

Chapter 2

Disease and disease transmission

An enormous variety of organisms exist, including some which can survive and even develop in the body of people or animals. If the organism can cause infection, it is an infectious agent. In this manual infectious agents which cause infection and illness are called pathogens. Diseases caused by pathogens, or the toxins they produce, are communicable or infectious diseases ⁽⁴⁵⁾. In this manual these will be called disease and infection.

This chapter presents the transmission cycle of disease with its different elements, and categorises the different infections related to WES.

2.1 Introduction to the transmission cycle of disease

To be able to persist or live on, pathogens must be able to leave an infected host, survive transmission in the environment, enter a susceptible person or animal, and develop and/or multiply in the newly infected host.

The transmission of pathogens from current to future host follows a repeating cycle. This cycle can be simple, with a direct transmission from current to future host, or complex, where transmission occurs through (multiple) intermediate hosts or vectors.

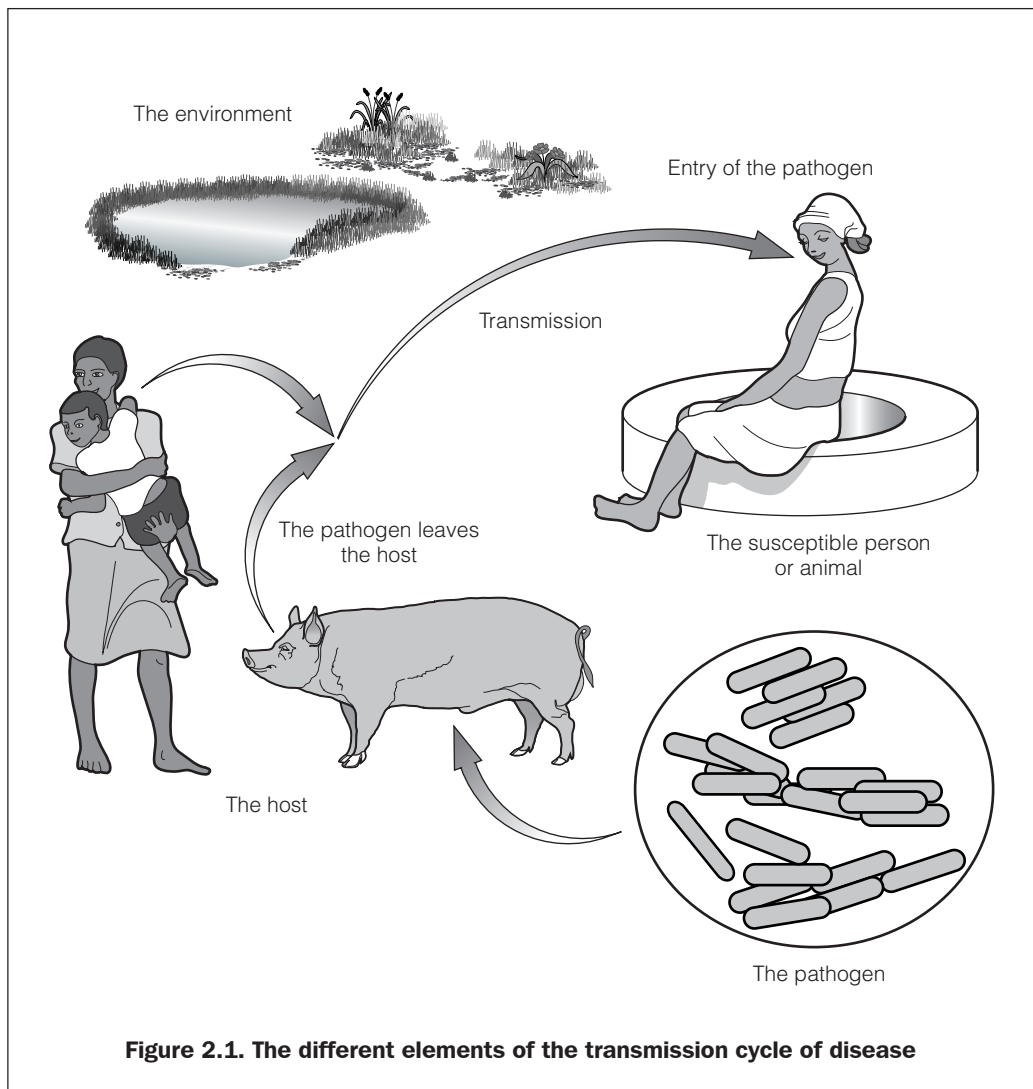
This cycle is called the transmission cycle of disease, or transmission cycle. The transmission cycle has different elements:

- The pathogen: the organism causing the infection
- The host: the infected person or animal 'carrying' the pathogen
- The exit: the method the pathogen uses to leave the body of the host
- Transmission: how the pathogen is transferred from host to susceptible person or animal, which can include developmental stages in the environment, in intermediate hosts, or in vectors

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- The environment: the environment in which transmission of the pathogen takes place.
- The entry: the method the pathogen uses to enter the body of the susceptible person or animal
- The susceptible person or animal: the potential future host who is receptive to the pathogen

To understand why infections occur in a particular situation, and to know how to prevent them, the transmission cycles of these infections must be understood. The rest of this chapter looks at the elements of the transmission cycle in more detail.



2.2 The pathogen

The pathogen is the organism that causes the infection.* Specific pathogens cause specific infections. Cholera is caused by the bacterium *Vibrio cholerae*, for example, and Leishmaniasis is caused by different species (spp.) of the protozoa *Leishmania*.

Specific infections also have specific transmission cycles. To be able to react appropriately to health problems in a population, the specific infection causing the problems must be known. Identification of the infection will usually be done by medical personnel.

Different categories of pathogens can infect humans. The pathogens causing the diseases covered in this manual include viruses, bacteria, rickettsiae, fungi, protozoa, and helminths (worms). All pathogens go through a lifecycle, which takes the organism from reproducing adult to reproducing adult. This cycle includes phases of growth, consolidation, change of structure, multiplication/reproduction, spread, and infection of a new host. The combination of these phases is called the development of the pathogen.

