The transmission and maintenance of infection

Infectious disease is the result of the invasion of a host by a pathogenic organism. The continued survival of infectious agents, with or without the induction of disease, depends on their successful transmission to a susceptible host, the instigation of an infection therein and replication of the agent to maintain the cycle of infection. The complete cycle of an infectious agent is its life history (life-cycle). A knowledge of the life history of an infectious agent is essential when selecting the most applicable control technique. This involves knowledge of:

- the modes of transmission and maintenance of infection;
- the ecological conditions that favour the survival and transmission of infectious agents.

Transmission may be either horizontal (lateral) or vertical.

- Horizontally transmitted infections are those transmitted from any segment of a population to another; for example, influenza virus from one horse to a stable-mate.
- Vertically transmitted infections are transmitted from one generation to the next by infection of the embryo or fetus while in utero (in mammals) or in ovo (in birds, reptiles, amphibians, fish and arthropods). Transmission by milk to offspring is also considered, by some, to be vertical.

Horizontal transmission

- Infections can be transmitted horizontally either directly or indirectly
- Direct transmission occurs when a susceptible host contracts an infection, either by physical contact with an infected host or by contact with the latter's infected discharges (e.g., the transmission of canine distemper in infected urine and faeces).
- Indirect transmission involves an intermediate vehicle, living or inanimate, that transmits infection between infected and susceptible hosts. This vehicle generally may be termed a vector, although the term is usually restricted, by common usage, to living carriers (see 'vector' below). Indirect transmission can involve a vector of a different species from that of the initially infected host.

- The life-cycle of infectious agents therefore may be complex, with several different hosts. Details of specific life-cycles are not presented in this chapter, but a basic knowledge of veterinary microbiology and parasitology is assumed.
- Airborne transmission of infectious agents, frequently over long distances, is often defined as indirect, although it is more correctly classified as direct because no intermediate vehicle is involved.

Types of host and vector

A variety of terms describe the range of host/parasite relationships, and are used by the epidemiologist, protozoologist, entomologist, helminthologist and microbiologist. Each of these may use terms specific to his discipline that have the same general meaning, from the point of view of the life cycle of the disease, as different words from other disciplines; for example, intermediate host in helminthology and biological vector in entomology.

Hosts

- Host A plant, animal or arthropod that is capable of being infected with, and therefore giving sustenance to, an infectious agent. Replication or development of the agent usually occurs in the host.
- Definitive host A parasitological term describing a host in which an organism undergoes its sexual phase of reproduction (e.g., Taenia pisiform is in dogs; Plasmodium spp. in mosquitoes).
- Final host A term used in a more general sense)i.e., in connection with all types of infectious agent(as a synonym for definitive host. Both 'final' and 'definitive' imply the 'end of the line'; in other words, the termination of a dynamic process. They are, in most cases, therefore improperly used.
- Primary (natural) host An animal that maintains an infection in the latter's endemic area (e.g., dogs infected with distemper virus). Since an infectious agent frequently depends upon a primary host for its long-term existence, the host is also called a maintenance host.
- Secondary (aberrant) host A species that additionally involved in the life-cycle of an agent, especially outside typical endemic areas (e.g., cattle infected with

strains of foot-and-mouth virus that usually cycle in buffaloes). A secondary host sometimes can act as a maintenance host .

- Paratenic host : A host in which an agent is transferred mechanically, without further development) e.g., fish, containing Diphyllobothrium spp. larvae, which are preyed upon by larger fish). This term is exclusive to helminthology, and could be considered to have entomological in the term of mechanical vectors.
- Intermediate host An animal in which an infectious agent undergoes some development, frequently with asexual reproduction (e.g., Cysticercus pisiform is in rabbits and hares). This term is parasitological in origin.
- Amplifier host An animal which, because of temporally associated changes in population dynamics that produce a sudden increase in the host population size, may suddenly increase the amount of infectious agent. Multlplication of the agent occurs in this type of host. This term is most commonly used in relation to virus diseases. An example is litters of baby pigs infected with Japanese encephalitis virus.
- Incidental (dead-end or accidental) host One that does not usually transmit an infectious agent to other animals (e.g., bulls infected with Brucella abortus.) 'Final' and 'definitive' can be applied validly to this type of host.
- Link host A host that forms a link between other host species (e.g., pigs linking infected herons to man in Japanese encephalitis:
- Reservoir A term commonly used as a synonym for, or prefix to, 'host'; ('reservoir hos!'). A reservoir host is one in which an infectious agent normally lives and multiplies, and therefore is a common source of infection to other animals; thus, it is frequently a primary host.

