Volume 4, Issue 6, 2026

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

ONE HEALTH AND THE EPIDEMIOLOGY OF ZOONOTIC DISEASES: INTEGRATING HUMAN, ANIMAL, AND ENVIRONMENTAL HEALTH FOR GLOBAL DISEASE PREVENTION AND CONTROL

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DOI: https://doi.org/10.5281/zenodo.21154722

Keywords
One Health, Epidemiology, Zoonotic diseases, Emerging infectious diseases, Public health, Disease prevention.

Article History
Received: 24 April 2026
Accepted: 06 June 2026
Published: 21 June 2026

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Abstract
Zoonotic diseases continue to pose significant threats to global public health, accounting for the majority of emerging and re-emerging infectious diseases worldwide. The increasing interaction among humans, animals, and ecosystems, driven by population growth, globalization, urbanization, environmental degradation, climate change, and intensified agricultural practices, has accelerated the emergence and transmission of zoonotic pathogens. The One Health approach has emerged as a comprehensive and interdisciplinary framework that recognizes the interconnectedness of human, animal, and environmental health. This review examines the epidemiology of zoonotic diseases through the lens of the One Health concept, highlighting major zoonotic pathogens, transmission pathways, determinants of disease emergence, surveillance systems, and control strategies. The review discusses bacterial, viral, parasitic, and fungal zoonoses of global significance, including COVID-19, Ebola virus disease, avian influenza, rabies, brucellosis, leptospirosis, and other neglected zoonotic diseases. Particular attention is given to epidemiological patterns, risk factors, ecological drivers, and the role of integrated surveillance in disease prevention. The review further explores challenges associated with implementing One Health strategies, including institutional barriers, resource limitations, antimicrobial resistance, and climate change. Finally, recommendations are provided for strengthening global preparedness, improving intersectoral collaboration, and enhancing zoonotic disease surveillance. The findings emphasize that effective prevention and control of zoonotic diseases require coordinated efforts across medical, veterinary, environmental, and public health disciplines. Adoption of the One Health framework is essential for achieving sustainable health security and mitigating future pandemic threats.

1. INTRODUCTION
Zoonotic diseases are infectious diseases that can be naturally transmitted between vertebrate animals and humans. They represent one of the most important challenges confronting global public health in the twenty-first century. According to the World Health Organization (WHO), approximately 60% of known infectious

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ISSN: (e) 3007-1607 (p) 3007-1593