Two terms are commonly used to describe pathogens leaving the host through faeces or urine: latency and persistence.

After excretion, a latent pathogen must develop in the environment or intermediate host before a susceptible person or animal can be infected. During the latent period the pathogen is not infectious. A non-latent pathogen does not need to go through a development, and can cause infection directly after being excreted.

Persistency describes how long a pathogen can survive in the environment. A persistent pathogen remains viable for a long period outside the host (perhaps months), while a non-persistent pathogen remains viable for only a limited period⁽⁶⁾ (days, or weeks).

Active immunity is the resistance the person or animal develops against the pathogen after overcoming infection or through immunisation (vaccination).⁽⁴⁵⁾ Depending on the pathogen, the effectiveness of active immunity often decreases over time.

* It is important to realise that not all infections will result in disease. While a pathogen may cause illness in one person, it may be killed or cause asymptomatic infection in another.

Usually immunity only develops against the specific pathogen that caused the infection. If there are different types (serotypes or strains) of the same pathogen (e.g. in dengue fever and scrub typhus), immunity will often only develop against the particular type which caused the infection. The person or animal can still develop the illness when infected with another serotype or strain of the pathogen⁽³⁾.

Table 2.1 presents the different categories of pathogenic organisms with some of their characteristics, including latency, persistence, and immunity. The information is general, and exceptions can occur.

2.3 The host

The host is the person or animal infected by the pathogen. The importance of the host in the transmission cycle is its roles as both reservoir and source of pathogens.

There are two types of host: definitive and intermediate host. The definitive host is the person or animal infected with the adult, or sexual, form of the pathogen. In the infections covered here, people are usually the definitive host. To keep things simple the definitive host is called just 'the host'.

The intermediate host is an animal or person infected by a larval, or asexual, form of the pathogen⁽³⁾. Cysticercosis and hydatid disease are the only infections covered here for which people are the intermediate host. Where intermediate host is meant, this term is used. Of the infections covered here, only helminths have both definitive and intermediate hosts. All other pathogens only have definitive hosts, although vectors function technically as intermediate hosts for protozoa.

Zoonosis: transmission from animal to person

Some pathogens are specific to humans, others to animals. Many pathogens are less specific and can infect both people and animals. Infections that can naturally be transmitted from animal to person are called zoonoses⁽³⁾. Zoonoses are very common; over half of the infections covered in this manual are zoonoses. Many of these infections normally occur in an animal cycle, with people being infected by chance.

The problem with zoonoses is that a continuous reservoir of pathogens exists outside humans. Even if all human infections were cured and transmission to people stopped, the presence of an animal reservoir would remain a continuous risk to people.

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Table 2.1. Categories of pathogenic organisms and their characteristics

Pathogen	Description	Latency	Persistence	Additional information
Virus	Particles invade living cells. The pathogen needs structures in these cells to reproduce. ⁽⁴⁵⁾	The pathogens are non-latent.	Viruses can survive for months in tropical temperatures. ⁽²⁸⁾	Where vector-borne, transmission to offspring is possible ⁽³⁾ . The immunity is often long-lasting. ⁽⁷³⁾
Rickettsiae	Organisms resemble bacteria. ⁽⁴⁵⁾ . However, similar to viruses, the pathogen needs to develop inside the cells of the host. ⁽²⁾	n/a	n/a	Transmission of the pathogen to the offspring of the vector occurs. ⁽⁷³⁾ . The immunity is usually long-lasting. ⁽³⁾
Bacteria	Bacteria are single cell organisms. They are considered more primitive than animal or plant cells. ⁽⁴⁵⁾	The pathogens are non-latent.	Persists up to several weeks. ^(16,73) . Can multiply outside the host. ⁽³⁾	The immunity developed is often incomplete or short-lived. ⁽³⁾
Fungi	A group of organisms which include yeast, moulds, and mushrooms. ⁽⁴⁵⁾	n/a	n/a	The duration of the immunity is variable. ⁽³⁾
Protozoa	Protozoa are single cell organisms. ⁽⁴⁵⁾	The pathogens are non-latent.	Forms a resistant cyst which can survive for months. ^(3,44)	The immunity is only maintained by repeated infections or vaccinations. ⁽⁷³⁾
Helminths (worms)	Helminths are worms (roundworms, flukes or tapeworms) ⁽⁴⁵⁾ . Often male and female must meet in host to reproduce, and sometimes they multiply in intermediate hosts.	The pathogen is latent. It often has a complex lifecycle with a development in the environment or intermediate hosts. ⁽⁷³⁾	The pathogen is persistent and some may survive for years in the environment. ^(3, 16)	Usually no immunity is built up against the pathogen. ⁽³⁾

n/a: Not applicable as the pathogens are not excreta-related.

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Prevention of zoonoses often includes control of animal hosts. This is possible by reducing the number of hosts (e.g. controlling rats), immunising domestic animals, or avoiding unnecessary contact with host animals.

Carriers: hosts without obvious illness

A person or animal who develops an illness is an obvious example of a host. It is very common, however, for infections to occur without the disease developing. The person or animal infected can potentially spread the pathogen, but does not show clear symptoms ⁽⁸⁾. The symptoms may be mild, or may be completely absent.

These hosts are called carriers, or asymptomatic carriers. Table 2.2 shows some infections that are frequently mild or asymptomatic. The host can be infectious for a short period in transient carriers, or over a prolonged period in a chronic carrier ⁽³⁾. Incubating carriers have been infected and can spread the pathogen, but do not yet show the symptoms of the illness. Convalescent carriers continue to spread the pathogen even though they have recovered from illness.

In many infections carriers play an important role in transmitting the pathogen. It is usually not possible to identify asymptomatic carriers ⁽⁷³⁾, and unless the family and other close contacts of the sick person or even the whole population can be treated, carriers will remain a threat to the health of those surrounding them.

