Epidemiology of Parasitic Infections

Vijaya Lakshmi Nag and Jitu Mani Kalita

Learning Objectives

1. To have an idea about the types of parasites and their hosts.
2. To review the epidemiological characteristics including transmission and geographic distribution and burden of parasitic infections.
3. To know about the basic principles of prevention and control of parasitic infections.

similar characteristics associated with the disease conditions, especially in people from low socioeconomic strata of the society. Social, geographical, economic, and political factors contribute to those conditions. Human behavior has an important role in the epidemiology of emerging or re-emerging parasitic diseases. Changes in demography and environmental alteration, climate change, technology, and land use favor the emergence and spread of parasitic diseases. This chapter outlines the generic concepts of the three cornerstones of epidemiology, namely, the agent, the host, and the environment. The global burden of infection and the general principles of surveillance, prevention, and control have also been described.

Introduction

The word *epidemiology* comes from the Greek words *epi*, meaning on or upon; *demos*, meaning people; and *logos*, meaning study. In the context of parasitic diseases, epidemiology is the study of any parasitic disease and disease-causing agent at the population level. The patterns of distribution and prevalence of the disease and the factors responsible for these patterns are the key points of epidemiological studies. The prevention and control of parasitic disease also constitute important components of epidemiology. Parasitic diseases have biological diversity and have

The Symbiosis

The coexistence of two living beings in close proximity has been described as symbiosis. The nature of interaction between these two living beings may differ, which may or may not be beneficial for one of them. Thus, a symbiotic relationship can be classified into three types as mentioned below:

1. **Mutualism**: It is an obligatory relationship, since neither of the partners can survive without the other. In this type of relationship, both the partners benefit from each other. This type of relationship is more common in nature and can be demonstrated, for example, between

V. L. Nag (✉) · J. M. Kalita
All India Institute of Medical Sciences, Jodhpur, India

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leeches and their gut bacteria and between termites and their intestinal flagellate protozoan partners. Filarial nematodes like *Wuchereria bancrofti* harbour the bacteria of the genus *Wolbachia*. Although the nature of metabolic dependence between the nematode and bacteria is not exactly known, it has been demonstrated that treatment with tetracyclines not only kills the bacteria but also causes simultaneous death of the nematode parasite.

2. **Commensalism**: It is a type of relationship in which one partner benefits but the other partner is neither benefitted nor harmed. Humans and animals are populated with a large number of bacteria as well as several protozoans which behave as commensals. For example, *Entamoeba gingivalis* lives in the mouth and feeds on food particles and dead cells without harming the human partner.
3. **Parasitism**: In this relationship, the parasite lives at the expense of the other who is termed the *host*. This kind of partnership is harmful for one partner. The *parasite* can inflict mechanical injury to the host, which in turn causes inflammatory and/or immune damage to the tissue; or else the parasite can deprive the host of essential nutrients.

The Parasite

Parasites are broadly divided into *endoparasites* and *ectoparasites*, depending on whether they reside inside the host or on the surface of the host. They are classified as follows:

1. **Obligate Parasite**: Obligate parasites are those which cannot exist without a host. In contrast to free-living parasites which can exist in nature without depending on any host, an obligate parasite lives in the host to complete its life cycle. During some stage of their life cycle, they may behave as free-living entities in water or soil, but they cannot survive for long outside a living host. The majority of pathogenic parasites are obligate parasites such as malaria parasites, *Toxoplasma*, and various helminths.
2. **Facultative Parasite**: Facultative parasites have both parasitic and free-living existence depending on the situation. Usually, these parasites are free living in nature, but if they gain access to the body, they cause harmful effects in the infected host. The free-living amoebae such as *Naegleria fowleri* or *Acanthamoeba* spp. or free-living nematode *Micronema* are a few examples of such parasites.
3. **Accidental/Incidental Parasite**: Parasites that infect an unusual host are called accidental parasites. These parasites enter the body of an unusual host, which is different from the normal host. In this unusual host, the parasite can develop to some extent, but complete development of the parasite is not possible. For example, *Echinococcus granulosus* causes hydatid cyst in humans, which is not the natural host for the parasite.
4. **Aberrant Parasites**: They are also called wandering parasites, and when they enter a host that is different from their natural host, they reach a site where they cannot live or develop further. *Toxocara canis* is a natural parasite of dogs, but when it enters the human body, its further development stops.

