

Disease Transmission and Virus-Associated Cancers

Zoonotic & Vector-Borne Diseases | Endemic-Epidemic-Pandemic | Vector Biology |
Oncoviruses

These notes cover five linked topics in disease epidemiology and medical microbiology: how diseases are classified by their source and mode of spread (zoonotic vs vector-borne), how outbreaks are classified by geographic scale (endemic, epidemic, pandemic), how arthropod vectors differ in their relationship with the pathogens they carry (mechanical vs biological vectors, and the propagative/cyclo-propagative/cyclo-developmental sub-types of biological transmission), and finally how certain viruses are causally linked to human cancers.

1. Zoonotic and Vector-Borne Diseases

1.1 Definitions

- **Zoonotic disease (zoonosis):** an infectious disease that is naturally transmitted between vertebrate animals and humans - the pathogen's natural reservoir is an animal, and humans are usually infected incidentally (a "spill-over" event), for example through a bite, contaminated food, or inhalation of contaminated material.
- **Vector-borne disease:** a human illness caused by parasites, viruses or bacteria that are transmitted by vectors - living organisms, typically blood-feeding arthropods, that carry a pathogen from an infected host (animal or human) to a new host.

According to WHO estimates, vector-borne diseases account for more than 17% of all infectious diseases and cause over 700,000 deaths every year; malaria alone causes roughly 600,000 deaths annually, and dengue affects populations in more than 130 countries. Major vectors include mosquitoes (*Aedes* - dengue, chikungunya, Zika, yellow fever; *Anopheles* - malaria, lymphatic filariasis; *Culex* - Japanese encephalitis, lymphatic filariasis, West Nile virus), ticks (Lyme disease, tick-borne encephalitis, rickettsial diseases), sandflies (leishmaniasis), tsetse flies (African trypanosomiasis) and triatomine bugs (Chagas disease).

1.2 How the two categories overlap

"Zoonotic" and "vector-borne" describe two independent properties of a disease - whether it has an animal reservoir, and whether a living vector is needed to transmit it - so a disease can be either, both, or neither. Many zoonotic diseases (plague, Lyme disease, Japanese encephalitis, Chagas disease) reach humans only via an arthropod vector that first picks up the pathogen from an animal reservoir, making them both zoonotic and vector-borne. Other zoonoses (rabies, anthrax, brucellosis, Nipah virus) spread directly from animal to human with no vector involved. Conversely, several important vector-borne diseases (urban-cycle dengue, chikungunya, Zika, lymphatic filariasis) cycle purely between humans and the mosquito vector, with no animal reservoir at all.

