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Biology Department

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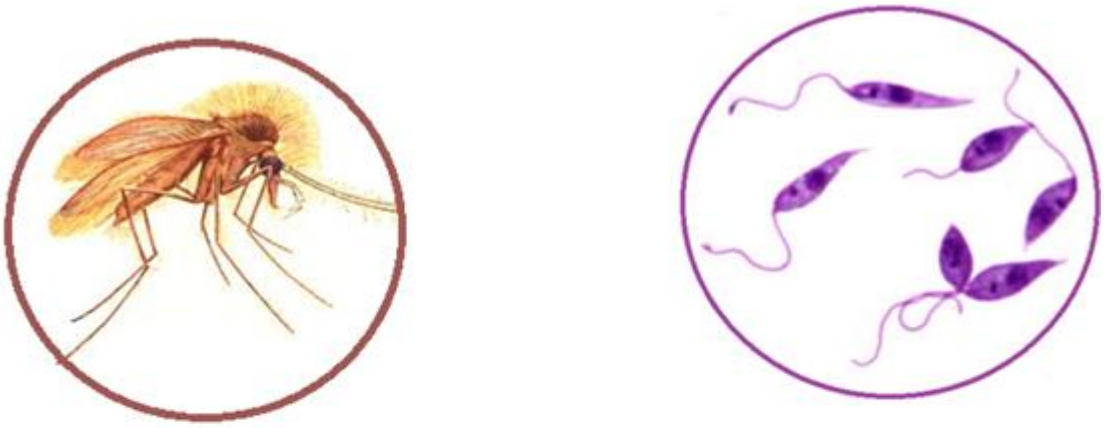

INTRODUCTION TO MEDICAL PARASITOLOGY

Textbook for students
of the English-speaking Medium of Medical University

Stavropol, 2017

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INTRODUCTION TO MEDICAL PARASITOLOGY: Textbook for students of the English-medium department of Medical University (in the English language) / E. N. Makarenko, N. V. Yerina, T. S. Kopteva, T. S. Nikolenko– Stavropol: Publishing house of StSMU, 2017. – 32 p.

The textbook is intended for first year students. In it general questions of parasitology, forms of animal interactions in nature are defined, parasitism as a biological phenomenon is described in detail. Classifications of parasites, their hosts, and carriers are given, influences of a parasite on the organisms of the hosts, adaptations of parasites are discussed, the notion of natural foci diseases is introduced.

There are many illustrations, diagrams and tables in the textbook, which will aid foreign students in preparation for practical lessons and biology examination.

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«Ставропольский государственный медицинский университет»
Министерства здравоохранения Российской Федерации

Кафедра биологии

Макаренко Э.Н., Ерина Н.В., Коптева Т.С., Николенко Т.С.

ВВЕДЕНИЕ В МЕДИЦИНСКУЮ ПАРАЗИТОЛОГИЮ

Учебно-методическое пособие для студентов
англоязычного отделения
медицинского вуза (на английском языке)

Ставрополь, 2017

УДК: 61:576. 6.8 (07)
ББК 52.67я 73

ВВЕДЕНИЕ В МЕДИЦИНСКУЮ ПАРАЗИТОЛОГИЮ: Учебно-методическое пособие для студентов англоязычного отделения медицинского вуза (на английском языке) / Э.Н. Макаренко, Н.В. Ерина, Т.С. Коптева, Т.С. Николенко – Ставрополь: Изд-во СтГМУ, – 2017. – 32 с.

Учебно-методическое пособие предназначено для студентов первого курса. В нем рассматриваются общие вопросы паразитологии, формы животных ассоциаций в природе, подробно описывается паразитизм как биологический феномен. Приводятся классификации паразитов, их хозяев, переносчиков, рассказывается о воздействиях паразита на организм хозяев, приспособлениях паразитов, вводится понятие о природно-очаговых заболеваниях.

Учебно-методическое пособие содержит много иллюстраций, диаграмм и таблиц, что поможет иностранным студентам при подготовке к практическим занятиям и экзамену по биологии.

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Chapter 1: Animal Associations

Introduction

The present work aims to clarify several aspects concerning parasites of medical importance to man. Parasite classification, general characters, biology, ecological factors that affect their transmission, the immune response of the body to invading parasites, diagnosis and control of the disease developed are highlighted.

Forms of symbiosis in nature

Every organism is a part and parcel of nature. Nature is not static. It changes continuously. New changes create new needs for organisms.

The organisms will survive, if only they adapt themselves to the changing conditions. Otherwise, they will perish. Organisms often depend on others for food, shelter, protection and reproduction. This dependency results either in **mutual cooperation** or **mutual antagonism** (Fig. 1). Such relations lead to the emergence of various animal associations. An association is either useful or harmful or neutral to one or both the partners.

In biology, the relationship between two organisms is mainly in the form of **symbiosis**, defined as "life together", i.e., the two organisms live in an association with one another. Thus, there are at least three types of relationships based on whether the symbiont has beneficial, harmful, or no effects on the other (*Todar, 2011*).

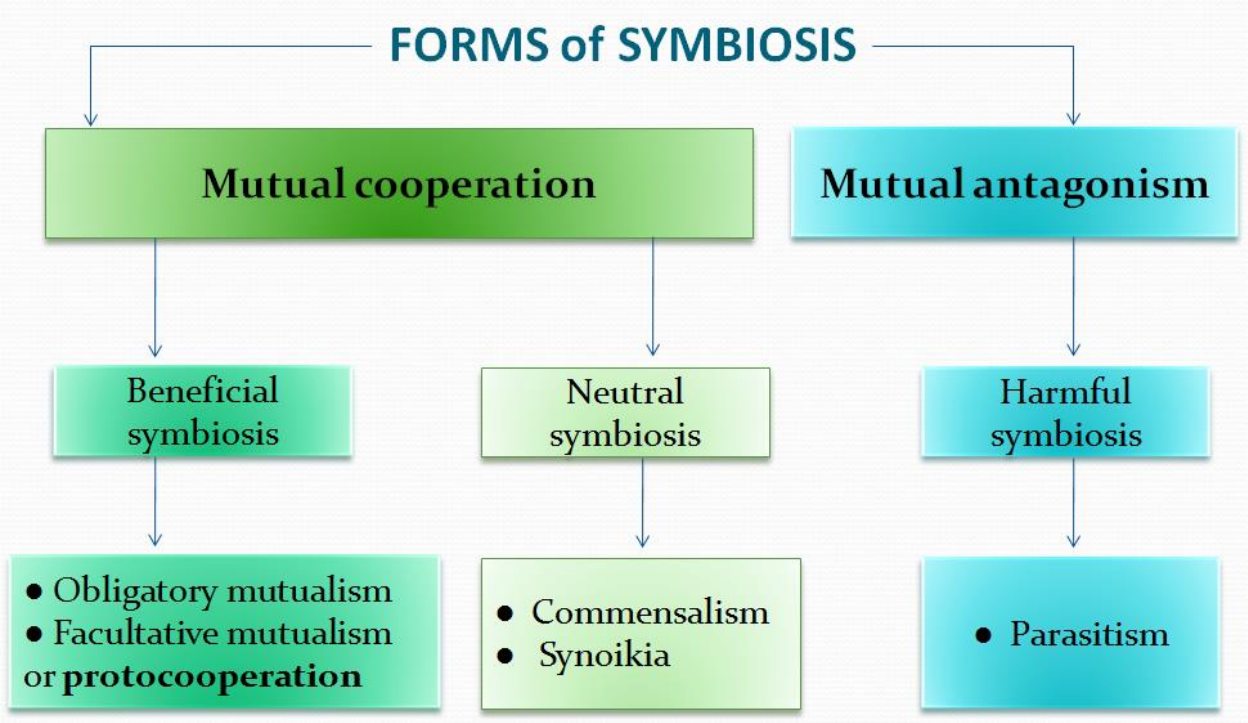


Fig. 1. Animal associations in nature.

Beneficial Associations

Definition: **When two different species of organisms live together and lead a mutually beneficial life, it is called *obligatory mutualism* and *facultative mutualism* (*protocooperation*).** The term, mutualism, is also defined as 'an intimate association' between two different organisms, in which each one derives benefit from the other. The two animal associations, viz., ***obligatory mutualism*** and ***protocooperation*** are defined as synonymous (with the same meaning). However, these two differ slightly from each other.

In **obligatory mutualism** the relationship between the two partners is more intimate than in protocooperation. When the obligatory symbionts are separated from each other, they cannot lead an independent life.

For examples: • Man and bacteria 'Escherichia coli' (Fig. 2) → bacteria live in the large intestine (colon) of man. It receives nourishment, shelter and completes its life cycle in the intestine. The bacteria in turn give protection to the man, because the harmful bacteriae cannot develop in the colon.

Fig. 2. Obligatory mutualism of man and bacteria 'Escherichia coli'.

• Algae and Fungi: another obligatory symbiotic relationship is seen between green alga and a colourless fungus (Fig. 3). They form obligatory symbiotic organisms called lichens. The alga supplies carbohydrates formed during photosynthesis to the fungus. In turn the fungus gives water, mineral salts and protection to the alga. Thus, both are benefited by symbiosis.

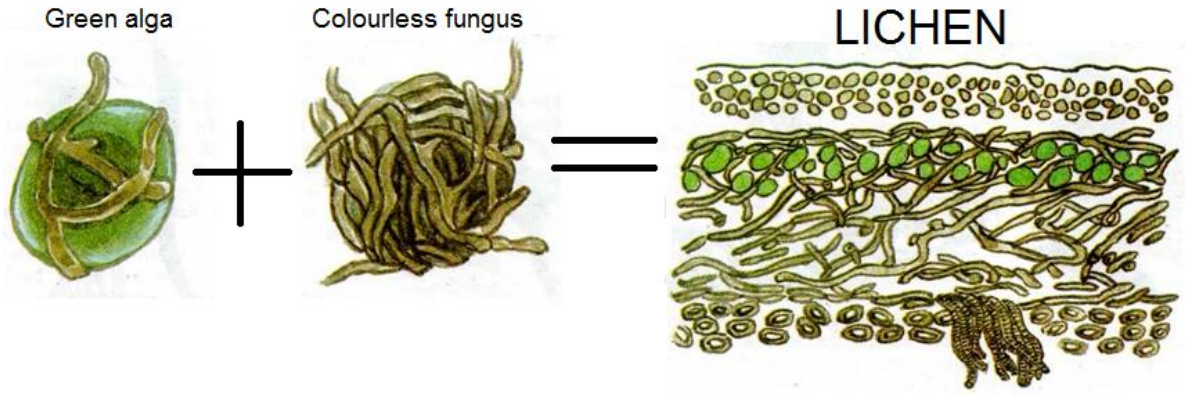


Fig. 3. Lichen as obligatory symbiotic organism.

Mutualism is usually obligatory, since in most cases physiological dependence has evolved to such a degree that one mutual cannot survive without the other (*Swift, 2009*).

• Blood-sucking leeches cannot digest blood, and overcome that by harbouring certain intestinal bacterial species to do the digestion for their hosts.

• At least 20% of insect species, as well as many mites, spiders, crustaceans, and nematodes, are mutually infected with bacteria of genus *Wolbachia* (*Warren, 2003*). Also, filarial nematodes such *Wuchereria bancrofti* and *Onchocerca volvulus* which cause serious human diseases, are mutually infected with *Wolbachia*, and they can be cured of their bacterial infections by treating patients with antibiotics, but the worms die too (*Rajan, 2003*).

On the other hand, the partners of **protocooperation** (**facultative mutualism**) can lead an independent life easily.

For examples: • Hermit crab and Sea anemone.

A coelenterate called sea anemone lives on the external surface of a gastropod shell occupied by an arthropod called hermit crab (Fig. 4). The crab carries sea anemone to different places where food is available. In return, the sea anemone gives protection to hermit crab. As sea anemones are attached to the shell, the crabs are not detected easily by their enemies. Further, due to the presence of cnidoblasts in sea anemone, the enemies will not approach the crab.

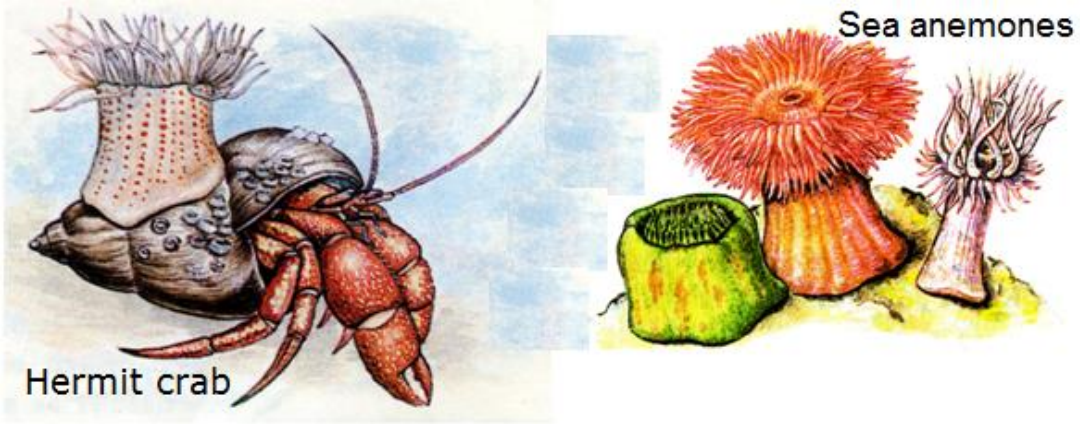


Fig. 4. Facultative mutualism between Hermit crab and Sea anemone.