The Host

A host is a living being which harbours the parasite and provides shelter and nutrition. Hosts may be humans, animals, birds, or insects. Hosts, on the basis of their part in the life cycle of the parasite, are classified into the following groups:

1. **Definitive Host**: Hosts in which parasites reproduce sexually or which harbor the most highly developed form of the parasite or adult stage are called definitive hosts. Humans, animals, and even arthropods can act as definitive hosts. For example, humans are the

definitive hosts for many helminths including *Ascaris* or hookworm, while mosquitoes are the definitive hosts for malaria parasites. In many infections transmitted from animals, vertebrates such as dogs, cats, cattle, etc. act as definitive hosts.

2. **Intermediate Host**: Hosts which harbor the larval forms or in which the parasites replicate asexually are called intermediate hosts. The larval developments of some of the parasites in their life cycle are completed in two different hosts; these are then referred to as first and second intermediate hosts. For example, snails are the first intermediate hosts and cray fish and freshwater crabs are the second intermediate hosts for *Paragonimus westermani*. Humans also serve as intermediate hosts, as seen with malaria parasites.
3. **Paratenic/Transport Host**: A host in which the parasite does not undergo any development but the larval form remains viable is called a paratenic or transport host. Such hosts may act as a bridge between the definitive and the intermediate host and help in transporting or transmitting the parasites. A paratenic host is more of an ecological than a physiological phenomenon. Under extreme environmental conditions, the transmission of parasites may be facilitated by these paratenic hosts. For example, freshwater shrimp, flatworms, and frogs act as paratenic hosts for *Angiostrongylus cantonensis*.
4. **Accidental Host:** Hosts in which a parasite is not normally found but where the parasite may undergo some developmental changes are defined as accidental hosts. These are normally dead-end hosts and further transmissions to other hosts do not take place. For example, humans are the accidental hosts for cattle eye worm (*Thelazia gulosa*).
5. **Reservoir Host:** These Hosts which harbor a parasite for a long time but do not suffer from any disease and serve as the source of infections are called reservoir hosts. For example, dogs and other canines are the reservoir hosts for *Leishmania infantum*.

Parasitic Zoonoses

The term **zoonosis** refers to an infection that is transmissible under natural conditions from animals to humans. Parasitic zoonoses are of four types:

1. **Direct zoonoses**: This is characterized by direct transmission of parasites from animals to humans. *Cryptosporidium parvum*, *Toxoplasma gondii*, *Hymenolepis nana*, and *Trichinella spiralis* are a few examples of such parasites.
2. **Meta-zoonoses**: This is characterized by transmission of parasites to humans, mediated by invertebrate intermediate hosts. *Babesia bovis*, *Plasmodium spp*., and *Clonorchis sinensis* are examples of parasites which cause meta-zoonoses.
3. **Cyclo-zoonoses**: This is characterized by transmission of parasites to humans mediated by the vertebrate intermediate hosts. Examples include *Echinococcus granulosus*, *Taenia* spp., and *Sparganum* spp.
4. **Sapro-zoonoses**: Human infections are transmitted from the soil or water and include *Ancylostoma caninum*, *Ascaris suum*, *Capillaria hepatica*, and *Trichuris vulpis*.

Sources of Infections

The source of an infection is the origin from which the infective form of the parasite enters the host. For human infections, the source may be animate (e.g., humans, animals, birds, crustaceans) or inanimate (air, water, or soil).

Humans

Humans do not act as the most important source of zoonotic parasitic infections, in contrast to other infectious disease. Human-to-human parasitic infection, known as anthroponoses, occurs in certain parasitic infections such as mother-to-fetus infection in toxoplasmosis or autoinfections seen in pinworm disease or in strongyloidosis.

Animals

Humans acquire zoonotic parasitic infections transmitted from animals in various ways. They may get the infection by consumption of meat from infected animals or from intermediate hosts or by biological vectors such as mosquitoes which can transfer the infective forms of the parasite to humans. Cattle, dogs, cats, pigs, and fish are some of the most important animal sources of infection. Pigs remain the most important source of *Balantidium coli*, *Taenia solium*, *Trichinella* spp., etc. Human infections associated with eating walrus meat or polar bear meat infected with *Trichinella nativa* have been observed in the Arctic region.

Wild animals like antelopes, bears, elephants, etc. may be sources of certain zoonotic parasitic infections (e.g., *Trypanosoma evansi*, *Cryptosporidium* spp., *Trichinella* spp., gastrointestinal *Strongyloides*). *Trichinella papuae* has been implicated in outbreaks of human trichinellosis in Thailand after eating wild boar meat. Fish and crabs, particularly undercooked, are important sources of clonorchiasis and paragonimiasis, respectively, in humans.

