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PRESENTS
Sources of Infective Stages and Modes of Transmission of Endoparasites

Epidemiology is the branch of science that deals with the distribution and spread of disease. How diseases are transmitted, i.e. how they are passed from an infected individual to a susceptible one is a major consideration. Classifying and developing terminology for what takes place has been approached in a variety of ways usually related to specific disease entities such as viruses, bacteria, etc. The definitions that follow apply to those disease entities usually classified as endoparasites i.e. those parasites that reside in a body passage or tissue of the definitive host or in some cases the intermediate host.

When the definition of terms for the "Source of Infection" or "Mode of Infection" relate to prevention and/or control of an endoparasitic disease, they should be clearly described. For the source of infection, the medium (water, soil, utensils, etc.) or the host organism (vector, or intermediate host) on which or in which the infective stage can be found should be precisely identified. For the mode of transmission, the precise circumstances and means by which the **infective stage** is able to come in contact with, enter, and initiate an infection in the host should be described.

SOURCE OF INFECTION

There are three quite distinct and importantly different kinds of sources of the infective stage of parasites: Contaminated Sources, Infested Sources, and Infected Sources.

CONTAMINATE SOURCES

Contaminated Source, in parasitology, implies something that has come in contact with raw feces and is thereby polluted with feces or organisms that were present in it. When the stage of a parasite that is passed in the feces is the infective stage, wherever it comes to rest, becomes a **contaminated source** for that parasite. This type of source is usually (but not always) inanimate such as soil, water, or some object. Food, clothing, or a body surface of an infected host may become contaminated and harbor the infective stage of a parasite.

There are two types of contaminated sources. If the infective stage of a parasite passed in the feces is a cyst, oocyst, or an egg, it either may be immediately infective or it may have to develop further before it becomes infective depending on the species. Even though the infective stage may go through some developmental changes, it remains a cyst, oocyst, or egg. Examples of parasites where the stage passed in the feces may be immediately infective are**:** cysts of the protozoa *Entamoeba histolytica* and *Giardia lamblia*, the oocysts of *Cryptosporidum parvum*, and the helminth eggs of

the cestode, *Hymenolepis nana*. An appropriate term for this type of contaminated source is an **"immediately infective contaminated source."**

Although the oocysts of the protozoan *Isospora belli and* eggs of the nematodes *Ascaris lumbricoides* and *Trichuris trichiura* are the stages that are infective, they are not immediately infective but must develop to the infective stage outside of the body of the host. The time for the embryos of these nematodes to develop to a first stage juvenile, the infective stage, varies from two weeks to several months depending on environmental conditions. The oocysts of *Isospora belli* may reach the infective stage in a few days after evacuation or may not become infective for a month or more. An appropriate term for this type of source a **"delayed infective contaminated source."**

INFESTED SOURCES

Infested Source implies a source in which the infective stage is free living and can actively move about. The infested source is usually water, vegetation, or ground on which we walk, sit, or lie.

Although, the eggs of *Necator americanus* and other hookworms, like those of *T trichiura*, are passed in feces, the eggs are not the infective stage. Under suitable conditions, the embryo develops within the egg to the first stage juvenile in a minimum of seven to ten days. It emerges from the egg as a rhabditiform (rhabditoid) juvenile. Juveniles molt to become the second stage and molt again to become the third stage, filariform juvenile that becomes infective after a few days depending on environmental conditions. In most endemic areas, the cycle, from egg, to infective filariform juvenile, usually is accomplished in twenty to thirty days. The infective stage moves about in the soil or surface vegetation that becomes an **"infested source"** of infection.

The embryonated eggs of trematodes of the family Schistosomatidae, the schistosomes (blood flukes), are evacuated with wastes of the definitive host in urine or feces. Eggs are not the infective stage. When an egg reaches water (fresh water for most species) the embryo is liberated from the egg as a free-swimming miracidium. The miracidium must find a suitable species of mollusk, usually a snail, in order to continue its development. Within the snail it metamorphoses into a primary sporocyst that produces a number of secondary (daughter) sporocysts that, in turn, each produce many cercariae. The cercariae that emerge from the snail into water are the infective stage. Water harboring free-swimming cercariae is an **"infested source"** of infection.