Zoonotic vs Vector-Borne Diseases

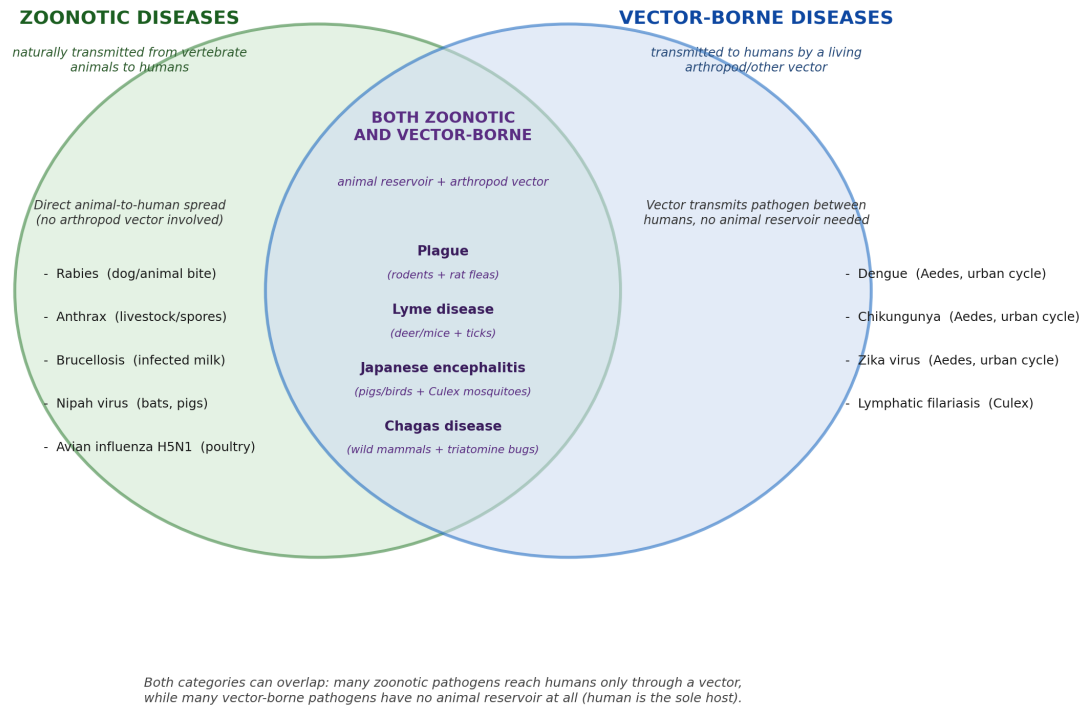


Fig. 1 - Overlap between zoonotic and vector-borne disease categories, with examples.

Key points

- Not all zoonotic diseases are vector-borne, and not all vector-borne diseases are zoonotic - classify a disease on two independent axes: source (animal reservoir present or not) and route (a living vector involved or not).
- Diseases with both an animal reservoir and a vector (plague, Lyme disease, Japanese encephalitis) are often the hardest to eliminate, since controlling the vector alone leaves the animal reservoir intact.

2. Endemic, Epidemic and Pandemic Diseases

2.1 Definitions

- **Endemic:** the constant, expected (baseline) presence of a disease in a particular population or region, occurring at a fairly predictable, steady level - e.g. malaria in parts of sub-Saharan Africa, or the common cold worldwide.
- **Outbreak:** a sudden increase in the number of cases above the expected baseline, generally confined to one community, institution or small geographic area - e.g. a cholera outbreak following a flood in a single district.
- **Epidemic:** disease spreads actively to affect a larger area than an outbreak - multiple communities, an entire country or a region - at a level clearly above what is normally expected there; e.g. the 2003 SARS epidemic, which affected roughly 8,000 people across some 29 countries.
- **Pandemic:** an epidemic that has spread across multiple countries or continents, affecting a very large number of people worldwide - e.g. the COVID-19 pandemic (2020 onward) and the 1918 influenza pandemic.