Arthropod Vectors

Arthropods act as intermediate hosts, as well as definitive hosts, to transfer parasitic infections human-to-human, animal-to-human, and animal-to-animal. Most of them are true or biological vectors inside which the parasite undergoes some multiplication or developmental changes. Sandflies transfer promastigotes of *L. donovani* through human-to-human anthroponotic infection in the Indian subcontinent, while *Anopheles* mosquitoes transmit *Plasmodium knowlesi* from monkeys to humans. Vectors like houseflies act as mechanical vectors in transferring the agent of amebiasis from human fecal materials to foodstuffs.

Water and Soil

Water and soil, which may get contaminated with human or animal excreta due to poor sanitation, may act as sources for human infections. For example, larval forms of hookworm in the soil or cercariae of schistosomes in water penetrate skin of the host, causing infections. Similarly, ingestion of water contaminated with infected Cyclops containing *Dracunculus medinensis* larvae may result in dracunculiasis. Water is also the main source for free-living amoebae such as *Naegleria fowleri*, causing a serious, often fatal, infection such as amoebic meningoencephalitis in humans. Recreational water (water used for swimming and other activities) illnesses are diseases that are transmitted by swallowing, breathing, or having contact with contaminated water from swimming pools, hot tubs, lakes, rivers, or the ocean. Diarrhea caused by *Cryptosporidium* and *Giardia intestinalis* is an example of such parasites transmitted by contaminated recreational water.

Transmission of Infections

Parasites may be transmitted in a variety of manners, and Table 1 shows the modes of transmission of important parasites. The following is a brief description of the types of transmission:

1. **Food and water transmission:** Numerous parasites are transmitted by a variety of foodstuffs which may include raw or undercooked fish, crabs, and molluscs (*Paragonimus* spp., *Clonorchis* spp., *Diphyllobothrium* spp., *Anisakis* spp., etc.), undercooked meat or meat products (*Toxoplasma* spp., *Taenia* spp., etc.), raw aquatic plants such as watercress, and raw vegetables (*Fasciolopsis* spp., *Fasciola* spp., etc.) that have been infected by the parasite or water contaminated by human or animal feces (*Cryptosporidium* spp., *Giardia* spp., *Echinococcus* spp., etc.).

Table 1 Some important parasites and their route of transmission

Food- and waterborne zoonotic parasites	
Name of parasite	Route of transmission
Entamoeba histolytica	Ingestion
Giardia intestinalis	Ingestion
Balantidium coli	Ingestion
Sarcocystis spp.	Ingestion
Toxoplasma gondii	Ingestion
Cryptosporidium spp.	Ingestion
Microsporidia spp.	Ingestion, inhalation
Naegleria spp.	Ingestion
Fasciolopsis buski	Ingestion
Echinostoma ilocanum	Ingestion
Heterophyes heterophyes	Ingestion
Metagonimus yokogawai	Ingestion
Gastrodiscoides hominis	Ingestion
Taenia solium	Ingestion
Taenia saginata	Ingestion
Echinococcus granulosus	Ingestion
Echinococcus multilocularis	Ingestion
Diphyllobothrium latum	Ingestion
Spargonia spp.	Ingestion
Ascaris spp.	Ingestion
Strongyloides spp.	Skin penetration
Ancylostoma braziliense	Skin penetration
Toxocara spp.	Ingestion
Trichinella spp.	Ingestion
Vector-borne zoonotic parasite	
Leishmania spp.	Sandfly bite
Trypanosoma brucei	Bite of tsetse fly
Trypanosoma cruzi	Reduviid bug
Zoonotic *Plasmodium* spp.	Mosquito bite
Babesia spp.	Tick bite
Dirofilaria spp.	Mosquito bite
Congenital	
Toxoplasma gondii	Transplacental

2. **Vector Transmission:** Vector-borne transmission of parasitic diseases takes place when the parasite enters the host through the saliva of the insect during a blood meal (malaria) or from parasites in the feces of the insect that defecates immediately after a blood meal (Chagas disease). Table 2 lists important vector-borne parasitic infections.
3. **Cutaneous Transmission:** The larvae of certain helminthic parasites are capable of invading the intact skin and can cause infection in distant parts of the body. For example, the infective larvae of hookworm or *Strongyloides* and cercariae of schistosomes larvae enter through skin but lodge in the intestines and other parts of the infected host.
4. **Iatrogenic and Vertical Transmission:** *Babesia* spp., *Plasmodium* spp., *Trypanosoma cruzi*, etc. during their life cycle are found in the blood during the acute phase of illness. These parasites may be transmitted through blood transfusion, if blood samples are not screened for these parasites before transfusing the blood or blood products. Vertical transmission of parasites from mother to fetus is rare but is an important complication of toxoplasmosis if the mother is infected during pregnancy.