Table 2.2. Examples of infections with asymptomatic carriers

Infection	Asymptomatic infections
Bacillary dysentery	common ⁽³⁾
Cholera (El Tor)	only 1 in 30-50 infections develops illness ⁽¹⁶⁾
Giardiasis	1 in 2-4 infections develops illness ⁽⁴⁴⁾
Polio	very common
Typhoid fever	very common ⁽⁷³⁾
Schistosomiasis	very common ⁽¹⁶⁾
Hookworm	very common
Yellow fever	common ⁽³⁾
Japanese Encephalitis	only 1 in 1,000 infections develops illness ⁽⁴⁴⁾
Filariasis	very common
Malaria	common ⁽³⁾
River blindness	common ⁽²⁾
Plague	common during epidemics ⁽⁷³⁾

Other reservoirs of pathogens

Besides hosts, there are several other pathogen reservoirs that can play a role in the transmission of disease. Some pathogens are very resistant, and can survive in the environment for considerable time. Though this will normally be an exception, roundworm eggs can remain viable in soil for years ⁽³⁾.

Intermediate hosts may be important reservoirs of pathogens, and several helminths can even multiply in the intermediate host.

Vectors are usually infectious for life, and several pathogens can be transmitted to the offspring of the vector over several generations ⁽²⁾. A soft tick, for example, can survive for more than five years and can pass to its offspring the pathogen which causes tick-borne relapsing fever ⁽⁷³⁾.

Some pathogens can live their entire lifecycle outside the host. These include threadworm and several faecal-oral bacteria which cause bacillary dysentery, (para)typhoid, and salmonellosis ⁽³⁾.

Animal hosts, asymptomatic carriers, and other potential reservoirs of pathogens can be important sources of infection, and this must be taken into account when trying to control disease. The whole population at risk may have to be treated, or animal hosts controlled. With several diseases these preventive measures will have to be maintained over a long period before a reduction in the occurrence of the infection will be noticeable.

2.4 Transmission of disease

To survive as a species, pathogens must infect new people or animals. To do this, they must leave the body of the host, find their way to a new susceptible person or animal, and enter the body of that person or animal. As the exit, transmission, and entry of the pathogens are closely associated, we will cover them together.

Water and environmental sanitation interventions that aim to improve the health of a population usually try to reduce the risk of transmission of infection. To do this appropriately, the WES specialist needs to be familiar with the pathogens' transmission route(s). It is this understanding that enables the specialist to determine which control measures will be most effective in a particular situation.

As many infections are linked to WES, it is useful to categorise the different diseases.

For a water and sanitation specialist the most useful categorisation is based on the transmission cycles of the infections. Generally speaking, diseases with similar transmission cycles can be controlled by similar preventive measures, and will occur in similar environments.

The infections are categorised and their transmission routes described at the same time. More information on the transmission routes and potentially effective preventive measures of specific diseases can be found in Annexe 1.

Some terms relating to the transmission or classification of infections are defined here:

Food-borne infections: infections which can be transmitted through eating food containing the pathogen.

Vector-borne infections: infections transmitted through vectors. We use vector-borne infections only for infections with a *biological vector*, that is a vector in which the pathogen goes through a development before further transmission is possible (e.g. mosquitoes, tsetse fly, body louse). We do not classify as vector-borne those infections which are transmitted by *mechanical vectors*, that is the animal is only a vehicle for transporting the pathogen (e.g. domestic flies, cockroaches).

Water-borne infections: infections which can be transmitted through drinking-water which contains the pathogen.

Water-washed infections: infections caused by pathogens whose transmission can be prevented by improving personal hygiene.

Infections can have either direct or indirect transmission routes.

2.4.1 Infections with direct transmission

A pathogen with a direct transmission route can infect a susceptible person or animal immediately after leaving the host. The pathogen does not need to develop in the environment, in an intermediate host, or in a vector.

In faecal pathogens these are the non-latent infectious agents.

This group contains three disease-groups: faecal-oral infections, leptospirosis, and infections spread through direct contact.

2.4.1.1 Faecal-oral infections

These pathogens leave the host through faeces, and enter the susceptible person or animal through ingestion. Transmission occurs mainly through direct contact with contaminated fingers; food contaminated directly with excreta, contaminated hands, domestic flies, soil, or water; contaminated drinking-water; or contaminated soil. Faecal-oral infections are food-borne, water-borne, and water-washed. As faecal-oral infections are transmitted directly, any route that will take matter polluted with faeces directly or indirectly to somebody’s mouth could potentially transmit the pathogen. Figure 2.2 shows some common transmission routes of faecal-oral infections.

Some of these infections have mainly animal hosts, while others are limited to humans. Faecal-oral infections include diarrhoeal diseases such as cholera and bacillary dysentery, typhoid, hepatitis A, and poliomyelitis.