diseases and nearly 75% of emerging infectious diseases affecting humans originate from animals (World Health Organization, 2022). The emergence of zoonotic diseases such as Severe Acute Respiratory Syndrome (SARS), Middle East Respiratory Syndrome (MERS), Ebola virus disease, avian influenza, Nipah virus infection, and Coronavirus Disease 2019 (COVID-19) has demonstrated the profound impact that animal-origin pathogens can have on human populations, economies, and healthcare systems (Li et al., 2025; Sharan et al., 2023). The increasing incidence of zoonotic diseases is closely linked to rapid environmental and socioeconomic changes. Population growth, urban expansion, agricultural intensification, wildlife habitat destruction, globalization, international travel, and climate change have significantly increased contact between humans, domestic animals, and wildlife (Jones et al., 2008; Allen et al., 2017). These interactions create opportunities for pathogens to cross species barriers and establish transmission cycles in new hosts. Consequently, zoonotic diseases have become a major concern for governments, international organizations, and public health agencies worldwide. Historically, the relationship between human and animal health was recognized by pioneering scientists such as Rudolf Virchow and William Osler, who emphasized the interconnected nature of diseases affecting humans and animals (Zinsstag et al., 2018). This perspective evolved into the concept of "One Medicine," later expanded into the modern "One Health" framework. One Health is defined as a collaborative, multispectral, and transdisciplinary approach that seeks to achieve optimal health outcomes by recognizing the interconnection between people, animals, plants, and their shared environment (Viral emergence and pandemic preparedness in a One Health framework, 2026). The One Health framework has gained considerable global recognition over the past two decades. International organizations including the World Health Organization (WHO), the Food and Agriculture Organization (FAO), the World Organization for Animal Health (WOAH, formerly OIE), and the United Nations Environment Programme (UNEP) have adopted One Health principles to address emerging infectious diseases and other health threats (Gebreyes et al., 2014). The framework promotes collaboration among physicians, veterinarians, epidemiologists, ecologists, environmental scientists, policymakers, and public health professionals. The significance of zoonotic diseases extends beyond their direct effects on human health. These diseases can cause substantial economic losses through livestock mortality, reduced agricultural productivity, trade restrictions, healthcare expenditures, and disruptions to tourism and commerce. The COVID-19 pandemic alone resulted in millions of deaths worldwide and unprecedented economic consequences, highlighting the need for proactive and integrated approaches to disease prevention and preparedness (Sharan et al., 2023). Epidemiology plays a critical role in understanding the distribution, determinants, and transmission dynamics of zoonotic diseases. Epidemiological investigations provide valuable insights into disease reservoirs, vectors, risk factors, outbreak patterns, and intervention strategies. Through surveillance, outbreak investigations, and risk assessments, epidemiologists contribute to the development of evidence-based policies aimed at reducing zoonotic disease burden (Loh et al., 2015). The epidemiology of zoonotic diseases is inherently complex because these infections often involve multiple hosts, environmental reservoirs, and vectors. Transmission pathways may include direct contact with infected animals, consumption of contaminated food or water, vector-borne transmission, airborne spread, and environmental exposure. Understanding these pathways requires an integrated approach that considers ecological, biological, social, and environmental factors (Singh et al., 2024). Recent outbreaks have demonstrated the importance of applying One Health principles to disease surveillance and control. For example, investigations into the origins of SARS-CoV-2 highlighted the potential role of wildlife reservoirs and animal-human interfaces in pathogen emergence (Biek et al., 2006; The recency and geographical origins of the bat viruses ancestral to SARS-CoV and SARS-CoV-2, 2025). Similarly, outbreaks of Ebola virus

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ISSN: (e) 3007-1607 (p) 3007-1593

disease have been linked to wildlife reservoirs, particularly bats, emphasizing the need for environmental and wildlife surveillance alongside traditional public health measures (Leroy et al., 2005; Mapping the zoonotic niche of Ebola virus disease in Africa, 2014). Another growing concern is the impact of climate change on zoonotic disease epidemiology. Rising temperatures, altered precipitation patterns, and changing ecosystems influence the distribution of disease vectors such as mosquitoes and ticks (Githeko et al., 2000; Climate change: A driver of increasing vector-borne disease transmission in non-endemic areas, 2024). These environmental changes can expand the geographic range of zoonotic diseases and introduce pathogens into previously unaffected regions. Antimicrobial resistance (AMR) further complicates the management of zoonotic diseases. The widespread use of antibiotics in human medicine, veterinary practice, and agriculture contributes to the emergence of resistant pathogens capable of spreading between animals and humans. Addressing AMR requires coordinated One Health strategies that integrate surveillance and stewardship across sectors (Integrated surveillance systems for antibiotic resistance in a One Health context: A scoping review, 2023). This review aims to provide a comprehensive examination of the epidemiology of zoonotic diseases within the One Health framework. Specifically, the review explores the concept of One Health, major zoonotic diseases of global importance, epidemiological determinants of disease emergence and transmission, surveillance and monitoring systems, challenges facing zoonotic disease control, and future directions for strengthening global health security. By synthesizing current knowledge and evidence, this review highlights the critical role of One Health in preventing and managing zoonotic disease threats in an increasingly interconnected world.