• Birds and grazing cattle (Fig. 5).

Fig. 5. Birds on back of buffalo as an example of protocooperation.

Several birds are seen sitting on the grazing cattle. They feed on the ectoparasites like ticks, mites and lice on the cattle. They also warn the cattle of ensuing dangers by making different sounds, besides removing the ectoparasites. As these birds feed on the lice, ticks and mites on the body of cattle, they do not need the search of their food.

Neutral Associations

Definition: **When two organisms of different species live together in an association which is beneficial to one and neither beneficial or harmful to the other, it is called *commensalisms* or *synoikia*. In such an association the organism which gives only a place of safety or food and shelter, is called the host. The organism that receives the refuge and nourishment is called as the 'commensal'.**

When organisms live on the external surface of the body of their hosts, they are called 'ectocommensals'. Such an association is called '**ectocommensalism**'.

For examples: ♣ Several protozoans like ciliates and suctorians live as ectocommensals on frogs, fishes, mollusks and arthropods.

♣ Some sedentary animals like ***Hydra, Obelia, Ascidian*** etc. Live as ectocommensals on the shells of several mollusks.

♣ Several snails and barnacles live on the king crab (Fig. 6).

Fig. 6. Snails on the body of crab as an example of ectocommensalism.

On the other hand, certain protozoans, saprophytic bacteria and fungi live in higher plants and in the tissues and cavities of several animals. They are called 'endocommensals'. Such an association is called '**endocommensalism**'.

For examples: ♣ *Entamoeba gingivales* (Fig. 7), protozoan of human mouth is a good examples (shelter is oral cavity; food – bacteria).

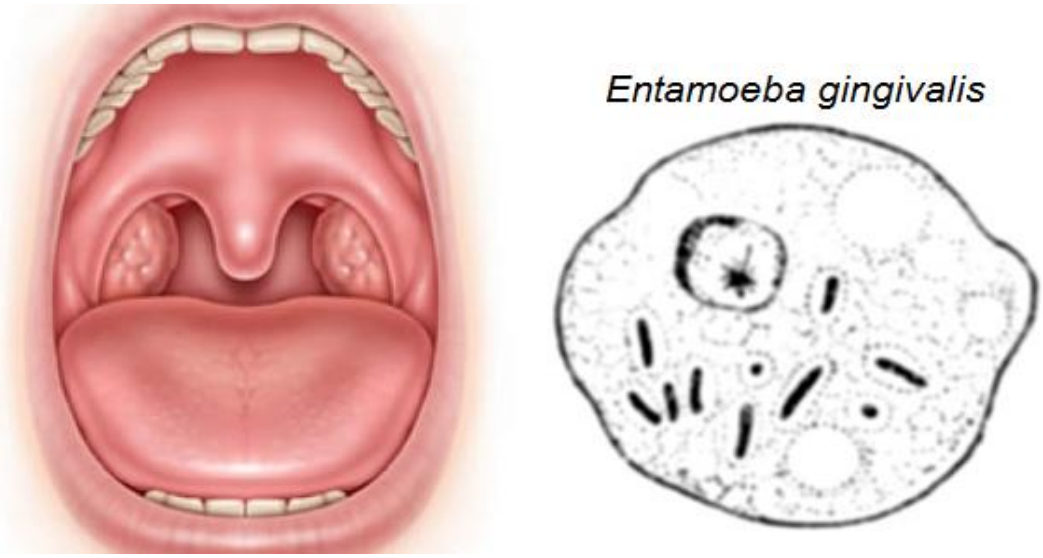


Fig. 7. Entamoeba gingivales as typical endocommensal.

Commensalism may be facultative, in the sense that the commensal may not be required to participate in an association to survive (*Swift, 2009*). Humans harbor several species of commensal protozoans that colonize in the intestinal tract such as *Entamoeba coli, Entamoeba hartmanni, Entamoeba moshkovskii, Entamoeba polecki, Endolimax nana, Iodomoeba butschlii* (*Ortega, 2006*).

When organism receives only shelter, this phenomenon is called as **synoikia**. It is not a continuous and regular process. It occurs intermittently between two organisms.

♣ The sucker fish, ***Echineis*** is temporarily attached to the body of a shark (Fig. 8) and carried to different places.

Fig. 8. The sucker fish on the body of the shark.

♣ Several animals such as frogs, squirrels, monkeys, lizards, snakes, insects, birds (Fig. 9) and others take temporary shelter on plants.

Fig. 9. Owl in a hollow tree.

Parasitism

Definition: **An organism which depends on other organisms for food, shelter, protection and reproduction is called parasite. In this relationship organism that gives shelter is called the host and the organism that receives shelter is called the parasite. The association between a host and a parasite is called *parasitism*.**

In parasitism one of the participants, the parasite, either harms or lives at the expense of the host. Parasites may cause mechanical injury, such as boring a hole into the host or digging into its skin or other tissues, stimulate a damaging inflammatory or immune response. Most parasites inflict a combination of these conditions on their hosts (*Taliaferro, 2009*).

Parasites are different from predators in that the host of a parasite is not necessarily killed. Instead, parasites derive benefits from their hosts, most often nutritional resources and shelter, over a longer period of time. It is in fact advantageous to parasites if they do not harm their hosts too badly, because that prolongs the period during which parasites can obtain benefits from hosts. However, in some cases, the impact of parasites on a host is great enough to cause disease, and in extreme cases, the death of the host may also occur (*Yeh, 2002*).

Classification and General Characters of Human Parasites

The classification of parasites is controversial as there is no universally accepted system.

Parasites form part of the animal kingdom which comprises about 800,000 identified species categorized into 33 phyla.

The most acceptable taxonomic classification of human parasites includes Endoparasites and Ectoparasites.

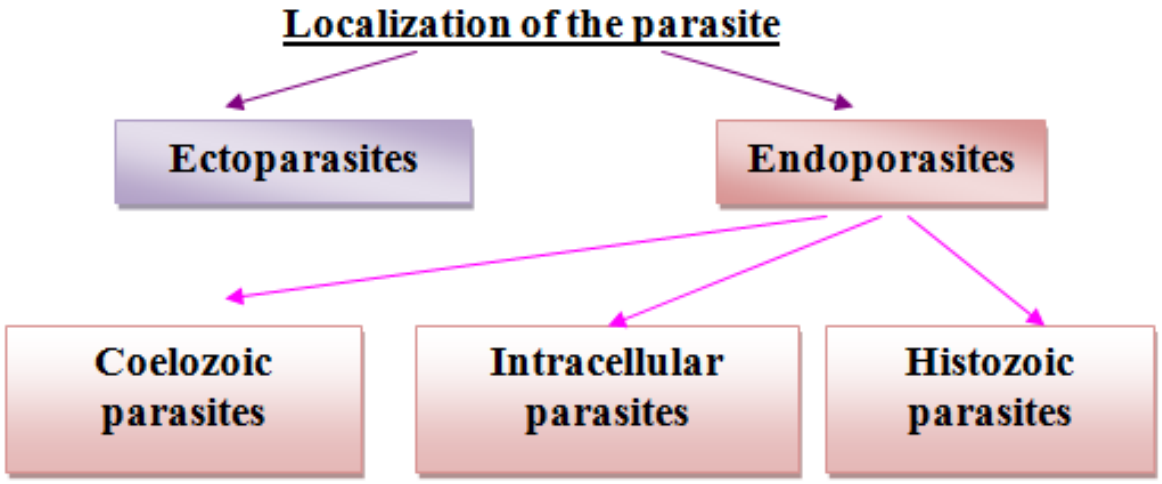


Fig. 10. Classification of parasites according to them localization.

- **Ectoparasites** or **Ectozoa** (Fig. 10)**:** The parasites, which live on the body of the host, are called **ectoparasites** ("ecto" – means outside of). They include fleas, lice, mosquitoes, bugs, mites, ticks etc. In general, ectoparasites attach to the skin to feed and do not remain on the host for their entire lives. For instance head louse lives as an ectoparasite in the hair of man.

Some of these organisms lie in a grey area between endoparasites and ectoparasites: scabies mites, for example, are generally considered ectoparasites though the female scabies mite does burrow into the skin. Fly larvae may feed on dead tissue in a wound, but some species never invade healthy tissue.

- **Endoparasites** or **Entozoa** (Fig. 10)**.** Most parasites of humans live inside the host ("endo" – means internal). These are helminthes (worms of various types), protozoa, or sometimes larval stages of arthropods (insects, mites, etc.)

The parasites, which live inside the body of the host, are called **endoparasites**. These three types are given below.

▸ **Coelozoic parasites:** These parasites live in the cavities of the host body. For example, ***Entamoeba*** and ***Giardia*** live in the lumen of the intestine of a man. Similarly, ***Trichomonas vaginalis*** lives in the vagina of women.

▸ **Intracellular parasites:** These parasites live in the cells of the host. For example, ***Plasmodium*** lives in the red blood corpuscles and liver cells of a man. Similarly ***Leishmania*** lives as an intracellular parasite in the reticulo-endothelial cells of the internal organs of a man.

▸ **Inter-cellular parasites:** These parasites live in the spaces between the cells of tissues or organs of the host body. They are also called as **histozoic parasites**. For instance, ***Trypanosomia gambiense*** resides in the plasma of blood between blood cells.

Endoparasites are sub-classified into Helminthic parasites (multicellular organisms) and Protozoan parasites (unicellular organisms). Helminthic parasites

are either flat worms (Trematodes), segmented ribbon like worms (Cestodes) or cylindrical worms (Nematodes).

Both helminthic and protozoan parasites can infect different tissues and organs of the human body. A great number of endoparasites live in the intestines, or at least pass through the intestines, having been swallowed in food or water. Virtually any organ can be affected, however some parasites like Trichinella spiralis and Toxoplasma gondii live in muscles, larvae of Echinococcus and liver flukes occupy the liver, Schistosoma hematobium targets the urinary bladder and most of the protozoan parasites circulate in blood.

According to the nature of the host-parasite interactions and the environmental factors, the parasite may be one of the following types.

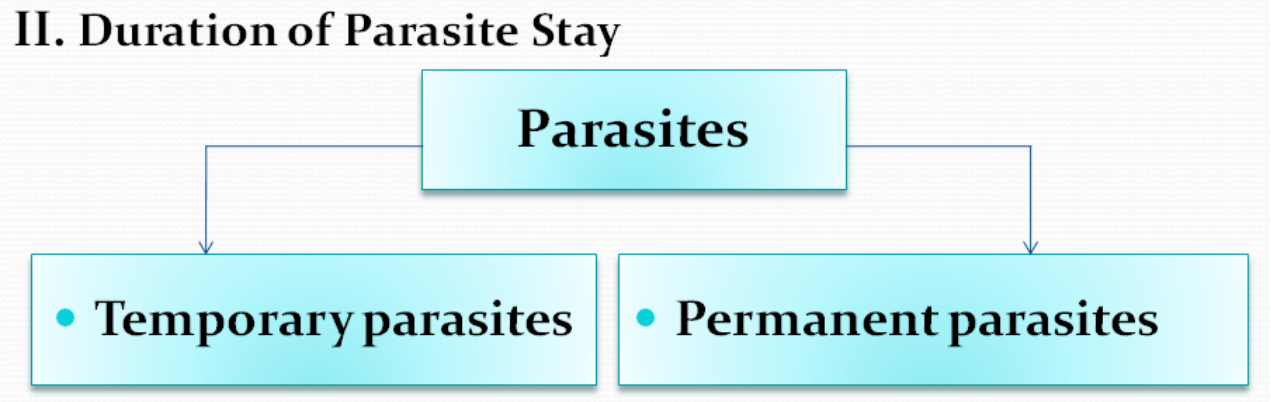


Fig. 11. Duration of stay in host.