Table 2 Important vector-borne parasitic infections

Disease	Parasite	Insect (vector)
African trypanosomiasis (sleeping sickness)	*Trypanosoma brucei gambiense*, *Trypanosoma brucei rhodesiense*	Tsetse flies
Babesiosis	*Babesia microti* and other species	*Babesia microti: Ixodes* (hard-bodied) ticks
Chagas disease	*Trypanosoma cruzi*	Triatomine ("kissing") bugs
Leishmaniasis	*Leishmania* spp.	Phlebotomine sandflies
Malaria	*Plasmodium* spp.	*Anopheles* mosquitoes

Geographical Distribution of Parasites

Geographic distribution of human parasites follows a regular pattern in which a latitudinal gradient of pathogen diversity is seen with low latitudes characterized by high species diversity of human pathogens. This may be surprising since, generally, tropical areas are considered as favoring the prevalence of parasitic diseases (Fig. 1). Various factors may have a bearing on the parasite diversity in a geographic area like age of colonization by humans and population densities. The Palaearctic and Oriental regions were colonized much earlier and reached high population densities, which explains both the diversity and the higher burden of parasites.

Parasitic infections are found worldwide but certain parasites are restricted to particular geographic areas and ecological niches. The distributions of African and American trypanosomiasis are prime examples of restricted occurrences of a particular parasite. The distribution of the causative vectors partly explains this limited prevalence. *Plasmodium knowlesi* is another parasite which has been seen only in Malaysia and in a few neighboring Southeast Asian countries coinciding with the presence of *Macaca fascicularis* and *Macaca nemestrina* monkey species and mosquitoes of the *Anopheles leucosphyrus* group.

Burden of Disease

The global burden of parasitic diseases is estimated to be 96 million disability-adjusted life years in 2015. There has been a decrease in prevalence of a few parasitic infections such as ascariasis, lymphatic filariasis, etc. since 1990, but some other parasitic infections such as leishmaniasis have increased due to conflict and collapsed health systems such as in Syria. The majority of these diseases are closely linked to poverty, especially in rural areas, but urbanization is also facilitating in spread of the disease. Intestinal protozoa are among the most common protozoal infections and top the list with a global burden of 500 million, followed by malaria (228 m), Chagas disease (7.6 m), leishmaniasis (1 m), toxoplasmosis (200,000), and African sleeping sickness (10,000). Except for toxoplasmosis and intestinal protozoal infections, which have global distribution, other parasitic infections are found mostly in Asia, South America, and sub-Saharan Africa in populations living in poverty and in rural areas. Helminthic infections affect almost 1.5–1.7 billion people worldwide, mostly in rural areas of resource-poor parts of the world. Soil-transmitted helminths (1 billion), schistosomiasis (240–400 m), filariasis (160–200 m), and foodborne trematode infections (85 m) are the more important infections in these groups of populations worldwide, although they are mostly prevalent in the continents of Asia, South America, and Africa.

Prevention and Control

Control and prevention of parasitic infections is complex but is essentially based on a multidisciplinary approach. These activities aim to reduce the burden of parasites in the community. These include various strategies including the management of ecology and the environment of the

