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INSECTS AS VECTORS OF DISEASES IN HUMANS AND ANIMALS

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ABSTRACT :

Insects are major biological and mechanical vectors of infectious diseases affecting both humans and animals, particularly in tropical and subtropical zones. Blood-feeding groups including mosquitoes, sand flies, tsetse flies, fleas, biting midges, and triatomine bugs transmit a wide variety of viruses, bacteria, and protozoan parasites. An insect's capability to transmit pathogens is fundamentally linked to its anatomical features, feeding habits, digestive physiology, salivary gland functions, and microbial interactions. The transmission cycle generally requires the insect to acquire the pathogen from an infected host, survive or multiply within its own tissues, migrate to specific locations, and ultimately release the infectious agent into a susceptible host during feeding or via fecal contamination. Key human illnesses transmitted by these vectors include malaria, dengue, leishmaniasis, African trypanosomiasis, plague, and Chagas disease, while prominent animal diseases include Rift Valley fever and bluetongue. This review explores insect anatomy and physiology, modes of pathogen transmission, prominent diseases, factors influencing vector competence, and modern control approaches.

Keywords: Insect vectors; disease transmission; vector competence; insect anatomy; physiology; biological transmission; mechanical transmission; zoonoses; mosquitoes; sand flies.

1. Introduction

Insects represent a highly diverse animal group and hold vital ecological roles across terrestrial and aquatic environments. While many species offer positive ecological benefits like pollination, decomposition, and natural pest control, certain groups possess medical and veterinary significance because they transmit infectious pathogens (Laroche *et al.,* 2018). These disease carrying insects are known as vectors because they transfer pathogens from infected hosts or contaminated environments to healthy individuals. The transmitted agents include viruses, bacteria, and protozoa, which cause diseases that affect humans, livestock, and wildlife (WHO, 2024). Vector-borne diseases remain a massive public health threat globally; the World Health Organization notes that they comprise more than 17% of all infectious diseases and cause over 700,000 human deaths each year. The geographic distribution and intensity of these diseases are shaped by vector populations, temperature, humidity, rainfall, host presence, land-use choices, and human behavioral patterns (WHO, 2024). Insects deliver pathogens via biological or mechanical routes, salivary injection, fecal contamination, or regurgitation (Laroche *et al.,* 2018). Consequently, understanding how insect anatomy and physiology interact with pathogen development is vital for deciphering disease epidemiology and creating robust vector control programs (Franz *et al.,* 2015).

2. Classification of Disease-Transmitting Insects

Insects that transmit diseases are found across several taxonomic classifications and possess specialized mouthparts structured for piercing, sucking, lapping, or sponging. The primary groups impacting medical and veterinary health include mosquitoes, sand flies, tsetse flies, biting midges, fleas, houseflies, and triatomine bugs (Laroche *et al.,*2018).

Insect group / vector	Representative genus or species	Important diseases
Mosquitoes	Anopheles	Malaria
Mosquitoes	Aedes	Dengue, Zika, chikungunya
Mosquitoes	Culex	West Nile fever, Japanese encephalitis
Sand flies	Phlebotomus, Lutzomyia	Leishmaniasis
Tsetse flies	Glossina	African trypanosomiasis
Biting midges	Culicoides	Bluetongue
Fleas	Xenopsylla	Plague
Triatomine bugs	Triatoma and related genera	Chagas disease
Houseflies	Musca domestica	Mechanical transfer of enteric pathogens

Ticks are also important vectors of human and animal pathogens; however, ticks belong to the class Arachnida rather than Insecta and are therefore not insects (Laroche *et al.,*2018).

3. General Anatomy of Insects

The external structure of a typical insect is divided into three distinct segments: the head, the thorax, and the abdomen. Each segment houses specialized organs designed for sensory input, locomotion, feeding, digestion, waste clearance, and reproduction (Hillyer and Pass, 2020).