- **Temporary parasites** (Fig. 11)**:** A temporary parasite that visits the host only for feeding and then leaves it, e.g. ***Bed bug*** and ***mosquito*** visiting man for a blood meal.
- **Permanent parasites** (Fig. 11)**:** A permanent parasite that lives in or on its host without leaving it, e.g. ***Ascaris*** and ***Taenia solium.***

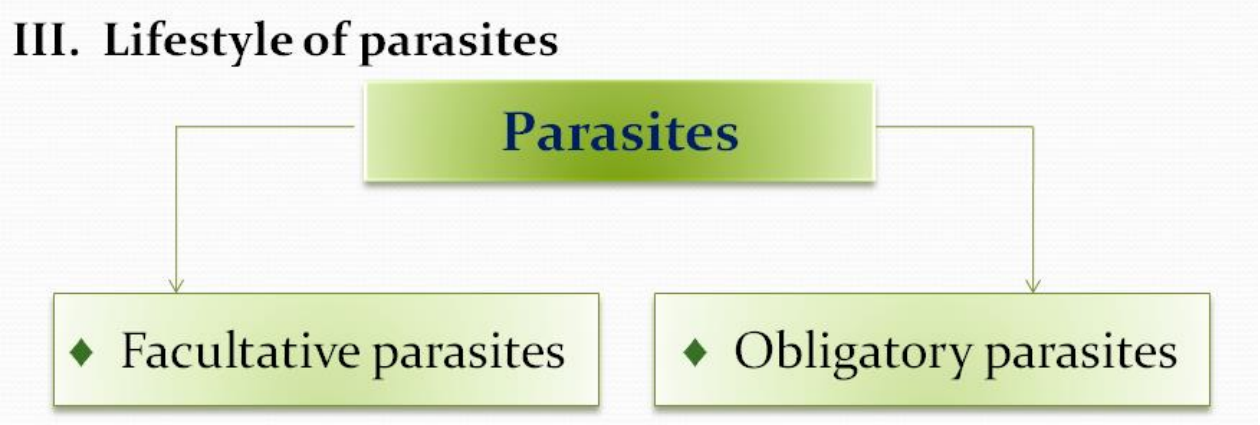


Fig. 12. Classification of parasites according to them mode of life.

- **Facultative parasites** (Fig. 12): A facultative parasite that can change its life style between free-living in the environment and parasitic according to the surrounding conditions. Facultative parasites spend part of their life cycle on the host and part of it independently. For example, ***Naegleria fowleri,*** which causes acute amoebic meningoencephalitis in man, is a facultative parasite.
- **Obligatory parasites** (Fig. 12): An obligatory parasite that is completely dependent on its host and can't survive without it. Obligatory parasites cannot live

independently. Hence they will not leave their hosts. For example ***Taenia solium,*** which lives in the intestine of man, cannot survive if it resides somewhere else.

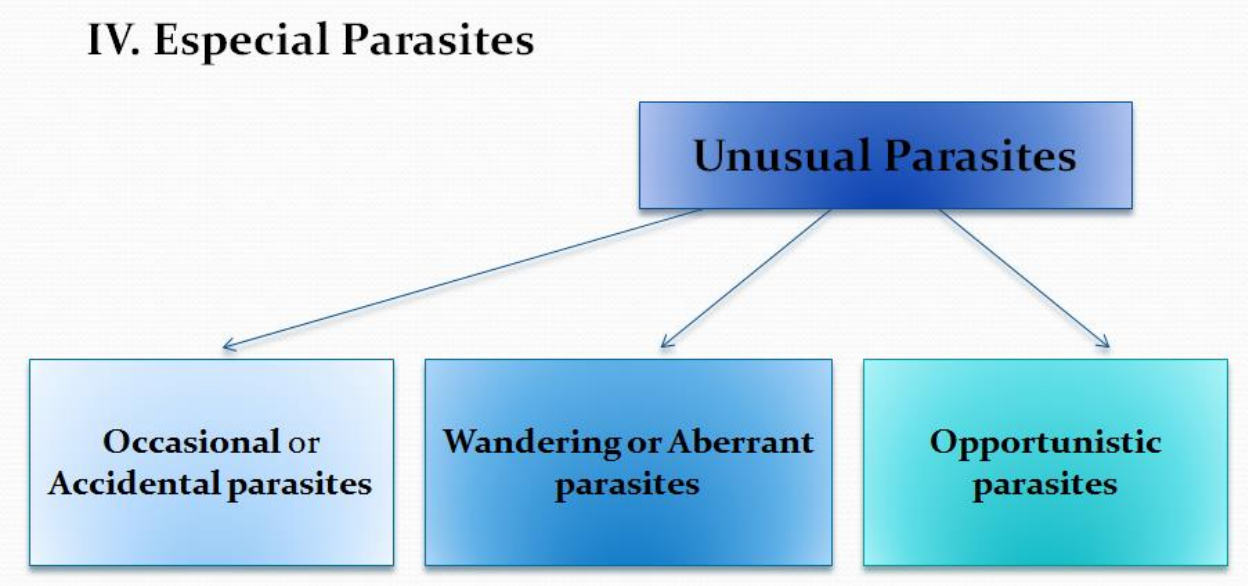


Fig. 13. Strange parasites.

- **Occasional** or **Accidental parasite** (Fig. 13)**:** Attacks an unusual host. For example, ***Dipilidium caninum,*** which uses the man as definitive host, is an occasional parasite. In usual conditions the dog is the usual definitive host.
- **Wandering** or **Aberrant parasite** (Fig. 13)**:** Happens to reach a place where it cannot live. For instance, ***Toxocara canis*** in man may present in larval form (infective egg → migrated larva in internal organs). The complete cycle of development takes place only in the body of dogs: infective egg → migrated larva in lung → adult in small intestine.
- **Opportunistic parasite** (Fig. 13) that is capable of producing disease in an immune deficient host (like AIDS and cancer patients). In the immuno-competent host, it is either found in a latent form or causes a self limiting disease e.g. ***Toxoplasma gondii***.

Types of Hosts

Hosts are classified according to their role in the life cycle of the parasite into (Fig. 14):

► **Primary** or **definitive host (DH):** that harbours the adult or sexually mature stages of the parasite (or in whom sexual reproduction occurs). In the majority of human parasitic infections, man is DH; in malaria and hydatid disease, however, man acts as the IH.

► **Secondary** or **intermediate host (IH):** that harbours larval or sexually immature stages of the parasite (or in whom asexual reproduction occurs), e.g. man is IH of malaria parasites.

In some cases larval developments are completed in two different intermediate hosts.

► **Additional host** is the second intermediary host.

► **Reservoir host (RH)**: that harbours the same species and same stages of the parasite as man. It maintains the life cycle of the parasite in nature and is therefore, a reservoir source of infection for man, e.g. sheep are RH for ***Fasciola hepatica***.

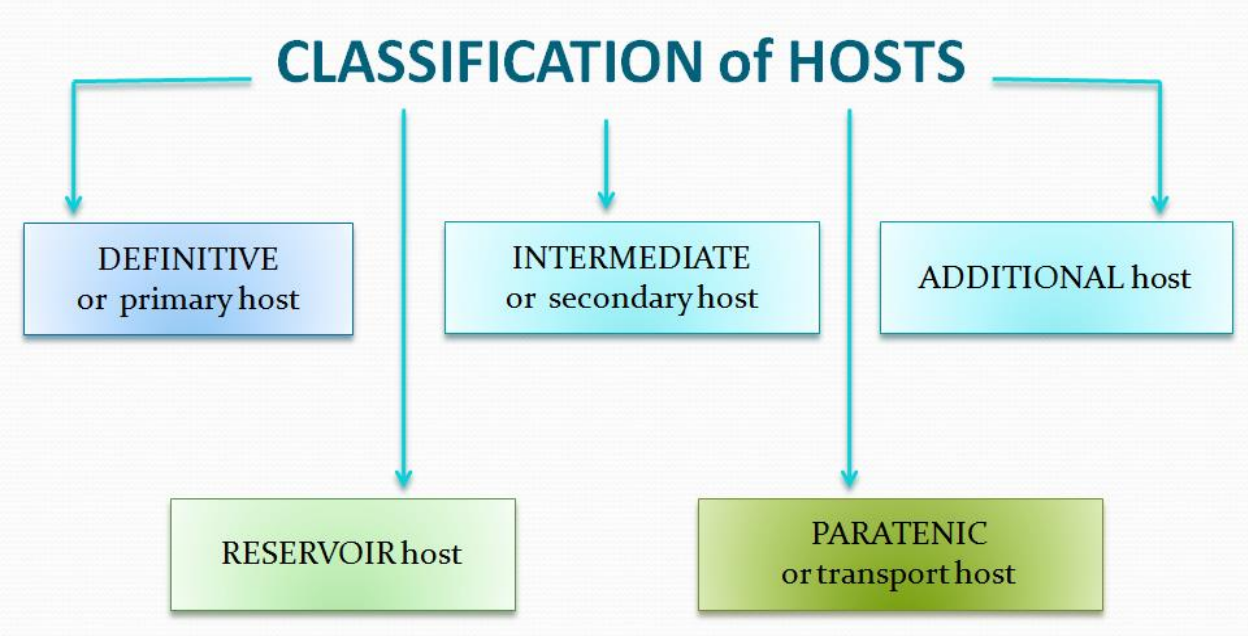


Fig. 14. Hosts of parasite.

► **Paratenic or transport host**: in whom the parasite does not undergo any development but remains alive and infective to another host. Paratenic hosts bridge gap between the intermediate and definitive hosts. For example, dogs and pigs may carry ***hookworm eggs*** from one place to another, but the eggs do not hatch or pass through any development in these animals.

Effects of Parasites on Hosts

1. Parasites utilize the food, tissues, and body fluids of the hosts. Hence the hosts become weak due to the loss of vitality. Further, their growth is retarded.

2. Parasites cause diseases in their hosts. For example malaria, sleeping sickness, schistosomiasis, ancylostomiasis are some dreadful diseases caused by parasites in man. They even lead to the death of the hosts some time.

3. The parasitic infection may contribute to the development of neoplastic growth. For instance *Clonorchis sinensis* and *Opisthorchis viverrini* have been associated with cholangiocarcinoma and *S. haematobium* with vesical carcinoma.

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

5. Parasites cause mechanical injury to the hosts and destroy their body parts. Sometimes they block the passage of food in the host body. For instance Ascaris

blocks small intestine (Fig. 15) and bile ducts in man. Ancylostoma, causes intestinal bleeding by injury.

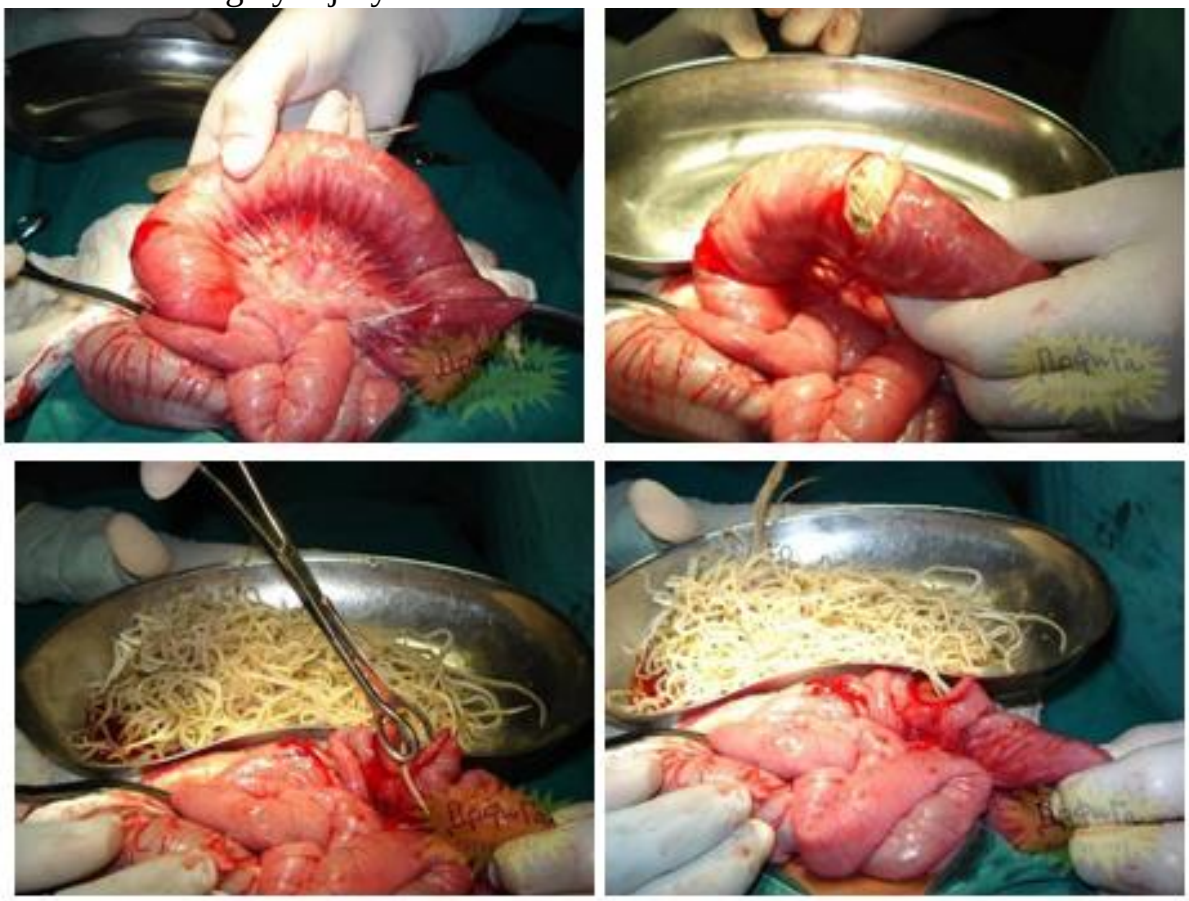


Fig. 15. Ascaris blocks small intestine.

