CHAPTER

1

General Parasitology

Parasitology is the study of invertebrate animals capable of causing disease in humans and other animals.

It is concerned with 200 or so species of helminth worms and about 80 species of protozoa that infect humans. Many of these are rare and accidental parasites, but about 100 species of protozoa and helminths are commonly found in humans. They range in size from tiny protozoa as small as 1–2 µm in diameter to tapeworms that may measure up to 10 metres in length.

PARASITE

A parasite is an organism that is entirely dependent on another organism, referred to as its host, for all or part of its life cycle and metabolic requirements. Strictly speaking, the term parasite can be applied to any infectious agent but, by convention, it is generally restricted to infections caused by protozoa and helminths and excludes the viruses, bacteria and fungi.

On the basis of their location, parasites may also be divided into two types:

- Ectoparasites
- Endoparasites

Ectoparasites

Organisms which live on the surface of the body, e.g. the human louse, *Pediculus humanus*, are known as ectoparasites. The infection by these parasites is known as infestation. They are important as vectors transmitting pathogenic microorganisms.

Endoparasites

Organisms that live within the body of the host (in the blood, tissues, body cavities, digestive tract and other organs) are known as endoparasites. All protozoan and helminthic parasites of man are endoparasites. The invasion by endoparasites is known as *infection*. These can be further subdivided into following types:

- ***Obligate parasites*:** Organisms that cannot exist without a host (e.g. *Toxoplasma gondii*).
- ***Facultative parasites*:** Organisms that under favourable circumstances may live either a parasitic or free-living existence (e.g. *Naegleria fowleri, Acanthamoeba* spp. and *Balamuthia mandrillaris*).
- ***Accidental parasites*:** Organisms that attack an unusual host (e.g. *Echinococcus granulosus* in man).
- ***Aberrant parasites:*** Organisms that attack a host where they cannot live or develop further (e.g. *Toxocara canis* in man).
- ***Free-living:*** The term free-living describes the non-parasitic stages of existence which are lived independently of a host, e.g. hookworms have active free-living stages in the soil.

WHY A HUMAN EMBRYO OR FOETUS IS NOT A PARASITE?

Human embryo or foetus develops inside the uterus of the mother for more than nine months deriving its nourishment from the mother. In spite of this it is not treated as a parasite (Table 1.1).

HOST

It is defined as an organism which harbours the parasite and provides the nourishment and shelter to the latter. It is of following types:

Definitive host

The host which harbours the adult parasite, the most highly developed form of a parasite or where the parasite replicates sexually. When the most highly developed form is not obvious, the definitive host is the mammalian host.

Intermediate host

This is the host which alternates with the definitive host and harbours the larval or asexual stages of a parasite. Some parasites require two intermediate hosts for completion of their life cycle. These are referred to as first and second intermediate hosts, respectively.

Table 1.1: Comparison between parasite and human embryo or foetus

Parasite	*Human embryo or foetus*
1. A parasite is an organism of one species living in or on an organism of other species (a hetero-specific relationship) and deriving its nourishment from the host.	A human embryo or foetus is an organism of one species (*Homo sapiens*) living in the uterine cavity of an organism of the same species and deriving its nourishment from the mother. This is a dependent relationship, but not a parasitic relationship.
2. A parasite is an invading organism coming to parasitize the host from an outside source.	A human embryo or foetus is formed from a fertilized egg coming from an inside source, being formed in the ovary of the mother from where it moves into the oviduct where it may be fertilized to form the zygote, the first cell of the new human being.
3. A parasite is generally harmful to some degree to the host.	A human embryo or foetus developing in the uterine cavity does not usually cause harm to the mother, provided proper nutrition and care is maintained by the mother.
4. A parasite makes direct contact with the host's tissues, often holding on by mouth parts, hooks or suckers to the tissues involved (intestinal lining, lungs, connective tissue, etc.).	A human embryo or foetus makes direct contact with the uterine lining of the mother for only a short period of time. It soon becomes isolated inside its own amniotic sac and makes indirect contact with the mother only by way of the umbilical cord and placenta.
5. When a parasite invades host tissue, the host tissue sometimes responds by forming a capsule of connective tissue to surround the parasite and cuts it off from other surrounding tissues.	When the human embryo or foetus attaches and invades the lining tissue of the mother's uterus, the lining tissue responds by surrounding the human embryo but does not cut it off from the mother. Rather it establishes a means of close contact (the placenta) between the mother and the new human being.
6. When a parasite invades a host, the host usually responds by forming antibodies in response to the somatic antigens (molecules comprising the body of the parasite) or metabolic antigens (molecules secreted or excreted by the parasite). Parasitism usually involves an immunological response on the part of the host.	Mother does react to the presence of the embryo by producing humoral antibodies, but the trophoblast (the jacket of cells surrounding the embryo) blocks the action of these antibodies and, therefore, the embryo or the foetus is not rejected. This reaction is unique to the embryo–mother relationship.

Paratenic host

It is a host in which larval stage of a parasite survives but does not develop further. It is often not a necessary part of the life cycle.

Reservoir host

It is a host that harbours the parasite and serves as an important source of infection to other susceptible hosts.

Compromised host

A compromised host is one in whom normal defence mechanisms are impaired (e.g. AIDS), absent (e.g. congenital deficiencies), or bypassed (e.g. penetration of skin barrier). Such hosts are extremely susceptible to a variety of common as well as opportunistic pathogens.

Zoonosis

This term is used to describe an animal infection that is naturally transmissible to humans either directly or indirectly via a vector. Examples of parasitic diseases that are zoonoses include leishmaniasis, South American trypanosomiasis, rhodesiense trypanosomiasis, japonicum schistosomiasis, trichinosis, fascioliasis, hydatid disease, and cryptosporidiosis.