Most parasitic arthropods that attack humans are classified as **ectoparasites** because, even though they may invade the body surface, they require direct access to the atmosphere so do not penetrate below the dermal layer of the skin. The larvae of the Human Bot Fly, *Dermatobia hominis*, penetrate the skin and burrow through subcutaneous tissues making it an endoparasite. Its life cycle is unique. The adult, gravid female seeks a blood-feeding arthropod, usually a female mosquito, and deposits a bundle of 15 to 20 eggs on the thorax of the arthropod, which becomes a **transport host**. The larvae in the eggs are immediately infective and when the arthropod harboring them feeds on a mammal or human, the larvae are stimulated by the warmth

of the body to emerge from the egg and attach to the skin. They are able to penetrate the skin within about 30 minutes. The larvae grow to mature larval stage, exit the lesion, drop to the ground, and pupate. Since the eggs are deposited on the surface of the arthropod transport host by the adult fly, it is an **"infested source"** of the infection.

INFECTED SOURCES

Infected Source refers to a living organism (such as a mollusk, arthropod, fish, mammal, or other organism) in which the infective stage of the parasite resides and that organism (a host of the infective stage) in some way, either actively or passively, provides for the parasite's access to a new host. There are a wide variety of organisms and plants that serve as intermediate hosts and/or vectors for parasites. Aquatic plants, such as water crest or water chestnuts to which metacercariae of trematodes become attached are also considered as infected sources. Also, man can become an aberrant intermediate host of some parasites, e.g. the life cycle reaches a **"dead end"** when man is infected with cysts of the tapeworms, *Echinococcus granulosis* and *Taenia solium* or the encysted juveniles of the nematode, *Trichinella spiralis* In such cases man is considered to be an **aberrant infected source.**

Different arthropods as hosts of particular parasites harbor the infective stage in a particular part of their body. The infective trypomastigote stage of *Trypanosoma cruzi* inhabit in the hindgut of species of reduviid bugs, *Triatoma sp. et al,* while those of the infective trypomastigote stage of *T brucei* are found in the salivary ducts of species of the tsetse flies, *Glossina*. The infective sporozoites of malarial parasites are in the salivary glands of anophiline mosquitoes. Usually, man is considered the definitive host but is the intermediate host of malarial parasites since fertilization, sexual reproduction, takes place in the mosquito. The infective filariaform juveniles of *Wuchereria bancrofti* are in the labium of the mouthparts of culicine mosquitoes. Infective juveniles of *Dracunculus medinensis* are in the body cavity (hemocoele) of copepods. Where the infective stage of the parasite resides in its intermediate host or vector host has an impact on the mode of transmission and may determine whether transmission is passive or active.

Different kinds of fish act as the infected source of parasites. The pleurocercoid of *Diphyllobothrium latum* is found in the muscle of lake fish. The metacercariae of *Clonorchis sinensis* and *Heterophyes heterophyes* reside in the muscle of species of carp.

Mammals can also harbor the infective stage of some parasites. The cysticercus of *Taenia saginata* resides in the muscle of cattle. The cysticercus of *Taenia* solium and the infective juveniles of *Trichinella spiralis* are found encysted in the muscle of pigs.

Uniquely, a mother may harbor stages of malarial parasites infective for her child in rare cases where parasites from the mother are transmitted across the placental barrier. The mother is an **infected source** for her unborn child.

MODE OF TRANSMISSION

The mechanism by which an individual becomes infected is designated, the **"Mode of Transmission"** and can be classified into two distinct categories: "**Passive Transmission"** and **"Active Transmission."**

PASSIVE TRANSMISSION

Passive Transmission implies that neither the infective agent itself nor the host or vector in or on which the infective stage resides plays an active role in transmission. Only the activities or actions of the susceptible individual host being infected play an active roll in **"**Passive Transmission**"** and transmission usually is either by accidental ingestion of the infective stage or an infected intermediate host of the parasite, or intentional ingestion some part of the intermediate host containing the infective stage.

PASSIVE TRANSMISSION FROM CONTAMINATED SOURCES

There are two categories of infective agents that are transmitted from a contaminated source, those agents that are infective immediately after being passed with the feces and those that require an incubation period to develop to the infective stage.

