Emergence and Global Spread of Infection: Introduction

Epidemiology, the study of the distribution of determinants of disease and injury in human populations, is a discipline that includes both infectious and noninfectious diseases. Most epidemiologic studies of infectious diseases have concentrated on the factors that influence acquisition and spread, because this knowledge is essential for developing methods of prevention and control. Historically, epidemiologic studies and the application of the knowledge gained from them have been central to the control of the great epidemic diseases, such as cholera, plague, smallpox, yellow fever, and typhus.

An understanding of the principles of epidemiology and the spread of disease is essential to all medical personnel, whether their work is with the individual patient or with the community. Most infections must be evaluated in their epidemiologic setting. For example, what infections, especially viral, are currently prevalent in the community? Has the patient recently traveled to an area of special disease prevalence? Is there a possibility of nosocomial infection from recent hospitalization? What is the risk to the patient's family, schoolmates, and work or social contacts?

The recent recognition of emerging infectious diseases has heightened appreciation of the importance of epidemiologic information. A few examples of these newly identified infections are cryptosporidiosis, hantavirus pulmonary syndrome, and severe acute respiratory syndrome (SARS) coronavirus disease. In addition, some well-known pathogens have assumed new epidemiologic importance by virtue of acquired antimicrobial resistance (eg, penicillin-resistant pneumococci, vancomycin-resistant enterococci, and multiresistant *Mycobacterium tuberculosis*).

Factors that increase the emergence or reemergence of various pathogens include:

- Population movements and the intrusion of humans and domestic animals into new habitats, particularly tropical forests
- Deforestation, with development of new farmlands and exposure of farmers and domestic animals to new arthropods and primary pathogens
- Irrigation, especially primitive irrigation systems, which fail to control arthropods and enteric organisms
- Uncontrolled urbanization, with vector populations breeding in stagnant water
- Increased long-distance air travel, with contact or transport of arthropod vectors and primary pathogens
- Social unrest, civil wars, and major natural disasters, leading to famine and disruption of sanitation systems, immunization programs, etc.
- Global climate change
- Microbial evolution, leading to natural selection of multi-resistant agents (eg, methicillin-resistant staphylococci, new, highly virulent strains of influenza A virus). In some instances, these changes can be accelerated considerably by indiscriminate use of anti-infective agents.

Infectious diseases of humans may be caused by exclusively human pathogens such as *Shigella;* by environmental organisms such as *Legionella pneumophila;* or by organisms that have their primary reservoir in animals such as *Salmonella*.

Noncommunicable infections are those that are not transmitted from human to human and include (١) infections derived from the patient's normal flora, such as peritonitis after rupture of the appendix; (٢) infections caused by the ingestion of preformed toxins, such as botulism; and (٣) infections caused by certain organisms found in the environment, such as clostridial gas gangrene. Some diseases transmitted from animals to humans (zoonotic infections), such as rabies and brucellosis, are not transmitted between humans, but others such as plague may be transmitted at certain stages. Noncommunicable infections may still occur as common-source outbreaks, such as food poisoning from an enterotoxin-producing *Staphylococcus aureus*–contaminated chicken salad or multiple cases of pneumonia from extensive dissemination of *Legionella* through an air-conditioning system. Because these diseases are not transmissible to others, they do not lead to secondary spread.

Noncommunicable infections are not spread from person to person but can occur as common-source outbreaks

Communicable infections require an organism to be able to leave the body in a form that is directly infectious or to be able to become so after development in a suitable environment. The respiratory spread of the influenza virus is an example of direct communicability. In contrast, the malarial parasite requires a developmental cycle in a biting mosquito before it can infect another human. Communicable infections can be **endemic,** which implies that the disease is present at a low but fairly constant level, or **epidemic,** which involves a level of infection higher than that usually found in a community or population. In some infections, such as influenza, the infection can be endemic, persisting at a fairly low level from season to season. Communicable infections that are widespread in a region, sometimes worldwide, and have high attack rates are termed **pandemic.**

Infection and Disease

An important consideration in the study of the epidemiology of communicable organisms is the distinction between infection and disease. **Infection** involves multiplication of the organism in or on the host and may not be apparent, for example, during the incubation period or latent when little or no replication is occurring (eg, with herpesviruses). **Disease** represents a clinically apparent response by, or injury to, the host as a result of infection. With many communicable microorganisms, infection is much more common than disease, and apparently healthy infected individuals play an important role in disease propagation. Inapparent infections are termed **subclinical,** and the individual is sometimes referred to as a **carrier.** The latter term is also applied to situations in which an infectious agent establishes itself as part of a patient's flora or causes low-grade chronic disease after an acute infection. For example, the clinically inapparent presence of *S aureus* in the anterior nares is termed **carriage,** as is a chronic gallbladder infection with *Salmonella* serotype Typhi that can follow an attack of typhoid fever and result in fecal excretion of the organism for years.

With some infectious diseases such as measles, infection is invariably accompanied by clinical manifestations of the disease itself. These manifestations facilitate epidemiologic control, because the existence and extent of infection in a community are readily apparent. Organisms associated with long incubation periods or high frequencies of subclinical infection, such as

human immunodeficiency virus (HIV) or hepatitis B virus, may propagate and spread in a population for long periods before the extent of the problem is recognized. This makes epidemiologic control more difficult.

Routes of Transmission

Various transmissible infections may be acquired from others by direct contact, by aerosol transmission of infectious secretions, or indirectly through contaminated inanimate objects or materials. Some infections, such as malaria, involve an animate insect vector. These routes of spread are often referred to as **horizontal transmission,** in contrast to **vertical transmission**—from mother to fetus.