Vector

A vector is an agent, usually an insect, that transmits an infection from one human host to another. It is of two types:

1. *Mechanical vector*: The term mechanical vector is used to describe a vector which assists in the transfer of pathogens between hosts but is not essential in the life cycle of the parasite, e.g. a housefly that carries parasite cysts and eggs, bacteria or viruses, on its body, from infected faeces to food that is eaten by humans. Vector-borne human parasitic infections (*see* Table 14.3).
2. *Biological vector*: A vector in which the pathogens multiply or undergo developmental changes with or without multiplication. Biological vectors are of three types:
   - *Propagative vector*: When a pathogen undergoes no cyclic change but multiplies in the body of the vector, transmission is said to be propagative, e.g. plague bacilli in rat fleas.
   - *Cyclo-propagative vector*: The pathogen undergoes a cyclic change and multiplies in the body of the arthropod, e.g. malaria parasites in female *Anopheles* mosquito.

- *Cyclo-developmental vector*: When pathogen undergoes cyclic changes but does not multiply in the body of the vector, e.g. filarial parasite in *Culex* mosquito and guinea worm larvae in cyclops.

HOST–PARASITE RELATIONSHIPS

Host–parasite relationships are of following types:

Symbiosis

An association in which both host and parasite are so dependent upon each other that one cannot live without the help of the other. Neither of the partners suffers from any harm from this association.

Commensalism

An association in which only parasite derives benefit without causing any injury to the host. A commensal lives on food residues or waste products of the body and is capable of leading an independent life.

Parasitism

Parasitism is a relationship in which a parasite benefits and the host provides the benefit. The host gets nothing in return and always suffers from some injury. The degree of dependence of a parasite on its host varies.

SOURCES OF INFECTION

Although many infectious diseases are caused by **endogenous** organisms that are part of the normal flora of the human host, this is not the case with most diseases caused by protozoan and helminthic parasites. These organisms are virtually always acquired from an **exogenous** source and as such have evolved numerous ways to enter the body of the human host:

1. ***Contaminated soil and water*:** Soil polluted with human excreta acts as a source of infection with *Ascaris lumbricoides*, *Trichuris trichiura*, *Ancylostoma duodenale*, *Necator americanus* and *Strongyloides stercoralis*. Before acquiring infectivity for man, eggs of these parasites undergo certain development in the soil. These are known as **soil-transmitted helminths**.

   Water polluted with human excreta may contain viable cysts of *Entamoeba histolytica*, *Giardia lamblia*, *Balantidium coli*, eggs of *Taenia solium*, *Hymenolepis nana*, and the infective cercarial stage of *Schistosoma haematobium*, *S. mansoni and S. japonicum*.
2. ***Freshwater fishes*** constitute the source of *Diphyllobothrium latum* and *Clonorchis sinensis*.
3. ***Crab and crayfishes*** are the sources of *Paragonimus westermani*.
4. ***Raw or undercooked pork*** is the source of *Trichinella spiralis*, *Taenia solium*, *T. asiatica and Sarcocystis suihominis*.
5. ***Raw or undercooked beef*** is the source of *T. saginata*, *Toxoplasma gondii* and *Sarcocystis hominis*.
6. ***Watercress*** is the source of *Fasciola hepatica*.
7. ***Blood-sucking insects*** transmit *Plasmodium* spp., *Wuchereria bancrofti*, *Brugia malayi*, *Onchocerca volvulus*, *Trypanosoma brucei gambiense*, *T. b. rhodesiense*, *T. cruzi*, *Leishmania* spp. and *Babesia* spp.
8. ***Housefly*** (mechanical carrier) is the source of *E. histolytica*.
9. ***Dog*** is the source of *Echinococcus granulosus* (hydatid cyst), and *Toxocara canis* (visceral larva migrans).
10. ***Cat*** is the source of *T. gondii*.
11. ***Man*** is the source of *E. histolytica*, *Giardia lamblia*, *Enterobius vermicularis* and *H. nana*.
12. ***Autoinfection*** may occur with *Enterobius vermicularis* and *S. stercoralis* leading to **hyperinfection**.

PORTAL OF ENTRY INTO THE BODY

Mouth

The commonest portal of entry of parasites is oral, through contaminated food, water, soiled fingers or fomites. Many intestinal parasites, e.g. *E. histolytica*, *G. lamblia*, *Balantidium coli*, *E. vermicularis*, *T. trichiura*, *A. lumbricoides*, *T. spiralis*, *T. solium*, *T. saginata*, *T. asiatica*, *D. latum*, *Fasciola hepatica*, *Fasciolopsis buski*, *C. sinensis and P. westermani*, enter the body in this manner.

Skin

Entry through skin is another important portal of entry of parasites. Infection with *A. duodenale*, *N. americanus* and *S. stercoralis* is acquired when filariform larvae of these nematodes penetrate the unbroken skin of an individual walking over faecally contaminated soil. Schistosomiasis caused by *S. haematobium*, *S. mansoni* and *S. japonicum* is acquired when the cercarial larvae, in water, penetrate the skin. A large number of parasites, e.g. *Plasmodium* spp., *W. bancrofti*, *B. malayi*, *O. volvulus*, *T. brucei gambiense*, *T. brucei rhodesiense*, *T. cruzi*, *Leishmania* spp. and *Babesia* spp. are introduced percutaneously when blood-sucking arthropods puncture the skin to feed.

Sexual Contact

Trichomonas vaginalis is transmitted by sexual contact. *E. histolytica* and *G. lamblia* may also be transmitted by anal-oral sexual practices among male homosexuals.