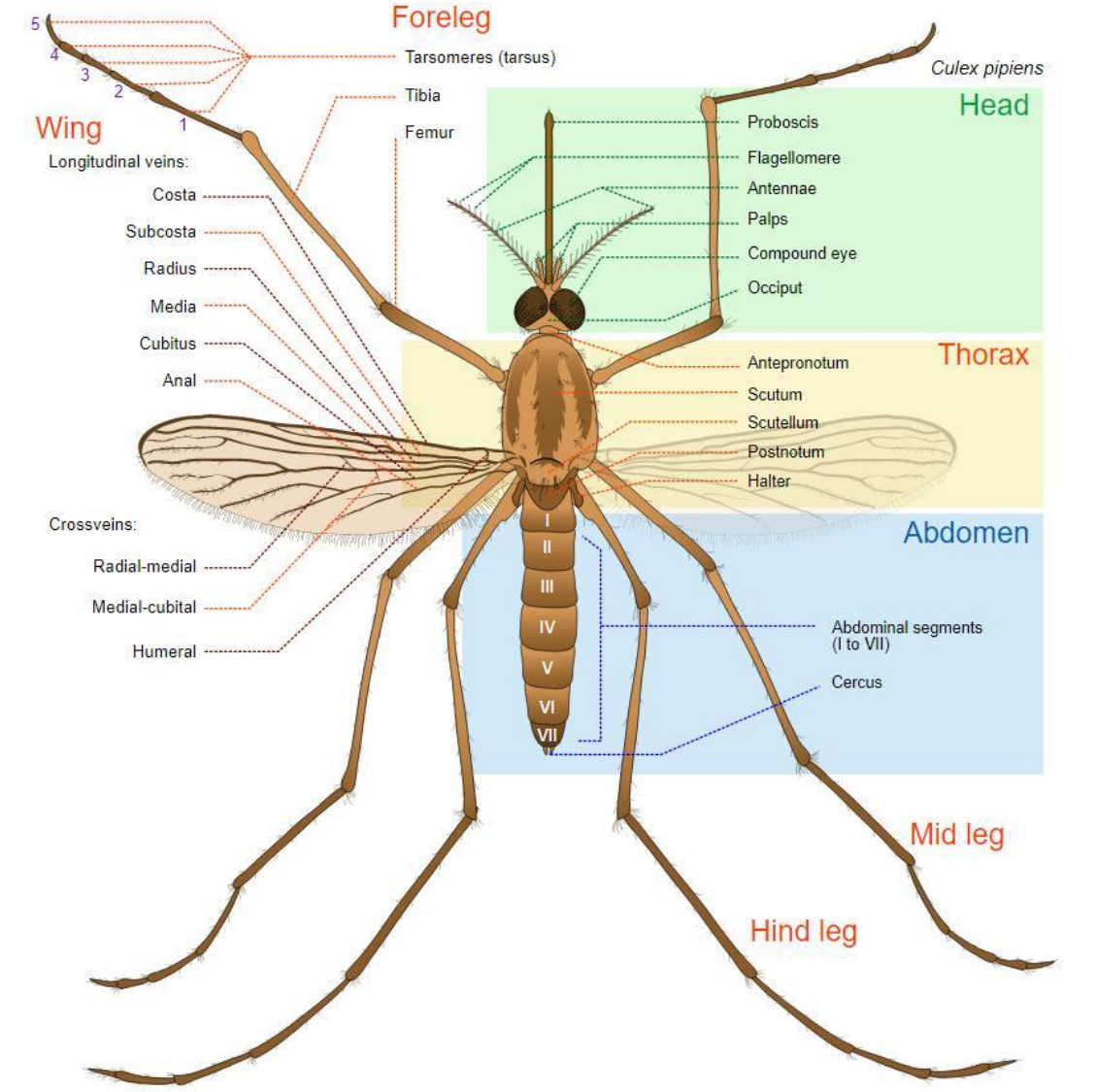


Figure 1. General external anatomy of an insect

3.1 Head

The head contains the compound eyes, antennae, mouthparts and sensory structures. Antennae detect odours and other environmental cues that help many blood-feeding insects locate hosts (WHO, 2024). Mouthparts are particularly important in disease transmission because they allow insects to pierce skin, obtain blood or other fluids, and introduce infectious material during feeding (Laroche *et al.,*2018). In mosquitoes, the female proboscis contains several slender stylets used to penetrate host tissues and locate blood, while the labium acts as an external supporting sheath during feeding (Clements, 1992).

3.1.1 Antennae

Antennae are paired, sensitive structures on the head primarily tuned to pick up chemical, mechanical, and ambient environmental signals.
Functions:

- Sense carbon dioxide and odors linked to hosts.
- Identify chemical markers given off by humans and animals.
- Track variations in ambient temperature, moisture levels, and environment.
- Guide insects directly to vulnerable hosts.
- In female mosquitoes, specialized antennal receptors locate human and animal hosts by evaluating smell and environmental cues.

3.1.2 Compound Eyes

Compound eyes are built from thousands of individual visual sensors called ommatidia, which help insects perceive movement, light fluctuations, and visual shapes.

Functions:

- Spot moving targets and potential hosts.
- Guide flight orientation.
- Help navigate and identify ideal habitats.

3.1.3 Mouthparts

Mouthparts represent a primary anatomical gateway for disease transmission, varying greatly depending on the insect's feeding mechanics.
Importance in disease transmission:

- Piercing-sucking mouthparts enable vectors to drill into host tissues to draw blood.
- Soiled mouthparts can mechanically transfer pathogens from one host to another.
- Salivary secretions can inject pathogens directly into host tissue during a blood meal.
- Sponging mouthparts permit houseflies to pick up and deposit harmful microbes onto food and ambient surfaces (Clements, 1992).

3.2 Thorax

The thorax is split into three segments: the prothorax, mesothorax, and metathorax. Every segment supports one pair of legs, and most flying insects have wings anchored to the mesothorax and metathorax. Strong thoracic muscles drive flight and walking, allowing vectors to travel, locate hosts, and find breeding or resting locations (Chapman, 2013).

