Transmission Pathway of Infectious Disease.

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[Abstract] The most important thing in public health to manage infectious diseases is to quickly find the transmission pathway. The pathogen itself, such as viruses, is not mobile. There is an intermediate medium that facilitates the movement of places. It is essential to discover intermediates. In recent years, the risk of airborne transmission is increasing. In indoor such as hospital, airborne transmission is the most dangerous because contaminated air is the main infectious route. Once an epidemic has occurred, the possibility of airborne transmission must be fully considered for effective control.

[Keyword] Infectious Diseases, Pathogen, Host, Vector, Transmission Pathway, Direct Transmission, Airborne Transmission.

Historical Lessons.
The birth of modern epidemiology is often attributed to John Snow's famous investigation of the 1854 cholera epidemic in London, and his identification of the Broad Street pump as the most important node in the cholera transmission network \[1,3,4\]. More than 150 years later, It is unknown what factors triggered the enormous cholera outbreaks in London in the summers of 1832, 1849, 1854 and 1866. In addition to the intrinsic interest of identifying the mechanisms of historical disease invasions, improving our understanding of cholera specifically is important because it remains a serious public health concern in areas where clean water is unavailable \[1,4\].

The recent cholera epidemics in Haiti in 2010 \[2,8\] are stark example. In global world, The incidence of globally infectious and pathogenic diseases such as H1N1 (swine flu) and Avian Influenza (AI) has recently increased. An infectious disease is a pathogen-caused disease, which can be passed from the infected person to the susceptible host\[2,9\]. Pathogens of infectious diseases, which are bacillus, virus, fungus, and parasite, etc., cause various symptoms such as respiratory disease, gastrointestinal disease, liver disease, and acute febrile illness.

They can be spread through various means such as food, water, insect, breathing and contact with other persons. Humans are still faced with challenges of pandemics, as well as emerging and re-emerging diseases, many of which originate in animals. In a modern society, however, infectious diseases are spread in a fast and complicated manner because of rapid development of transportation (both ground and underground). Therefore, It is necessary to develop new system, which can prevent the spread of infectious diseases by predicting its pathway. The aim of this study is to find out the detailed pathways of infectious diseases for real-time monitoring and control.

Basic Concepts

Arthropod-borne infectious diseases are an
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international public health concern. Cholera is an acute intestinal infectious disease caused by the bacterium *Vibrio cholerae*. It can spread rapidly and lead to death within days if left untreated[9,10]. The basis of vector borne disease epidemiology is the triangle between pathogen, vector and hosts. As with other type of infectious diseases, the pathogens (virus, parasites, bacteria) cause disease, yet they depend on the vector to be transmitted to the hosts. The natural (or primary) host of a vector-borne disease is part of the reservoir that maintains the pathogen in natural cycles of infection and transmission by vectors to other susceptible natural hosts. The spread of vector-transmitted pathogens relies on complex interactions between host, vector and pathogen[1]. Pathogen-mediated mechanisms that manipulate the interactions of vector-host systems are suggested to have long-reaching effects on ecosystem dynamics and structure[17].

The purpose of studies on the relationship between pathogens, the vectors that carry them, and the hosts they infect are to identify new ways to prevent disease through exploring the similarities and differences of vector/pathogen/host interactions among groups of microorganisms. Recent research focus in how pathogens may use arthropod products to facilitate infection of the mammalian host. Microbes could use specific arthropod molecules to enable successful infection of the host: a triangular interaction at the ephemeral pathogen-vector-host interface that occurs while an arthropod is feeding on a vertebrate. Understanding these interactions may lead to new ways to interrupt the life cycle of arthropod-borne pathogens and new vaccine strategies against these diseases. In the medical field, vectors are understood to be organisms that play a role in the transmission of a pathogen between humans or from animals to humans. In practice, vectors tend to be blood-sucking insects that ingest the disease-causing organism with the blood from an infected host and then inject it into a new host at the time of their next blood-meal[2].