6. Parasites induce their hosts to produce antibodies and develop immunity to these antibodies.

7. Parasites induce cell division and cause an increase in the number of cells in the hosts. For example, ***Fasciola hepatica*** causes the thickening of bile ducts in the sheep by stimulating of a cell division. This condition characterized by an increase in the number of cells is known as '**hyperplasia**' (Fig. 16).

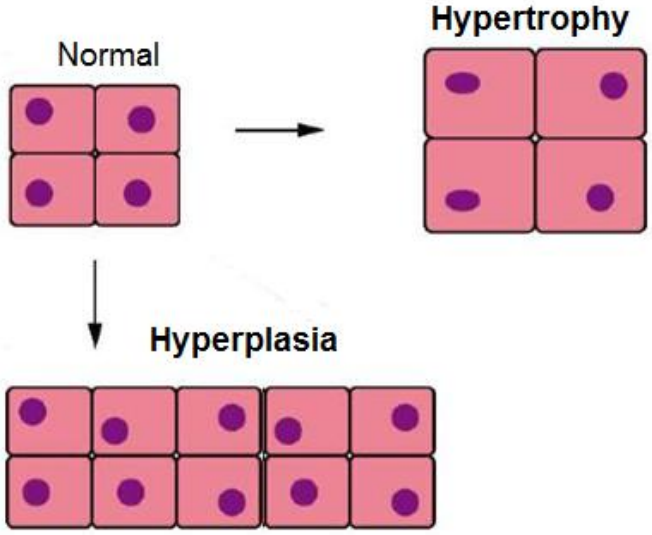


Fig. 16. Scheme illustrating the mechanisms of hypertrophy and hyperplasia.

8. Some parasites can cause an increase in the size of cells. For instance, the red blood corpuscles affected by Plasmodium are enlarged. This condition is called '**hypertrophy**' (Fig. 16).

9. Some parasites cause an abnormal growth in the body of hosts. This results in gigantism. For instance snails infected by trematodes become very large. Similirly, the body weight of sheep infected by Fasciola also increases. Elephantiasis in man (Fig. 17) is a typical sign of ***Bancroftian filariasis*** and occurs in the legs and external genitals, especially in the scrotum.

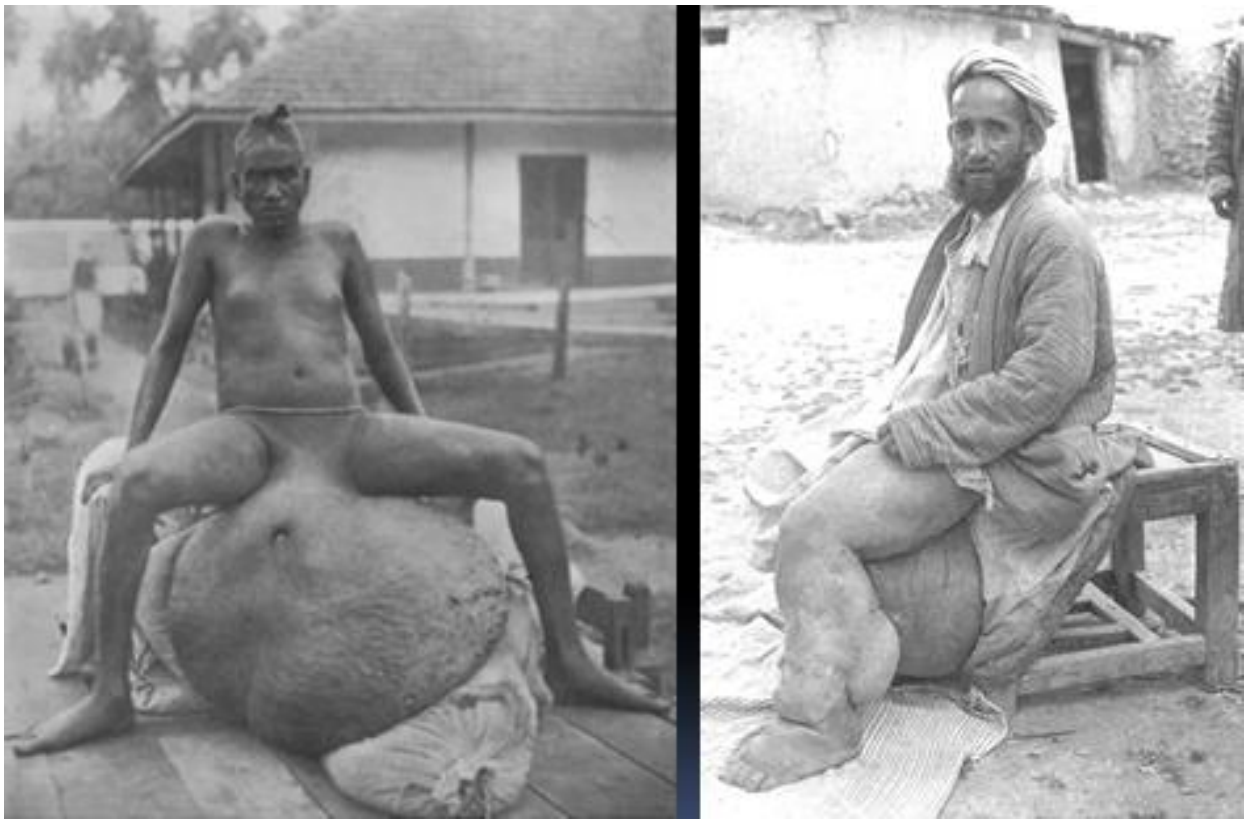
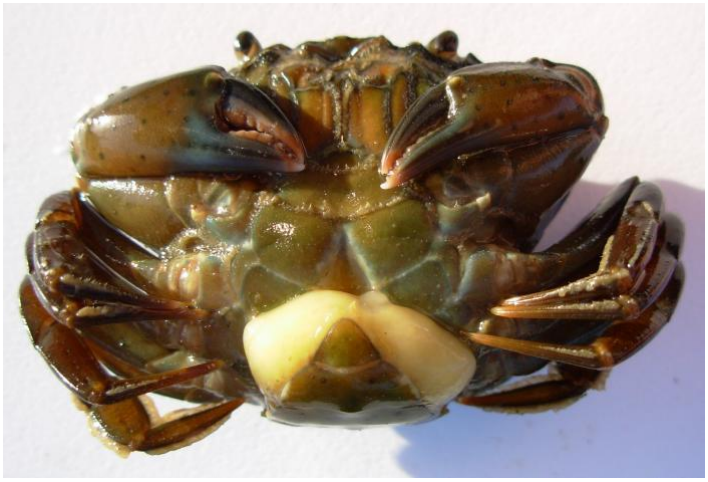


Fig. 17. Elephantiasis in man.

10. Parasites destroy gonads of some hosts. This results in sexual impotency or sex reversal. For instance, the parasite ***Sacculina*** (Fig. 18) can bring about female characters in male crab. Gradually, the crab may become a hermaphrodite. This kind of a sexual change is called 'parasitic castration'.



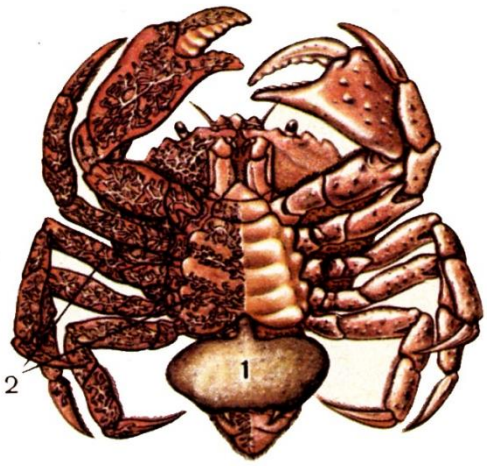


Fig. 18. Sacculina carcini is parasite of crabs: 1 – Sacculina attached to crab; 2 – root-like processes of Sacculina inside the crab body.

11. Some parasites bring about a change in the behaviour of their hosts. For example, ***Trypanosoma*** causes drowsiness, sleep or even coma in man.

Parasitic Adaptation and Effects on Parasites

Due to the parasitic mode of life, certain adaptations occur in the parasites. Some of them are listed below.

1. Typical epidermis is absent in endoparasites. In its place a thick cuticle (**tegument**) is present (Fig. 19). It protects the parasites against the action of digestive enzymes of the host.

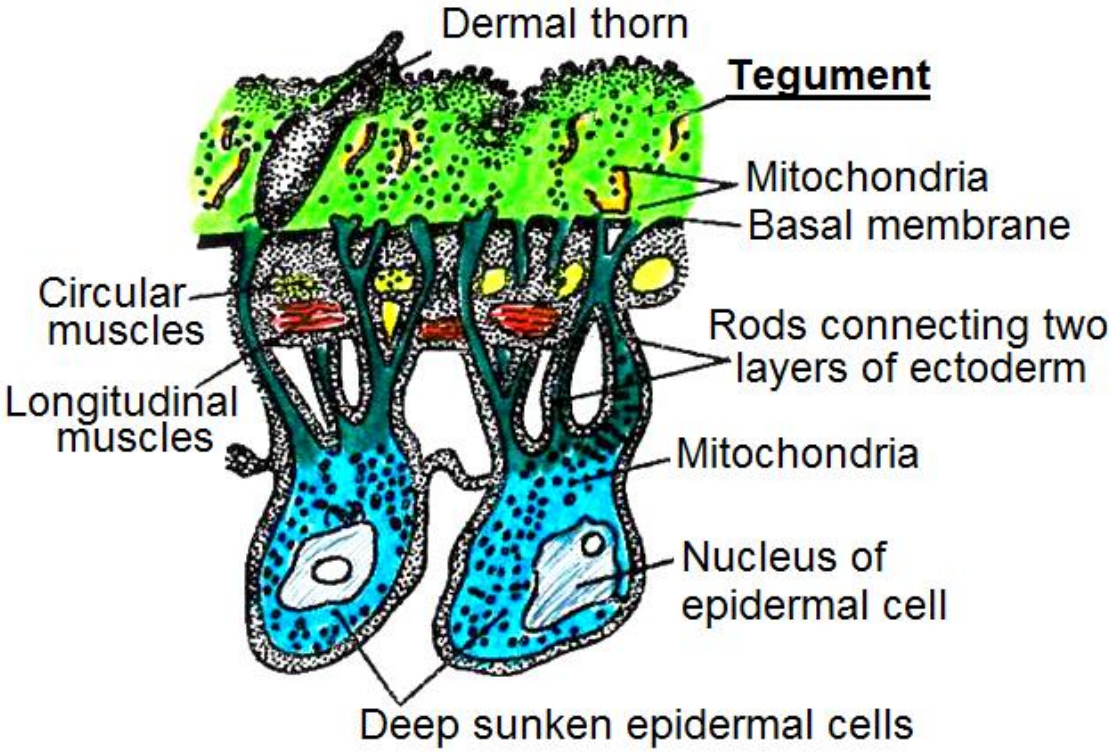


Fig. 19. Dermomuscular sac of Trematoda.

2. Some endoparasites secrete antienzymes to neutralize the action of digestive enzymes of their hosts.

3. Endoparasites do not have organs of locomotion. However, ectoparasites possess locomotory organs.

4. Parasites have developed structures like hooks, suckers and teeth (Fig. 20). They help the parasite to attach firmly to the internal organs of the host.