3.2.1 Legs

Insects possess three pairs of jointed legs attached to the thorax. Each leg generally consists of the coxa, trochanter, femur, tibia, and tarsus.
Importance in disease transmission:

- Legs facilitate vector movement between infected and healthy hosts.
- Houseflies accumulate and spread microorganisms on their legs and body surfaces when visiting waste materials.
- Fleas rely on highly developed hind legs to leap across hosts.
- Mosquitoes stabilize themselves on host skin using their legs while taking a blood meal.

3.2.2 Wings

Most disease-transmitting flying insects possess one or two pairs of functional wings.
Examples include:

- Mosquitoes: a single functional pair of wings.
- Houseflies: a single functional pair of wings, with the rear pair transformed into halteres.
- Sandflies: two pairs of wings.
- Tsetse flies: a single functional pair of wings.

Importance in disease transmission: Wings facilitate the movement of vectors between breeding habitats, infected hosts, and susceptible hosts. This increases the geographical spread of vector-borne diseases.

3.2.3 Halteres

Halteres are specialized, modified hindwings seen in the order Diptera (true flies). They serve as gyroscopic balance organs that stabilize the insect during flight, playing an essential role for mosquitoes, houseflies, sandflies, and tsetse flies (Chapman, 2013).

3.3 Abdomen

The abdomen houses a major portion of the digestive, excretory, and reproductive networks. The midgut and hindgut are critical zones for vector biology, as they handle food processing and act as initial infection or developmental sites for several types of pathogens (Franz *et al.,* 2015). In female mosquitoes, the abdomen stretches considerably following a blood meal to digest the heavy influx of nutrients required for egg development (Clements, 1992).

4. Internal Anatomy and Physiology of Disease-Transmitting Insects

The internal organ systems of insects maintain physiological processes that influence pathogen acquisition, persistence and transmission. Important systems include the digestive, salivary, circulatory, respiratory, excretory, nervous and reproductive systems (Chapman, 2013; Hillyer and Pass, 2020).

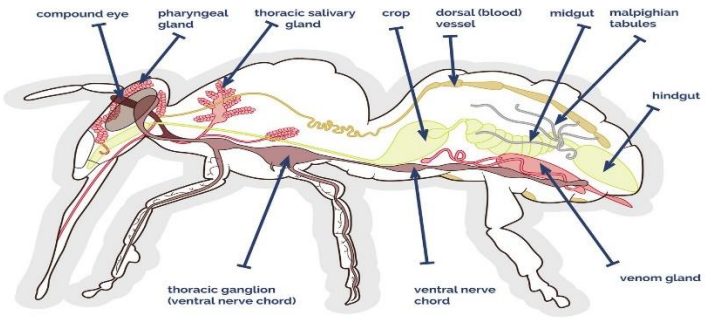


Figure 2. Representation of major internal insect systems

4.1 Digestive System

The alimentary canal is broadly separated into the foregut, midgut, and hindgut. The foregut takes in and moves food forward; the midgut serves as the primary zone for breakdown and nutrient absorption; and the hindgut handles water, ionic balance, and waste extraction (Chapman, 2013). The midgut represents an important combat zone for pathogen interactions; for instance, arboviruses and malaria parasites must penetrate midgut cellular barriers before spreading to other bodily systems (Franz *et al.,*2015).

4.2 Salivary Glands

Salivary glands create secretions loaded with enzymes, proteins, and biological molecules. In blood-feeding insects, saliva counteracts blood clotting, platelet grouping, inflammation, and host immunity to make blood meals easier to acquire (Ribeiro and Francischetti, 2003). For saliva-transmitted pathogens, these glands serve as prime sites for infection or pathogen grouping. Malaria sporozoites journey to the salivary glands of *Anopheles* mosquitoes, and multiple arboviruses colonize mosquito salivary tissues before being injected into a host during subsequent feeding. Salivary glands are crucial for biological transmission since certain pathogens must explicitly invade them to reach a new host.
Examples:

- *Plasmodium* sporozoites group within mosquito salivary glands prior to human injection.
- Dengue virus spreads out to the salivary glands of infected mosquitoes.
- Salivary transmission occurs when infected saliva flows directly into host tissues during feeding (Franz *et al.,* 2015; CDC, 2024a).

4.3 Circulatory System

Insects feature an open circulatory system where haemolymph flows freely through the body cavity (haemocoel). The dorsal vessel, comprising a rear heart and a front aorta, moves haemolymph through the insect. Haemolymph delivers nutrients, hormones, metabolites, and immune factors, but does not act as the primary oxygen vector since air exchange is handled by the tracheal network.
Role in pathogen transmission: In multiple vectors, pathogens crossing the midgut wall enter the haemocoel to circulate and find new target tissues. Mosquito-borne arboviruses, for instance, journey from the midgut through the haemocoel to reach the salivary glands, an essential step for transmission during later feeds (Hillyer and Pass, 2020).