Mosquitoes are best known for their role in transmitting diseases, but some blood-sucking flies can do the same. As a rule, the association between a vector and a disease-causing organism is specific. The transmission of vector-borne diseases is seasonal, linked to rainfall patterns. Temperature is also a key determinant of the boundaries of disease distribution, either because it limits the distribution of vectors or because below certain minimum night temperatures the pathogen cannot complete its life cycle within the vector[2]. First of all, It is need to know the relationship between pathogens and their vectors. the pathogen depends on a single species of vector for transmission, the pathogen can be transmitted by a wide range of vector. Transmission often requires highly specific pathogen transport mechanisms in the vector. Vector-borne pathogens cause a wide range of diseases in animals and plants. It is conceptually easier to suppress vector populations or target pathogens after host infection, little is known about vector-pathogen interfaces. If a vector prefers uninfected hosts or infected hosts, It could find out how does that affect the pathogen’s spread. Pathogen spread is greatly influenced by the way that vectors choose which host to feed upon. Epidemiologists insist that many vectors make feeding choices based on whether the host is infected with the pathogen or not[3]. For example, some mosquito species prefer to feed on animals (including humans) that are infected with malaria. At the same time, epidemiologists also report that hosts vary in their susceptibility to a disease. Some hosts are resistant to infection, meaning that the pathogen replicates poorly in them. Other hosts
are tolerant to the disease, meaning that the pathogen can replicate but the host simply does not express disease[5]. Resistance and tolerance are both forms of defense against a pathogen. While vector feeding preference and host defense are clearly important for the spread of a pathogen, it is interested in understanding how the two factors may interact to influence pathogen spread, the relationships between vector preference and host defense, and the spread of a pathogen in interacting host and vector populations under different scenarios for vector preference and host defense. It should be highlighted the importance of understanding both vector feeding behavior and the precise form of host defense in predicting pathogen spread. Insects are among the most important vectors of both plant and animal pathogens, and most insects have specific adaptations for host finding and feeding that can potentially be exploited to facilitate transmission of parasites from infected to healthy hosts[45]. Among plant pathogens, viruses represent a widespread and diverse group, and the transmission of many plant viruses is obligately dependent on insect vectors (e.g. aphids, leafhoppers, mealybugs, thrips and beetles). Thus, the presence and abundance of insect vectors, and the preferences and movements of vectors in relation to infected and healthy plants, are theoretically important regulators of virus spread[45].

Diseases transmission at wild-domestic interfaces is an important epidemiological issue on most continents[23]. The infectious contacts between domestic and wild hosts seem to be crucial to understand the complex dynamics of multi-hosts systems[23]. Some study provide strong evidence that contact rate with wild buffalo significantly influences Foot and mouth disease (FMD) dynamics in cattle populations living at the periphery of conservation areas[23]. The virus of FMD is highly contagious in cattle populations and can be transmitted via direct contact between individuals, but also via environmental contamination such as air, water, insect [23,24].

The network that is generated provides insights into the epidemiological dynamics defines potential transmission routes, knowledge of its structure can be used as part of disease control. For example, contact tracing aims to identify likely transmission network connections from known infected cases and hence treat or contain their contacts thereby reducing the spread of infection. Contact tracing is a highly effective public health measure as it uses the underlying transmission dynamics to target control efforts and does not rely on a detailed understanding of the etiology of the infection[19]. Larger human populations and