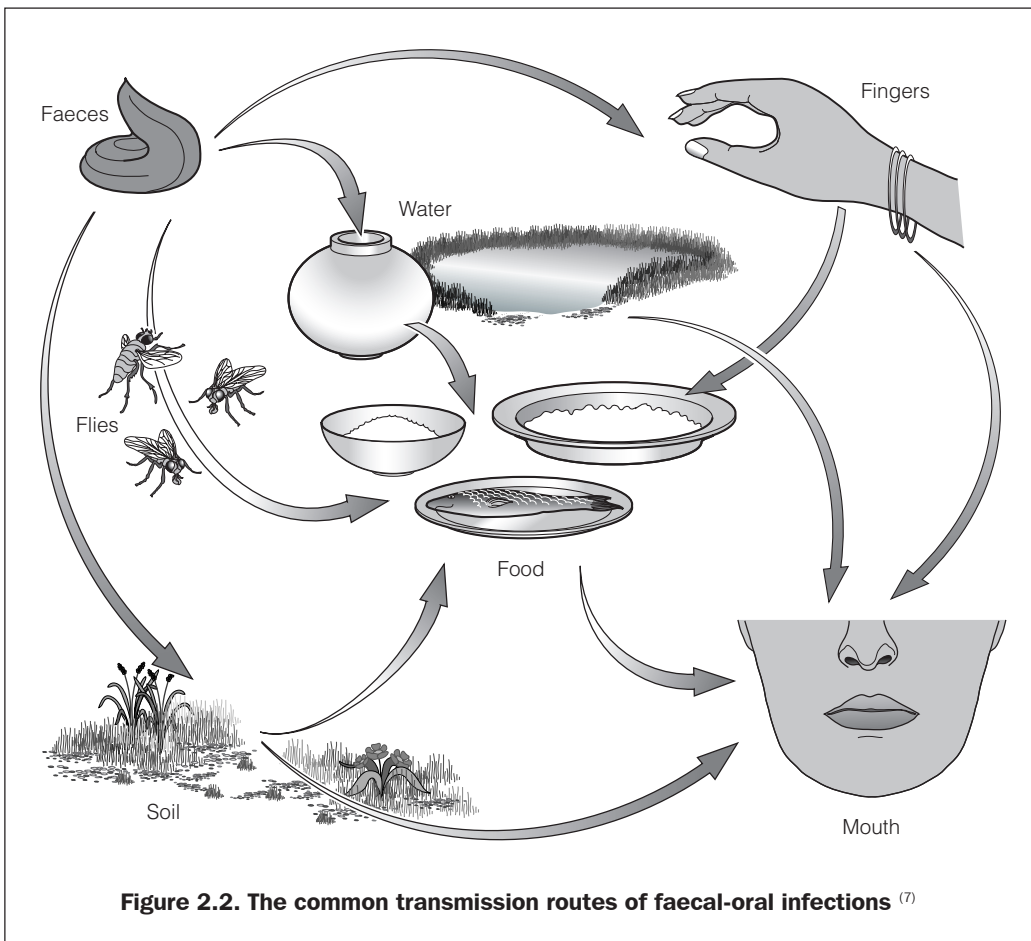


Figure 2.2. The common transmission routes of faecal-oral infections ⁽⁷⁾

2.4.1.2 *Leptospirosis*

The main reservoir of leptospirosis is normally rats, though many other animals can potentially transmit the infection. The pathogen leaves the animal host through urine. People are usually infected through direct skin contact with water, moist soil, or vegetation contaminated with urine from infected animals. Other ways of transmission are direct contact with body tissues of infected animals or ingesting food contaminated with urine. Transmission from person to person is rare ⁽³⁾.

2.4.1.3 *Infections of direct contact*

All the diseases covered in this manual that fall into this category are infections which affect the skin or eyes. Pathogens are present on the skin or in the discharges of affected body parts or eyes. The pathogens are transmitted directly through contaminated hands, clothes, domestic flies, or any other contaminated material.

The pathogen enters the body through skin or mucous membranes such as the eyes. These infections are associated with poor personal hygiene and are water-washed.

Few of these infections have animal hosts. The diseases in this category include conjunctivitis, trachoma, yaws, and scabies.

2.4.2 *Infections with indirect transmission*

A pathogen with an indirect transmission route must go through a development phase outside the host before it can infect a new susceptible person or animal. This development will take place in a specific intermediate host, vector, or type of environment.

This need to go through a particular organism or environment gives the transmission route a focus, which preventive measures can target, for example by vector control or improved food preparation.

In the faecal pathogens these are the latent infectious agents.

The disease-groups with indirect transmission are soil-transmitted helminths, water-based helminths, beef/pork tapeworm infection, Guinea-worm infection, and vector-borne infections.

2.4.2.1 Soil-transmitted helminths

These worms leave the body through faeces as eggs or larvae. After excretion they have to develop in soil. They can be further divided based on how the pathogen enters the human body.

Entrance by penetration of the skin: the pathogen enters the body through skin which is in direct contact with contaminated soil. This is the method used by hookworms and threadworms.

Entrance by ingestion: if either contaminated soil, or food or hands contaminated with polluted soil come into contact with the mouth, the pathogen can be transmitted. These infections can be food-borne and water-washed. This method is used by roundworms and whipworms.

The infections covered here do not have animal hosts. Figure 2.3 presents the transmission routes of the soil-transmitted helminths.