Escalating Scale of Disease Occurrence

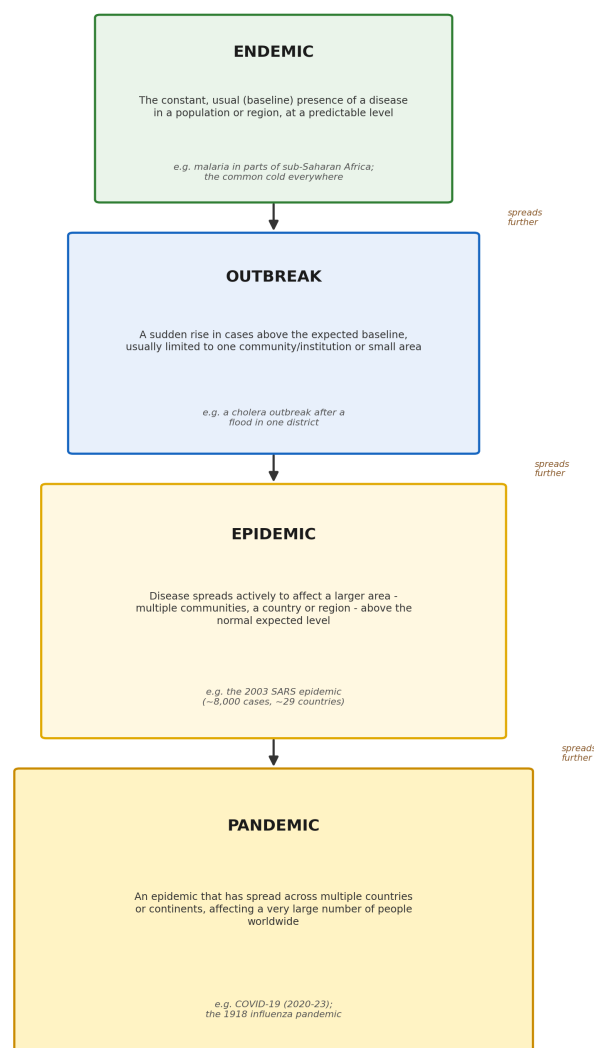


Fig. 2 - Escalating geographic scale: endemic to outbreak to epidemic to pandemic.

2.2 What drives escalation

Whether a disease is classed as endemic, an outbreak, an epidemic or a pandemic depends on how its case numbers compare with what is normally expected in a given place and time, and how far that elevated spread extends geographically - it is a statement about scale and spread, not directly about how severe individual cases are. A pathogen typically escalates along this ladder when it combines effective person-to-person (or vector-borne) transmission with a population that has little pre-existing immunity; public-health measures such as surveillance, quarantine, vaccination and vector control aim to interrupt this escalation at the earliest possible stage.

Key point

- A disease can be endemic and still be a major killer (malaria is endemic across much of Africa but remains one of the leading causes of death there) - "endemic" describes steady, expected occurrence, not mildness.

3. Mechanical and Biological Vectors of Diseases

A vector is a living organism - almost always a blood-feeding arthropod - that transmits an infectious pathogen from one host to another. Vectors are classified into two types based on what, if anything, happens to the pathogen while it is inside the vector.

3.1 Mechanical vectors

In mechanical transmission, the pathogen is simply carried passively on or in the vector's body - on its legs, wings or mouthparts, or passed unchanged through its gut - with no development or multiplication of the pathogen inside the vector. The vector acts purely as a contaminated "carrier", transferring the pathogen from a contaminated source (commonly faecal matter or waste) to a new surface, such as food. The classic example is the **housefly** (*Musca domestica*), which picks up bacteria such as *Salmonella*, *Shigella* and *Vibrio cholerae*, and cysts of *Entamoeba histolytica*, on its legs and mouthparts while feeding on faeces or refuse, and then deposits them on food or utensils.

3.2 Biological vectors

In biological transmission, the pathogen undergoes part of its life cycle - development, multiplication, or both - inside the vector before it becomes infective and can be transmitted to a new host; the vector is therefore a biologically essential (obligate) part of the pathogen's life cycle, not just a passive carrier. Examples include the *Anopheles* mosquito (*Plasmodium*, causing malaria), the *Aedes* mosquito (dengue, Zika and chikungunya viruses), the sandfly (*Leishmania*), the tsetse fly (*Trypanosoma brucei*), the triatomine bug (*Trypanosoma cruzi*, causing Chagas disease) and the rat flea (*Yersinia pestis*, causing plague).