Kissing

E. gingivalis is transmitted from person-to-person by kissing or from contaminated drinking utensils.

Congenital

Infection with *T. gondii* and *Plasmodium* spp. may be transmitted from mother to foetus transplacentally.

Inhalation

Airborne eggs of *E. vermicularis* may be inhaled into posterior pharynx leading to infection.

Iatrogenic infection

Malaria parasites may be transmitted by transfusion of blood from the donor with malaria containing asexual forms of erythrocytic schizogony. This is known as **trophozoite-induced malaria or transfusion malaria.** Malaria parasites may also be transmitted by the use of contaminated syringes and needles. This may occur in drug addicts.

LIFE CYCLE OF HUMAN PARASITES

On the basis of their life cycles human parasites can be divided into three major groups (Table 1.2).

Table 1.2: Life cycle of human parasites

No intermediate host	
Protozoa	*Helminths*
• *Entamoeba histolytica* • *Giardia lamblia* • *Chilomastix mesnili* • *Trichomonas vaginalis* • *Balantidium coli*	• *Enterobius vermicularis* • *Trichuris trichiura* • *Ascaris lumbricoides** • *Ancylostoma duodenale** • *Necator americanus** • *Hymenolepis nana*
One intermediate host	
Intermediate host	*Parasite*
Pig	• *Taenia solium*
	• *T. asiatica*
	• *Trichinella spiralis*
Cow	• *Taenia saginata*
Man	• *Echinococcus granulosus*
	• *Plasmodium* spp.
Flea	• *Dipylidium caninum*
	• *Hymenolepis diminuta*
Triatomine bug	• *Trypanosoma cruzi*
Mosquito	• *Wuchereria bancrofti*
	• *Brugia malayi*
Snail	• *Schistosoma* spp.
Copepod	• *Dracunculus medinensis*
Fly Sandfly Tsetse fly	 • *Leishmania* spp. • *Trypanosoma* spp.
Chrysops	• *Loa loa*
Simulium	• *Onchocerca volvulus*
Two intermediate hosts	
Intermediate hosts	*Parasite*
Snail, crustacean	• *Paragonimus westermani*
Cyclops, fish	• *Diphyllobothrium latum*
Snail, fish	• *Clonorchis sinensis*
Snail, plant	• *Fasciola* spp.

*Require a period of maturation in the soil after passage before they are infective.

PATHOGENICITY

A parasite may live in or on the tissues of its host without causing evident harm. However, in majority of cases the parasite has the capacity to produce damage. With the advent of AIDS there is an increase in the incidence of newer parasitic infections caused by *Cryptosporidium parvum, Cytoisospora belli, Cyclospora cayetanensis* and other hitherto unheard of parasites. These parasites also cause infections in patients who are immunocompromised, e.g. patients receiving cytotoxic drugs or organ transplant. Following are the ways in which the damage may be produced by the parasites.

Traumatic damage

Relatively slight physical damage is produced by entry of filariform larvae of *S. stercoralis, A. duodenale* and *N. americanus,* and cercarial larvae of *S. haematobium, S. mansoni* and *S. japonicum* into the skin. Migration of several helminthic larvae through the lung produces traumatic damage of pulmonary capillaries leading to extravasation of blood into the lung. Similar damage in cerebral, retinal or renal capillaries may lead to serious injury.

Eggs of *S. haematobium* and *S. mansoni* cause extensive damage with haemorrhage as they escape from vesical and mesenteric venules, respectively, into the lumen of the urinary bladder and the intestinal canal.

Attachment of hookworms (*A. duodenale* and *N. americanus*) to the intestinal wall results in traumatic damage of the villi. They ingest blood and, moreover, move from site to site in the gut mucosa, leaving small bleeding lesions. These two facts are responsible for the chief pathological manifestation of heavy infection with hookworms—iron deficiency anaemia.

Mechanical blockage

Many of the pathogenic consequences of helminthic infections are related to the size, movement, and longevity of the parasites. The host is exposed to long-term damage and immune stimulation, as well as the sheer physical consequences of being inhabited by large foreign bodies. The most obvious forms of direct damage from helminthic parasites are those resulting from mechanical blockage of internal organs or from the effects of pressure exerted by growing parasites. Large adult *Ascaris* organisms can physically block the intestine and the bile ducts.

Likewise, blockage of lymph flow, leading to elephantiasis, is associated with the presence of adult *Wuchereria* parasites in the lymphatic system. Some neurologic manifestations of cysticercosis are due to the pressure exerted by the slowly expanding larval cysts of *Taenia solium* in the central nervous system (CNS) and eyes. Migration of helminths (usually larval forms) through body tissues such as skin, lungs, liver,

intestines, eyes, and CNS can damage the tissues directly and initiate hypersensitivity reactions.

Lytic necrosis

E. histolytica secretes lytic enzyme which lyses tissues for its nutritional needs and helps it to penetrate into the tissues of the colon and extraintestinal viscera. Obligate intracellular parasites, e.g. *Plasmodium* spp., *Leishmania* spp., *Trypanosoma cruzi* and *Toxoplasma gondii* cause necrosis of parasitized host cells during their growth and multiplication.

Physiological effects

Large numbers of *Giardia lamblia* covering the walls of the small intestine can lead to malabsorption, especially of fats.

Competition for specific nutrients

Diphyllobothrium latum competes with the host for vitamin B_{12} leading to **parasite-induced pernicious anaemia**. Other forms of anaemia result from blood loss, especially in hookworm infection, and from red blood cell destruction in malaria.