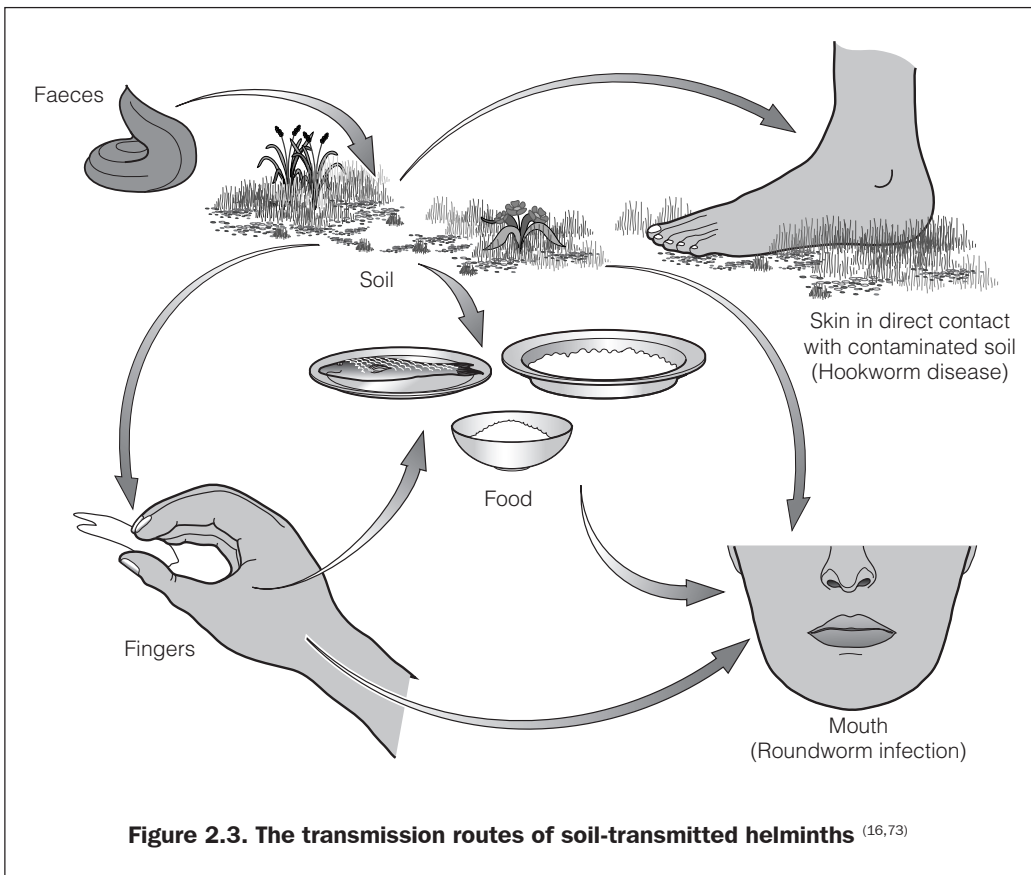


Figure 2.3. The transmission routes of soil-transmitted helminths (16,73)

2.4.2.2 Water-based helminths

These pathogens leave the body through excreta. The infectious agents must develop in intermediate hosts living in freshwater. The transmission of these infections is therefore only possible if excreta containing the pathogens reaches fresh surface water in which there are suitable intermediate host(s). Based on transmission cycle, this category can be sub-divided in two groups:

Schistosomiasis. After excretion, the pathogen infects a freshwater snail, in which it develops and multiplies. The snail releases the pathogens into the water, and people are infected when these pathogens penetrate skin which is in direct contact with infected freshwater. Only one type of schistosomiasis (which occurs only in Asia) has an important reservoir in an animal host; all other types have people as the only host of importance.

Water-based helminths with two water-based intermediate hosts. The first intermediate host is a freshwater snail or copepod. The second intermediate host is a freshwater plant, fish, or crabs/crayfish. The intermediate hosts are specific to the pathogen. These infections are food-borne and people become infected when they eat the second intermediate host without properly cooking it. All these infections affect both animals and people. These diseases include opisthorchiasis, clonorchiasis, and lung fluke disease.

The transmission routes of the water-based helminths are presented in Figure 2.4.

2.4.2.3 Beef/pig tapeworm infection

The pathogens leave the person through faeces. The excreted eggs then have to be ingested by either cattle or pigs. Once the pathogen is ingested by the animal, it will develop in the body of the cow or pig. The infections are food-borne and people become infected when they eat undercooked beef or pork containing the pathogen. People are the only hosts to the infection.

A dangerous complication called cysticercosis is possible when people ingest the eggs of the pig tapeworm. The pathogen will form cysts throughout the person's body. Transmission of this infection is like faecal-oral infections.

2.4.2.4 Guinea-worm

In this infection the pathogen, a large worm, creates a blister on the person's skin, which erupts when it comes into contact with water, releasing the worm's larvae. These larvae then infect a copepod (*Cyclops*), in which it develops. The disease is water-borne. People become infected by drinking water containing *Cyclops*, and