Transmission Types.
more demand for space have led to increased contact between humans, wildlife and domestic animals, which creates more opportunities for pathogen transmission[15]. Although direct transmission of infectious diseases from host-to-host is typically considered to be the main route of infection transmission, there are many diseases for which the primary route of transmission is through the environment[10]. The mechanisms of disease transmission and spread are usually complex and possibly involve social, economic and psychological factors in addition to the intrinsic disease biology and ecology. In particular, human behavior could have significant influence on disease transmission and vice versa. For example, individuals avoid close contact with obviously sick persons to protect themselves and therefore the frequency and strength of contacts between uninfected and infected people generally are reduced[12,13]. Infectious diseases result from the interaction of agent, host, and environment. More specifically, transmission occurs when the agent leaves its reservoir or host through a portal of exit, is conveyed by some mode of transmission, and enters through an appropriate portal of entry to infect a susceptible host. This sequence is sometimes called the chain of infection. The reservoir of an infectious agent is the habitat in which the agent normally lives, grows, and multiplies. Reservoirs include humans, animals, and the environment. The reservoir may or may not be the source from which an agent is transferred to a host. Many common infectious diseases have human reservoirs. Diseases that are transmitted from person to person without intermediaries include the sexually transmitted diseases, measles, mumps, streptococcal infection, and many respiratory pathogens. Because humans were the only reservoir for the smallpox virus, naturally occurring smallpox was eradicated after the last human case was identified and isolated. Human reservoirs may or may not show the effects of illness. A carrier is a person with inapparent infection who is capable of transmitting the pathogen to others. Asymptomatic or passive or healthy carriers are those who never experience symptoms despite being infected. Incubatory carriers are those who can transmit the agent during the incubation period before clinical illness begins. Convalescent carriers are those who have recovered from their illness but remain capable of transmitting to others. Chronic carriers are those who continue to harbor a pathogen such as hepatitis B virus, the causative agent of typhoid fever, for months or even years after their initial infection. Carriers commonly transmit disease because they do not realize they are infected, and consequently take no special precautions to prevent transmission. Symptomatic persons who are aware of their illness, on the other hand, may be less likely to transmit infection because they are either too sick to be out and about, take precautions to reduce transmission, or receive treatment that limits the disease. Humans are also subject to diseases that have animal reservoirs. Many of these diseases are transmitted from animal to animal, with humans as incidental hosts. Many newly recognized infectious diseases in humans, including HIV/AIDS, Ebola infection and SARS, are thought to have emerged from animal hosts, although those hosts have not yet been identified. Plants, soil, and water in the environment are also reservoirs for some infectious agents. 1850, in London, Snow reported that cholera could be spread in water, everyone accepted that there was an association between mortality from cholera and a district’s water supply[46]. Portal of exit is the path by which a
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Pathogen leaves its host. The portal of exit usually corresponds to the site where the pathogen is localized. The water compartment could be contaminated by infected and infectious persons and could in turn infect susceptible persons[1]. An infectious agent may be transmitted from its natural reservoir to a susceptible host in different ways. Although host-to-host disease transmission has been traditionally considered as the main cause of infection spread, the role of environment-to-host disease transmission is becoming more evident. A contaminated environment such as food, water, soil, objects and contact surfaces may transmit infection to susceptible hosts[3]. Pathogens in a free-living state adapt to the environment by morphological and physiological changes that promote their survival[3] and even growth[36] in the environment. In addition, the presence of a free-living pathogen in the environment can be replenished by infectious hosts that excrete the pathogen for a considerable amount of time.

Genomic information on pathogens can shed light on whether outbreaks tend to occur as long chains of transmission or as large bursts from single hosts, and whether transmissions tend to be associated with specific environments or hosts, even if individual transmission events remain uncertain[22].

Cholera is an acute intestinal infection caused by the bacterium Vibrio cholerae. Its dynamics are complicated by the multiple interactions between the human host, the pathogen and the environment[4], which contribute to both direct human-to-human and indirect environment-to-human transmission pathways[5]. Some diseases may be spread in more than one manner. For example, cholera may be spread both directly by person-to-person contact and indirectly through a pathogen released by infectives through a medium such as contaminated water[14]. In direct transmission, an infectious agent is transferred from a reservoir to a susceptible host by direct contact or droplet spread. Viruses represent a common cause of infectious disease acquired indoors, as they are easily transmitted especially in crowded, poorly ventilated environments[35].

During and after illness, viruses are shed in large numbers in body secretions, including blood, feces, urine, saliva, and nasal fluid. Consequently, viral transmission routes are diverse, and include direct contact with infected persons, indirect contact with contaminated surfaces, fecal-oral transmission (through contaminated food and water), droplet and airborne transmission[35]. Direct contact occurs through skin-to-skin contact, kissing, and sexual intercourse. Direct contact also refers to contact with soil or vegetation harboring infectious organisms. Droplet spread refers to spray with relatively large, short-range aerosols produced by sneezing, coughing, or even talking. Droplet spread is classified as direct because transmission is by direct spray over a few feet, before the droplets fall to the ground. Pertussis and meningococcal infection are examples of diseases transmitted from an infectious patient to a susceptible host by droplet spread. Droplet transmission occurs when viruses travel on relatively large respiratory droplets (> 10 μm) that people sneeze, cough, or exhale during conversation or breathing (primary aerosolization). A single cough can release hundreds of droplets, a single sneeze thousands (up to 40 000) at speeds of up to 50-200 miles per hour, each droplet containing millions of viral particles (although the number varies greatly in the course of infection). Aerosol droplets travel only short distances (1-2 meters) before settling on surfaces, where viruses can remain infectious for hours or days. Virus survival on fomites is
influenced by temperature, humidity, pH and exposure to ultraviolet light[36].

**Airborne Transmission**

Droplet transmission is not to be confused with airborne transmission. Droplets do not remain suspended in the air. On the other hand, airborne transmission depends on virus-containing droplet nuclei (small-particle residue ≤ 5 μm) of evaporated droplets or dust particles that can remain suspended in the air for long periods[36]. Viruses contained within the droplet nuclei can be transported over considerable distances by air currents to be inhaled by a susceptible host, penetrating deep into the respiratory system due to their small size[36]. Indirect transmission refers to the transfer of an infectious agent from a reservoir to a host by suspended air particles, inanimate objects (vehicles), or animate intermediaries (vectors).

