develop into larvae, then into oncospheres, and ultimately into infective tapeworm cysts, called cysticercus. Humans acquire the cysts through consumption of uncooked or under-cooked pork and the cysts grow into adult worms in the small intestine.

Life cycle



Definitive host

Humans are colonised by the larval stage, the cysticercus, from undercooked pork or other meat. Each microscopic cysticercus is oval in shape, containing an inverted scolex (specifically "protoscolex"), which everts once the organism is inside the small intestine. This process of evagination is stimulated by bile juice and digestive enzymes (of the host). Then, the protoscolex lodges in the host's upper intestine by using its crowned hooks and 4 suckers to enter the intestinal mucosa. Then, the scolex is fixed into the intestine by having the suckers attached to the villi and hooks extended. It grows in size using nutrients from the surroundings. Its strobila lengthens as new proglottids are formed at the foot of the neck. In 10–12 weeks after initial colonisation, it is an adult worm.[16] The exact life span of an adult worm is not determined; however, evidences from an outbreak among British military in the 1930s indicate that they can survive for 2 to 5 years in humans.

As a hermaphrodite, it reproduces by self-fertilisation, or cross-fertilisation if gametes are exchanged between two different proglottids. Spermatozoa fuse with the ova in the fertilisation duct, where the zygotes are produced. The zygote undergoes holoblastic and unequal cleavage resulting in three cell types, small, medium and large (micromeres, mesomeres, megameres). Megameres develop into a syncytial layer, the outer embryonic membrane; mesomeres into the radially striated inner embryonic membrane or embryophore; micromeres become the morula. The morula transforms into a six-hooked embryo known as an oncosphere, or hexacanth ("six hooked") larva. A gravid proglottid can contain more than 50,000 embryonated eggs. Gravid proglottids often rupture in the intestine, liberating the oncospheres in faeces. Intact gravid proglottids are shed off in groups of four or five. The free eggs and detached proglottids are spread through the host's defecation (peristalsis). Oncospheres can survive in the environment for up to two months.