PASSIVE TRANSMISSION FROM:

An Immediately Infective Contaminated Sources is usually accidental in that the individual being infected is unaware of coming in contact with the infective agent. The source of the infective agent may be water, food, soil, inanimate objects, clothing, or anything that is contaminated. A contaminated body surface also can be the source of infection as seen in mental institutions where infections with *Enterobius vermicularis* occur with intimate contact between individuals. Embryonated eggs may be distributed in clothing and on the body surface through uncleanly practices and accidentally ingested during intimate behavior. The final site of *E. vermicularis* is the colon.

The cysts of *Giardia lamblia* and the oocysts of *Cryptosporidium* are immediately infective and are usually transmitted passively by drinking water that was contaminated with feces containing cysts and/or oocysts and thereby is an **immediately infective contaminated sources.** The final site for *G.* lamblia and *C. parvum* is the small intestine in the definitive host and man is a **typical definitive host**.

The mature cysts of *Entamoeba histolytic* passed in feces are also immediately infective and may be transmitted by eating contaminated food or eating from utensils that have been contaminated by unclean food handling practices. The cysts remain infective for a limited time depending on environmental conditions. The final site in typical infections is the colon and man is a **typical definitive host.**

The Cestode (tapeworm) eggs of *Hymenolepis nana, Taenia solium,* and *Echinococcus granulosa* are immediately infective and remain infective for considerable time. Infection is usually by accidental ingestion of the eggs form dirt or food that was contaminated earlier.

By ingesting eggs, man becomes the **typical definitive host** of *H. nana* with the adult tapeworm developing in the small intestine. Mice are alternate definitive hosts and cereals containing mouse dropping are frequently a source of infection.

By ingesting eggs of either *T. solium* or *E. granulosa*, man may become an **"aberrant intermediate host"**. Man becomes infected with a larval stage located in some body tissue. Because that larva is not generally available to be ingested by a suitable host, the parasite will fail to continue its life cycle.

Man is the typical definitive host of *T. solium* and wherever feces from an infected individual is deposited becomes an **immediately infective contaminated source.** The intermediate hosts are usually pigs but many mammals can be atypical and/or alternate intermediate hosts, including man. Through poor sanitary practices, an infected human as the definitive host, may be responsible for infecting himself and/or others, human or mammal, that can serve either as an **"alternate intermediate host**" or an **"aberrant intermediate hosts"** of the tapeworm.

The typical definitive hosts of *E. granulosa* are canines and whatever feces from an infected dog contaminates becomes an **immediately infective contaminated source**. Undulates are the usual intermediate hosts and ingest the eggs when grazing. Man usually becomes infected by accidentally ingesting eggs from a contaminated source but man becomes an **aberrant intermediate host** and the life cycle stops. There have been rare cases in Africa where the body of a dead human, infected with the cysts of *E. granulosa*, was not buried but was left in a field and was eaten by hyenas, an **alternate definitive host** for the parasite, and the life cycle was continued.

PASSIVE TRANSMISSION FROM:
A Delayed Infective Contaminated Source Since the eggs of *Trichuris trichiura* and *Ascaris lumbricoides* are not infective when passed in the feces, the medium or object that was contaminated becomes a **"delayed infective contaminated source"** and the source must remain contaminated for several weeks before infection could be transmitted. The eggs are resistant and may live for several months so infection may occur at any time after the incubation period necessary for the embryo to reach the infective stage. The final site of *A. lumbricoides* is the small intestine whereas that of *T. trichiura* is the colon. Man is the **typical definitive host** of both parasites. The usual mode of infection is by accidental ingestion of food or simply dirt that was contaminated earlier.

PASSIVE TRANSMISSION FROM:
Infested Sources Since the infective stages in an infested source are essentially free-living and can move about to find and attack a susceptible individual, the mode of transmission is always active.

PASSIVE TRANSMISSION FROM:
Infected Sources This mode of transmission is almost always by unknowingly ingesting the infective agent when either "accidentally ingesting the infected

intermediate host source" or by "intentionally ingesting a part of the intermediate host source" that contains the infective agent.

Ingesting the infected host source:

When drinking water from a natural resource, a copepod infected with juveniles of the nematode, *Dracunculus* sp. may be ingested resulting in dracontiasis. The location in man, a **typical definitive host,** is the intermuscular fascia.