![Infectious Droplets & Droplet Nuclei Travel Lengths](image)

**[Figure 2]** Citated from somamedical.net online.


Airborne transmission occurs when infectious agents are carried by dust or droplet nuclei suspended in air. Airborne dust includes material that has settled on surfaces and become resuspended by air currents as well as infectious particles blown from the soil by the wind. Droplet nuclei are dried residue of less than 5 microns in size. In contrast to droplets that fall to the ground within a few feet, droplet nuclei may remain suspended in the air for long periods of time and may be blown over great distances. Measles, for example, has occurred in children who came into a physician's office after a child with measles had left, because the measles virus remained suspended in the air. Airborne disease spread plays a small but significant role in disease spread in the epidemic. A large number of infected animals (preferably pigs) excreting virus into the atmosphere under ideal meteorological conditions would infection be possible at more than a few km from the source[24]. In the event of an outbreak of FMD it is essential for those responsible for controlling and eradicating the disease to quickly assess how the initial animals became infected and its potential for further spread. Foot-and-mouth disease (FMD) is a highly infectious disease of cloven-hoofed animals, which can be transmitted by direct contact, fomites or through the air[24], it is very important in the control of any outbreak to be able to both accurately and speedily identify livestock that are at risk to airborne virus. It should be noted, however, that speed is essential if accurate prediction of airborne transmission is to contribute to the control and prevention of transmission and successful eradication of disease[24]. Airborne transmission over considerable distances may occur in suitable conditions, particularly if high relative humidity (greater than 60%)[26]. It is apparent that the amount of virus released by a
species of animal is only one of the factors influencing the degree of airborne spread after an initial outbreak[27,28]. The outbreak of SARS at the Amoy Gardens apartment complex in Hong Kong was caused by airborne transmission. In the official investigation, airborne transmission was seriously considered because most communicable respiratory infections are transmitted by means of large droplets over short distances or through contact with contaminated surfaces[29]. It is difficult, however, to detect contaminated air, because infectious aerosols are usually extremely dilute, and it is hard to collect and culture fine particles[29]. The SARS epidemic provides an opportunity for the critical reevaluation of the aerosol transmission of communicable respiratory diseases[30]. Human-human transmission of disease can result from direct contact with an infected person or an indirect contact through an intermediate object. A direct contact infection could be caused by caregivers not washing hands prior to attending patients [31]. Another common direct contact transmission is due to large infectious aerosols that travel a short distance from the source to the receptor. An important mode of indirect contact is airborne transmission occurring via the spread of fine aerosols, skin flakes, and fungal spores in room air over long distances and time scales[31]. Aerosols can be generated and released by human expiratory actions (speech, coughing, and sneezing), skin shedding, or resuspension from surfaces. For airborne transmission, this can mean reducing the generation of pathogens from an infectious person, using disinfection techniques to kill pathogens released to the air, or simply isolating infectious people in special rooms. For the airborne transmission pathway, personal protection consists of some form of mask or respirator to prevent either the distribution or inhalation of pathogens[31]. Mechanical ventilation systems are fan driven. Positive pressure mechanical ventilation systems are fanned on intake and result in exfiltration of space (i.e., air tends to leak out of ventilated space). On the other hand, negative pressure mechanical ventilation systems are fanned on exhaust and result in infiltration of space [32]. Natural ventilation systems rely on natural forces such as wind or a density-generated pressure differences between indoor and outdoor to drive air through building openings. Some purpose-built openings include doors, windows, solar chimneys, and wind towers[32]. The room airflow structure can have a major impact on infectious aerosol concentration (factor of two or more) beyond the simple effect of increased ventilation rate. The MERS outbreak in South Korea occurred in hospital settings through contacts with infected outpatients and inpatients. This transmission pathway is characterized by the transmission through super-spreaders and nosocomial transmission in healthcare facilities[32]. Patients, healthcare workers and visitors are all sources of the infection and can cause nosocomial influenza outbreaks[33]. Patients with suspected or confirmed MERS-CoV infection are given care in negative pressure isolation rooms equipped with HEPA filters. Patients would acquire infection in hospital, either from another patient or an airborne pathogen. The transfer of the influenza virus is seen primarily as direct contact or contact with contaminated objects. Therefore, the prevention measures focus primarily on isolation and sanitation, not ventilation. Influenza’s main route of transmission is by contact or droplet spread[33]. The relative impact of airborne dissemination is challenging to measure due to the large number of factors that have been found to influence airborne transmission. These include, temperature,
humidity, and survival rate of microbes[33]. In order to be considered an airborne virus, the particle size must be between 1-4 μm. The airborne particles are small particles evaporated from larger droplets that have settled[33]. Various means such as specially designed masks, capture cones or boxes, etc, have been used to capture, characterize, and quantify exactly how much pathogen (nucleic acid only or viable organisms) is present in droplets of differing sizes[34]. The ambient air from which people inhale has the potential risk of inhaling an airborne respiratory pathogen that could lead to infection and disease. It is difficult to estimate the number of people actually contracting infection and disease from such infectious agents in air, but, Public health team would guide people preventative policies by means of estimating potential incidence rates[34]. Some experimental studies demonstrate that influenza virus can remain infectious in small particle aerosols, and can transit across rooms[36]. It means the potential contribution of aerosols to influenza transmission. The last step of the airborne transmission pathway is recipient inhalation, it means that an inhalable airborne pathogen arrives at a susceptible host. Blocking at the final stage of the airborne transmission pathway in indoor is the most effective way to prevent spread of infection. Further research will also be needed to achieve a better understanding of virus survival in aerosols and on surfaces, and to elucidate the relationship between viruses and indoor environmental characteristics (including temperature, relative humidity and CO₂ concentration). Vehicles that may indirectly transmit an infectious agent include food, water, biologic products (blood), and fomites (inanimate objects such as handkerchiefs, bedding, or surgical scalpels). A vehicle may passively carry a pathogen — as food or water may carry hepatitis A virus. Alternatively, the vehicle may provide an environment in which the agent grows, multiplies, or produces toxin — as improperly canned foods provide an environment that supports production of toxin. Foot-and-mouth disease (FMD) virus causes an acute vesicular disease of domesticated and wild ruminants and pigs. Identifying sources of FMD outbreaks is often confounded by incomplete epidemiological evidence and the numerous routes by which virus can spread (movements of infected animals or their products, contaminated persons, objects, and aerosols)[18,20].