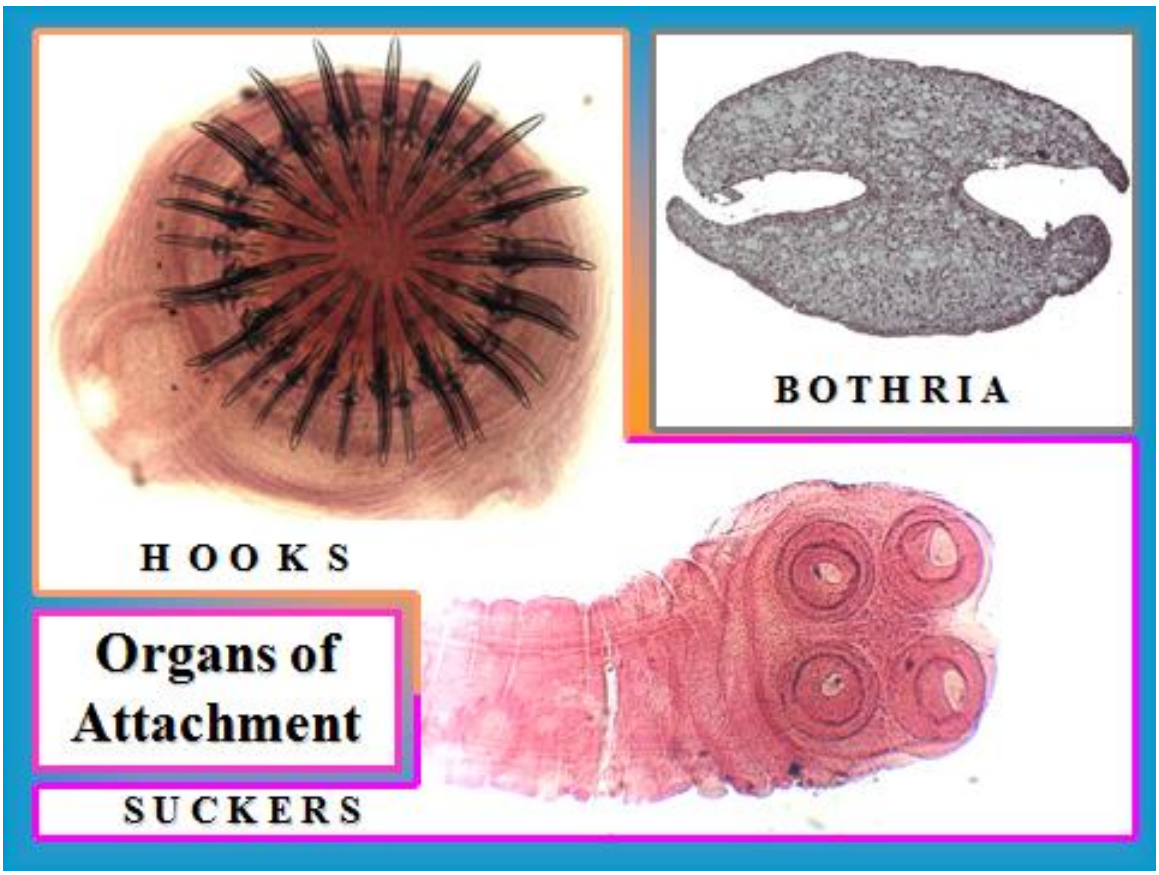


Fig. 20. Special organs of fixation in Tape worms.

5. Sense organs and nervous system are reduced in endoparasites. However, they are well developed in ectoparasites.

6. Digestive tract and digestive glands are reduced in endoparasites. However, some like ***Fasciola hepatica*** (liver fluke) and ***Schistisoma*** (Blood fluke) do have mouth and alimentary canal.

7. Reproductive system is well developed in several parasites. In order to protect their species against any risks they lay large number of eggs. For instance ***Ascaris*** lays two hundred thousand eggs every day.

8. Endoparasites respire anaerobically.

9. The body fluids of parasites are isotonic to those of their hosts.

10. Some parasites show polyembryony and parthenogenesis in order to ensure perpetuation of the species. For instance, during the life cycle of ***Fasciola hepatica***, parthenogenesis takes place.

Chapter 2: Medical Parasitology

Introduction

Parasitology is area of biology concerned with the phenomenon of dependence of one living organism from another. Parasitology is a dynamic field because the relationships between parasites and their hosts are constantly changing.

Parasitism comprises an ecological relationship between two individuals of different species where the parasite's environment is another living organism. Parasites often cause important diseases of humans and animals (*Bogitsh et al., 2005*). For this reason, Parasitology is an active field of study in which advances in biotechnology have raised expectations for the development of new drugs, vaccines, and other control measures. However, these expectations are dampened by the inherent complexity of parasites and host-parasite relationships, the entrenchment of parasites and vectors in their environments, and the vast socioeconomic problems in the geographical areas where parasites are most prevalent (*McGraw-Hill, 2005*).

Medical Parasitology is the science dealing with parasites that infect man, causing disease and misery in most countries of the tropics. They plague billions of people, kill millions annually, and inflict debilitating injuries such as blindness and disfiguration on additional millions. World Health Organization estimates that one person in every four harbors parasitic worms.

Medical Parasitology is the branch of medical sciences dealing with organisms (parasites) which live temporarily or permanently, on or within the human body (host).

Classification of parasites in Medical Parasitology

There are different types of parasites and hosts. The competition for supremacy that takes place between the host and the parasite is referred to as host-parasite relationship.

Accordingly, the host may have the upper hand and remains healthy or loses the competition, and a disease develops. Human parasites are either unicellular (protozoa) or multicellular (helminthes and arthropods).

Proposed by ***Whittaker*** in 1969, all living organisms belong to five kingdoms: Monera, Protista, Fungi, Plantae and Animalia (Fig. 21).

Protozoa which are eukaryotic unicellular organisms belong to the kingdom Protista.

Helminths which are eukaryotic multicellular organisms varying in length from less than 1 millimeter to more than a meter as well as arachnids and insects belong to the kingdom Animalia.

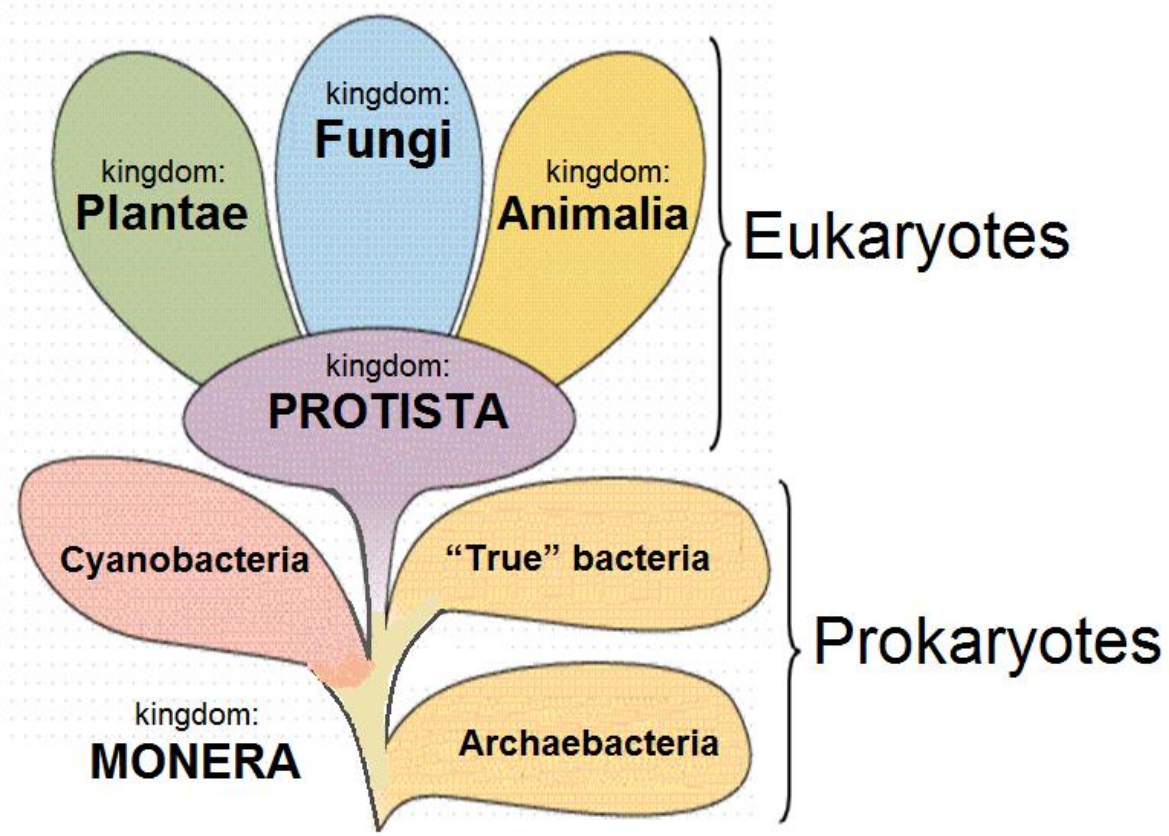


Fig. 21. Five kingdoms of living organisms.

The animal parasites which medical men have to deal with are divided into four main groups:

1.	Phylum Protozoa		**Medical Protozoology**
2.	Phylum Plathelminthes and Phylum Nemathelminthes		**Medical Helminthology**
3.	Phylum Arthropoda	Class Arachnoidea	**Medical Arachnology**
4.	Phylum Arthropoda	Class Insecta	**Medical Entomology**

The parasites may live inside the host (endoparasites) or on the host surface (ectoparasites). They obtain nourishment and protection while offering no benefit in return. Consequently, the host suffers from various diseases, infections, and discomforts. However, in some cases, the host may show no signs at all of infection by the parasite (UXL Encyclopedia of Science, 2002).

Endoparasites are classified into intestinal, atrial or they may inhabit body tissues causing serious health problems. Ectoparasites are arthropods that either cause diseases, or act as vectors transmitting other parasites. Human evolution and parasitic infections have run hand in hand and most parasitic diseases and methods of their transmission have been discovered thousands of years ago. Environmental changes, human behavior and population movement have a great effect on transmission, distribution, prevalence, and incidence of parasitic diseases in a community. Parasites can invade the human body in different ways; through oral route, skin, arthropod vectors or sexual contact.

Host defense mechanisms consist of innate immunity which mediates initial protection against infection and adaptive immunity which is more effective. Once parasites have evaded innate host defenses, adaptive cellular and humoral immune responses are promoted against a wide array of antigenic constituents.

Diagnosis of parasitic diseases depends on several laboratory methods, imaging techniques and endoscopy in addition to clinical picture and geographic location.

Parasitic diseases may be presented by a wide variety of clinical manifestations according to the tissue invaded. Direct microscopy is based on detection of the parasite by examination of different specimens (stool, urine, blood, CSF and tissue biopsies).

Immunodiagnostic techniques include antigen and antibody-detection assays.

Molecular-based diagnostic approaches offer great sensitivity and specificity. Recently, nanotechnology can be applied as diagnostic procedures utilizing nanodevices. Control and prevention of parasitic diseases depend on the interactions among many factors such as the environment, the human behavior, and socio-cultural factors that determine transmission and persistence of parasites.

Historical aspect of Medical Parasitology

Humans are hosts to nearly 300 species of parasitic worms and over 70 species of protozoa. The first written records of what are almost certainly parasitic infections come from a period of Egyptian medicine from 3000 to 400 BC. Later, there were many detailed descriptions of various diseases that might or might not be caused by parasites, specifically fevers, in the writings of Greek physicians between 800 to 300 BC, such as the collected works of Hippocrates and from physicians from other civilizations including:

- China from 3000 to 300 BC (e.g., in the oldest medical book over 2200 years ago).
- India from 2500 to 200 BC:
  - the early texts on Ayurveda (Indian traditional medicine) *Charaka Samhita* and *Sushruta Samhita* document malaria and its main symptoms as fever and enlarged spleens.
  - The *Bhrigu Samhita* from 1000 BC makes the earliest reference to amebiasis. The symptoms were given as bloody and mucosal diarrhea.
- Rome from 700 BC to 400 AD: *Celsus* (25 BC to AD 50) and *Galen* (Galenus of Pergamon, AD 129 to 200) were familiar with the human roundworms (maw warm and pinworm) and tapeworms.
- The Arab Empire in the latter part of the first millennium.

As time passed, the descriptions of infections became more accurate and Arabic physicians, particularly *Rhazes* (AD 850 to 923) and *Avicenna* (AD 980 to 1037), wrote important medical works that contain a great deal of information about diseases clearly caused by parasites.

In Europe, the Dark and Middle Ages, characterized by religious and superstitious beliefs, held back medical progress until the Renaissance, which

released a flurry of activity that eventually led to the great discoveries that characterized the end of the 19th century and the beginning of the 20th. These discoveries included the demolition of the theory of spontaneous generation and the evolution of the germ theory by *Louis Pasteur*, the demonstration by Pasteur that diseases could be caused by bacteria, the introduction by *Robert Koch* of methods of preventing diseases caused by microorganisms, and the incrimination by *Patrick Manson* of vectors in the transmission of parasites. The great personalities of this period made discoveries in a number of fields, and their findings and ideas fed off one another.

BASIC CONCEPTS IN MEDICAL PARASITOLOGY

In medical parasitology, each of the medically important parasites are discussed under the standard subheadings of morphology, geographical distribution, means of infection, life cycle, host/parasite relationship, pathology and clinical manifestations of infection, laboratory diagnosis, treatment and preventive/control measures of parasites. In the subsequent section some of these criteria are briefly presented.

Morphology: includes size, shape, color and position of different organelles in different parasites at various stages of their development. This is especially important in laboratory diagnosis which helps to identify the different stages of development and differentiate between pathogenic and commensal organisms. For example, *Entamoeba histolytica* and *Entamoeba coli*.

Geographical Distribution. Environmental factors, social customs and habits of person greatly influence the distribution of parasites and accordingly each parasite has got a specific distribution.

Even though revolutionary advances in transportation has made geographical isolation no longer a protection against many of the parasitic diseases, many of them are still found in abundance in the tropics. Distribution of parasites depends upon:

1. The presence and food habits of a suitable host:

• Host specificity, for example, *Ancylostoma duodenale* requires man as a host where *Ancylostoma caninum* requires a dog.

• Food habits, e.g. consumption of raw or undercooked meat or vegetables predisposes to Taeniasis

2. Easy escape of the parasite from the host- the different developmental stages of a parasite which are released from the body along with faeces and urine are widely distributed in many parts of the world as compared to those parasites which require a vector or direct body fluid contact for transmission.