4.4 Respiratory System

The insect breathing network is composed of external spiracles, tracheae, and microscopic tracheoles. Air enters through the spiracles and moves through branching channels that supply oxygen straight to tissues while cycling out carbon dioxide (Chapman, 2013).

4.5 Excretory System

Malpighian tubules represent the primary filtering organs in insects, clearing metabolic waste from the hemolymph and managing fluid and ionic balances (Chapman, 2013). This regulation is vital for blood-feeders, which process large volumes of fluid during a single meal. The excretory loop consists of thin tubules located near the intersection of the midgut and hindgut.
Functions:

- Removal of nitrogenous waste.
- Regulation of water and ionic balance.
- Maintenance of internal physiological conditions.

Malpighian tubules help maintain the physiological environment required for insect survival. Although they are not generally the principal route of pathogen transmission, their metabolic and osmoregulatory functions support vector fitness (Chapman, 2013).

4.6 Nervous and Sensory Systems

The insect nervous framework consists of the brain, a ventral nerve cord, segmental ganglia, and diverse sensory structures (Chapman, 2013). It orchestrates locomotion, feeding actions, sensory collection, and environmental adaptation. Mosquitoes rely on olfactory, thermal, and visual signals to seek out vertebrate targets (WHO, 2024).

4.7 Reproductive System

The reproductive tract yields eggs to preserve and grow insect populations. For many female mosquitoes, a blood meal yields the exact nutrients needed for egg maturation, directly linking host-seeking behavior to reproductive drive. Certain vector-borne pathogens can pass directly from an infected female to her larvae via vertical transmission, including transovarial pathways in specific vector-pathogen loops (WHO, 2024).
Importance in disease transmission: Reproduction contributes indirectly to disease transmission by maintaining vector populations. In some insect–pathogen relationships, vertical transmission occurs when pathogens pass from infected females to their offspring through eggs. However, vertical transmission is pathogen-specific and does not occur in every vector-borne disease (Clements, 1992).

5. Mechanisms of Disease Transmission by Insects

An insect's potential to spread a pathogen is determined by its feeding choices, anatomical framework, physiological state, compatibility with the pathogen, and surrounding environmental conditions (Franz *et al.,*2015; Laroche *et al.,*2018).

5.1 Biological Transmission

Biological transmission happens when a pathogen invades an insect vector and undergoes mandatory development, multiplication, or both before it can infect another host (WHO, 2024). This sequence involves gathering the pathogen from an infected host, establishing it within the vector, development or replication, moving to a transmission site, and releasing it into a healthy host (Franz *et al.,*2015).

- **Acquisition:** The vector bites an infected host and ingests the pathogen.
- **Establishment:** The pathogen survives the digestive tract and infects a target tissue, frequently the midgut.
- **Development or multiplication:** The pathogen replicates its numbers or transitions through life stages inside the vector.
- **Dissemination:** The pathogen travels from the initial infection site to other internal organs, such as the salivary glands.
- **Transmission:** The infectious vector delivers the pathogen to a new host during feeding or through alternative vector-specific pathways.

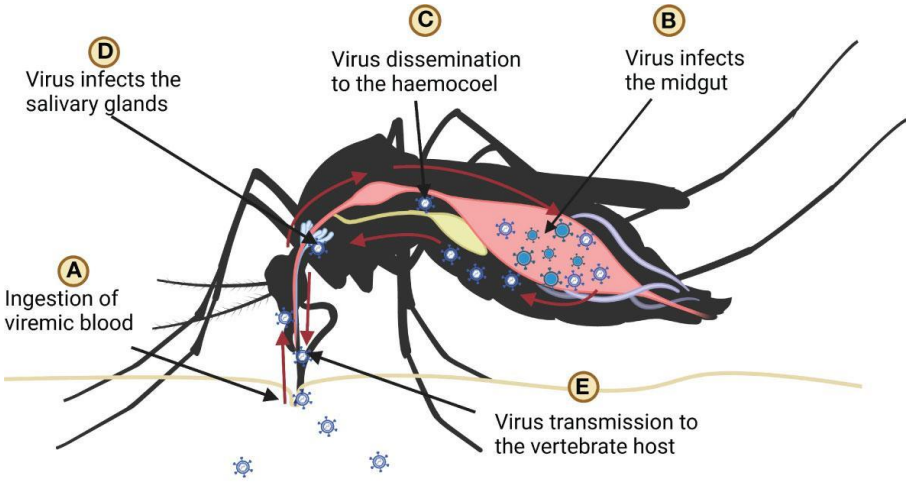


Figure 3. Generalized biological transmission pathway in a mosquito

5.2 Mechanical Transmission

Mechanical transmission occurs when an insect physically transports a pathogen from one host or surface to another without any mandatory development or multiplication occurring inside the insect's body (Laroche *et al.,* 2018). Microbes stick to the legs, mouthparts, or outer body surfaces. Houseflies regularly move microorganisms between feces, animal waste, human food, and living spaces, particularly in areas with poor sanitation (Graczyk *et al.,*2001).