Ingestion of a copepod with a procercoid larva of a Diphyllobothriid tapeworm results in sparganosis, an infection where a migrating pleurocercoid larva may be located in any body tissue. Man becomes a dead end, an **"aberrant intermediate host."**

A number of species of trematodes of the family Echinosotomatidae infect man, the most common being *Echinostoma ilocanum*. A variety of animals serve as the definitive hosts and which are the typical definitive hosts is uncertain. A variety of mollusks serve as the second intermediate hosts. Man eats raw and swallows hole some fresh water mollusks, such as the snails *Pila conica* in the Philippines and *Viviparus javanicus* in Java. Mollusks are also the second intermediate host of *Gastrodiscoides hominis,* a fluke infects the cecum and ascending colon of man. Ingestion of infected snails harboring metacercariae any of these species can result in an intestinal fluke infection and man becomes an **accidental definitive host**.

A liver fluke, *Dicrocoelium dendriticum*, has been reported from man. Its first intermediate host is a land snail and the second intermediate host is a field ant. Sheep, the definitive host, accidentally ingest infected ants when grazing. Man can become an accidental definitive host by accidentally ingesting an infected ant usually when eating fresh vegetables or salads harboring infected ants.

Ingesting a part of the host source containing the infective agent:

Eating inadequately cooked pork or bear meat containing cysts of the nematode, *Trichinella spiralis* can result in trichinosis. The cyst encasing the juvenile worms is digested and the juveniles grow into adult males and females in the small intestine and man becomes a **definitive host**. After copulation, the female worm produces eggs that hatch in her uterus and the juveniles are extruded in the intestinal track of the host. The juvenile worms penetrate the intestinal villi, reach capillaries or lymphatic vessels and are carried by the circulation throughout the body. They escape the vessels and enter muscle where they become encysted and develop to the infective juvenile stage. In man, they reach a dead end and man becomes an **aberrant intermediate host**.

Eating inadequately cooked pork containing cysts of the cestode *Taenia solium* can result in an intestinal tapeworm infection. Similarly, an intestinal tapeworm infection can be acquired by Ingesting inadequately cooked beef (a good rare steak) containing the cysts of the cestode, *T. saginata.* In both cases, man is the **typical definitive host**.

Where plants are the infected source, ingestion of the uncooked, infected plants as fresh vegetables or in salads is a form of passive, accidental transmission. The metacercariae of the liver fluke (trematode), *Fasciola hepatica,* attaches to water

vegetation such as water crest that usually is eaten fresh. Man is an **accidental definitive host** with the parasite reaching the bile ducts of the liver as their final site.

Metacercariae of the intestinal fluke, *Fasciolapsis buski* will attach to water chestnuts, which also may be eaten uncooked resulting in an intestinal infection. The parasites develop to adulthood attached to the villi of the small intestine.

The metacercariae of a number of species of trematodes encyst in the muscles of fish. Cercariae emerge from the snail intermediate host and swim about in search of a suitable fish. They attach to the scales, migrate under the scales, through the skin, and reach the intermuscular fascia where they encyst to become metacercariae. At this point, the fish becomes the second intermediate host and the source of infection for the definitive host. There are many recipes that call for pickled, uncooked, or partially cooked fish that do not kill the metacercariae. Ingested viable metacercariae excyst and will either develop to maturity attached to the villi (*Metagonimus yokogawai* and *Heterophyes heterophyes*) or will migrate to and up the common bile duct to smaller biliary passages where they grow to maturity (*Clonorchis sinensis, Opisthorchis viverini*, or *O. felineus*). Man is a definitive host.

The cercariae of *Paragonimus westermani* that are ingested by freshwater shrimp or prawns encyst as metacercariae in muscle tissue. When infected prawns or shrimp are eaten uncooked, the larval trematode emerges from the cyst and normally penetrates the villi, enters the peritoneal cavity, and migrates to and penetrates the diaphragm to enter the pleural cavity. It will enter the lungs through to lung capsule and migrate to the bronchioles, its final site, and grows to maturity. Man is a definitive host.

The nematode, *Anisakis marina* and some other nematode species are found in marine mammals. The intermediate hosts can be any of a wide variety of salt-water fish. If infected fish are eaten inadequately cooked, man can become a second but **aberrant intermediate host**. The juveniles usually become embedded in the tissues of the small intestine. Anisakiasis is characterized by severe abdominal symptoms and infection may persist for a year or more.