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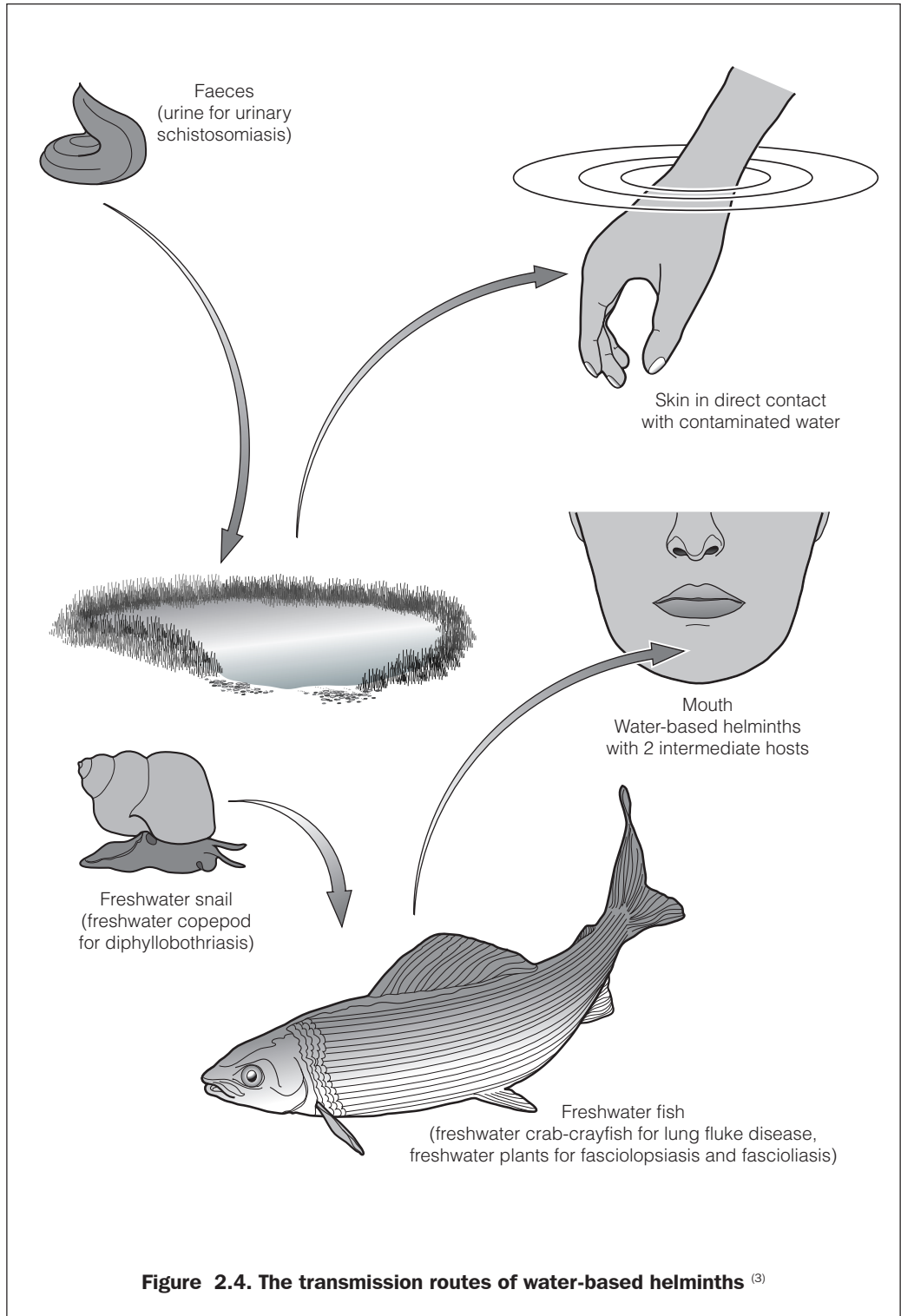
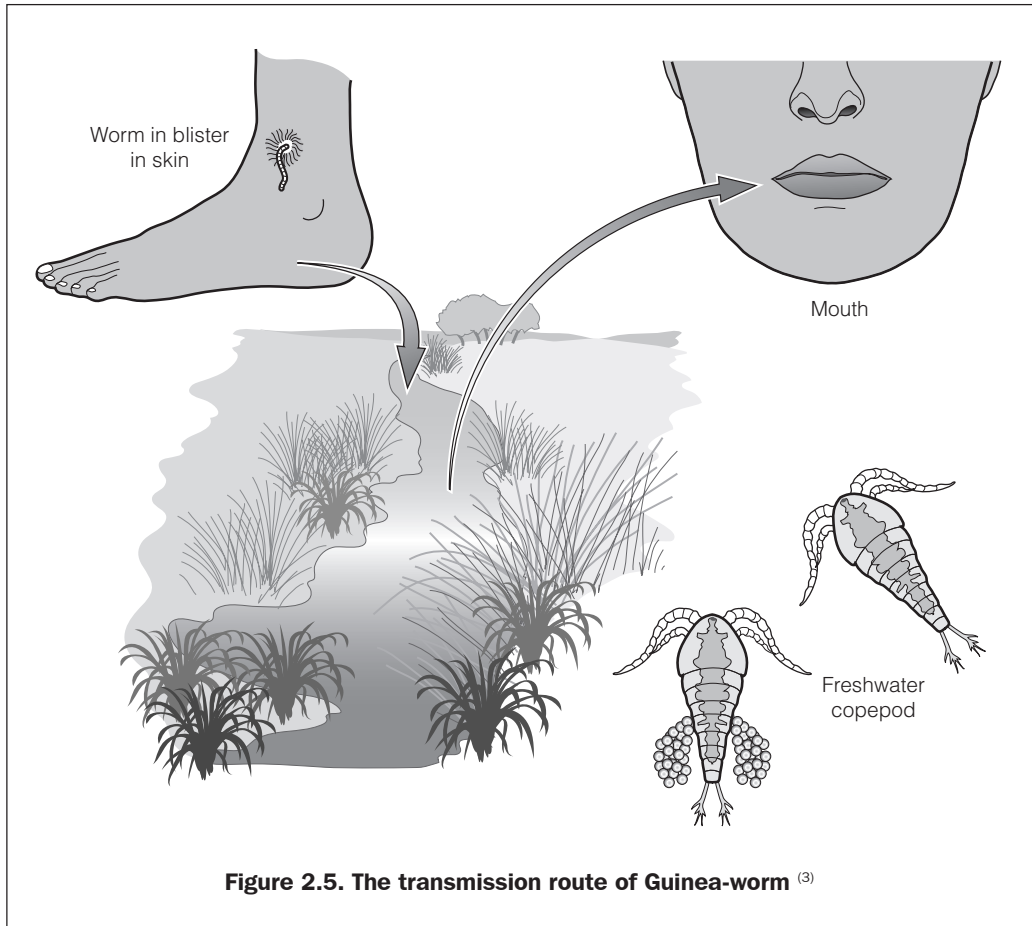


Figure 2.4. The transmission routes of water-based helminths ⁽³⁾



are the only host to this infection. Figure 2.5 shows the transmission route of Guinea-worm.

2.4.2.5 Vector-borne diseases

These infections are transmitted by vectors. Vectors are arthropods (insects, ticks, or mites) which can transmit infections from host to future host ⁽⁷³⁾. The pathogen exists in the blood or skin of the host. The vector becomes infected when it feeds on a host. The pathogen develops and multiplies inside the vector, which then becomes infectious. People are usually infected through the bite of an infectious vector, though other ways of entry are possible. With several vector-borne diseases animal hosts are important reservoirs. Vector-borne diseases include yellow fever, malaria, sleeping sickness, plague, epidemic louse-borne typhus fever, and louse-borne relapsing fever.

2.5 The environment

The environment is everything that surrounds the pathogen in its transmission from host to susceptible person or animal. Obviously the environment is a vast subject, and we can only look at some of the more important environmental factors here.

Interventions which involve WES will often modify the environment to try to reduce the transmission risk.

The environmental factors that we will look at here are climate, landscape, human surroundings, and human behaviour. Environmental factors are often associated, for example higher altitudes result in lower temperatures, landscapes are formed by the climate.

2.5.1 The climate

The climate and its seasonal changes play an important role in disease transmission. The presence of vectors and intermediate hosts often depends on rain and temperature.

The climatological requirements of the vector or intermediate hosts can predict whether an infection is likely to be a problem in an area. Malaria, for example, will normally not occur in temperatures below 16°C and infection is thus unlikely at altitudes above 2,000 metres.