5.3 Salivary Transmission

Salivary transmission takes place when an infected, blood-feeding insect introduces pathogens along with its saliva during a bite. Saliva carries specialized agents that aid blood collection by blocking host clotting and localized immune reactions (Ribeiro and Francischetti, 2003). Dengue and various arboviruses are spread when infected mosquitoes drop virus-laden saliva directly into the skin of a susceptible host (WHO, 2024).

5.4 Fecal or Stercorarian Transmission

In stercorarian transmission, pathogens are discharged in vector feces and enter a new host through a bite wound, damaged skin, or mucous membranes. This is the signature pathway for Chagas disease: infected triatomine bugs defecate close to their feeding bite, and *Trypanosoma cruzi* enters when the host accidentally rubs the contaminated material into the wound, eyes, or mouth (WHO, 2024).

5.5 Regurgitative Transmission

Regurgitative transmission involves shedding previously swallowed infectious matter from the digestive tract during or around a feeding event. Flea-based spread of *Yersinia pestis* frequently relies on this mechanism, driven by a bacterial blockage in the flea's proventriculus (Hinnebusch *et al.,*2017).

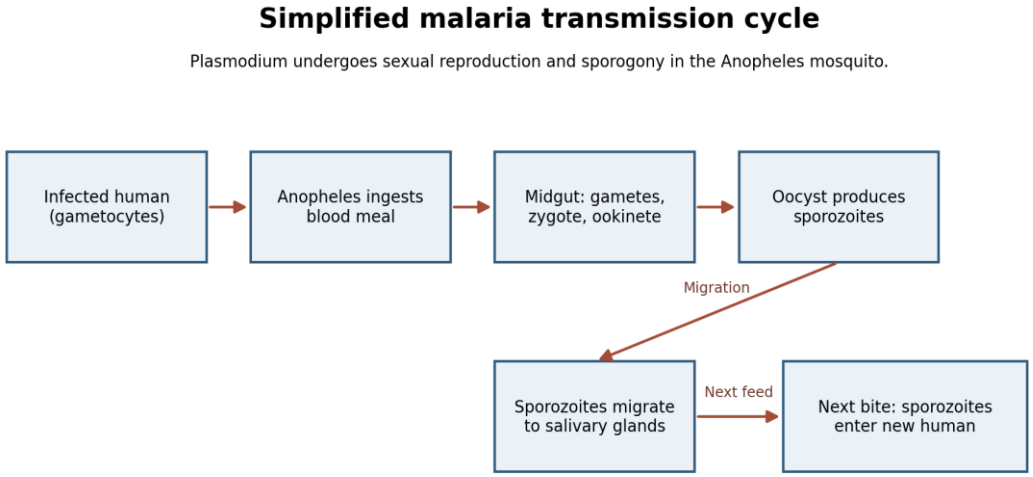
5.6 Vertical and Transovarial Transmission

Vertical transmission occurs when a pathogen transfers straight from an infected parent vector to its offspring. Transovarial transmission is a specific subtype where the pathogen passes into developing eggs. This pathway enables pathogens to survive between active transmission seasons, as seen with the Rift Valley fever virus in certain *Aedes* mosquito populations (WHO, 2024).

6. Major Diseases Transmitted by Insects in Humans

6.1 Malaria

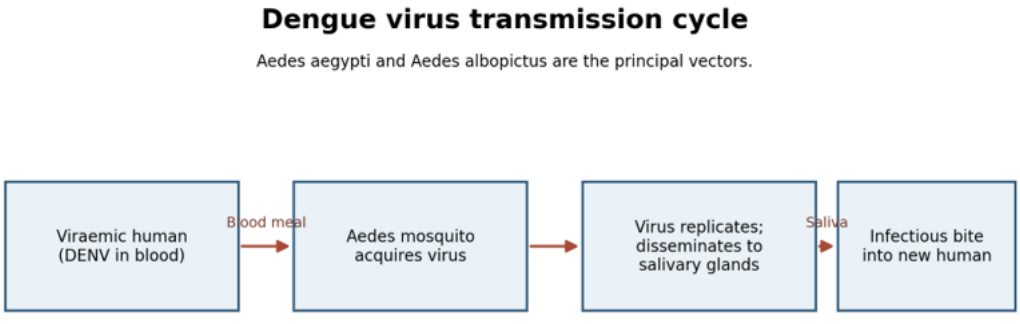
Causative agent: *Plasmodium* species.
Principal vectors: Infected female *Anopheles* mosquitoes.
Transmission cycle: Malaria is a parasitic illness spread when an infected female *Anopheles* mosquito drops sporozoites into a human during a blood meal. Key human malaria parasites include *P. falciparum*, *P. vivax*, *P. malariae*, and *P. ovale*. After a mosquito swallow gametocytes from an infected individual, male and female gametes form and fuse in the mosquito midgut to create a zygote. This zygote develops into a mobile ookinete, which drills through the midgut wall to form an oocyst. Sporozoites grow inside this oocyst, burst into the haemocoel, migrate directly to the salivary glands, and are injected into a new human host during a subsequent bite (CDC, 2024a).