The table below shows the main route of transmission with some examples.

Respiratory	Aerosol droplet inhalation	Influenza virus; tuberculosis
	Nose or mouth hand or object nose	Common cold (rhinovirus)
Salivary	Direct salivary transfer (eg, kissing)	Oral-labial herpes; Epstein-Barr virus, cytomegalovirus
	Animal bite	Rabies
Gastrointestinal	Stool hand mouth and/or stool object, water or food mouth	Enterovirus; hepatitis A
	Stool water or food mouth	Salmonellosis; shigellosis
Skin	Skin discharge air respiratory tract	Varicella, smallpox, or monkeypox
	Skin to skin	Human papilloma virus (warts); syphilis
Blood	Transfusion or needle prick	Hepatitis B; cytomegalovirus infection; malaria; HIV
	Mosquito bite	Malaria; arboviruses
Genital secretions	Urethral or cervical secretions	Gonorrhea; herpes simplex; *Chlamydia*
	Semen	Cytomegalovirus
Urine	Urine hand catheter	Hospital-acquired urinary tract infections

Eye	Conjunctival	Adenovirus
Zoonotic	Animal bite	Rabies
	Contact with carcasses	Tularemia
	Tick bite	Rickettsia; Lyme disease

Vertical Transmission

Certain diseases can spread from mother to fetus through the placental barrier. This mode of transmission involves organisms such as rubella virus that can be present in the mother's bloodstream and may occur at different stages of pregnancy with different organisms. Another form of transmission from mother to infant occurs by contact during birth with organisms such as group B streptococci, *C trachomatis,* and *N gonorrhoeae,* which colonize the vagina. Herpes simplex virus and CMV can spread by both vertical methods as it may be present in blood or may colonize the cervix. CMV may also be transmitted by breast milk, a third mechanism of vertical transmission.

Incubation Period and Communicability

The incubation period is the time between the exposure to the organism and the appearance of the first symptoms of the disease. Generally, organisms that multiply rapidly and produce local infections, such as gonorrhea and influenza, are associated with short incubation periods (eg, ٢-٤ days). Diseases such as typhoid fever, which depend on hematogenous spread and multiplication of the organism in distant target organs to produce symptoms, often have longer incubation periods (eg, ١٠ days to ٣ weeks). Some diseases have even more prolonged incubation periods because of slow passage of the infecting organism to the target organ, as in rabies, or with slow growth of the organism, as in tuberculosis. Incubation periods for one agent may also vary widely depending on route of acquisition and infecting dose; for example, the incubation period of hepatitis B virus infection may vary from a few weeks to several months.

Communicability of a disease in which the organism is shed in secretions may occur primarily during the incubation period. In other infections, the disease course is short but the organisms can be excreted from the host for extended periods. In yet other cases, the symptoms are related to host immune response rather than the organism's action, and thus the disease process may extend far beyond the period in which the etiologic agent can be isolated or spread. Some viruses can integrate into the host genome or survive by replicating very slowly in the presence of an immune response. Such dormancy or latency is exemplified by the herpesviruses, and the organism may emerge long after the original infection and potentially infect others.

The inherent infectivity and virulence of a microorganism are also important determinants of attack rates of disease in a community. In general, organisms of high infectivity spread more easily and those of greater virulence are more likely to cause disease than subclinical infection. The infecting dose of an organism also varies with different organisms and thus influences the chance of infection and development of disease.

Epidemics

The characterization of epidemics and their recognition in a community involve several quantitative measures and some specific epidemiologic definitions. **Infectivity,** in epidemiologic terms, equates to attack rate and is measured as the frequency with which an infection is transmitted when there is contact between the agent and a susceptible individual. The **disease index** of an infection can be expressed as the number of persons who develop the disease divided by the total number infected. The **virulence** of an agent can be estimated as the number of fatal or severe cases per total number of cases. **Incidence,** the number of new cases of a disease within a specified period, is described as a rate in which the number of cases is the numerator and the number of people in the population under surveillance is the denominator. This is usually normalized to reflect a percentage of the population that is affected. **Prevalence,** which can also be described as a rate, is primarily used to indicate the total number of cases existing in a population at risk at a point in time.

Factors controlling the spread of epidemics:

a) Interaction between host and parasite determines extent and severity of an epidemic.
b) Attack rates and disease severity can vary widely by age.
c) Immune status of a population influences epidemic behavior.
d) Immunity in population influences spread.
e) Sudden appearance of "new" agents can result in pandemic spread.
f) Social and ecological factors determine aspects of epidemic diseases.

Control of Epidemics

The first principle of control is recognition of the existence of an epidemic. This recognition is sometimes immediate because of the high incidence of disease, but often the evidence is obtained from ongoing surveillance activities, such as routine disease reports to health departments and records of school and work absenteeism. The causative agent must be identified, and studies to determine route of transmission (eg, food poisoning) must be initiated.

Measures must then be adopted to control the spread and development of further infection. These methods include:

(١) Blocking the route of transmission, if possible (eg, improved food hygiene or arthropod control).

(٢) Identifying, treating, and, if necessary, isolating infected individuals and carriers.

(٣) Raising the level of immunity in the uninfected population by immunization.

(٤) Making selective use of chemoprophylaxis for subjects or populations at particular risk of infection, as in epidemics of meningococcal infection.

(٥) Correcting conditions such as overcrowding or contaminated water supplies that have led to the epidemic or facilitated transfer.