ACTIVE TRANSMISSION

Active Transmission implies that the infective stage of the parasite actively pursues the host and infects it (from infested sources) or the intermediate host harboring the infective stage of the parasite seeks out a host and either injects (definitive host in the case of malarial parasites) the infective stage of the parasite or deposits the infective agent on the body surface of the host and the parasite itself invades the tissues of the host (infected sources). In the latter case, the intermediate host becomes a **transport host or vector**.

ACTIVE TRANSMISSION FROM:

Contaminated Sources. Since the parasites involved in contamination are inactive and play no role in transmission, active transmission from contaminated sources does not occur in parasitic diseases.

ACTIVE TRANSMISSION FROM:

Infested Sources implies that the infective agent is essentially free-living and that the agent itself acts independently, searches for, and infects a suitable host. If a transport host is involved, it functions only to bring the infective stage to a susceptible host. If the host it infects is unsuitable, the life cycle is stopped and the host is designated an aberrant host.

The free-swimming, fork-tailed cercariae, the infective stage of members of the family Schistosomatidae, swim about freely in water. They are attracted to warm-blooded animals including man. When contacting the skin, they penetrate the superficial layer of the skin leaving their tails on the surface. They frequently initiate an allergic response especially in previously sensitized individuals. In man, it appears that all of the nonhuman, bird and animal parasites are destroyed by the body defenses in the superficial layers of the skin (cercarial dermatitis) in this **aberrant host**. If man is a **typical host**, the larval schistosome, now a schistosomule, penetrates blood or lymphatic vessels, is carried through the heart, lungs, and eventually to the liver. In the venules of the liver, it grows to maturity, mates, and then migrates against the venous circulation to the site of egg production in the mesenteric venules (in man, those of the intestine, *Schistosoma mansoni*, *S. intercalatum,* and *S. japonicum* or those of the bladder, *Schistosoma hematobium*). Man is the a typical definitive host.

The third stage, filariform juveniles that are the infective stage of hookworms and *Strongyloides stercoralis*, that were deposited on the ground earlier in the life cycle, move about on the surface of moist soil or on moist vegetation. In dry conditions, they burrow deeper in the soil to keep from becoming dehydrated and, in that way; they prolong their life and the site may remain potentially infective for some time. On the surface, they will literally crawl to the highest point of moist grass awaiting contact with a warm-blooded host. If they contact the body surface of a possible host (or even moist clothing) they will begin the process of mechanically penetrating the skin and subcutaneous layers of the dermis. During this period, the migrating worms incite an immediate response with severe itching, papules, and edematous tracks. If the host is not typical or suitable, the juveniles will continue to migrate within the layers of the skin for up to ten days or until they die (creeping eruption) in this **aberrant host.** In a **typical host**, the juveniles enter lymphatic or blood vessels and are carried to the heart and lungs during which time they continue to develop. Some juveniles will be coughed up from bronchioles of the lung and swallowed and develop to mature adults in the small intestine.

The eggs of the Human Bot Fly, *Dermatobia hominis*, usually are deposited on the ventral thorax of a mosquito that functions as a **transport host**. The larvae within the eggs are infective within a few days and the transport host becomes an **infested source** since the eggs are on its surface. When the arthropod to which the eggs are attached feeds on a mammal or human, the larvae are stimulated by the warmth of the body to emerge from the egg, attach to, and penetrate the skin. The mode of transmission is active from an infested source, the transport host (vector). Man becomes an accidental definitive host of *Dermatobia hominis*.

ACTIVE TRANSMISSION FROM:

An Infected Source implies that the infective stage is located within some organism and that organism may function as an intermediate host and that host and/or the parasite play an active role in transmitting the parasite to a new host. The mode of transmission varies greatly depending on what is functioning as and location of the infective stage in the intermediate host.

The Infected Source Injects The Infective Agent

The infective stage of parasites causing malaria and African sleeping sickness are located in the salivary glands of their respective arthropod, intermediate hosts. When the intermediate host feeds (anophiline mosquitoes for malaria and tsetse flies for African sleeping sickness), the infective stage is injected along with salivary fluids to initiate infection.