2. Concept and Evolution of One Health

The One Health concept is founded on the recognition that the health of humans, animals, and ecosystems is inextricably linked. Although the term "One Health" gained widespread recognition during the early twenty-first century, its philosophical foundations date back to the nineteenth century. Rudolf Virchow, a German physician and pathologist, argued that there should be no dividing line between human and veterinary medicine. Later, Sir William Osler, considered one of the founders of modern medicine, further promoted collaboration between veterinary and human health disciplines (Zinsstag et al., 2018). The modern One Health movement emerged in response to increasing concerns about emerging infectious diseases, many of which originated at the human-animal-environment interface. The outbreaks of highly pathogenic avian influenza (H5N1), severe acute respiratory syndrome (SARS), and other zoonotic diseases highlighted the limitations of sector-specific disease management approaches (Di Guardo, 2025; Pardo-Roa et al., 2025). Consequently, international organizations including the World Health Organization (WHO), the Food and Agriculture Organization (FAO), and the World Organisation for Animal Health (WOAH) began promoting collaborative frameworks for disease prevention and control. One Health encompasses several core principles. First, it recognizes that human health cannot be separated from animal health. Domestic animals serve as reservoirs for numerous infectious agents, while wildlife populations may harbor emerging pathogens capable of crossing species barriers. Second, One Health acknowledges the crucial role of environmental factors in disease emergence and transmission. Ecosystem disturbances, biodiversity loss, pollution, and climate change can alter pathogen dynamics and increase opportunities for spillover events (Gottdenker et al., 2014). Third, the approach emphasizes interdisciplinary collaboration involving medicine, veterinary science, epidemiology, ecology, microbiology, environmental science, public health, sociology, and policy development. The One Health framework has expanded beyond infectious disease management to include food safety, antimicrobial resistance, environmental health, ecosystem sustainability, and global health security. However, zoonotic diseases remain one of its most important areas of application because of their significant impact on human and animal populations worldwide.