3. Environmental conditions favoring survival outside the body of the host, i.e. temperature, the presence of water, humidity etc.

4. The presence of an appropriate vector or intermediate host – parasites that do not require an intermediate host (vector) for transmission are more widely distributed than those that do require vectors.

Once we are clear about the geographical distribution and conditions favoring survival in relation to different parasites, effective preventive and control measures can more easily be devised and implemented.

Habitat. Each parasite, according to the mode of its existence, selects a particular place of abode in the host. The parasite, after entering into the body, may directly establish itself in the place where it is introduced or the parasite, on entering the body through a particular route, may travel through various organs till it riches its normal abode for its growth to sexual maturity. In some cases, the larval form of the parasite, after getting into its normal habitat, does not develop directly into adult worm but takes a circumroutous path and on arrival for the second time at the same place starts growing to maturity, as in the case of *Ascaris lunbricoides*. The parasite, in some cases, may grow to maturity at its normal site of localization and then may migrate to a suitable site to enable its progeny to be transferred to a second host, as in *Schistosoma*; or it may discharge its larvae which are carried to some distant place either to be taken up by an intermediate host, as in *Wuchereria* or remain encysted in the striped muscle, as in *Trichinella*. The sites of such localization will no doubt give an idea about the pathogenic effects and the channels through which the progeny may come out of the human host.

Parasites' Life Cycles. Life cycles of parasites may be simple or complex. Parasites that are characterized by a simple or direct life cycle have only one host and are described as **monoxenous** (e.g. life cycle of *Ascaris lumbricoides*, Fig. 22).

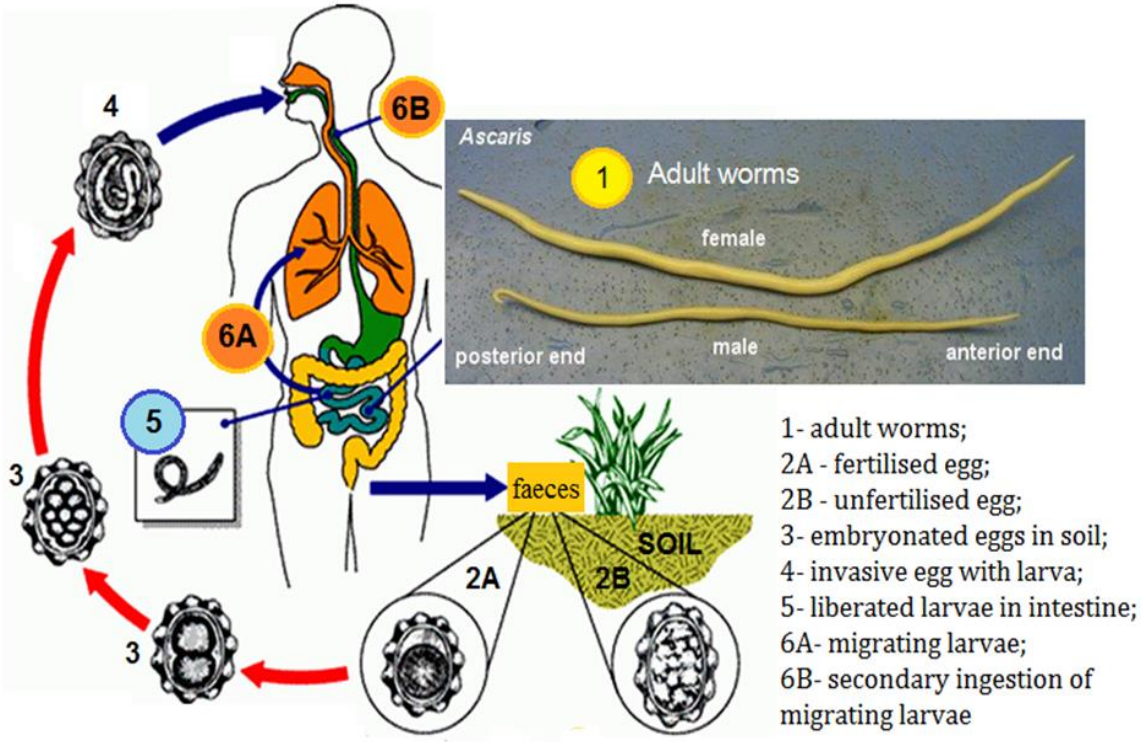


Fig. 22. Monoxenous life cycle of Ascaris lumbricoides.

The parasite generally spends most of its life in or on the host, and may reproduce within the host. Because offspring must be transmitted to other hosts, however, the parasite or its progeny must have some way of leaving the host, surviving in the external environment for some period, and locating and infecting a new host. Parasites with simple life cycles have both parasitic and free-living life

stages. The proportion of the total life cycle spent in each stage varies according to the parasite.

Parasites with more complex life cycles involving multiple hosts are described as having indirect or **heteroxenous** life cycles (e.g. life cycle of *Taenia saginata*, Fig. 23).

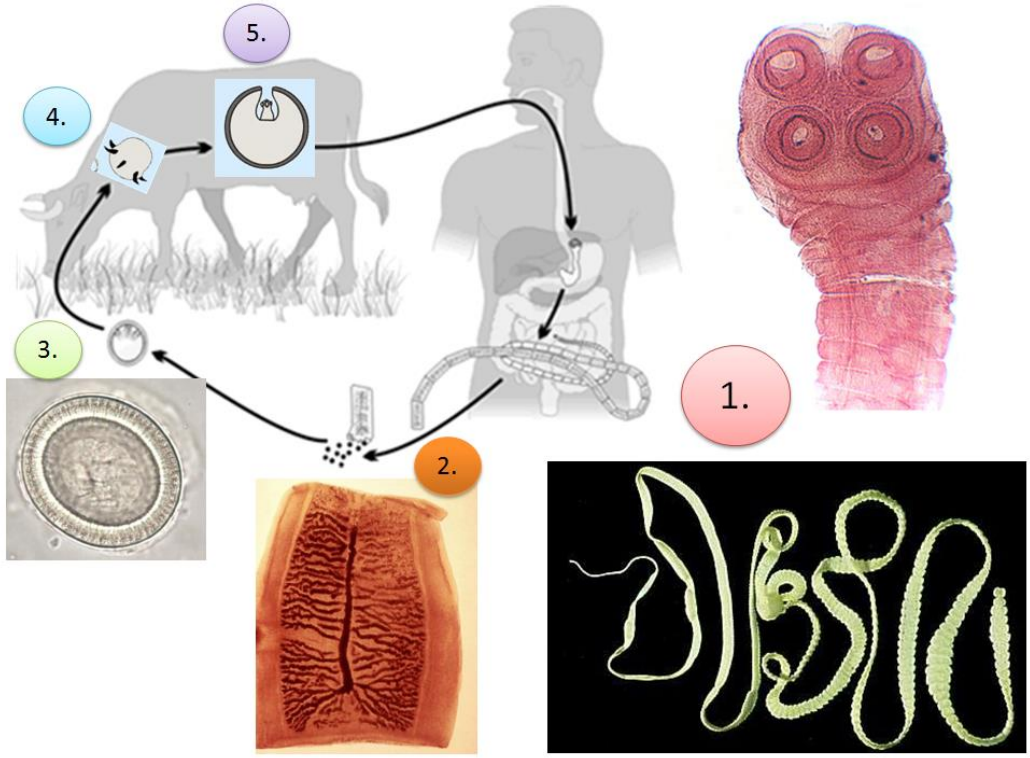


Fig. 23. Heteroxenous life cycle of Taenia saginata: 1 – adult worm in intestine of man, 2 – gravid proglottid in faeces, 3 – eggs on grass, 4 – first larval stage (Oncosphere) in blood of cow, 5– second larval stage (Cysticerci) in muscles of cow.

The primary or definitive host of a heteroxenous species is the one in which adult parasites live and reproduce sexually. The secondary or intermediate host (IH) is the host where immature life stages of the parasite live and reproduce asexually. In many cases, the parasite passes through critical developmental stages in the IH. The latter may also aid in transmitting parasites to their final host. Rat flea, for example, is the IH for mammalian parasites such as the tapeworm; Hymenolepis diminuta.

Some parasites are transmitted directly from one host to another, often by insects, described as vectors. One particularly effective vector for vertebrate parasites is the mosquito, which plays a role in transmission of numerous parasites including heartworm, the viruses that cause yellow fever and encephalitis, and Plasmodium, the protozoan that causes malaria.

Stages of Parasite, having medical importance. Under this heading the general structure of the parasite and the various stages through which it passes, are studied. The parasite may pass its life cycle in one and the same host or it may change its host.

Pathogenic stage is form of the parasite in its life cycle causing the development of disease in an organism of the host.

Transmission of the parasite from one host to another is effected by certain forms which are known as **infective stage**. The means by which different infecting agents are transferred from one host to another and the avenues through which they enter to human host require careful consideration (diagram #1).

In an endemic area a parasitic infection is continually kept up by the presence of hosts acting as reservoirs of infection; such hosts may be either animals or man. Where an insect intermediate host (vector) plays the part in dissemination of the disease, its bionomics should also be carefully studied.

Role of reservoir hosts or reservoirs of infection. In a majority of cases man is the main reservoir. In such cases the parasite does not produce any manifest symptoms but remain in the host and keeps up the infection, thus helping to maintain a "carrier state". During this "carrier state" the parasite evolves certain resistant forms which help in the dissemination of the disease, e.g., cysts of *E. histolytica*, gametocytes of malarial parasite. In certain species of parasites, both men and lower animals are infected, the latter serving as reservoirs of infection: examples are "Rhodesian" trypanosomiasis (antelope), Oriental sore (dog), kala-azar occurring in China and Mediterranean areas (dog), balantidiasis (pig), trichinelliasis (pig and rat) and hydatid disease (sheep and cattle).

Host parasite relationship: infection is the result of entry and development within the body of any injurious organism regardless of its size. Once the infecting organism is introduced into the body of the host, it reacts in different ways and this could result in:

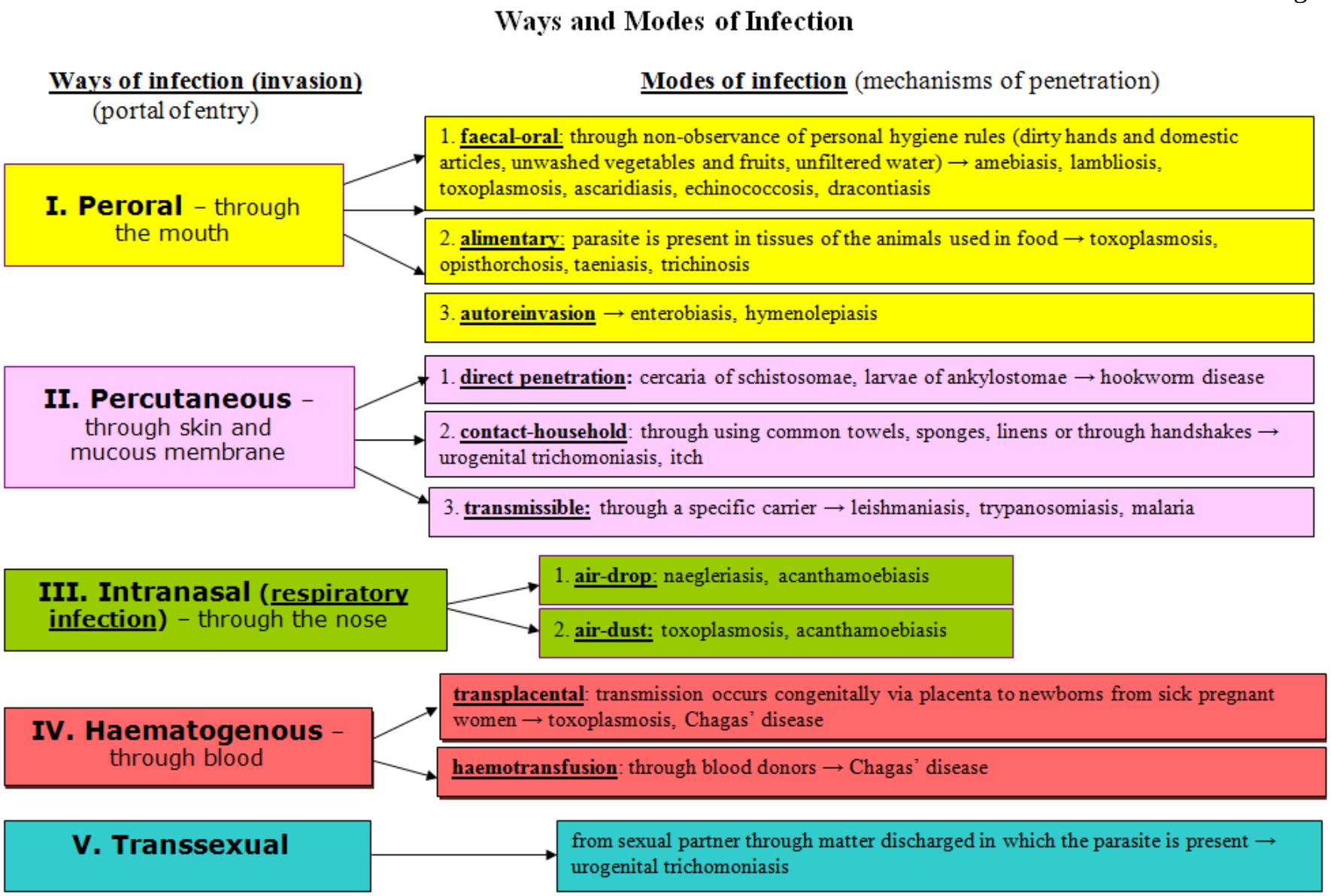
a. Carrier state → a perfect host parasite relationship where tissue destruction by a parasite is balanced with the host's tissue repair. At this point the parasite and the host live harmoniously, i.e. they are at equilibrium.

b. Disease state → this is due to an imperfect host parasite relationship where the parasite dominates the upper hand. It can result either from lower resistance of the host or a higher pathogenecity of the parasite.

c. Parasite destruction → occurs when the host takes the upper hand.