In general, direct sunlight, a dry environment, and high temperatures will reduce the survival times of pathogens in the environment.

Conditions may not be suitable to transmission year round, and many infections are seasonal, occurring when the environment is favourable to transmission. Mosquito-borne infections, like malaria and yellow fever, are linked to the rainy season^(16,44). The occurrence of diarrhoeal diseases often increases with the first rains after the dry season, as faecal pollution is washed into rivers. Ponds which disappear in the dry season may in the wet season contain water with snails that will transmit schistosomiasis⁽⁷³⁾.

The climate influences human behaviour. In cold climates people will crowd together and wear more clothing. If this is combined with poor personal hygiene the the body-lice, vector of louse-borne typhus fever and louse-borne relapsing fever, can thrive.

In warmer climates children are also likely to play in surface water, where they can be infected with schistosomiasis.

2.5.2 The landscape

The landscape consists of the larger physical structures in the environment. These structures are usually natural, but can be man-made. They include mountains, deserts, rivers, jungle, artificial water reservoirs, and deforested areas. Aspects of the landscape that would influence disease transmission most are the micro-climate, the presence of water, and types of vegetation.

Man-made modifications of the landscape often increase the risk of disease transmission by creating a habitat favourable to vectors or intermediate hosts. Large artificial water reservoirs frequently increase the occurrence of malaria and schistosomiasis ⁽⁶⁾, for example, and introducing irrigation schemes can increase the occurrence of schistosomiasis ⁽¹⁵⁾.

Although the WES specialist working in the field must recognise the risk-factors linked to the landscape, he or she will normally not be able to modify the landscape to reduce the risks of disease transmission.

2.5.3 The human surroundings

Landscape and human surroundings are closely linked, and it is difficult to divide the two clearly. The difference is one of scale; while the landscape normally cannot be modified or improved by individual people, individuals can modify the human surroundings.

Although the landscape will normally be similar for all people living in an area, the human surroundings may be very different for people living in the same region, village, or even household. Many infections are linked to specific circumstances, and people with specific occupations, socio-economic status, gender, or religion may be far more at risk than others. While the father of an African family may be exposed to leptospirosis and plague because he works in sugarcane fields and regularly traps rats, the mother may be exposed to sleeping sickness as she goes to the river to wash clothes, and the children may be exposed to schistosomiasis while playing in the local pond.

The human surroundings are created by a combination of natural elements and how people have modified these elements.

People adapt their surroundings to their needs. If these adaptations are well done, they can help to prevent the transmission of disease. In practise they often

encourage the transmission of disease, however, as people do not have the space, motivation, understanding, time, energy, or financial or material means to do them properly.

In relation to the WES aspects, human surroundings are concerned with water supply, proper handling of excreta, removal of unwanted water, adequate management of solid waste, and control of vectors or intermediate hosts through modification of the environment or change in behaviour.

Waste products like excreta, wastewater, and refuse are disposed of in the human surroundings. These wastes must be properly managed to prevent them becoming a health risk.

The WES specialist working in the field will have to know what aspects of the human surroundings increase the risk of disease transmission. This will enable him or her to determine which aspects play an important role in the transmission of disease in a specific situation. Based on this, an intervention can be planned which will reduce the health risks to the population. More on the health risks relating to the human surroundings, and the components from WES interventions can be found in Chapter 5.

2.5.4 Human behaviour

People behave in a certain way because they believe that they are making the most of their lives. Human behaviour is complex. It is influenced by culture, for example religion, attitudes, and traditional beliefs; by social position, such as gender or age; by availability of means, for example money, energy, time, or material; and by politics.

One type of handpump may be acceptable in one culture, but unacceptable in another. One type of latrine may be preferred by men, while women or children might prefer another. People may not accept things from a government they despise, or from an insulting development worker.

Having access to a safe water supply, or technically adequate sanitation, does not automatically mean people will use them ⁽²⁵⁾. If people do not regard structures as acceptable, appropriate, or as an improvement to their quality of life, they will not be used, or will not be used to their full potential.

Interventions that have only focused on structural improvements have often given poor results in controlling infections. Studies in disease prevention indicate that the most important factor in reducing the transmission of diseases related to WES

is hygiene improvements resulting from changes in behaviour ⁽¹³⁾. Changing human behaviour in relation to WES should therefore be one of the priorities of the WES specialist.

The specialist will have to identify existing behaviour, attitudes, and behaviour concerning WES and their causes. This will form a base from which health and hygiene promotion can be introduced. All interventions should look at human behaviour, and where needed, reinforce existing positive behaviour while trying to modify behaviour that favours disease transmission.

2.6 The future host

The success of a pathogen in infecting a person will depend on:

- the infectious dose of the pathogen, and the number of infectious agents which manage to enter the potential new host (this applies mainly to faecal-oral infections); and
- whether the pathogen can overcome the barriers of the host.

These two factors are now considered in more detail.

2.6.1 The infectious dose

The infectious dose is the number of pathogens which have to enter the body of a susceptible person to cause infection. Although this figure should not be seen as exact, it does give an indication of how easily an infection can occur.

The infectious dose is normally only used for faecal-oral infections. As every larva of a helminth can become an adult worm, worms have a very low infectious dose.

Table 2.3 gives the infectious doses of several faecal-oral infections.

Infections with a low infectious dose are more likely to be spread by direct person-to-person contact than infections with a high infectious dose. Measures such as improving drinking-water quality, or reducing the concentration of pathogens in surface water (for example by treating sewage), are more likely to have effect on infections with high infectious doses than on those with low ones ⁽⁷³⁾. Intuitively one would say that flies are more likely to transmit infections with a low infectious dose, but this is complicated by the fact that several bacteria can multiply in food, and thus reach the infectious dose in this way.