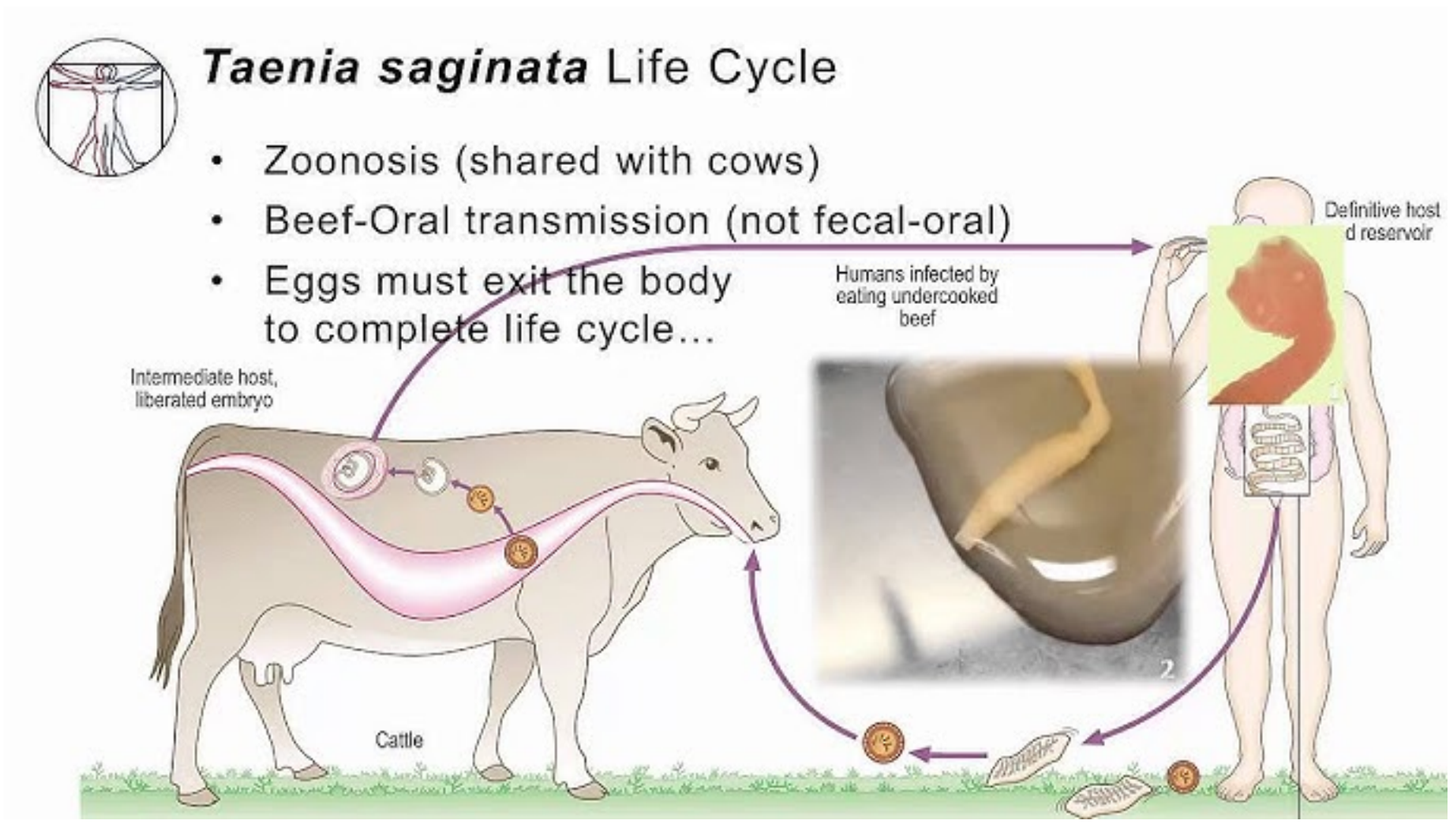
Intermediate host

Pigs are the principal intermediate hosts that ingest the eggs in traces of human faeces, mainly from vegetation contaminated with it such as from water bearing traces of it. The embryonated eggs enter intestine where they hatch into motile oncospheres. The embryonic and basement membranes are removed by the host's digestive enzymes (particularly pepsin). Then the free oncospheres attach on the intestinal wall using their hooks. With the help of digestive enzymes from the penetration glands, they penetrate the intestinal mucosa to enter blood and lymphatic vessels. They move along the general circulatory system to various organs, and large numbers are cleared in the liver. The surviving oncospheres preferentially migrate to striated muscles, as well as the brain, liver, and other tissues, where they settle to form cysts — cysticerci. A single cysticercus is spherical, measuring 1–2 cm (about ½") in diameter, and contains an invaginated protoscolex. The central space is filled with fluid like a bladder, hence it is also called bladder worm. Cysticerci are usually formed within 70 days and may continue to grow for a year.[19]

Humans are also accidental secondary hosts when they are colonised by embryonated eggs, either by auto-colonisation or ingestion of contaminated food. As in pigs, the oncospheres hatch and enter blood circulation. When they settle to form cysts, clinical symptoms of cysticercosis appear. The cysticercus is often called the metacestode.[20]

Taenia saginata

T. saginata is the largest of species in the genus *Taenia*. An adult worm is normally 4 to 10 m in length, but can become very large; specimens over 22 m long are reported. Typical of cestodes, its body is flattened dorsoventrally and heavily segmented. It is entirely covered by a tegument. The body is white in colour and consists of three portions: scolex, neck, and strobila. The scolex has four suckers, but they have no hooks. Lack of hooks and a rostellum is an identifying feature from other *Taenia* species. The rest of the body proper, the strobila, is basically a chain of numerous body segments called proglottids. The neck is the shortest part of the body, and consists of immature proglottids. The midstrobila is made of mature proglottids that eventually lead to the gravid proglottids, which are at the posterior end. An individual can have as many as 1000 to 2000 proglottids.