Inflammatory reaction

Most of the parasites provoke cellular proliferation and infiltration at the site of their location. In many instances, the host reaction walls off the parasite by fibrous encapsulation. In metazoan and in some protozoan parasitoses, there is a moderate-to-notable eosinophilia. *E. histolytica* may produce inflammation of the large intestine leading to the formation of amoebic granuloma or **amoeboma**. Parasitization of fixed macrophages in the spleen, bone marrow, and lymph nodes by *L. donovani* causes proliferation of reticuloendothelial cells.

Allergic manifestations

In certain helminthic infections, the normal secretions and excretions of the growing larvae and the products liberated from dead parasites may give rise to various allergic manifestations, e.g.:

- Schistosomes cause cercarial dermatitis and eosinophilia
- *D. medinensis* and *T. spiralis* infections cause urticaria and eosinophilia, and
- Rupture of hydatid cyst may precipitate anaphylaxis.

Neoplasia

The parasitic infection may contribute to the development of neoplastic growth, e.g. *C. sinensis* and *Opisthorchis viverrini* have been associated with **cholangiocarcinoma** and *S. haematobium* with **vesical carcinoma**.

Secondary infection

In some helminthic infections (e.g. strongyloidiasis, trichinosis and ascariasis), the migrating larvae may carry bacteria and viruses from the intestine to the blood and tissues leading to secondary infection.

IMMUNITY IN PARASITIC INFECTIONS

There are two main types of immunity—innate and acquired.

Innate immunity

Innate immunity is not dependent on prior contact with the parasites or their products. It is due to genetic and constitutional make up of an individual. Examples of genetic innate immunity of man to human parasitic infections are as under:

- West Africans are more resistant than white Americans to hookworm infection.
- Presence of **abnormal haemoglobin** like thalassemia haemoglobin and foetal haemoglobin confers resistance against all *Plasmodium* spp., while sickle cell anaemia trait and haemoglobin E protect against *P. falciparum* and *P. vivax*, respectively.
- A genetic deficiency known as **glucose-6-phosphate dehydrogenase (G6PD) trait** confers some protection against *P. falciparum* infection. This enzyme is essential for respiratory process of the parasite.
- The presence of **Duffy factor** on red blood cells increases the susceptibility to malaria. It is believed that Duffy factor present on red blood cells acts as receptor for attachment of malaria parasite.

Acquired immunity

Because of their biochemical and structural complexity, protozoa and helminths present a large number of antigens to their hosts. Protozoa are small and multiply within their vertebrate host, often inside cells, thus posing an immediate threat unless contained by an appropriate immune response. Helminths are large and do not multiply within their vertebrate host. Thus, they do not present an immediate threat after initial infection. However, the host must protect itself from large infections and reinvasion by infective stages by eliciting an appropriate immune response. Therefore, immune responses to protozoa and helminths are different from one another.

Like other infectious agents, parasites also elicit both humoral as well as cellular responses. But immunological protection against parasitic infections is much less efficient than it is against bacterial and viral infections. This is due to following factors:

- As compared to bacteria and viruses, parasites are large and more complex structurally and antigenically so that immune system may not be able to mount immune response against the protective antigens.
- Many protozoan parasites (e.g. *Leishmania* spp., *T. cruzi* and *T. gondii*) are **intracellular**. This protects them from immunological attack.

- Many parasites, both protozoa and helminths, live inside the intestines. This location limits the efficiency of immunological attack and also facilitates dispersal of the infective forms of the parasites.
- *T. brucei gambiense* and *T. b. rhodesiense* exhibit **antigenic variations** within the host. When antibody response to one antigenic type reaches peak, antigenic variation of the parasite occurs by mutation. The new antigenic type is unaffected by the antibodies against the parent strain. This enables the prolonged persistence of the parasite in the host.
- *Plasmodium* spp., the cause of malaria, also change their surface antigens and are poorly antigenic. Malaria may continue for several months in a person before the immune response is sufficiently strong to reduce the number of the parasites.
- Blood flukes of humans, *Schistosoma* spp., adsorb host-produced molecules onto their surface so that the host fails to recognize the worms as nonself. The blood flukes can remain alive in the blood vessels of the human host for 20–30 years at least in part by utilizing this mechanism.
- Many nematodes have a cuticle which is antigenically inert and evokes little immune response.
- *L. donovani* causes extensive damage to the reticuloendothelial system thus leading to immunological tolerance.
- *E. vermicularis* does not breach the integrity of gut wall, thus immune system is not stimulated.
- In most of the parasitic infections, immunity lasts only till original infection remains active. This is known as **concomitant immunity** (previously called **premunition** or **infection-immunity**). A possible exception is cutaneous leishmaniasis in which the ulcer heals leaving behind good protection against reinfection.

All the above mechanisms have made the production of vaccine against eukaryotic parasites extremely difficult.

The protective immune response to parasitic infections has four arms:

1. Cytotoxic T (Tc) cells.
2. Natural killer (NK) cells.
3. Activated macrophages.
4. Antibodies (produced by B cells).

The first three constituting 'cell-mediated immunity' and the last constituting 'humoral immunity'. The main classes of antibodies (immunoglobulins) produced are IgM, IgG and IgE. The first to appear is IgM which marks the presence of acute infection. IgG antibodies are usually the most abundant type in parasitic infections. Helminths and ectoparasites also provoke high titres of IgE antibodies.

Laboratory diagnosis

Laboratory diagnosis of parasitic infections can be carried out by:

- Demonstration of parasite.
- Immunodiagnosis.
- Molecular biological methods.