Table 2.3. Examples of infective doses of faecal-oral diseases

<i>Disease</i>	<i>Infectious dose (in number of pathogens)</i>
Bacillary dysentery (shigellosis) ⁽¹⁶⁾	10 to 100
Giardiasis ⁽¹⁶⁾	10 to 100
Rotaviral enteritis ⁽¹⁶⁾	100 to 10,000
Cholera ⁽⁷³⁾	Usually 10 ⁶ to 10 ⁸
Typhoid ⁽⁷³⁾	10 ³ to 10 ⁹

2.6.2 The barriers of the body against pathogens

The body has a range of mechanisms that prevent a pathogen from causing infection.

The skin and mucous membranes have anti-microbial substances, and the stomach is acid to act as the first barriers against pathogens. Low acidity in the stomach or an open wound (e.g. insect bite, cut, abrasion) can make this barrier ineffective.

The next barriers are mechanisms that react to the pathogen, and try to counter its development. These barriers are not specific to the pathogen, and the body does not need to have been in contact with the pathogen for them to be effective. These mechanisms are the host's resistance against pathogens ⁽⁴¹⁾. Resistance is lowered if someone is suffering from other infections ⁽⁷³⁾, or is malnourished, stressed, or fatigued ⁽⁴¹⁾. Women have a higher risk of infection when pregnant ⁽⁷³⁾.

An individual's immune system may have experienced a pathogen through an earlier infection or immunisation (vaccination) with inactivated pathogens. When the pathogens enter the person's body, their immune system will recognise the pathogen and make antibodies which will attack the pathogen. This is called active immunity ⁽⁴⁵⁾. The effectiveness of active immunity depends on the pathogen, and the length of time since the body has been in contact with the pathogen. Active immunity is effective only against that particular pathogen. The effectiveness against bacteria and viruses usually lasts for years ⁽³⁾.

Passive immunity is created by introducing foreign antibodies into the body. An unborn baby receives antibodies from the mother through the placenta, which will protect it for some time after birth. Vaccination with antibodies is another way of creating passive immunity ⁽⁷³⁾. The foreign antibodies will slowly disappear from the body, and passive immunity will usually only last days or months ⁽³⁾.

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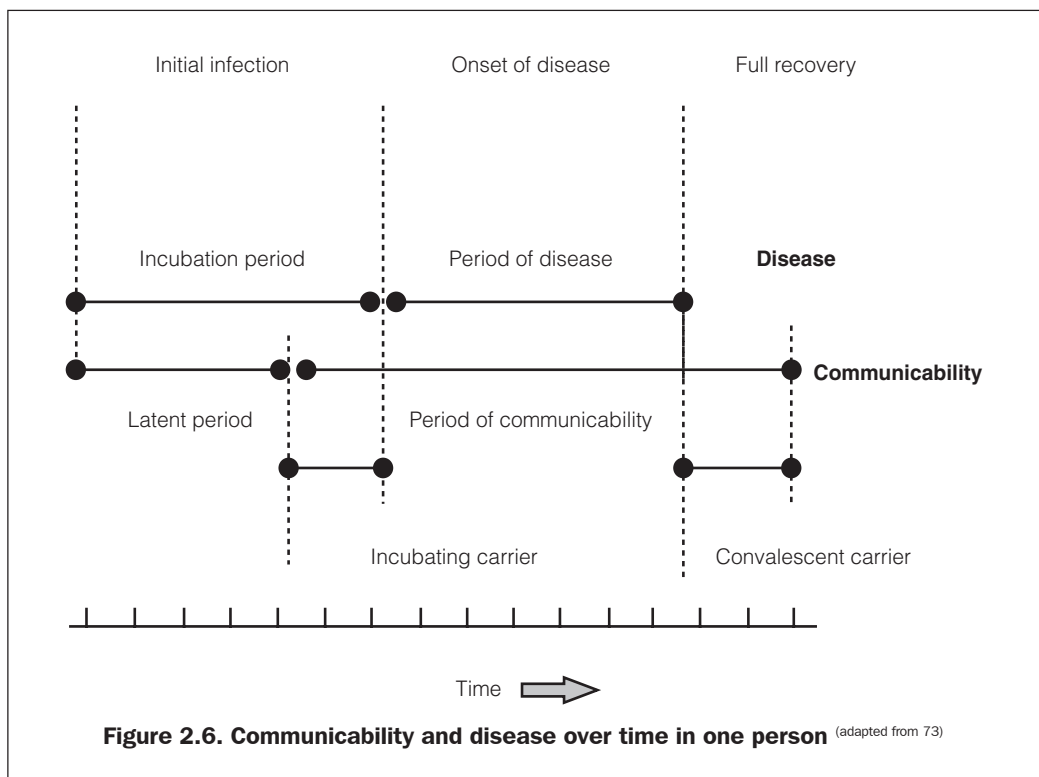
A person or animal who lacks effective barriers (has a poor resistance and/or a low immunity) against a pathogen is susceptible to this infectious agent ⁽⁴⁵⁾.

Two important practical points define the susceptibility of a population:

- A population that is weakened because of poor nutrition or a high occurrence of disease, fatigue, or stress has an increased risk of disease.
- When a pathogen is very common in a population, or the population is immunised, most people will have some form of immunity against it. In this case the disease will attack mainly children. If the same pathogen is introduced into a population which has low immunity, there is a risk of an outbreak (an epidemic) which can attack all ages.

2.6.3 The infection over time

When a pathogen is introduced in sufficient numbers, and overcomes the resistance and immune system of a person or animal, infection will follow. The time between entrance of pathogen and appearance of the first signs of disease or symptoms is called the incubation period. As mentioned earlier, not all infections will result in disease, and for many infections asymptomatic carriers are common.



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The period of communicability is the period in which the host is infectious, or the period in which pathogens are shed in the environment. The time between entrance of pathogen and the onset of communicability is the latent period. This is shown on a timeline in Figure 2.6.

In some infections the period of communicability starts before illness is apparent. Hosts who can transmit the pathogen before showing symptoms are called incubating carriers. If the period of communicability extends beyond the end of the illness, the hosts are called convalescent carriers.