Intermediate host

Cattle acquire the embryonated eggs, the oncospheres, when they eat contaminated food. Oncospheres enter the duodenum, the anterior portion of the small intestine, and hatch there under the influence of gastric juices. The embryonic membranes are removed, liberating free hexacanth ("six-hooked") larvae. With their hooks, they attach to the intestinal wall and penetrate the intestinal mucosa into the blood vessels. The larvae can move to all parts of the body by the general circulatory system, and finally settle in skeletal muscles within 70 days. Inside the tissue, they cast off their hooks and instead develop a protective cuticular shell, called the cyst. Thus, they become fluid-filled cysticerci. Cysterci can also form in lungs and liver. The inner membrane of the cysticercus soon develops numerous protoscolices (small scolices) that are invertedly attached to the inner surface. The cysticercus of *T. saginata* is specifically named *cysticercus bovis* to differentiate from that of *T. solium*, *cysticercus cellulosae*.

Definitive host

Taenia saginata - oncosphere

Humans contract infective cysticerci by eating raw or undercooked meat. Once reaching the jejunum, the inverted scolex becomes evaginated to the exterior under stimuli from the digestive enzymes of the host. Using the scolex, it attaches to the intestinal wall. The larva mature into adults about 5 to 12 weeks later. Adult worms can live about 25 years in the host. Usually, only a single worm is present at a time, but multiple worms are also reported. In each mature proglottid, self-fertilisation produces zygotes, which divide and differentiate into embryonated eggs called oncospheres. With thousands of oncospheres, the oldest gravid proglottids detach. Unlike in other *Taenia*, gravid proglottids are shed individually. In some cases, the proglottid ruptures inside the intestine, and the eggs are released. The free proglottids and liberated eggs are removed by peristalsis into the environment. On the ground, the proglottids are motile and shed eggs as they move. These oncospheres in an external environment can remain viable for several days to weeks in sewage, rivers, and pastures.

Unit IV

Plasmodium Vivax

Plasmodium vivax is a protozoal parasite and a human pathogen. This parasite is the most frequent and widely distributed cause of recurring malaria.[2] Although it is less virulent than *Plasmodium falciparum*, the deadliest of the five human malaria parasites, *P. vivax* malaria infections can lead to severe disease and death, often due to splenomegaly (a pathologically enlarged spleen).[3][4] *P. vivax* is carried by the female *Anopheles* mosquito; the males do not bite

Lifecycle

Like all malaria parasites, *P. vivax* has a complex life cycle. It infects a definitive insect host, where sexual reproduction occurs, and an intermediate vertebrate host, where asexual amplification occurs. In *P. vivax*, the definitive hosts are *Anopheles* mosquitoes (also known as the vector), while humans are the intermediate asexual hosts. During its life cycle, *P. vivax* assumes various different physical forms (see below).

Asexual forms:

Sporozoite: Transfers infection from mosquito to human

Immature trophozoites (Ring or signet-ring shaped), about 1/3 of the diameter of a RBC.

Mature trophozoites: Very irregular and delicate (described as *amoeboid*); many pseudopodial processes seen. Presence of fine grains of brown pigment (malarial pigment) or hematin probably derived from the haemoglobin of the infected red blood cell.

Schizonts (also called meronts): As large as a normal red cell; thus the parasitized corpuscle becomes distended and larger than normal. There are about sixteen merozoites.