Ways and Modes of Infection

Diagram #1.



Laboratory diagnosis: depending on the nature of the parasitic infections, the following specimens are selected for laboratory diagnosis:

a) Blood – in those parasitic infections where the parasite itself in any stage of its development circulates in the blood stream, examination of blood film forms one of the main procedures for specific diagnosis. For example, in malaria the parasites are found inside the red blood cells. In Bancroftian and Malayan filariasis, microfilariae are found in the blood plasma.

b) Stool – examination of the stool forms an important part in the diagnosis of intestinal parasitic infections and also for those helminthic parasites that localize in the biliary tract and discharge their eggs into the intestine.

In protozoan infections, either trophozoites or cystic forms may be detected; the former during the active phase and the latter during the chronic phase, for example, amoebiasis, giardiasis, etc.

In the case of helmithic infections, the adult worms, their eggs, or larvae are found in the stool.

c) Urine – when the parasite localizes in the urinary tract, examination of the urine will be of help in establishing the parasitological diagnosis. For example in urinary schistosomiasis, eggs of *Schistosoma haematobium* are found in the urine. In cases of chyluria caused by *Wuchereria bancrofti*, microfilariae are found in the urine.

d) Sputum – examination of the sputum is useful in the following:

• In cases where the habitat of the parasite is in the respiratory tract, as in paragonimiasis, the eggs of *Paragonimus westermani* are found.

• In amoebic abscess of lung or in the case of amoebic liver abscess bursting into the lungs, the trophozoites of *E. histolytica* are detected in the sputum.

e) Biopsy material – varies with different parasitic infections. For example spleen punctures in cases of kala-azar, muscle biopsy in cases of cysticercosis, trichinelliasis, and Chagas' disease, skin snip for onchocerciasis.

f) Urethral or vaginal discharge – for *Trichomonas vaginalis*

Indirect evidences – changes indicative of intestinal parasitic infections are:

a. Cytological changes in the blood – eosiniphilia often gives an indication of tissue invasion by helminthes, a reduction in white blood cell count is an indication of kala-azar, and anemia is a feature of hookworm infestation and malaria.

b. Serological tests – are carried out only in laboratories where special antigens are available.

Treatment: many parasitic infections can be cured by specific chemotherapy. The greatest advances have been made in treatment of protozoal diseases.

For treatment of intestinal helminthiasis, drugs are given orally for direct action on the helminthes. To obtain maximum parasiticidal effect, it is desirable that the drugs administered should not be absorbed and the drugs should also have minimum toxic effect on the host.

Prevention and control: measures may be taken against every parasite infecting humans. Preventive measures designed to break the transmission cycle are crucial to successful parasitic eradication. Such measures include:

▪ Reduction of the source of infection- the parasite is attacked within the host, thereby preventing the dissemination of the infecting agent. Therefore, a prompt diagnosis and treatment of parasitic diseases are an important components in the prevention of dissemination.

▪ Sanitary control of drinking water and food.

▪ Proper waste disposal – through establishing safe sewage systems, use of screened latrines, and treatment of night soil.

▪ The use of insecticides and other chemicals used to control the vector population.

▪ Protective clothing that would prevent vectors from resting on the surface of the body and inoculating pathogens during their blood meal.

▪ Good personal hygiene.

▪ Avoidance of unprotected sexual practices.

Mechanisms of Transmissible Mode of Infection

● **Vector** (Fig. 24) is an arthropod that transmits parasites from one host to another, e.g. female sand fly transmits *Leishmania* parasites (*Bogitsh et al., 2005*).

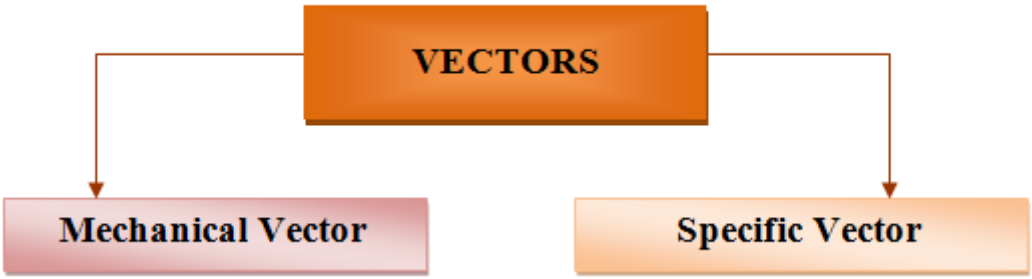


Fig. 24. Kinds of vectors.

● **Mechanical Vector** (Fig. 25): this is a vector which assists in the transfer of parasitic forms between hosts but is not essential in the life cycle of the parasite, e.g. a housefly that transfers amoebic cysts from infected faeces to food that is eaten by humans.

Fig. 25. Mechanical vectors: a cockroach and a housefly.

● **Specific Vector** is an arthropod in the organism of which the agent of diseases has certain stages of development or reproduction (Fig. 26).

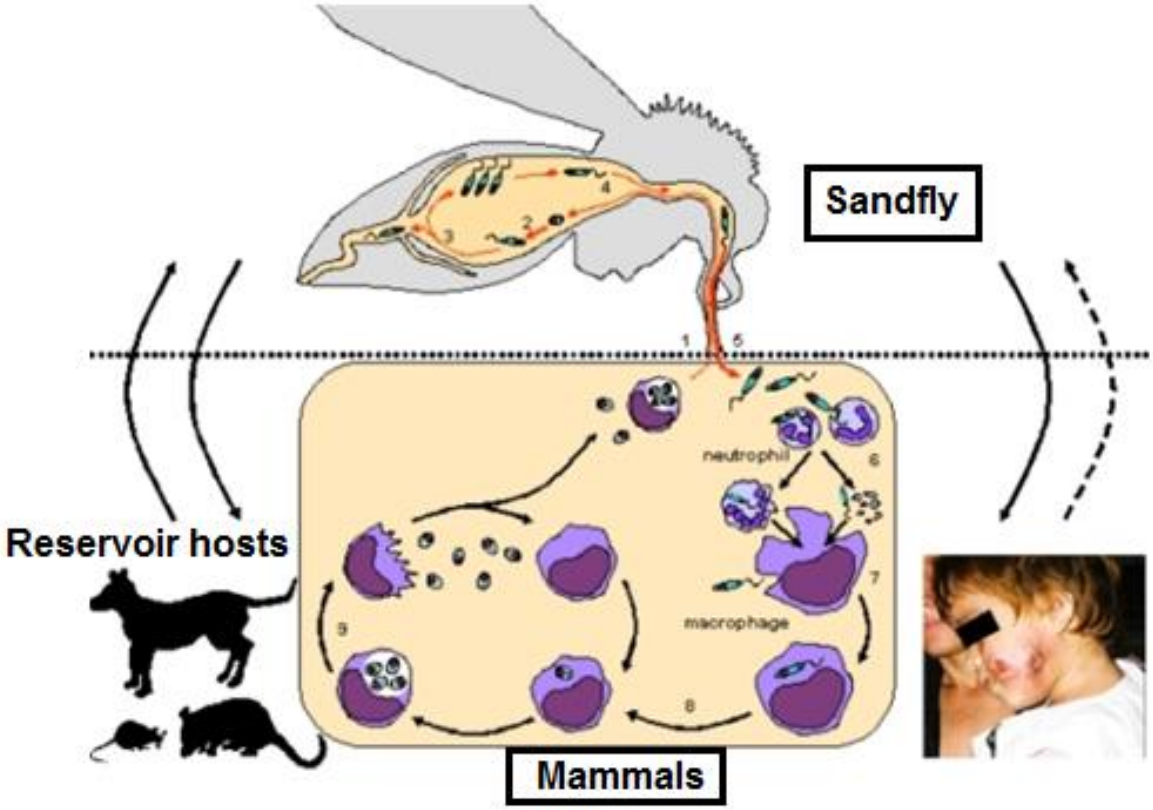


Fig. 26. Specific vector.

An infected blood-sucking arthropod may introduce the organism directly into the blood, into the skin or into the skin layers at the time of obtaining a blood-meal (Fig. 27), e.g., Plasmodia (malarial parasites) by Anopheline mosquitoes, Trypanosoma by Glossina (tsetse flies), Leishmania by Phlebotomus (sandflies) and Wuchereria by Culicine mosquitoes. In this group, the parasites undergo a biological development for a certain period before becoming infective to a human.

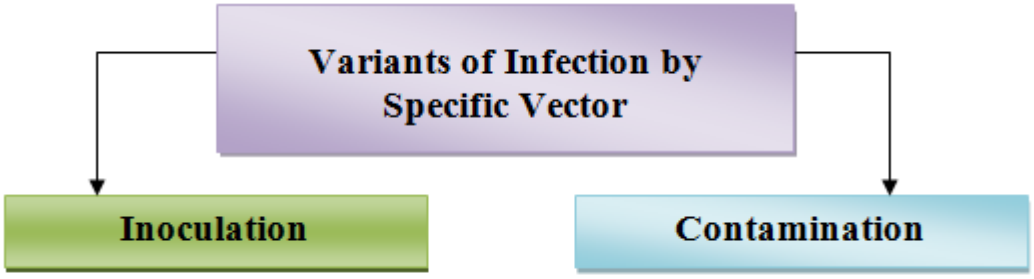


Fig. 27. Modes of infection by specific vectors.

Inoculation (Fig. 28) is introduction of infecting agent in wound **by the bite** of an infected vector.

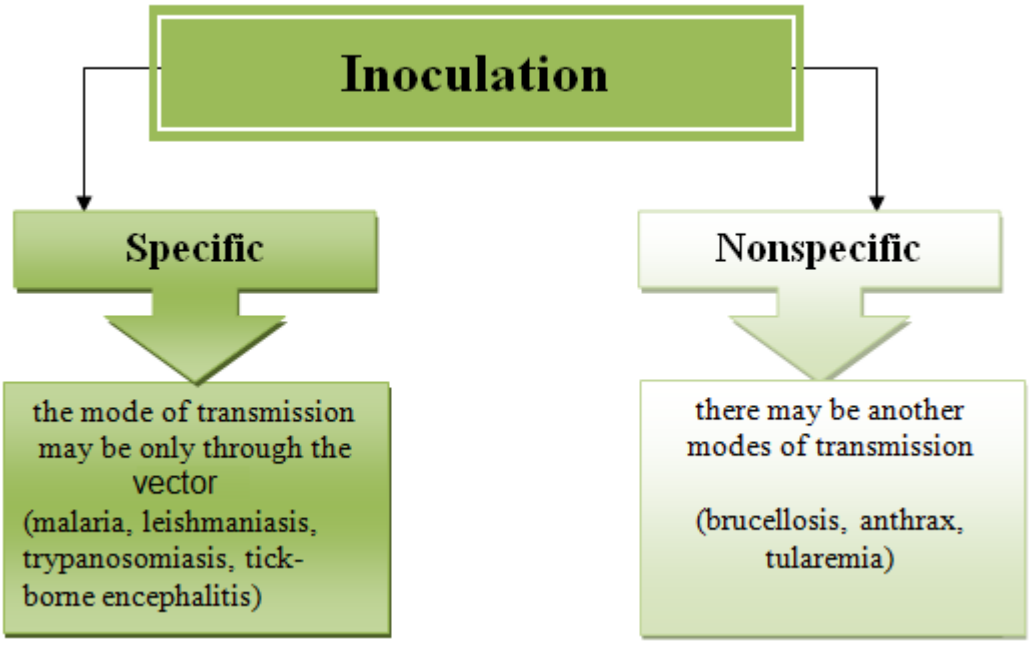


Fig. 28. Kinds of inoculation.

Contamination is introduction either **by faecal matter** of the vector being rubbed into the wound caused by a bite or by a possible contamination of the conjunctivae and other exposed mucous membranes with fingers.

The infecting agent is located in intestines or haemolymph of arthropod (American trypanosomiasis, epidemic [louse-borne] typhus and relapsing fever).