Clinical signs: Symptoms include fever, chills, headache, and fatigue. Advanced malaria can lead to severe anemia, organ failure, cerebral malaria, and death, especially among high-risk groups (WHO, 2024).

6.2 Dengue

Causative agent: Dengue virus (DENV).
Principal vectors: *Aedes aegypti* and *Aedes albopictus* (WHO, 2024).
Transmission cycle: Dengue is spread primarily by infected female *Aedes* mosquitoes (WHO, 2024). After drinking blood from a viraemic person, the virus infects the mosquito's midgut, replicates, and expands into secondary tissues like the salivary glands (Franz *et al.,* 2015; WHO, 2024). Virus-laden saliva is then transferred to another host during a future blood meal.



Clinical signs: Dengue typically presents with high fever, headache, muscle and joint pain, nausea, and skin rashes. Severe dengue cases can involve plasma leakage, internal bleeding, circulatory shock, and acute organ damage (WHO, 2024).

6.3 Leishmaniasis

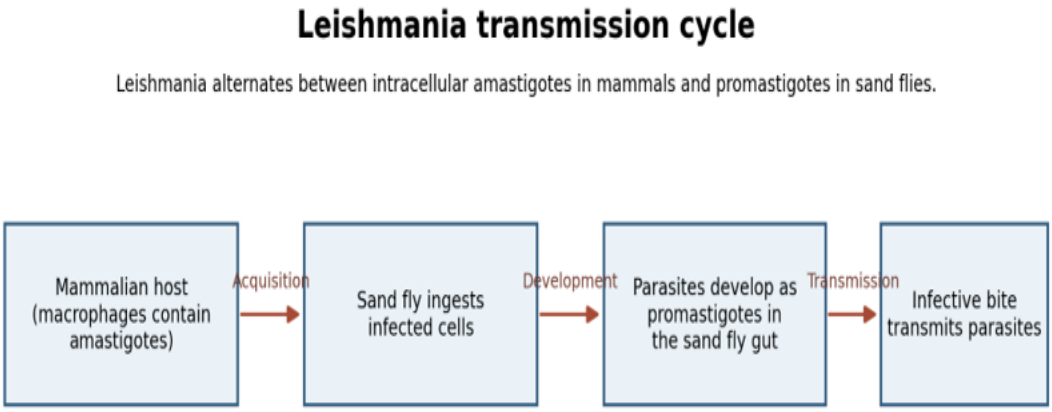
Causative agent: *Leishmania* species.

Vectors: Female phlebotomine sand flies, specifically *Phlebotomus* and *Lutzomyia* species.

Transmission cycle: During feeding, infected sand flies inject promastigote forms of the parasite. These are engulfed by host macrophages and transform

into intracellular amastigotes, which replicate inside host cells (CDC, 2024b).

Clinical signs: The disease manifests in three primary clinical forms: cutaneous leishmaniasis (causing skin ulcers), mucocutaneous leishmaniasis (damaging mucous membranes), and visceral leishmaniasis (targeting internal organs like the spleen, liver, and bone marrow) (WHO, 2024).



6.4 African Trypanosomiasis

Causative agents: Trypanosoma brucei gambiense and T. b. rhodesiense.
Vector: Tsetse flies (Glossina species).
Transmission cycle: Human African trypanosomiasis, or sleeping sickness, is transmitted via the bite of an infected tsetse fly across sub-Saharan Africa. The fly collects bloodstream trypanosomes from an infected host. These parasites undergo developmental shifts inside the fly, transforming into infective metacyclic forms within the salivary glands before injection into a mammal during a subsequent bite (WHO, 2023; CDC, 2024c).
Clinical signs: The illness initially attacks the blood and lymphatic networks, later invading the central nervous system to trigger severe sleep disruptions and neurological degradation (WHO, 2023).

6.5 Plague

Causative agent: *Yersinia pestis*.
Important vector: Infected fleas, notably *Xenopsylla cheopis*.
Transmission cycle: Plague is a bacterial zoonosis sustained within rodent-flea lifecycles that overflows to humans via flea bites or direct contact with infected animals (CDC, 2024d). Following a blood meal on an infected host, *Y. pestis* multiplies and forms physical clusters within the flea's digestive tract. Transmission regularly involves a blockage of the proventriculus, forcing the flea to regurgitate bacteria into the wound during a bite (Hinnebusch *et al.,* 2017).
Clinical signs: Human plague occurs in bubonic, septicaemic, and pneumonic varieties, with clinical signs featuring fever, weakness, and agonizingly swollen lymph nodes (CDC, 2024d).