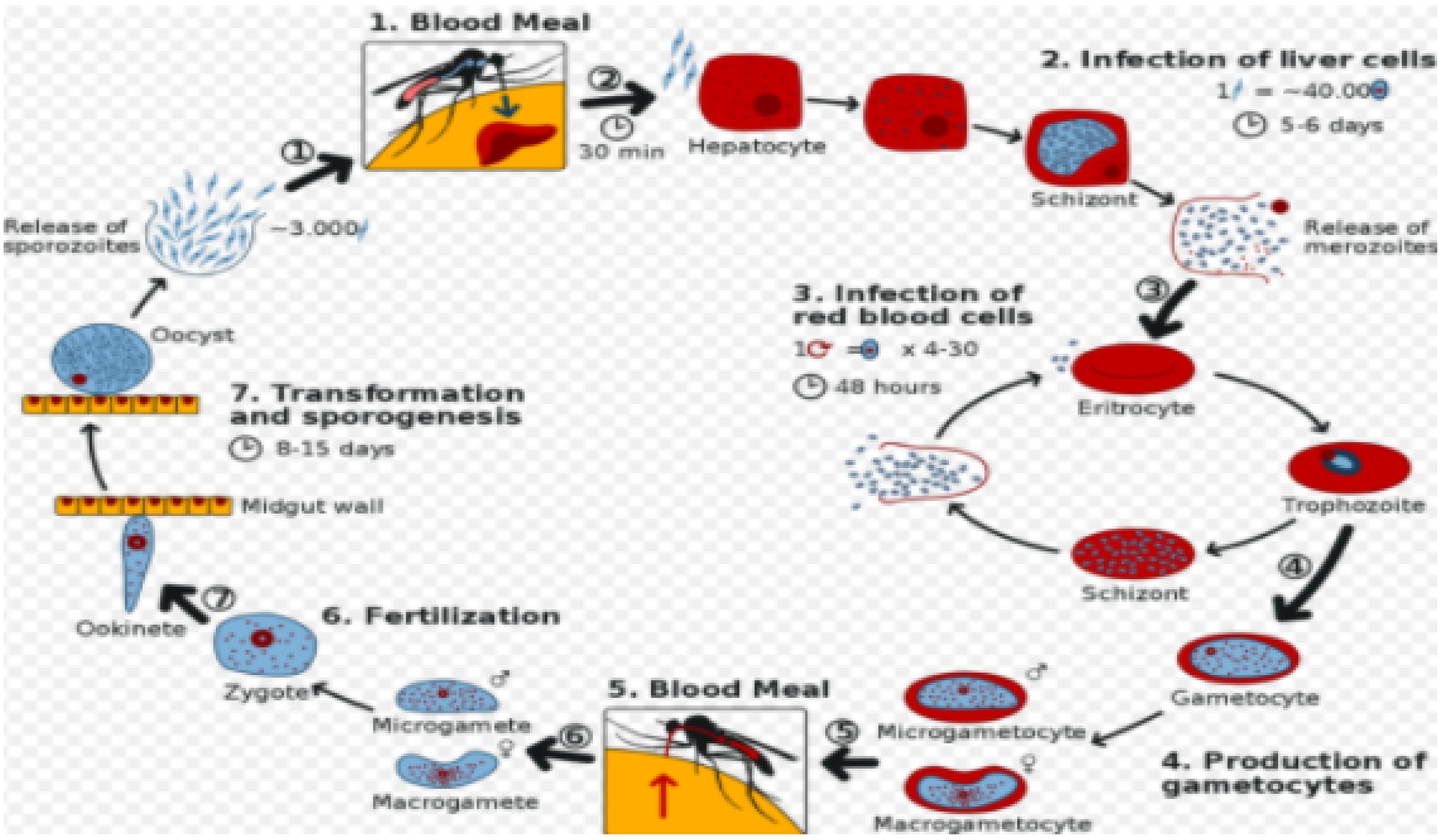
Sexual forms:

Gametocytes: Round. *P. vivax* gametocytes are commonly found in human peripheral blood at about the end of the first week of parasitemia.

Gametes: Formed from gametocytes in mosquitoes.