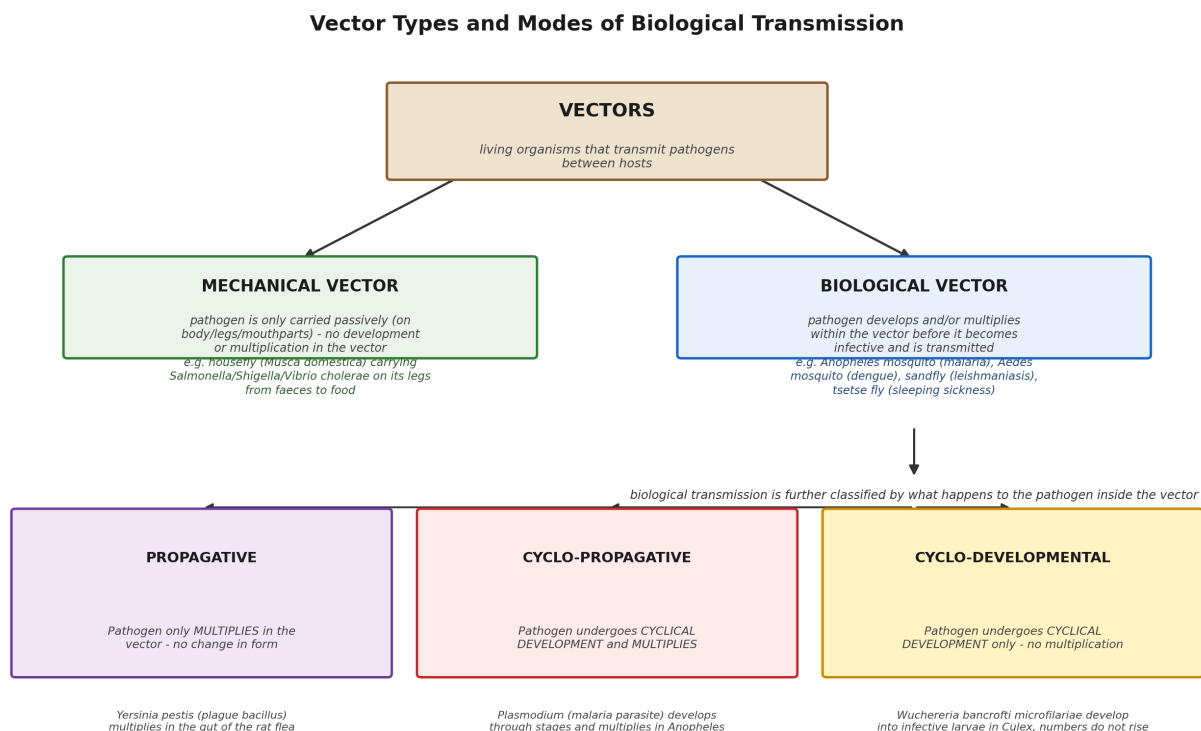


Fig. 3 - Mechanical vs biological vectors, and the three modes of biological transmission (elaborated in Section 4).

Key point

- The exam-relevant test to distinguish the two: does the pathogen change form or increase in number inside the vector? If no, it is a mechanical vector; if yes, it is a biological vector.

4. Propagative, Cyclo-Propagative and Cyclo-Developmental Transmission

Biological transmission (Section 3.2) is further divided into three sub-types, based on whether the pathogen multiplies in number, changes its developmental form, or both, while inside the biological vector (see Fig. 3).

4.1 Propagative transmission

The pathogen only **multiplies** in number inside the vector - it does not pass through any distinct developmental stages or change its form. *Yersinia pestis*, the plague bacillus, multiplies in the gut of the rat flea (*Xenopsylla cheopis*) without any change in its morphology; several arboviruses (such as the dengue and chikungunya viruses) likewise simply replicate within mosquito tissues before reaching the salivary glands.

4.2 Cyclo-propagative transmission

The pathogen undergoes both **cyclical developmental change** (passing through distinct life-cycle stages) **and multiplication** inside the vector. The malaria parasite, *Plasmodium*, is the textbook example: after a female *Anopheles* mosquito ingests gametocytes with a blood meal, they undergo sexual reproduction and a developmental cycle (zygote to ookinete to oocyst) while also multiplying enormously, eventually producing thousands of infective sporozoites in the mosquito's salivary glands.