6.6 Chagas Disease

Causative agent: *Trypanosoma cruzi*.
Vector: Triatomine bugs, colloquially termed "kissing bugs".
Transmission cycle: Chagas disease is primarily spread when infected bug feces contaminate a bite wound, broken skin, or mucous membranes; transmission rarely occurs through the bug's saliva. This disease serves as a prime classic example of stercorarian transmission (WHO, 2024).
Clinical signs: Acute infections can provoke fever and localized swelling, whereas chronic stages can trigger severe cardiac damage, heart failure, and digestive tract complications (WHO, 2024).

7. Major Insect-Transmitted Diseases in Animals

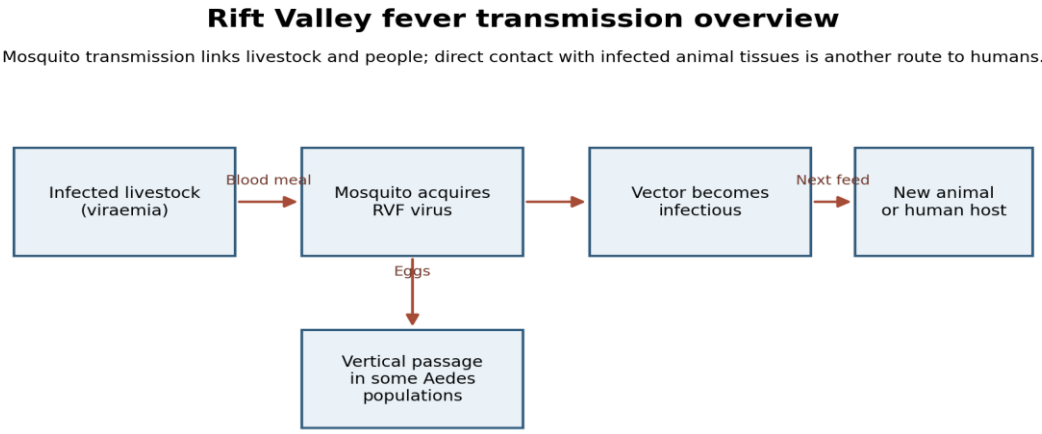
7.1 Rift Valley Fever

Causative agent: Rift Valley fever virus (RVFV).

Vectors: Several mosquito groups, including *Aedes*, *Culex*, and *Anopheles*.

Transmission cycle: Rift Valley fever is a mosquito-borne zoonosis that primarily targets sheep, goats, cattle, and other ruminants, though it can cross into humans. Mosquitoes pick up the virus while feeding on viremic animals. The virus replicates across vulnerable mosquito tissues and transfers during later feeding events. In certain *Aedes* species, vertical passage via infected eggs helps keep the virus alive between major outbreaks (WHO, 2024).

Clinical signs: In livestock, the disease provokes high fever, sweeping mortality rates among young animals, mass abortions, and liver degradation. Humans can contract the virus through mosquito bites or via direct contact with the blood, tissues, or aborted remains of infected livestock (WHO, 2024; WOAH).



7.2 Bluetongue

Causative agent: Bluetongue virus (BTV).
Vector: Biting midges belonging to the genus *Culicoides*.
Transmission cycle: Bluetongue is a non-contagious, insect-borne viral condition targeting domestic and wild ruminants like sheep, cattle, and goats. Female *Culicoides* midges contract the virus while drawing blood from infected animals and pass it to healthy livestock during later meals.
Clinical signs: Affected animals display fever, swelling around the face and lips, mouth lesions, lameness, and drops in productivity, with severity shifting by host species and viral strain. Bluetongue is non-zoonotic and presents no health risks to humans (WOAH).

Comparison of Major Transmission Mechanisms

Mechanism	Main process	Representative example
Biological	Pathogen develops or multiplies inside the insect	Malaria; dengue
Salivary inoculation	Pathogen is introduced with saliva during feeding	Dengue; African trypanosomiasis
Stercorarian	Pathogen enters through infected faeces	Chagas disease
Mechanical	Pathogen is physically carried without essential development in the insect	Enteric microorganisms carried by flies
Regurgitative	Infectious material is released from the digestive tract	Flea-associated plague transmission
Vertical / transovarial	Pathogen passes from female vector to offspring or eggs	Rift Valley fever virus in certain Aedes populations

9. Factors Affecting Insect Vector Competence

Vector competence defines the biological capability of an arthropod vector to acquire a pathogen, support its internal lifecycle or replication, and successfully pass it to a vulnerable host. It remains distinct from vectorial capacity, which incorporates wider ecological and behavioral dynamics such as vector population density, survival rates, and biting frequency (Franz *et al.,*2015).

9.1 Anatomical Factors

Mouthpart architecture, midgut epithelial wall barriers, salivary gland access, and tissue-specific cellular receptors all heavily dictate pathogen entry, internal spread, and eventual discharge (Franz *et al.,* 2015).