Zygote: Formed from combination of gametes.

Oocyst: Contains zygote, develops into sporozoites.



The life cycle of *Plasmodium vivax* in humans

Plasmodium falciparum

Plasmodium Falciparum is a unicellular protozoan parasite of humans, and the deadliest species of *Plasmodium* that causes malaria in humans.[2] The parasite is transmitted through the bite of a female *Anopheles* mosquito and causes the disease's most dangerous form, falciparum malaria. It is responsible for around 50% of all malaria cases.[3][4] *P. falciparum* is therefore regarded as the deadliest parasite in humans. It is also associated with the development of blood cancer (Burkitt's lymphoma) and is classified as a Group 2A (probable) carcinogen.

Plasmodium Falciparum The name Jalciparum comes from the characceristic sickle shape of the gametocytes of this species (Jalx: sickle, parere: to bringforth). 1his is the highly pathogenic of all the plasmodia and hence, the name malignant tertian or pernicious malaria for its infection. • The disease has a high rate of complications and unless treated, is often fatal. The species is responsible for almost all deaths caused by malaria. Schizogony: The sporozoites are sickle-shaped. the tissue phase consists of only a single cycle of pre-erythrocytic schizogony. No hy pnozoites occur. The ma ture liver schizont releases about 30,000 merozoites.

• They attack both young and mature erythrocytes and so the population of cells affected is very large. Infected erythrocytes present a brassy coloration. Ringform: The early ring form in the erythrocyte is very d elicate and tiny, measuring only a one-sixth of the red cell diameter. Rings are often seen attached along th e margin of the red cell, the so-called form applique or accole. Binucleate rings (double chromatin) are common resembling stereo headphones in appearance. Several rings may be seen within a single erythrocyte. In course of time, the rings become larger, about a third of the size of the red cell and may have I or 2 grains of pigment in its cytoplasm .

• The subsequent stages of the asexual cycle- late trophozoite, early and mature schizoncs- a re not ordinarily seen in peripheral blood, except in very severe or pernicious malaria. The presence of P. falciparum schizonts in peripheral smears indicates a grave prognosis .