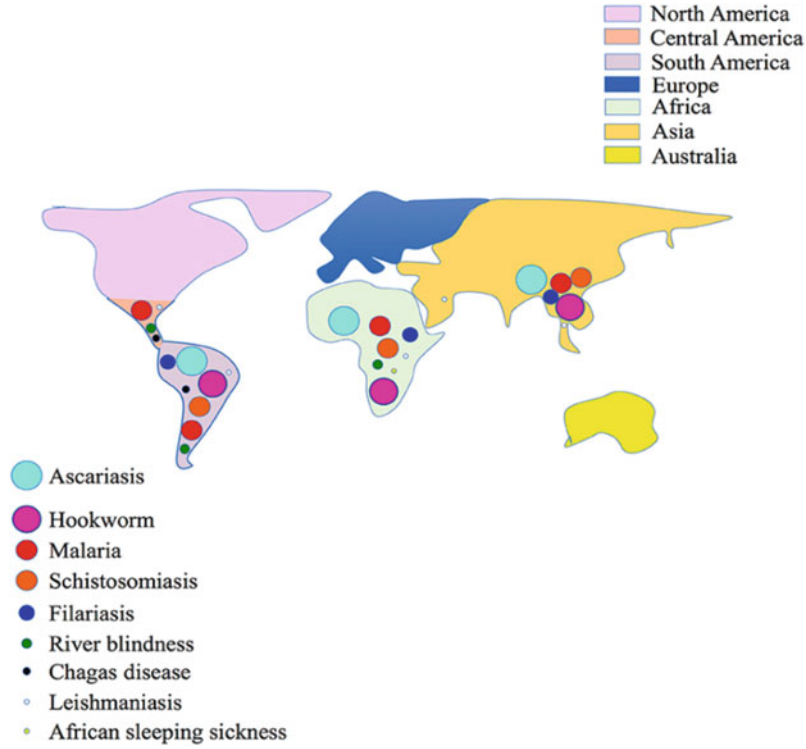

Fig 1 Distribution of important parasitic diseases (Source: Cao B and Guiton P (2018) Important Human Parasites of the Tropics. Front. Young Minds. 6: 58. doi: https://doi.org/10.3389/frym.2018.00058)

region to decrease the parasite load and to halt the transmission risks, and education and behavioral changes of the population at risk, to ensure the success and sustenance of the control and prevention programs.

The various measures can be summarized as follows:

1. **Reduction of Parasite Burden**: Industrialization of pig production with screening measures has considerably reduced the level of *T. spiralis* infection in many European countries, although the practice of organic farming and also the high level of infection in wild boars may reintroduce trichinellosis in these communities. Mass drug treatment in a community has also proven to be of value in reducing the quantum of parasites in a given community.
2. **Animal Reservoir and Vector Measures**: One of the time-tested methods for preventing animal and human infection is education of pet owners and regular deworming of dogs and cats. Health education of pet owners on preventive measures such as personal hygiene, clearing up pet feces regularly, and minimizing exposure of children and pregnant women to the pets and contaminated environment is important. Anthelminthic treatments are most effective when they are initiated early for treatment of young pets. Insecticide-impregnated nets and dog culling have been recommended for control of zoonotic visceral leishmaniasis in a community.
3. **Better Diagnostic Methods:** Availability of economical, rapid, and point-of-care diagnostic tests, such as card test for visceral leishmaniasis and American trypanosomiasis, that are used by minimally trained personnel at the field level facilitates in surveillance and implementation of control measures against parasitic diseases.
4. **Environmental and Ecological Measures:** Geographical information systems, remote sensing, and geostatistics have added new dimensions to the study of the ecology and spatial distribution of parasites, which are key

factors in the control and preventive measures for these parasites. They have been successfully used for schistosomiasis control and have potential for application in areas endemic for a single or multiple parasitic infections.

5. **Human Behavioral and Educational Measures:** An increase in the prevalence of trichinellosis in certain European countries due to the recent increased consumption of raw horse meat is one example that advocates for change in human behavior by initiating several educational activities. The practice of consumption of raw or undercooked fish has been associated with increased incidence of clonorchiasis, opisthorchiasis, metorchiasis, and anisakiasis infection. Both public health personnel and veterinary professionals therefore play a key role in public education for change in human behavior to prevent zoonotic infections.
6. **Financial Resources and International Cooperation:** Effective public health initiatives depend on availability of adequate financial resources for programme implementation and sustenance. The World Health Organization (WHO) has been advocating for implementing integrated disease control programs with primary health care to contain infectious diseases including parasitic diseases. These integrated programs, while operational and successful in developed countries, are not so successful in resource-challenged countries with a higher prevalence of parasitic diseases. Therefore, the involvement of international agencies and institutions, such as the WHO and the Food and Agriculture Organization (FAO), together with the commitment of policymakers, scientists, and field workers is essential for the sustainable control and prevention of parasitic infections.

Case Study

A 37-year-old man attended emergency with complaints of multiple convulsions. CT scan of the brain showed numerous small cystic lesions in both hemispheres. No abnormality was observed in CSF cytology and biochemistry. The patient tested negative for HIV. The patient was a strict vegetarian and gave a history of eating vegetable salad frequently.

Questions

1. What are the parasitic diseases transmitted by consumption of raw vegetables?
2. What precautions should be taken at individual level to prevent this type of infection?
3. What are the preventive measures needed to stop the transmission of such infections?

Research Questions

1. What are reasons for the lack of knowledge regarding the source of infection and control measures for uncommon parasites like *Mammomonogamus*?
2. Is this the right time to relook at the reservoir hosts like dogs for guinea worm disease given the sporadic cases which are being reported from areas where the disease has been eradicated?
3. Is the Indian form of visceral leishmaniasis really an anthroponosis? Is there any reservoir host for *L. donovani*?

Further Readings

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