Vector

- An animate transmitter of infectious agents. By common usage, vectors are defined as invertebrate animals - usually arthropods - that transmit infectious agents to vertebrates.
- The dictionary definition of the term implies independent movement; that is, a living vehicle.
- Inanimate carriers of agents (e.g., feed concentrates contaminated with Salmonella spp.) usually are called 'fomites' (singular: fomes, from the Greek

meaning tinder'; because fomites were thought metaphorically to be the 'tinder' by which the 'fire' of an epidemic was ignited).

A - Mechanical vector

- An animal (usually an arthropod) that physically carries an infectious agent to its primary or secondary host (e.g., mosquitoes and fleas transmitting myxomatosis virus between rabbits). The infectious agent neither multiplies nor develops in the mechanical vector.

B - Biological vector

- A vector (usually an arthropod) in which an infectious agent undergoes either a necessary part of its life-cycle, or multiplication, before transmission to the natural or secondary host. Three types of biological transmission occur:
    1. developmental transmission: with an essential phase of development occurring in the vector (e.g,. Dirofilaria immitis in mosquitoes;(
    2. propagative transmission: when the agent multiplies in the vector (e.g., louping-ill virus in ixodid ticks;(
    3. cyc1opropagative transmission: a combination of 1 and 2 (e.g., Babesia spp. in ticks).

Factors associated with the spread of infection

Three factors are important in the transmission of infection:

1 . characteristics of hosts;

2. characteristics of pathogens;

3. effective contact.

Characteristics of hosts

- A host's susceptibility and infectiousness determine its ability to transmit infection. Susceptibility to infection may be limited to a single species or group of species.
- For example, only equids are naturally susceptible to equine rhinopneumonitis virus infection. Alternatively, several widely different species may be susceptible to an infection; for example, all mammals are susceptible to rabies.

- Susceptibility within a species may vary markedly and may be associated with selection of genetically resistant animals following exposure to an infectious agent. For example, the mortality in rabbits, exposed experimentally to a standard dose of myxomatosis, fell from 90% to 25% over a 7-year period (Fenner and Ratcliffe, 1 965).'Infectiousness' refers to:

✓ the duration of the period when an animal is infective;

✓ the relative amount of an infectious agent that an animal can transmit

Characteristics of pathogens

- Three important characteristics of pathogens that affect transmission of infectious agents are infectivity, virulence and stability.
- Infectivity relates to the amount of an organism that is required to initiate infection.
- Virulence also affects transmission and can change. Repeated passage through the same species of animal tends to increase virulence for that species but to simultaneously lower virulence for the original natural host. Thus, serial passage of Ross River virus in suckling mice increases its virulence for mice , but alternate passage in mice and the mosquito Aedes aegypti does not alter virulence.
- The length of time for which an organism can remain infective outside its host is the organism's stability. Some organisms survive only for short periods of time; that is, they are very labile (e.g., Leptospira spp. in dry environments), whereas others are more resistant . Stability is frequently facilitated by protective capsules, such as those forming the outer layer of bacterial spores (e.g., Bacillus anthracis).

Effective contact

- Effective contact describes the conditions under which infection is likely to occur. For a particular infection it depends on the stability of the organism and the routes by which the organism leaves an infected host and enters a susceptible one.
- Effective contact may be very short (e.g., seasonally transmitted, vector-borne diseases) or potentially of many years' duration (e. g., anthrax spores in soil:

- The duration of infectiousness determines the number of susceptible that can be infected by an infected animal. Thus, upper respiratory tract infections (e. g., kennel cough in dogs) result in short periods of infectiousness of several days' duration, whereas cows infected with bovine tuberculosis may excrete the bacterium in their milk for several years.