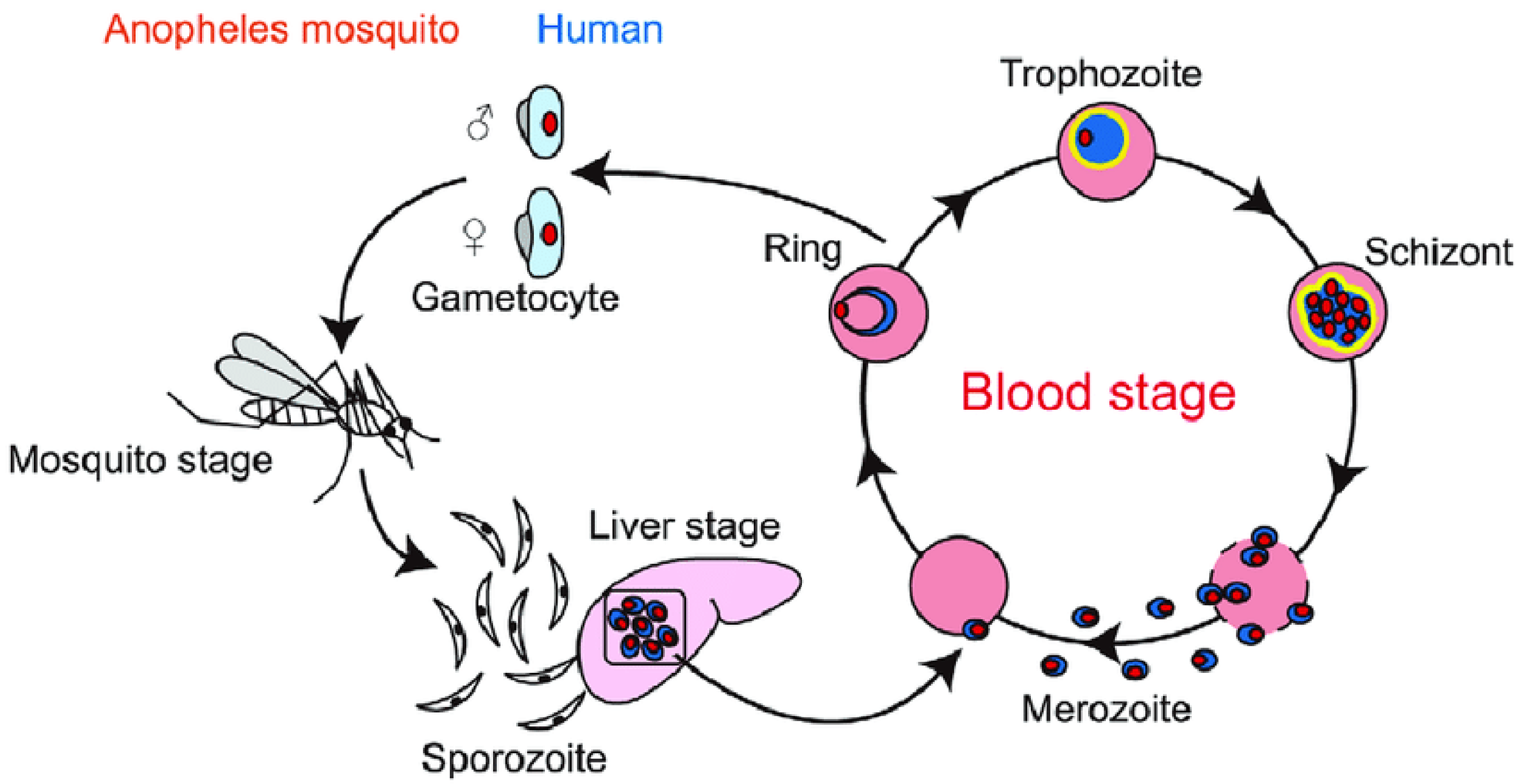
• The mature schizont is smaller than in an y other species and has 8-24 (usually 16) merozoites. The erythrocytic schizogony takes about 48 hours or less, so that the periodicity of febrile paroxysms is 36-48 hours. Very high intensity of parasitization is

seen in Jalciparum malaria. In very severe infections, the rate of parasitized cells may even be up to 50%.

• The infected erythrocytes are of normal size. They show a few (6- 12) coarse brick-red dots which are called Maurer's clefts. Some red cells show basophilic stippling. Gametogony: It begins after several gen erations of schizogony. Gametocytes are seen in circulation about 10 days after the ring stage first appears. The early gametocytes seldom appear in peripheral circulation. The mature gametocytes, which are seen in peripheral smears are curved oblong structures, described as crescentic, sickle, sausage, or banana-shaped. They are usually referred co as crescents

• The male gametocytes are broad and sausage-shaped or kidney-shaped, with blunt rounded ends as compared to the female gametocytes, which are thinner and more typically crescentic, with sharply rounded or pointed ends. The mature gametocyte is longer than the diameter of the red cell and so produces gross distortion and sometimes even apparent disappearance of the infected red cell. The red cell is often seen as a rim on the concave side of the gametocyte. The cytoplasm in the female gametocyte is deep blue, while in the male it is pale blue or pink. The nucleus is deep red and compact in the female, with the pigment granules closely aggregated around it, while in the male, it is pink, large and diffuse, with the pigment granules scattered in the cytoplasm.

• Falciparum crescents can survive in circulation for up to 60 days, much longer than in other species. Gametocytes are most numerous in the blood of young children, 9 months to 2 years old. They, therefore serve as the most effective source of infection to mosquitoes.



Life Cycle of Plasmodium Falciparum