Demonstration of parasite

The diagnosis of parasitic infections may be very difficult, particularly in non-endemic setting. The clinical manifestations of parasitic diseases are seldom specific enough to raise the possibility of these processes in the mind of the clinician, and routine laboratory tests are seldom helpful. Although **peripheral eosinophilia** is widely recognized as a useful indicator of parasitic disease, this phenomenon is characteristic only of helminthic infection and even in these cases it is frequently absent. Proper diagnosis requires that:

a. The physician considers the possibility of parasitic infection,
b. Appropriate specimens be obtained and transferred to the laboratory in a timely fashion, and
c. The laboratory competently performs the appropriate procedures for the recovery and identification of the etiological agent.

For most parasitic diseases, appropriate test selection and interpretation is based on an understanding of the life cycle of the parasite, as well as the pathogenesis of the disease process in humans. Although the mainstay of diagnostic clinical microbiology is the isolation of the causative pathogen in culture, the diagnosis of parasitic diseases is accomplished almost entirely by morphologic (usually microscopic) demonstration of parasites in clinical material.

Blood

In those parasitic infections, where the parasite itself, or in any stage of its development, circulates in the blood stream, the examination of blood film forms the main procedure for specific diagnosis, e.g. demonstration of *Plasmodium* spp. and *Babesia* spp. inside the erythrocytes, *L. donovani* inside monocytes, trypomastigotes of *T. b. gambiense, T. b. rhodesiense* and *T. cruzi*, and microfilariae of *W. bancrofti* and *B. malayi* in the blood.

Stool

Examination of stool is important for the diagnosis of intestinal parasitic infections and helminthic infections of the biliary tract in which eggs are discharged in the intestine. In protozoal infections, the trophozoites (during active phase) and cysts (during chronic phase) of *E. histolytica, G. lamblia* and *B. coli* can be demonstrated by wet mount of stool in normal saline and Lugol's iodine. In helminthic infections eggs, larvae and adult worms may be demonstrated (Table 1.3). When

Table 1.3: Parasites found in stool	
CYSTS/TROPHOZOITES	
Protozoa	
• *Entamoeba histolytica*	• *Giardia lamblia*
• *Dientamoeba fragilis*	• *Balantidium coli*
• *Sarcocystis hominis*	• *S. suihominis*
• *Cytoisospora belli*	• *Cyclospora cayetanensis*
• *Cryptosporidium parvum*	• *Encephalitozoon intestinalis*
• *Enterocytozoon bieneusi*	
EGGS	
Cestodes	
• *Diphyllobothrium latum*	• *Taenia solium*
• *T. saginata*	• *T. asiatica*
• *Hymenolepis nana*	• *H. diminuta*
• *Dipylidium caninum*	
Trematodes	
• *Schistosoma mansoni*	• *S. japonicum*
• *Fasciolopsis buski*	• *Fasciola hepatica*
• *F. gigantica*	• *Clonorchis sinensis*
• *Gastrodiscoides hominis*	• *Watsonius watsoni*
• *Heterophyes heterophyes*	• *Metagonimus yokogawai*
• *Opisthorchis* spp.	
Nematodes	
• *Trichuris trichiura*	• *Ancylostoma duodenale*
• *Necator americanus*	• *Enterobius vermicularis*
• *Capillaria philippinensis*	• *Trichostrongylus orientalis*
LARVAE	
• *Strongyloides stercoralis*	• *Trichinella spiralis* (rarely)
ADULT WORMS	
Cestodes	
• *Taenia solium*	• *T. saginata*
• *T. asiatica*	• *Diphyllobothrium latum*
Nematodes	
• *Ascaris lumbricoides*	• *Ancylostoma duodenale*
• *Necator americanus*	• *Enterobius vermicularis*
• *Trichinella spiralis*	

direct stool smears are repeatedly negative for ova and cysts then the concentration methods such as salt floatation or formalin-ether sedimentation may be used. *Cryptosporidium parvum, Cytoisospora belli* and other coccidia in stool specimens may be detected by **modified acid-fast staining** of the fixed smear (*see* Chapter 13). Demonstration of parasites in the stool confirms the diagnosis and is the gold standard in the diagnosis of intestinal parasitic infections.

Perianal skin scrapings may show the eggs or adult worms of *E. vermicularis*.

Urine

When the parasite localises in the urinary tract, the examination of urine is useful in establishing the parasitological diagnosis, e.g. eggs of *S. haematobium* and trophozoites of *T. vaginalis* may be demonstrated in the urine. In case of chyluria caused by *W. bancrofti*, microfilariae are often demonstrated in chylous urine.

Genital specimens

Trophozoites of *T. vaginalis* may be demonstrated in the vaginal and urethral discharge and in the prostatic secretions.

Cerebrospinal fluid (CSF)

Trypomastigotes of *T. brucei gambiense* and *T. b. rhodesiense*, and trophozoites of *Naegleria fowleri, Acanthamoeba* spp. and *Balamuthia mandrillaris* may be demonstrated in the CSF.

Sputum

In cases where the habitat of the parasite is in the respiratory tract, as in paragonimiasis, the eggs of *Paragonimus westermani* may be demonstrated in the sputum specimen. Rarely, migrating larvae of *A. lumbricoides*, *S. stercoralis*, *A. duodenale*, and *N. americanus* may be found in the sputum. In amoebic abscess of lung or in the case of amoebic liver abscess bursting into the lungs, the trophozoites of *E. histolytica* can be detected in the sputum.