4.3 Cyclo-developmental transmission

The pathogen undergoes **cyclical developmental change** inside the vector but does **not multiply** in number. The filarial worms *Wuchereria bancrofti* and *Brugia malayi* illustrate this: microfilariae ingested by a *Culex* mosquito develop through successive larval stages (L1 to L2 to L3, the infective stage) inside the mosquito, but the number of larvae does not increase - each microfilaria simply matures into one infective larva.

Type of transmission	Multiplication in vector?	Developmental change?	Classic example
Propagative	Yes	No	<i>Yersinia pestis</i> in the rat flea (plague); dengue virus in mosquito tissues
Cyclo-propagative	Yes	Yes	<i>Plasmodium</i> (malaria parasite) in the <i>Anopheles</i> mosquito
Cyclo-developmental	No	Yes	<i>Wuchereria bancrofti</i> microfilariae in the <i>Culex</i> mosquito

Key point

- Remember the pattern by the prefix: "propagative" alone = multiplication only; adding "cyclo-" means the pathogen also (cyclo-propagative) or only (cyclo-developmental) passes through developmental stages in the vector.

5. Virus-Associated Human Cancers

5.1 The concept of oncoviruses

An **oncovirus** (or tumour virus) is a virus that can cause, or substantially contribute to, cancer in its host. Oncoviruses drive tumour formation through several overlapping mechanisms: expressing viral oncoproteins that inactivate host tumour-suppressor proteins (such as p53 and the retinoblastoma protein, Rb); integrating viral DNA into the host genome and disrupting nearby genes (insertional mutagenesis); driving chronic inflammation and tissue damage that promotes mutation and abnormal cell growth over time; and causing immunosuppression that allows other cancer-associated processes to go unchecked. Globally, viral infections are estimated to be causally linked to roughly 12-20% of all human cancers, with the burden weighted heavily towards regions with less access to vaccination, screening and antiviral treatment.