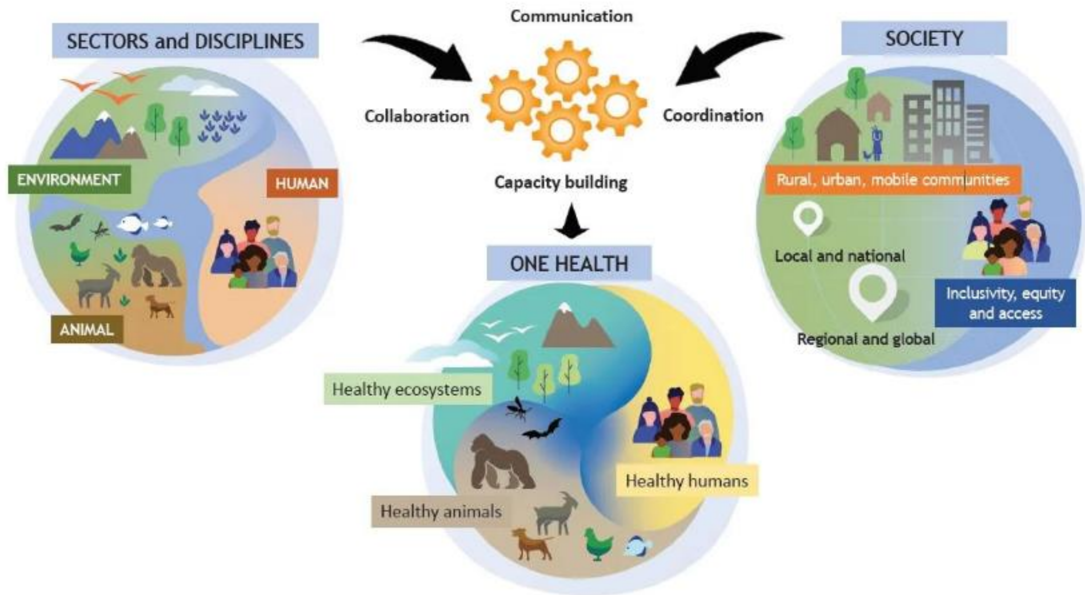

Figure 1: Concept and Evolution of One Health

3. Epidemiology of Major Zoonotic Diseases
3.1 Viral Zoonotic Diseases
3.1.1Coronavirus Disease 2019 (COVID-19)

The COVID-19 pandemic represents one of the most significant zoonotic disease events in modern history. Caused by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), the disease was first identified in Wuhan, China, in late 2019. Although the precise origin remains under investigation, scientific evidence strongly suggests an animal origin involving wildlife reservoirs, particularly bats, with a possible intermediate host facilitating transmission to humans (Biek et al., 2006; The recency and geographical origins of the bat viruses ancestral to SARS-CoV and SARS-CoV-2, 2025). The rapid global spread of COVID-19 demonstrated how zoonotic pathogens can exploit modern transportation networks and densely populated urban centers. Epidemiological studies identified respiratory droplets, aerosols, and direct contact as primary transmission routes. The pandemic emphasized the importance of early detection, genomic surveillance, and coordinated international responses within a One Health framework. COVID-19 also highlighted reverse zoonosis, where infected humans transmitted the virus to animals, including mink, cats, dogs, and zoo animals (Will animal reservoirs give us the next SARS-CoV-2 variant 2026). These events demonstrated the bidirectional nature of disease transmission between humans and animals.

3.1.2 Severe Acute Respiratory Syndrome (SARS)

The SARS outbreak emerged in southern China in 2002 and spread to multiple countries, causing more than 8,000 infections and approximately 800 deaths. Epidemiological investigations linked the virus to wildlife markets, with civets acting as intermediate hosts and bats serving as the natural reservoir (The recency and geographical origins of the bat viruses ancestral to SARS-CoV and SARS-CoV-2, 2025). The outbreak provided one of the earliest modern examples of a pathogen emerging from wildlife-human interactions and becoming a global public health threat.

3.1.3 Middle East Respiratory Syndrome (MERS)

Middle East Respiratory Syndrome, caused by MERS coronavirus (MERS-CoV), was first

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identified in Saudi Arabia in 2012. Dromedary camels serve as the primary animal reservoir responsible for transmission to humans (Haagmans et al., 2014). Although human-to-human transmission occurs, particularly in healthcare settings, zoonotic transmission remains the principal source of infection. The disease is associated with a high case fatality rate, making it a continuing concern in affected regions (Modelling transmission of Middle East respiratory syndrome coronavirus in camel populations, 2025).

3.1.4 Avian Influenza

Avian influenza viruses, particularly H5N1 and H7N9 strains, pose substantial zoonotic risks. Wild aquatic birds serve as natural reservoirs, while domestic poultry often facilitate transmission to humans. Human infections typically occur through direct contact with infected birds or contaminated environments (Garg et al., 2025). Epidemiological surveillance has demonstrated the capacity of influenza viruses to undergo genetic reassortment, potentially generating strains capable of efficient human-to-human transmission (Pardo-Roa et al., 2025). Consequently, avian influenza remains a significant pandemic threat requiring continuous monitoring under One Health surveillance systems (The global H5N1 influenza panzootic in mammals, 2024; Di Guardo, 2025).

3.1.5 Ebola Virus Disease

Ebola virus disease is a severe hemorrhagic fever characterized by high mortality rates. Fruit bats are considered the most likely natural reservoir, while transmission to humans may occur through contact with infected wildlife, including primates and bats (Leroy et al., 2005). Human-to-human transmission occurs through direct contact with bodily fluids. Major outbreaks in West Africa between 2014 and 2016 highlighted the importance of integrating wildlife surveillance, community engagement, and public health interventions (Mapping the zoonotic niche of Ebola virus disease in Africa, 2014). The epidemic underscored how ecological changes and human activities can facilitate zoonotic spillover events.

3.2 Bacterial Zoonotic Diseases

3.2.1 Brucellosis

Brucellosis is among the most widespread bacterial zoonoses globally. The disease is caused by bacteria of the genus *Brucella* and primarily affects cattle, sheep, goats, and pigs. Human infection occurs through direct contact with infected animals or consumption of contaminated dairy products. The disease is particularly prevalent in developing countries where livestock vaccination and food safety measures may be inadequate (Brucellosis: A neglected zoonosis, 2024). Epidemiological studies have identified occupational exposure among farmers, veterinarians, slaughterhouse workers, and laboratory personnel as significant risk factors (Seroprevalence of brucellosis in humans and livestock in Sub-Saharan Africa: A systematic review and meta-analysis, 2025).