Tissue biopsy and aspiration

1. Scolices and brood capsules may be demonstrated in the fluid aspirated from hydatid cyst.
2. Amastigote forms of *L. donovani* may be demonstrated inside the reticuloendothelial cells in the aspirates of spleen, bone marrow, liver and lymph nodes.
3. Larvae of *T. spiralis, T. solium* and *T. multiceps* may be demonstrated in the muscle biopsy.
4. Trophozoites of *G. lamblia* may be demonstrated in the bile aspirated from duodenum by intubation.
5. Trophozoites of *E. histolytica* may be demonstrated in pus aspirated from amoebic liver abscess and in the necrotic tissue obtained from the base of the ulcers in the large intestine.

Culture

Some parasites like *Entamoeba histolytica, Naegleria fowleri, Acanthamoeba* spp., *Balamuthia mandrillaris, Leishmania* spp., *Trypanosoma* spp., *Trichomonas vaginalis, Giardia lamblia* and *Balantidium coli* can be cultured in the laboratory. Cultures of parasites grown in association with an unknown microbiota are referred to as **xenic cultures**. A good example of this type of culture is stool specimens cultured for *E. histolytica*. If the parasites are grown with a single known bacterium, the culture is referred to as **monoxenic**. An example of this type of culture is clinical specimen cultured with *Escherichia coli* as a means of recovering species of *Acanthamoeba* and *Naegleria*. If parasites are grown as pure culture without any bacterial associate, the culture is referred to

as **axenic**. An example of this type of culture is the use of media for isolation of *Leishmania* spp. or *Trypanosoma cruzi*.

Animal Inoculation

Animal inoculation is a sensitive means of detecting infection caused by blood and tissue parasites such as *Toxoplasma gondii, Trypanosoma brucei gambiense, T. b. rhodesiense, T. cruzi*, and *Leishmania* spp.

Xenodiagnosis

The technique of xenodiagnosis employs the use of laboratory-raised arthropod vectors to detect low levels of parasites in infected individuals. Classically, this approach was used to diagnose Chagas' disease by allowing an uninfected reduviid bug to feed on an individual suspected of having the disease. Subsequently, the bug was dissected and examined microscopically for the evidence of developmental stages of *T. cruzi*. This technique may be used in endemic areas.

Immunodiagnosis

Immunological tests are of two types:

1. Skin tests.
2. Serological tests.

Skin tests

These tests are performed by intradermal injection of parasitic antigens and are read as under:

1. ***Immediate hypersensitivity reaction:*** It reveals wheal and flare response within 30 minutes of intradermal injection. This reaction is seen in cases of hydatid disease, filariasis, schistosomiasis, ascariasis and strongyloidiasis.
2. ***Delayed hypersensitivity reaction:*** It reveals erythema and induration after 48 hours of injection. This reaction is seen in cases of leishmaniasis, trypanosomiasis, toxoplasmosis and amoebiasis.

Serological tests

These tests detect antibodies or antigens in the patient serum and other clinical specimens (Table 1.4).

Molecular biological methods

These include DNA probes and polymerase chain reaction (PCR).

DNA probes

DNA probe is a radiolabelled or chromogenically labelled piece of single-stranded DNA complementary to a segment of parasitic genome and unique to a particular parasitic strain, species and genus. Specific probe is added to the clinical specimen. If the specimen contains the parasitic DNA, probe will hybridize with it which can be detected. DNA probes are available for the detection of the infection with *P. falciparum, W. bancrofti, T. b. gambiense, T. b. rhodesiense, T. cruzi* and *Onchocerca* spp.

Table 1.4: Important serological tests used for the diagnosis of parasitic infections

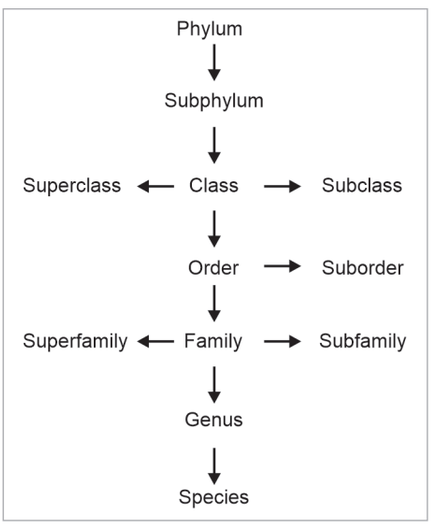
Test	*Applications*
Enzyme-linked immuno-sorbent assay and radio-immunoassay	Toxoplasmosis, toxocariasis, leishmaniasis, Chagas' disease, malaria and schistosomiasis
Indirect haemagglutination test	Amoebiasis, hydatid disease, filariasis, cysticercosis and strongyloidiasis
Indirect fluorescent antibody test	Amoebiasis, malaria, toxoplasmosis and schistosomiasis
Complement fixation test	Paragonimiasis, Chagas' disease and leishmaniasis
Agglutination tests • Direct agglutination • Bentonite flocculation	 Visceral leishmaniasis Trichinellosis and hydatid disease

Polymerase chain reaction (PCR)

PCR is a DNA amplification system that allows molecular biologist to produce microgram quantities of DNA from picogram amounts of starting material. It has been employed for the diagnosis of infections caused by *Giardia lamblia, Entamoeba histolytica, Plasmodium falciparum, Leishmania donovani, Toxoplasma gondii, Trichomonas vaginalis, Cryptosporidium parvum*, etc.

CLASSIFICATION OF PARASITES

Human parasites are classified within four eukaryotic kingdoms – Protozoa, Stramenopila, Fungi and Animalia (Tables 1.5 and 1.6). Kingdom is the highest taxonomic category. It is subdivided as follows:



NOMENCLATURE OF PARASITES

It refers to the naming of parasites. Each parasite possesses a generic and a specific name. The genus name is capitalized followed by species name which is not capitalized. Both the genus and species are italicized. Often the genus name is abbreviated by using the first letter of the genus followed by a period and the full species name, which is never abbreviated, such as *A. lumbricoides, E. histolytica*.