5.2 Major human oncoviruses

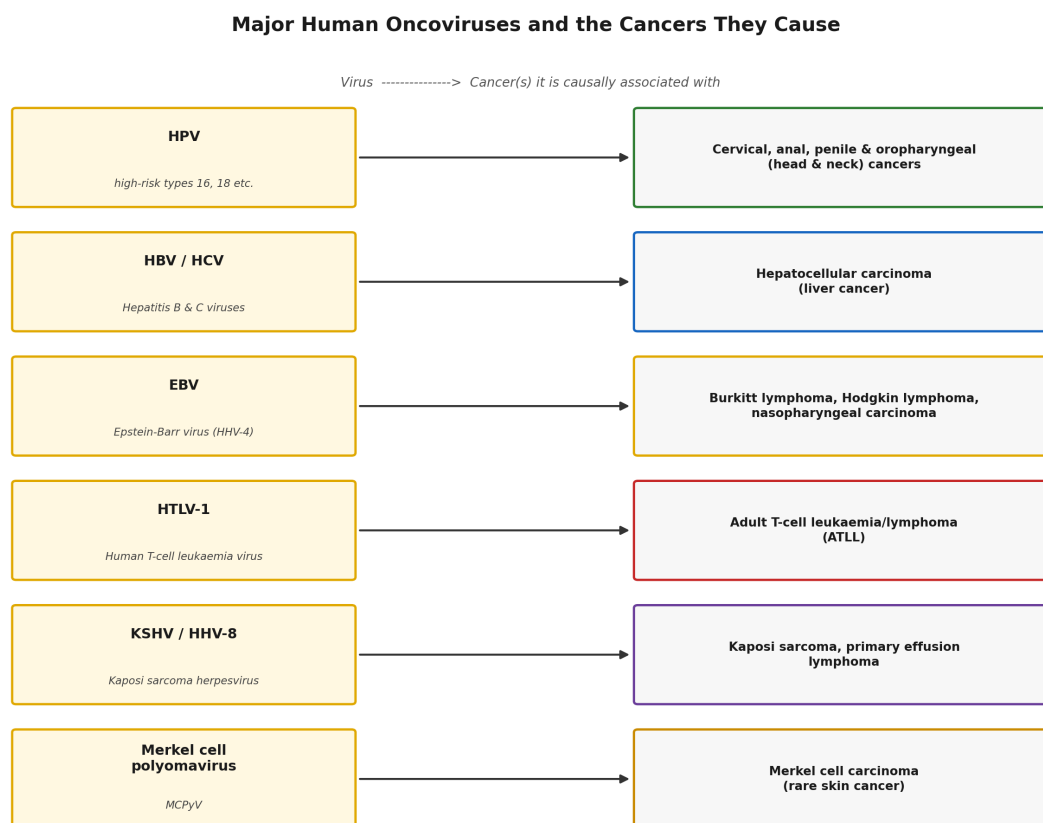


Fig. 4 - Major human oncoviruses mapped to the cancers they are causally associated with.

Virus	Cancer(s) caused	Key mechanism
Human papillomavirus (HPV), high-risk types 16 & 18	Cervical, anal, penile, vulvar/vaginal and oropharyngeal (head & neck) cancers	Viral E6 and E7 oncoproteins degrade p53 and Rb tumour-suppressor proteins

Virus	Cancer(s) caused	Key mechanism
Hepatitis B and C viruses (HBV, HCV)	Hepatocellular carcinoma (liver cancer)	Chronic liver inflammation and cirrhosis; HBV DNA can also integrate into the host genome
Epstein-Barr virus (EBV / HHV-4)	Burkitt lymphoma, Hodgkin lymphoma, nasopharyngeal carcinoma, some gastric cancers	Immortalises infected B cells; viral proteins (EBNA, LMP) drive proliferation
Human T-cell leukaemia virus type 1 (HTLV-1)	Adult T-cell leukaemia/lymphoma (ATLL)	Viral Tax protein drives uncontrolled proliferation of infected T cells
Kaposi sarcoma herpesvirus (KSHV / HHV-8)	Kaposi sarcoma, primary effusion lymphoma, multicentric Castleman disease	Viral proteins promote abnormal blood-vessel growth and cell proliferation; common in immunosuppressed (e.g. HIV-positive) patients
Merkel cell polyomavirus (MCPyV)	Merkel cell carcinoma (a rare, aggressive skin cancer)	Clonal integration of viral DNA; expression of large T antigen disrupts cell-cycle control

Worth noting

- Vaccines against HPV and HBV are, in effect, cancer-prevention vaccines - they are among the clearest real-world demonstrations that a substantial share of human cancer can be prevented by blocking the infection that causes it, rather than only by treating the tumour after it forms.

Key points

- Not every infection with an oncovirus leads to cancer - viral oncogenesis usually needs years of chronic infection plus cofactors (immune status, co-infections, environmental exposures such as aflatoxin with HBV) before a tumour develops.
- HPV and hepatitis B/C together account for the large majority of cancers attributable to viruses worldwide, mainly cervical and liver cancer.

6. Quick Comparison

Concept	Defining criterion	Example
Zoonotic disease	Animal reservoir; humans infected directly or via a vector	Rabies (direct); plague (via flea)
Vector-borne disease	Transmitted by a living vector; reservoir may be animal or purely human	Malaria (human-mosquito cycle, human reservoir); dengue (urban human-mosquito cycle)
Endemic	Constant expected baseline level in a region	Malaria in parts of Africa
Epidemic	Spread clearly above baseline across a wide area	2003 SARS epidemic
Pandemic	Epidemic spread across multiple countries/continents	COVID-19
Mechanical vector	Pathogen only carried passively, no change	Housefly + <i>Vibrio cholerae</i>
Biological vector	Pathogen develops and/or multiplies in vector	<i>Anopheles</i> + <i>Plasmodium</i>
Oncovirus	Virus causally linked to cancer development	HPV to cervical cancer

Notes prepared for study purposes. Consult current primary literature for details required in formal citation.