Classification of Illnesses

Disease should not be confused with infection; a person may be infected without becoming diseased. If the host has upper hand, due to increased host resistance, it remains healthy and the parasite is either driven away or assumes a benign relationship with the host, but if the host loses the competition, a disease develops (*Schmidt and Roberts, 2009*).

I. According to origin of disease (Fig. 29):

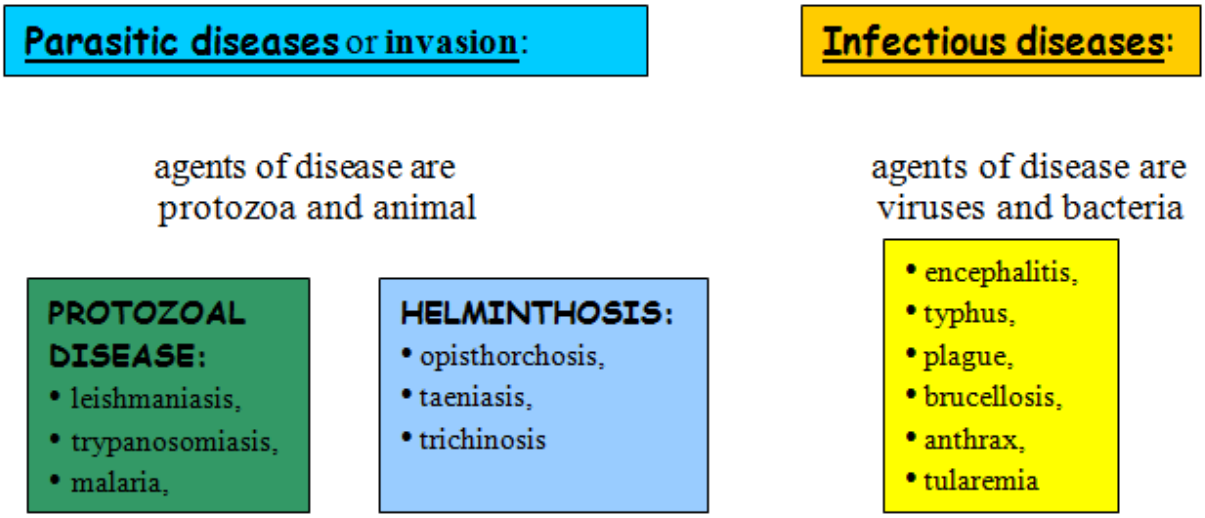


Fig. 29. Classification of diseases according to origin of illness.

Parasitic diseases are cosmopolitan and may affect all the world population. They kill several million people every year. The migration and tourism make that even tropical diseases can be frequently met outside their geographical distribution area. Except the arthropod-borne infections, the great majority of these diseases are in relation with the faecal contamination of soil, the general level of hygiene and the food practices. The socio-political and climatic upheavals may result in a creeping extension of the geographical limits of many parasites.

II. According to presence of specific carriers (Fig. 30):

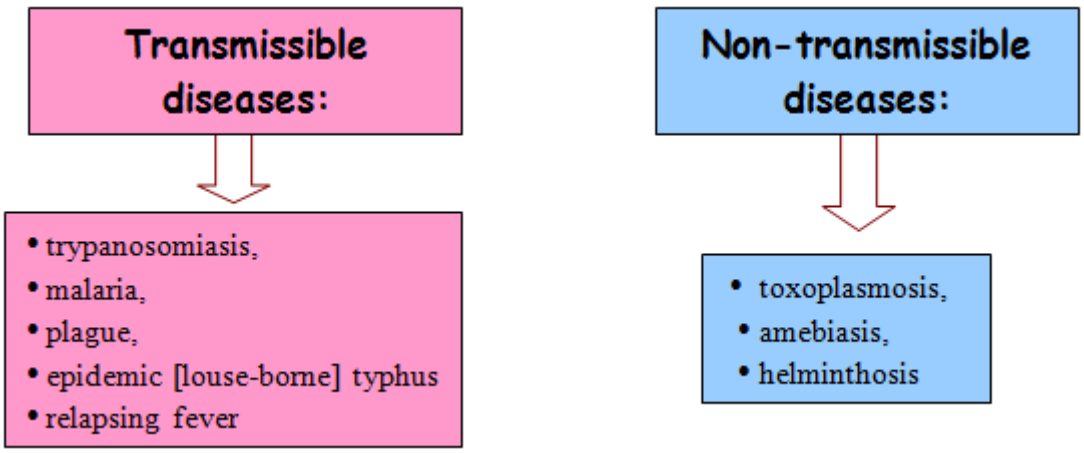


Fig. 30. Classification of parasitic diseases according to presence of specific carriers.

III. <u>According to susceptibility to disease agent (Fig. 31):</u>

Parasitic diseases are classified into:

- **Anthroponosis** – a parasitic disease, the agents of which are transmitted by vectors exclusively from human to human, e.g. malaria, louse-borne spotted fever.
- **Zoonosis** – a parasitic disease in which only an animal is the host.
- **Anthropozoonosis** – a parasitic disease in which an animal is normally the host but which can also infect humans.

Parasites, which constitute roughly 50% of the species on Earth, typically feed on only one or a few host species. In evolution, the parasites as well as their hosts developed special adaptations, defence and counterdefence adaptation.

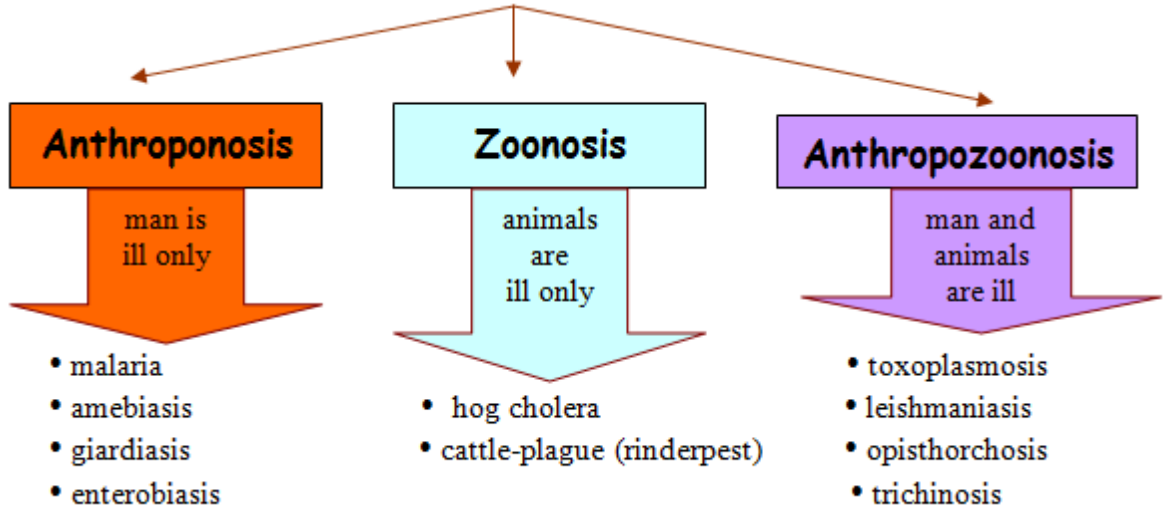


Fig. 31. Classification of parasitic diseases according to susceptibility to disease agents.

IV. <u>According to foci of diseases (Fig. 32):</u>

There are two foci of illness: natural focus and synanthropic focus. As a result parasitic diseases are classified into:

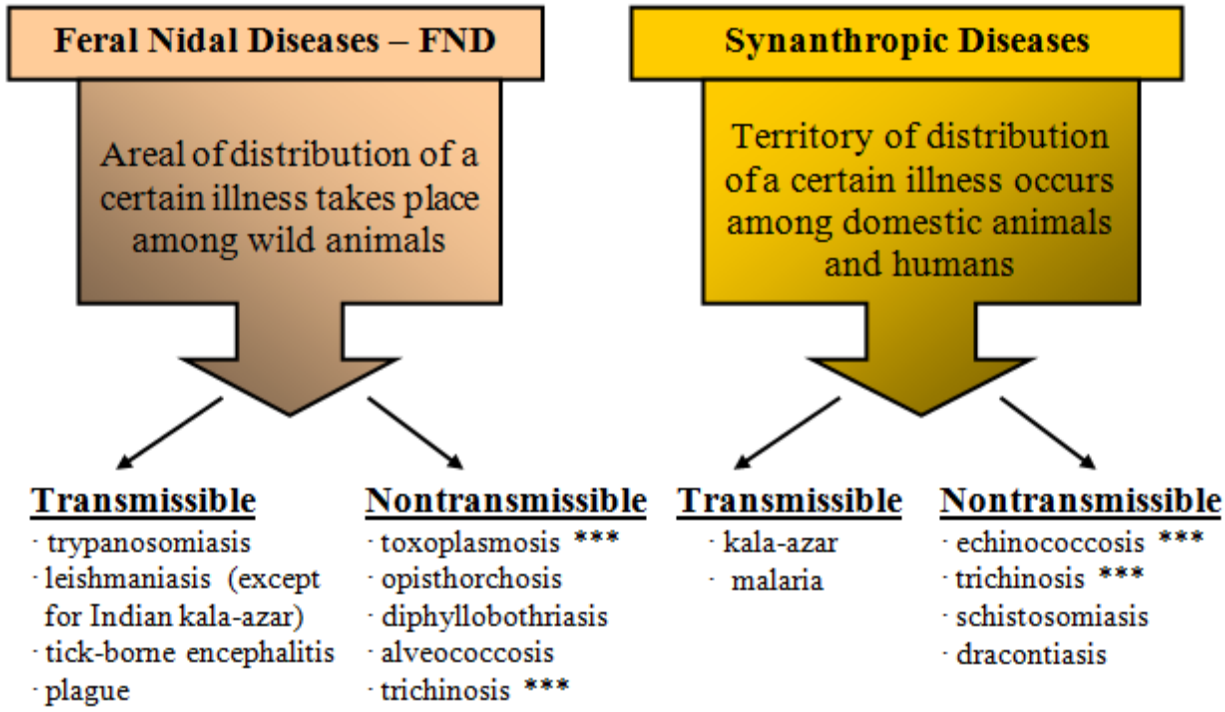


Fig. 32. Natural and synanthropic foci.

*** Trichina, Toxoplasma and Echinococcus can form both feral nidal, and synanthropic foci.

• **Feral nidal diseases (FND)** – the illnesses distributed in certain territory among wild animals.

The doctrine about feral nidal diseases has been developed by Russian scientist ***E.N.Pavlovskii*** in 1938 (Fig. 33).

Fig. 33. Russian scientist, academician E.N.Pavlovskii.

The following components are characteristic for feral nidal diseases (Fig. 34):

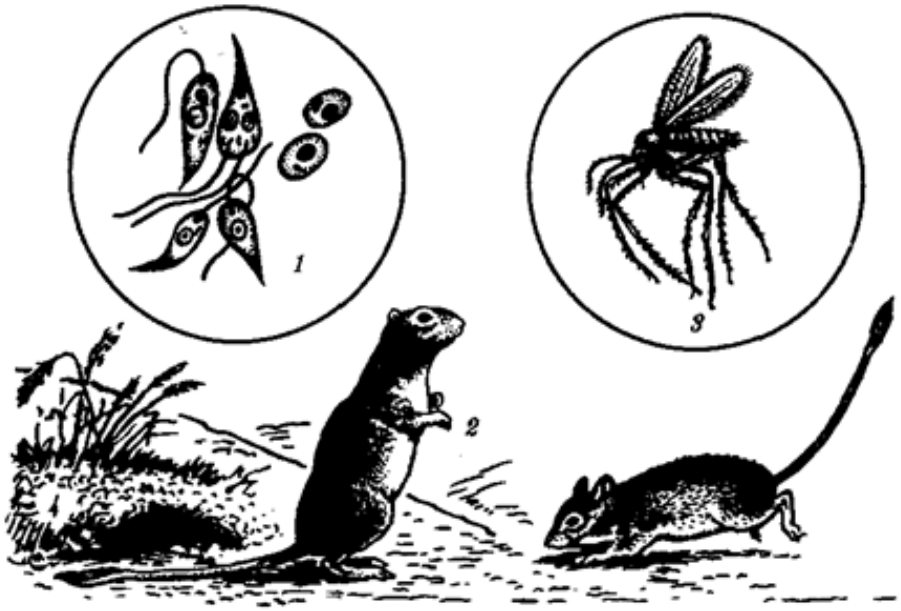


Fig. 34. The structure of the focus for Feral nidal disease – leishmaniasis: 1 – agent of disease (leishmania), 2 – reservoir hosts (rodents), 3 – specific vector (sandfly).

1) **areal** with a certain complex of natural-climatic conditions;
2) presence of an **agent** of disease;
3) presence of **hosts** among wild animals necessarily;
4) presence of a human unessentially;
5) presence of a **specific carrier**, if the illness is an obligate transmissible disease.

Thus, the diseases circulating in the nature irrespective of a human being on a certain area, which are determined by presence of wild animals – reservoir hosts of the parasite, are called **feral nidal diseases**.

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CONTENTS

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