Traditionally, parasite classification has taken into account the morphology of intracytoplasmic structures, such as the nucleus, the type of locomotive organelles, and the mode of reproduction. The Protozoa and Stramenopila are animals whose life functions occur in a single cell. The microsporidians are also single-celled organisms and were previously classified among the protozoans; however, they are now thought to be more closely related to fungi than to Protozoa and have been reclassified with the Fungi (Table 1.5). The members of the kingdom Animalia (Table 1.6), also known as metazoans, are multicellular animals in which the life functions occur in cellular structures organized as tissue and organ systems.

Table 1.5: Classification of medically important unicellular parasites

Kingdom	*Phylum*	*Class*	*Order*	*Parasites*
Protozoa	Metamonada	Trepomonadea (intestinal flagellates)	Diplomonadida Enteromonadida	*Giardia lamblia* *Enteromonas hominis*
		Retortamonadea	Retortamonadida	*Chilomastix mesnili*, *Retortamonas intestinalis*
	Parabasala (flagellates)	Trichomanadea (intestinal and related flagellates)	Trichomonadida	*Dientamoeba fragilis*, *Trichomonas vaginalis*, *T. hominis*, *T. tenax*
	Percolozoa (flagellates)	Heterolobosea	Schizopyrenida	*Naegleria fowleri*
	Euglenozoa (flagellates)	Kinetoplastidea (Kinetoplastid flagellates)	Trypanosomatida	*Lesishmania donovani*, *L. infantum*, *L. major*, *L. tropica*, *L. braziliensis*, *L. mexicana*, *L. aethiopica*, *L. peruviana*, *L. chagasi*, *Trypanosoma brucei gambiense*, *T. b. rhodesiense*, *T. cruzi*, *T. rangeli*
	Amoebozoa (amoebae)	Amoebaea (amoebae)	Acanthopodida	*Acanthamoeba castellanii*, *A. culbertsonii*, *A. polyphaga*, *Balamuthia mandrillaris*
		Entamoebidea (intestinal amoebae)	Euamoebida	*Entamoeba histolytica*, *E. coli*, *E. dispar*, *E. hartmanni*, *E. gingivalis*, *E. polecki*, *Endolimax nana*, *Iodamoeba bütschlii*
	Sporozoa (sporozoans)	Coccidea	Eimeriida	*Cryptosporidium parvum*, *C. hominis*, *C. felis*, *C. meleagridis*, *C. canis*, *C. muris*, *Toxoplasma gondii*, *Cyclospora cayetanensis*, *Cytoisospora belli*, *Sarcocystis hominis*, *S. lindemanni*, *S. suihominis*
			Piroplasmida	*Babesia microti*, *B. divergens*, *B. bovis*
			Haemosporida	*Plasmodium vivax*, *P. falciparum*, *P. malariae*, *P. ovale*, *P. knowlesi*
	Ciliophora (ciliates)	Litosmomatea	Vestibuliferida	*Balantidium coli*
Stramenopila	Bigyra	Blastocystea		*Blastocystis hominis*
Fungi	Microspora (microsporidians)	Microsporea	Microsporida	*Encephalitozoon cuniculi*, *E. hellem*, *E. intestinalis*, *Enterocytozoon bieneusi*, *Microsporidium ceylonensis*, *Nosema ocularum*, *Pleistophora ronneafiei*, *Trachipleistophora hominis*, *T. anthrophthera*, *Vittaforma corneae*, *Anncaliia* (formerly *Brachiola*) *algerae*, *A. connori*, *A. vesicularum*

Table 1.6: Classification of medically important parasites of kingdom Animalia

Phylum	*Class*	*Superfamily*	*Family*	*Parasites*
Nemathelminthes (roundworms)	Adenophorea	Trichinelloidea	Trichinellidae	*Trichinella spiralis*
			Trichuridae	*Trichuris trichiura, Capillaria philippinensis, C. aerophila, C. hepatica*
	Secernentea (Phasmidea)	Ancylostomatoidea	Ancylostomatidae	*Ancylostoma duodenale, A. braziliense, A. caninum, A. ceylanicum, Necator americanus*
		Ascaridodiea	Ascarididae	*Ascaris lumbricoides, A. suum, Toxocara canis, T. catis*
			Anisakidae	*Anisakis simplex*
		Dracunculoidea	Dracunculidae	*Dracunculus medinensis*
		Filariodea	Onchocercidae	*Wuchereria bancrofti, Brugia malayi, B. timori, Loa loa, Onchocerca volvulus, Dirofilaria immitis, D. repens, D. tenuis, D. ursi, Mansonella ozzardi, M. perstans, M. streptocerca*
		Gnathostomatoidea	Gnathostomatidae	*Gnathostoma spinigerum*
		Oxyuroidea	Oxyuridae	*Enterobius vermicularis, E. gregorii*
		Rhabditoidea	Strongyloididae	*Strongyloides stercoralis*
		Strongyloidea	Chabertiidae	*Oesophagostomum bifurcum, O. aculeatum, Ternidens derminutus*
		Thelazioidea	Thelaziidae	*Thelazia callipaeda*
		Trichostrongyloidea	Trichostrongylidae	*Trichostrongyloides colubriformis, T. orientalis*
			Dioctophymatidae	*Dioctophyma renale*
Platyhelminthes	Digenea (Trematoda, flukes)		Schistosomatidae	*Schistosoma haematobium, S. japonicum, S. mansoni, S. mekongi, S. intercalatum*
			Fasciolidae	*Fasciola hepatica, F. gigantica, Fasciolopsis buski*
			Gastrodiscidae	*Gastrodiscoides hominis, Watsonius watsoni*
			Heterophyidae	*Heterophyes heterophyes, Metagonimus yokogawai*
			Opisthorchidae	*Clonorchis sinensis, Opisthorchis felineus, O. viverrini*
			Paragonimidae	*Paragonimus westermani*
	Cestoidea (Cestoda, tapeworms)		Diphyllobothriidae	*Diphyllobothrium latum*
			Dipylidiidae	*Dipylidium caninum*
			Hymenolepididae	*Hymenolepsis nana, H. diminuta*
			Taeniidae	*Taenia solium, T. saginata, T. asiatica, T. multiceps, Echinococcus granulosum, E. multilocularis, E .vogeli, Multiceps multiceps*