The Infected Source Deposits The Infective Agent

The infective metacyclic trypomastigotes of *Trypanosoma cruzi* reside in the hindgut of infective reduviid bugs. When the bug feeds, it defecates on the skin surface and the trypomastigotes present penetrate the body surface through mucous membranes, hair follicles, or breaks in the skin. The intermediate host functions as a transport host or vector. One in the host, the infective stages are either transported by the blood vascular system or migrate to various organs, mainly endothelial tissues, where they penetrate the cells, lose their flagella, and become amastigotes (leishmania).

The infective filariaform juveniles of parasites causing filariasis and onchocerciasis reside in the labium (the sheath in which to other mouthparts are enclosed) of their respective intermediate hosts (culicine mosquitoes for filariasis and species of Simulidae for onchocerciasis). When the insect feeds on a suitable host, the infective juveniles escape from the labium onto the skin surface. Many of the infective juveniles become dehydrated and die on the skin surface. Those of *Onchocerca* volvulus that are able to penetrate the superficial layer migrate through the intermuscular fascia and, eventually, surviving males and females mate and the female begins producing microfilariae. The juveniles of species causing filariasis migrate in dermis and eventually to lymphatic vessels where they grow to maturity, mate, and the female begins producing microfilariae.

Autoinfection

Autoinfection is another form of active transmission from an infected source. The eggs of *Hymenolepis nana* are infective when released from a gravid proglottid. In individuals with severe constipation or reverse peristalsis, onchospheres may be liberated from the eggs before it is evacuated. They penetrate the villi where they develop to the cysticercoid stage as they do when eggs are ingested. After about two weeks, the villus will break releasing the cysticercoid which will attach to the intestinal wall and develop into adult tapeworm without leaving the intestine of the infected individual. Autoinfection can lead to hyper infection with many small tapeworms creating a more severe symptoms and possible toxemia.

In cases of *Strongyloides stercoralis* where infected individual is taking immunosuppressive drugs or is experiencing severe constipation and/or reverse peristalsis, the juveniles can reach the infective stage and penetrate the gut wall. In such cases, reinfection of the same individual occurs without the parasites being evacuated. When the juvenile enters through the intestinal wall, it is disorientated and, rather than following its usual life cycle, it continues to migrate through various tissues causing inflammation as it travels. Typical infections are remarkably persistent and hyperinfection resulting from autoinfection can result in a fatal outcome.

Active Transmission Between Individuals

This specific mode of transmission from an infected individual to an uninfected one occurs through intimate contact. The opportunity for infection of the new host occurs when an actively motile stage of a parasite within the infected individual comes in contact with the body surface of the uninfected one.

In the case of *Trichomonas vaginalis*, the opportunity for transmission occurs during sexual intercourse. Infections can be initiated either when the trophozoite from an infected female host enters the urethra of the penis of the male or when a trophozoite from an infect male enters the vagina of the female.

Rarely, infection of the skin of the penis with *Entamoeba histolytica* has occurred. Apparently, trophozoites present in the rectum of the infected host gained entrance into a cutaneous area of the penis through breaks in the skin during anal sex.

Transmission Across The Placental Barier

Although the exact mechanism is not clearly understood, there are cases where the fetus of a pregnant woman with malaria have become infected when merozoites from the blood of the mother have crossed the placental barrier and entered the erythrocytes of the fetus. Infection of the fetus of pregnant women with *Trypanosoma rhodesiense* also has occurred apparently under similar conditions. There are a large number of species of parasites that are in the circulatory system at some point during their life cycle. There is always the possibility that trans-placental infections by other species may occur especially in individuals with a compromised immune system.

EPILOGUE

In this attempt to clearly define the mechanisms whereby endoparasitic infectious organisms can be transmitted from infected to uninfected individuals, the various sources and the modes of transmission have been presented. The definitions given may apply not only to infectious endoparasitic disease entities but also may apply to other infectious disease organisms, e.g. viruses and bacteria. For organisms other than endoparasites, additional, unique modes of transmission may be more important, especially for viruses. The variety of those mechanisms presented should at least stimulate the exploration of the specific source and possible mode of transmission in any outbreak of an infectious disease and, this knowledge should provided a basis for methods of control and prevention.