3.2.2 Leptospirosis

Leptospirosis is caused by pathogenic species of *Leptospira* and is transmitted through contact with water, soil, or food contaminated by urine from infected animals. Rodents are major reservoirs, although domestic animals can also contribute to transmission. The disease is common in tropical and subtropical regions and is frequently associated with flooding, poor sanitation, and occupational exposure (Spatiotemporal dynamics of leptospirosis in Europe: A retrospective observational study with prospective projections, 2026). Climate-related increases in extreme weather events have contributed to the growing importance of leptospirosis as a public health concern.

3.2.3 Anthrax

Anthrax is caused by *Bacillus anthracis* and primarily affects herbivorous mammals. Human infection occurs through contact with infected animals or contaminated animal products. The disease can manifest as cutaneous, inhalational, or gastrointestinal anthrax. Anthrax remains endemic in several regions of Africa, Asia, and the Middle East. Effective surveillance and livestock vaccination programs are essential components of One Health strategies aimed at reducing disease transmission (Allen et al., 2017; Jones et al., 2008).

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3.2.4 Plague

Plague, caused by *Yersinia pestis*, persists in natural rodent reservoirs and is transmitted through flea vectors. Although modern outbreaks are relatively rare, plague remains endemic in several regions worldwide. Epidemiological monitoring of rodent populations and flea vectors is critical for preventing outbreaks (Gottdenker et al., 2014).

3.3 Parasitic Zoonotic Diseases

3.3.1Toxoplasmosis

Toxoplasmosis is caused by the protozoan parasite *Toxoplasma gondii*. Domestic and wild cats serve as definitive hosts, while humans become infected through ingestion of contaminated food, water, or undercooked meat. Although many infections are asymptomatic, severe disease may occur among immunocompromised individuals and pregnant women (Dubey & Jones, 2008). The widespread distribution of *T. gondii* illustrates the importance of environmental contamination in zoonotic disease transmission.

3.3.2 Echinococcosis

Echinococcosis is a parasitic disease caused by tapeworms of the genus *Echinococcus*. Dogs serve as definitive hosts, while livestock and humans act as intermediate hosts. Human infection occurs through ingestion of parasite eggs from contaminated environments. The disease imposes substantial public health and economic burdens in endemic regions. Effective control requires integrated veterinary, environmental, and public health interventions (Echinococcosis: Disease, detection and transmission, 2023).

3.3.3 Cryptosporidiosis

Cryptosporidiosis is caused by *Cryptosporidium* species and is transmitted through contaminated water, food, and animal contact. The disease is particularly problematic in areas with inadequate sanitation and water treatment infrastructure. Livestock, especially calves, represent important reservoirs (Cryptosporidium prevalence in calves and its effect on local water quality, 2025; Food and Waterborne Cryptosporidiosis from a One Health Perspective: A Comprehensive Review, 2024).

3.4 Neglected Zoonotic Diseases

Neglected zoonotic diseases disproportionately affect low-income populations and often receive limited attention despite their significant health impacts. Examples include rabies, cysticercosis, leishmaniasis, bovine tuberculosis, and sleeping sickness.