**Vector Abone Transmission**

**Vectors** such as mosquitoes, fleas, and ticks may carry an infectious agent through purely mechanical means or may support growth or changes in the agent. Examples of mechanical transmission are flies carrying *Shigella* on their appendages and fleas carrying *Yersinia pestis*, the causative agent of plague, in their gut. In contrast, in biologic transmission, the causative agent of malaria or guinea worm disease undergoes maturation in an intermediate host before it can be transmitted to humans. Aquatic birds such as Anseriformes (ducks, geese and swans) and Charadriiformes (gulls, terns and waders) are the major reservoir of all influenza A viruses, including the highly pathogenic H5N1 AI virus transmitted to humans[2,7]. Understanding of the ecology of avian influenza (AI) virus and its dynamics in wild birds is useful in predicting influenza dynamics in human population and devising control strategies[2]. In the context of AI dynamics in wild birds, in addition to
transmission of AI from bird to bird, another highly efficient route of transmission is through the excretion of AI virus by infected birds, followed by ingestion of virus in the drinking water of uninfected birds [2,7]. Insects are among the most important vectors of both plant and animal pathogens, and most insects have specific adaptations for host finding and feeding that can potentially be exploited to facilitate transmission of parasites from infected to healthy hosts[37]. Among plant pathogens, viruses represent a widespread and diverse group, and the transmission of many plant viruses is obligately dependent on insect vectors (e.g. aphids, whiteflies, planthoppers, leafhoppers, mealybugs, thrips and beetles). Thus, the presence and abundance of insect vectors, and the preferences and movements of vectors in relation to infected and healthy plants, are theoretically important regulators of virus spread[37].

**Conclusion.**
Knowledge of the portals of exit and entry and modes of transmission provides a basis for determining appropriate control measures. In general, control measures are usually directed against the segment in the infection chain that is most susceptible to intervention. Vehicle-borne transmission may be interrupted by elimination or decontamination of the vehicle. To prevent fecal-oral transmission, efforts often focus on rearranging the environment to reduce the risk of contamination in the future and on changing behaviors, such as promoting hand-washing. For airborne diseases, strategies may be directed at modifying ventilation or air pressure, and filtering or treating the air. To interrupt vector-borne transmission, measures may be directed toward controlling the vector population, such as spraying to reduce the mosquito population. Some interventions aim to increase a host’s defenses. Vaccinations promote development of specific antibodies that protect against infection.
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