Routes of infection

- The site or sites by which an infectious agent gains entry to a host (Figure 6.6), and by which it leaves the host

A - The oral route

- Infection via the mouth is one of the more common routes of entry, especially in relation to the enteric organisms, which often 'escape' from an infected animal in the faeces.
- Organisms such as rotaviruses, Salmonella spp. and gastrointestinal parasites may contaminate water and foodstuffs, which then act as fomites. Ingested agents may be excreted in the faeces, producing the faecal-oral transmission cycle.
- Agents that gain entry to the body orally may be disseminated from the infected animal by a variety of routes, apart from in the faeces. Brucella abortus often infects cows orally but is excreted later in the milk and uterine discharges.
- Similar circumstances occur in relation to infection of ruminants with the rickettsia Coxiella burnetii, the cause of Q fever. Such agents may then be retransmitted by both the oral and other routes.
- Although some organisms can be transmitted by the oral route, the low pH of gastric secretions is an effective barrier against this method of transmission for a wide variety of organisms.

B - The respiratory route

- The respiratory route is also a common method of transmission for many infectious agents, including those that are not restricted to the respiratory tract (e.g., Salmonella typhimurium:. Infectious agents seldom occur as individual airborne particles, but are usually associated with other organic matter in the form of droplets or dust.

- The nature and size of such composite particles affect their dispersal and stability. Particles of a diameter of 5 nm or greater do not reach the alveoli of the lung and therefore initially cause infection only of the upper respiratory tract.
- Infections spread by the respiratory route are more likely to occur where population densities are high and ventilation is poor. Examples of such conditions are enzootic pneumonia in intensively reared pigs, and occupationally acquired brucellosis in meat workers.
- In environmental extremes, diseases that are spread rarely by the respiratory route become transmissible by this method. These circumstances arise in the airborne transmission of rabies from insectivorous bats to animals and man within the confines of a cave. Similarly, African swine fever virus, which is usually transmitted by Ornithodoros spp. ticks, spreads rapidly by the oral route in piggeries.
- In crowded and poor living conditions, pneumonic plague is transmitted directly between people, rather than by the bites of infected fleas, the latter method of transmission inducing the less severe bubonic plague.

C - Infection via skin, cornea and mucous membranes

- Transmission via the skin is percutaneous (Latin: per = through, across; cut = skin). Certain agents infect only the skin, and transmission is always by direct contact with either another infected animal or a fomes; examples are 'ringworm' and ectoparasitic infestations. The incidence of such infections and infestations is particularly influenced by the population density of the susceptible hosts. Intact skin acts as an effective barrier to the majority of infectious agents, but some, particularly the immature stages of some nematodes and trematodes, can penetrate this barrier and cause infection. Examples include blood fluke (Schistosoma spp.) and hookworm (Ancylostoma spp.) infections, the latter infection also being zoonotic and the cause of cutaneous larva migrans in man.
- If the skin is cut or abraded, then infection by a variety of organisms can occur, resulting in localized infections of the skin (e.g. by Staphylococcus spp. and the cutaneous form of human anthrax). Other agents, such as leptospires and swine

vesicular disease virus, may gain entry to the body percutaneously and then develop a more generalized infection.

- Another important form of percutaneous infection is from bites by both vertebrates and arthropods. Agents that are present in the saliva, such as the viruses of rabies and lymphocytic choriomeningitis, and bacteria such as Streptobacillus moniliformis (a common inhabitant of the oropharynx of rats), are transmitted by animal bites. Diseases transmitted by the bites of infected arthropod vectors constitute a particular class of infections that was introduced earlier in this chapter during the description of hosts and vectors.
- Infection of the cornea may remain localized, for example, bovine keratoconjunctivitis caused by Moraxella bovis. Alternatively, the infection may spread to other parts of the body, for instance, corneal infection of birds with Newcastle disease virus.

Methods of transmission

- Six main methods of transmission, which bring infectious agents into contact with the sites of infection, can be identified:
    1. ingestion;
    2. aerial transmission;
    3. contact;
    4. inoculation;
    5. iatrogenic transmission;
    6. coitus.