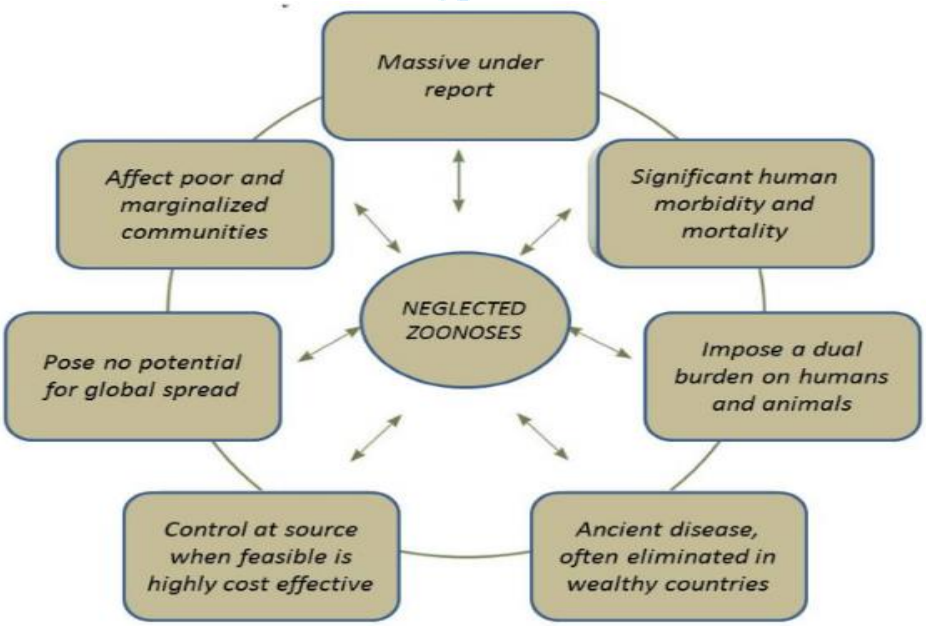

Figure 2: Basic features of neglected zoonotic diseases

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3.4.1 Rabies

Rabies remains one of the deadliest zoonotic diseases, causing nearly 100% mortality once clinical symptoms develop. Domestic dogs account for the majority of human cases worldwide, particularly in Africa and Asia (Cleaveland et al., 2014). Mass dog vaccination programs represent one of the most successful One Health interventions for disease prevention (Chazya et al., 2025). The global burden of neglected zoonotic diseases, including rabies, remains substantial and requires sustained international attention (di Bari et al., 2022).

3.4.2 Bovine Tuberculosis

Bovine tuberculosis, caused by *Mycobacterium bovis*, affects livestock, wildlife, and humans. Transmission may occur through consumption of unpasteurized dairy products or direct contact with infected animals. Control efforts require coordinated surveillance across human and veterinary health sectors (Bovine Tuberculosis as a Neglected Zoonotic Disease in Mexico and Latin America, 2026).

Table 1: Major Zoonotic Diseases of Global Importance within the One Health Framework

Disease	Causative Agent	Primary Animal Reservoir	Transmission Route	Public Health Significance	One Health Intervention	References
COVID-19	SARS-CoV-2	Bats (probable), intermediate hosts	Respiratory droplets, aerosols	Global pandemic with high morbidity and mortality	Wildlife surveillance, genomic surveillance, integrated outbreak response	(Li et al., 2025)
SARS	SARS-CoV	Bats, civets	Respiratory contact	First major coronavirus outbreak	Wildlife market regulation, surveillance	(Biek et al., 2006)
MERS	MERS-CoV	Dromedary camels	Direct animal contact	High case fatality rate	Camel surveillance and public awareness	(Haagmans et al., 2014)
Avian Influenza	H5N1, H7N9	Wild birds, poultry	Direct contact with infected birds	Pandemic potential	Poultry vaccination and surveillance	(Garg et al., 2025; Di Guardo, 2025)

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Ebola	Ebola virus	Fruit bats	Wildlife contact, body fluids	Severe hemorrhagic fever	Wildlife monitoring and community surveillance	(Leroy et al., 2005)
Rabies	Rabies virus	Dogs	Animal bites	Nearly 100% fatal after symptom onset	Mass dog vaccination	(Cleaveland et al., 2014; Chazya et al., 2025)
Brucellosis	*Brucella* spp.	Cattle, sheep, goats	Raw milk, occupational exposure	Occupational zoonosis	Livestock vaccination and pasteurization	(Cleaveland et al., 2014)
Leptospirosis	*Leptospira* spp.	Rodents	Contaminated water	Flood-associated outbreaks	Environmental sanitation	(Chazya et al., 2025)
Toxoplasmosis	*Toxoplasma gondii*	Cats	Foodborne, environmental	Congenital infections	Food hygiene and cat management	(Dubey & Jones, 2008)
Bovine Tuberculosis	*Mycobacterium bovis*	Cattle	Milk, direct contact	Chronic zoonosis	Test-and-slaughter, milk pasteurization	(Haagmans et al., 2014)

4. Drivers of Zoonotic Disease Emergence

The emergence and re-emergence of zoonotic diseases result from complex interactions among biological, environmental, socioeconomic, and ecological factors.