Further Reading

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Important Question

Write short notes on:

(a) Parasite
(b) Host
(c) Host–parasite relationships
(d) Sources of infection of parasites
(e) Portal of entry of parasites
(f) Pathogenicity of parasitic infections
(g) Immunity in parasitic infections
(h) Laboratory diagnosis of parasitic infections
(i) Classification of parasites

Multiple Choice Questions

1. Which type of vector of malaria parasite is female *Anopheles* mosquito?
   (a) Mechanical
   (b) Propagative
   (c) Cyclo-developmental
   (d) Cyclo-propagative

2. Blood-sucking insects may transmit:
   (a) *Ancylostoma duodenale*
   (b) *Ascaris lumbricoides*
   (c) *Wuchereria bancrofti*
   (d) *Strongyloides stercoralis*

3. Crab may transmit:
   (a) *Diphyllobothrium latum*
   (b) *Clonorchis sinensis*
   (c) *Paragonimus westermani*
   (d) *Enterobius vermicularis*

4. Undercooked pork may act as a source of:
   (a) *Taenia solium*
   (b) *Taenia saginata*
   (c) *Diphyllobothrium latum*
   (d) *Ancylostoma duodenale*

5. Which of the following parasites is transmitted by cat?
   (a) *Balantidium coli*
   (b) *Toxoplasma gondii*
   (c) *Echinococcus granulosus*
   (d) *Toxocara canis*

6. Which of the following parasites is transmitted by dog?
   (a) *Echinococcus granulosus*
   (b) *Hymenolepis nana*
   (c) *Taenia solium*
   (d) *Diphyllobothrium latum*

7. Which of the following parasites may be transmitted congenitally?
   (a) *Toxoplasma gondii*
   (b) *Wuchereria bancrofti*
   (c) *Entamoeba histolytica*
   (d) *Giardia lamblia*

8. Parasite which may be transmitted by sexual contact is:
   (a) *Trichomonas vaginalis*
   (b) *Trypanosoma cruzi*
   (c) *Leishmania donovani*
   (d) *Enteromonas hominis*

9. Parasite transmitted by percutaneous route is:
   (a) *Entamoeba histolytica*
   (b) *Giardia lamblia*
   (c) *Babesia* spp.
   (d) *Naegleria fowleri*

10. Pernicious anaemia is seen in:
    (a) Diphyllobothriasis (b) Malaria
    (c) Hookworm disease (d) Filariasis

11. Cholangiocarcinoma is associated with:
    (a) *Clonorchis sinensis*
    (b) *Schistosoma haematobium*
    (c) *Paragonimus westermani*
    (d) *Fasciola hepatica*

12. Which of the following parasites can be demonstrated in blood film?
    (a) *Naegleria fowleri*
    (b) *Leishmania donovani*
    (c) *Endolimax nana*
    (d) *Entamoeba histolytica*

13. Which of the following parasitic eggs is excreted in urine?
    (a) *Schistosoma haematobium*
    (b) *Schistosoma japonicum*
    (c) *Schistosoma mansoni*
    (d) *Clonorchis sinensis*

14. Trophozoites of *Naegleria fowleri* can be demonstrated in:
    (a) CSF (b) Blood
    (c) Stool (d) Urine

15. Larvae of which of the following parasites can be demonstrated in muscle biopsy?
    (a) *Trichinella spiralis*
    (b) *Dracunculus medinensis*
    (c) *Wuchereria bancrofti*
    (d) *Brugia malayi*

16. Animal inoculation is **not** useful for detection of:
    (a) *Toxoplasma gondii*
    (b) *Babesia* spp.
    (c) *Leishmania donovani*
    (d) *Trichomonas vaginalis*

17. A parasite that must spend at least part of its life cycle on or in a host is called:
    (a) Facultative parasite
    (b) Hyperparasite
    (c) Obligate parasite
    (d) Pathogenic parasite

18. Parasites may damage their host's body by:
    (a) Taking nutrients from the host
    (b) Triggering inflammatory response
    (c) Causing internal haemorrhages
    (d) All of these

19. Large parasites, such as helminths, are most likely attacked by:
    (a) Neutrophils (b) Eosinophils
    (c) Basophils (d) Platelets

20. A host which harbours the larval or asexual stage of a parasite is known as:
    (a) Definitive host
    (b) Intermediate host
    (c) Reservoir host
    (d) Paratenic host

21. A host which harbours adult parasite or where parasite replicates sexually is known as:
    (a) Definitive host
    (b) Intermediate host
    (c) Reservoir host
    (d) Paratenic host

Answers

1. d **2.** c **3.** c **4.** a **5.** b **6.** a **7.** a **8.** a **9.** c **10.** a **11.** a **12.** b
13. a **14.** a **15.** a **16.** d **17.** c **18.** d **19.** b **20.** b **21.** a