9.2 Physiological and Immune Factors

Digestive enzyme output, metabolic states, salivary secretions, and internal innate immune pathways all influence whether a pathogen survives and matures inside the insect (Hillyer and Pass, 2020; Franz *et al.,* 2015).

9.3 Genetic Factors

Inherent genetic differences across distinct vector populations alter their vulnerability to infection and dictate how efficiently pathogens cross internal tissue boundaries (Franz *et al.,*2015).

9.4 Environmental Factors

Fluctuations in temperature, humidity, rainfall, breeding site presence, and seasonal weather trends impact insect growth rates, survival, field abundance, and the speed of pathogen replication inside the vector (WHO, 2024).

9.5 Feeding Behavior

Host preferences, biting frequency, peak feeding times, and the capability to take multiple partial blood meals altogether shape the odds of pathogen acquisition and transmission (WHO, 2024).

10. Importance in Veterinary and Public Health

Insect vectors serve as critical links connecting pathogen reservoirs, vulnerable hosts, livestock herds, and human communities. Their impact extends far beyond isolated bites because vector populations actively maintain and broaden the geographic reach of infectious agents (WHO, 2024). In animal farming, vector-borne illnesses lower herd productivity, cause reproductive failures, spike mortality rates, and disrupt animal transport and international trade (FAO; WOAH). In human populations, these diseases drive up sickness, death rates, medical costs, and socioeconomic stress, particularly within vulnerable, low-income communities (WHO, 2024). Consequently, studying insect vectors is an indispensable cornerstone of medical entomology, veterinary entomology, parasitology, microbiology, and epidemiology (Laroche *et al.,*2018).

11. Prevention and Management of Insect-Borne Diseases

Successful prevention requires an Integrated Vector Management (IVM) framework, blending environmental, biological, chemical, and personal protection tactics with active disease tracking and clinical or veterinary care (WHO, 2024).

- **Environmental management:** Drain or treat standing water, optimize drainage infrastructure, and eliminate unneeded water vessels to destroy mosquito breeding zones (WHO, 2024).
- **Chemical control:** Deploy approved insecticides responsibly, alongside regular resistance tracking and strict safety protocols for humans, livestock, and local ecosystems (WHO, 2024).
- **Biological control:** Introduce safe, compatible biological control agents into wider integrated vector management operations when appropriate (WHO, 2024).
- **Personal protection:** Distribute and use insecticide-treated bed nets, protective clothing, insect repellents, and window screens to minimize exposure to biting insects (WHO, 2024).
- **Livestock protection:** Merge veterinary tracking, targeted livestock vaccination when available, vector population containment, and early clinical diagnosis to mitigate animal disease impacts (FAO, WOAH).
- **Disease surveillance:** Track vector population levels and test trapped vectors or sentinel animals for pathogens to establish early-warning frameworks (WHO, 2024).
- **One Health coordination:** Bridge human health, veterinary care, entomology, and environmental science, since many vector-borne conditions span multiple species and complex ecosystems (FAO; WHO, 2024).

12. Future Prospects and Research Opportunities

Future studies must continue to untangle the molecular, cellular, and physiological connections between insect vectors and infectious pathogens (Franz *et al.,* 2015). Relying on genomics, transcriptomics, proteomics, and functional assays will help uncover specific genes and proteins that dictate vector immunity, pathogen maturity, and tissue barrier thresholds (Franz *et al.,* 2015). Investigating salivary proteins and vector-host interfaces can clarify transmission dynamics and yield entirely new tracking or control tools (Ribeiro & Francischetti, 2003). Additionally, combining climate-linked forecasting, molecular pathogen detection in wild vectors, and unified surveillance will help fortify predictive early-warning systems (WHO, 2024). Ultimately, blending medical entomology, veterinary entomology, Agricultural entomology, molecular biology, ecology, and epidemiology within a shared One Health approach is critical to lowering the global burden of insect-borne diseases (WHO, 2024; FAO).

13. Conclusion

Insects stand as prominent biological and mechanical vectors for a wide array of infectious diseases that strike humans and animals. Their proficiency at spreading pathogens stems from specialized mouthparts, feeding patterns, digestive chemistry, salivary gland biology, and relationships with microbes. The lifecycle changes or multiplication of pathogens within insect organs—particularly the midgut and salivary glands—are foundational to the biological transmission of multiple high-impact diseases. Diseases like malaria, dengue, leishmaniasis, African trypanosomiasis, plague, and Chagas disease showcase the vast diversity of human transmission routes, while Rift Valley fever and bluetongue underscore the veterinary hazards of insect vectors. Gaining an explicit grasp of insect anatomy, physiology, vector competence, and transmission pathways is a fundamental prerequisite for building effective management frameworks. Moving forward, integrated partnerships drawing together entomologists, microbiologists, veterinarians, public health authorities, and environmental scientists are vital to shield people, animals, and broader ecosystems from vector-borne threats.

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