Ingestion

- This may occur via a mechanical vehicle (fomes), for example, contaminated water, or by ingestion of intermediate hosts, such as cestode cysts in meat.
- Ingested agents are usually excreted in the faeces, producing the faecal-oral transmission cycle. Some agents are excreted only faecally because they are localized to the intestine (e.g., the Johne's disease bacillus in cattle).
- Other agents, if they invade the bloodstream, can be excreted by additional means, such as the urine (e.g., Salmonella spp.). Sometimes, agents are excreted on the breath (e.g., reoviruses and rinderpest virus).

Aerial transmission

- This involves airborne transmission of infectious agents via contaminated air. It is the usual method of transmission with the hardy spores of fungi and some bacteria, and also occurs with pathogens of the respiratory tract that are expired on the breath of infected animals and enter susceptible ones during inspiration. Quasistable suspensions of liquids or solids in gases, that are capable of floating for some time, are formed only when droplet diameters do not exceed 5 nm.
- Expiratory droplets range in size from 15 to 1 00 nm and thus even the smallest sediment rapidly (within 3 seconds). Therefore, they cannot travel far. Direct infection from expiratory droplets is thus limited to the area directly in front of the infected individual (the 'expiratory cone'). Very localized droplet infection can occur on food bowls and by sniffing.
- Aerosol transmission is a type of airborne transmission involving transmission via an aerosol which is defined variously as 0) any solution in the form of a fine spray in which the droplets approximate colloidal size 0-1 00 nm), and (2) finely divided virus particles hanging or floating in air. Thus, quasistable suspensions and expiratory droplets can both be involved in aerosol transmission.
- Some agents that are not primarily pathogens of the respiratory tract can contaminate the air and therefore may also be airborne. An example is foot-and mouth disease virus shed from ruptured vesicles Similarly, some Salmonella spp. infections are airborne and infect animals via the conjunctiva

Contact

- Contact transmission is transmission without transmission factors (e.g., mechanical vectors) and without participation of an external medium. This is particularly important in relation to infectious agents that are shed from the body surfaces, such as vesicular viruses, and with agents that gain entry through the body surface Very few agents are transmitted merely by touch; some degree of trauma is necessary, albeit microscopic.
- Transmission may be by bites (e.g., rabies and rat bite fever), or by scratches (e.g., cat scratch fever).

- Diseases transmitted by contact may be described as 'contagious' (Latin: contagio = to touch closely) but this term now is used less commonly than previously.

Inoculation

- Inoculation (Latin: inoculatus engrafted, or implanted) is the introduction into the body, by puncture of the skin or through a wound, of infectious agents.
- Although classified separately here, inoculation is frequently associated with contact transmission (e.g bites from rabid dogs). Arthropods that act as vectors may inoculate infectious agents into the blood by biting)e.g., tsetse flies infected with Trypanosoma spp,. in which development of the parasite occurs in the salivary gland, gut and mouthparts).

Iatrogenic transmission

- Iatrogenic literally means 'created by a doctor'. Thus, an iatrogenically transmitted infection is one that is transferred during surgical and medical practice.
- There are two main types, involving:

1. introduction of pathogens by dirty instruments, (e.g., during non-aseptic surgery and tattooing) or by contaminated body surfaces;
2. introduction of pathogens contaminating prophylactic or therapeutic preparations (e.g., Pseudomonas aeruginosa in intra mammary dry-cow antibiotic preparations: Nicholls et al., 1981; porcine reproductive and respiratory syndrome virus in needles:

Coitus

- Some infectious agents may be transmitted during coitus. Certain diseases are transmitted only in this way. These were called venereal diseases (Latin: venereus = pertaining to sexual love).
- In human medicine they now are referred to as sexually transmitted diseases (STDs). Sexual transmission can occur not only in vertebrates but also in arthropods. For example, African swine fever virus can be sexually transmitted from male to female ticks of the genus Ornithodoros (Plowright et al., 1974).

- The mode of transmission of agents frequently governs the epidemic picture. Thus, agents that are transmitted by the faecal-oral and airborne modes often produce sudden explosive epidemics, whereas coitally transmitted diseases spread more slowly, over a long period of time.

Long-distance transmission of infection

- Infectious diseases can be transmitted by the methods described above over long distances as a result of the mobility of infected animals, microorganisms and parasites, vectors and fomites