4.1 Land Use Change and Deforestation

Deforestation and habitat fragmentation increase contact between humans and wildlife by disrupting natural ecosystems. As human populations expand into previously undisturbed habitats, opportunities for pathogen spillover increase (Gottdenker et al., 2014; Global evidence synthesis on land-use change and zoonotic risks, 2026). Numerous studies have linked deforestation to outbreaks of Ebola virus disease, malaria, and other infectious diseases (Fire-Driven Land Cover Change and Zoonotic Disease Risk in African Landscapes, 2025; Environmental degradation as a recipe for emerging viral diseases: Implications for global health, 2026).

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4.2 Wildlife Trade
Legal and illegal wildlife trade creates conditions conducive to pathogen transmission. The transportation, confinement, and sale of wild animals facilitate close contact among species that would not naturally interact. Wildlife markets have been implicated in several zoonotic disease emergence events (Loh et al., 2015).

4.3 Agricultural Intensification
Intensive livestock production systems can amplify pathogen transmission and increase opportunities for genetic mutation and reassortment. High-density animal populations provide favorable conditions for disease emergence, particularly among poultry and swine populations (Jones et al., 2008).

4.4 Urbanization
Rapid urbanization contributes to zoonotic disease risks through overcrowding, inadequate sanitation, and increased human-animal interactions. Informal settlements often provide favorable conditions for rodent populations and vector proliferation (Singh et al., 2024).

4.5 Climate Change
Climate change influences zoonotic disease epidemiology by altering vector distributions, host migration patterns, and ecosystem dynamics. Rising temperatures and changing precipitation patterns have expanded the geographic range of many vector-borne diseases, including Lyme disease, dengue fever, and Rift Valley fever (Githeko et al., 2000; Climate change: A driver of increasing vector-borne disease transmission in non-endemic areas, 2024; Zinsstag et al., 2018).

4.6 Globalization and International Travel
Global travel and trade facilitate the rapid spread of infectious diseases across international borders. The COVID-19 pandemic demonstrated how interconnected societies can accelerate disease dissemination on a global scale (Salkeld et al., 2023).

Table 2: Major Drivers of Zoonotic Disease Emergence

Driver	Mechanism	Representative Diseases	One Health Mitigation Strategy	References
Deforestation	Increased wildlife-human contact	Ebola, Nipah	Forest conservation	(Gottdenker et al., 2014)
Wildlife Trade	Cross-species transmission	SARS, COVID-19	Wildlife trade regulation	(Loh et al., 2015)
Agricultural Intensification	High-density livestock production	Avian influenza	Improved farm biosecurity	(Jones et al., 2008)
Climate Change	Expansion of vectors	Dengue, Rift Valley Fever	Climate-adaptive surveillance	(Githeko et al., 2000; Zinsstag et al., 2018)
Urbanization International Travel	Increased rodent/vector habitats Rapid global spread	Leptospirosis COVID-19	Urban sanitation Border surveillance	(Singh et al., 2024) (Salkeld et al., 2023)
Antimicrobial Misuse	Selection of resistant pathogens	MRSA, MDR Salmonella	Antimicrobial stewardship	(Zinsstag et al., 2018)
Biodiversity Loss	Reduced ecosystem resilience	Multiple zoonoses	Habitat restoration	(Gottdenker et al., 2014)
Environmental Pollution	Contaminated ecosystems	Waterborne zoonoses	Environmental monitoring	(Gebreyes et al., 2014)

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Driver	Mechanism	Representative Diseases	One Health Mitigation Strategy	References
Weak Surveillance	Delayed outbreak detection	All zoonoses	Integrated One Health surveillance	(Singh et al., 2024)

5. One Health Surveillance and Epidemiological Approaches

Effective surveillance is a cornerstone of zoonotic disease prevention and control. Traditional disease surveillance systems often focus on human populations alone, limiting the capacity to detect emerging threats originating in animals or environmental reservoirs. The One Health approach addresses this limitation by integrating surveillance across human, animal, and environmental sectors.

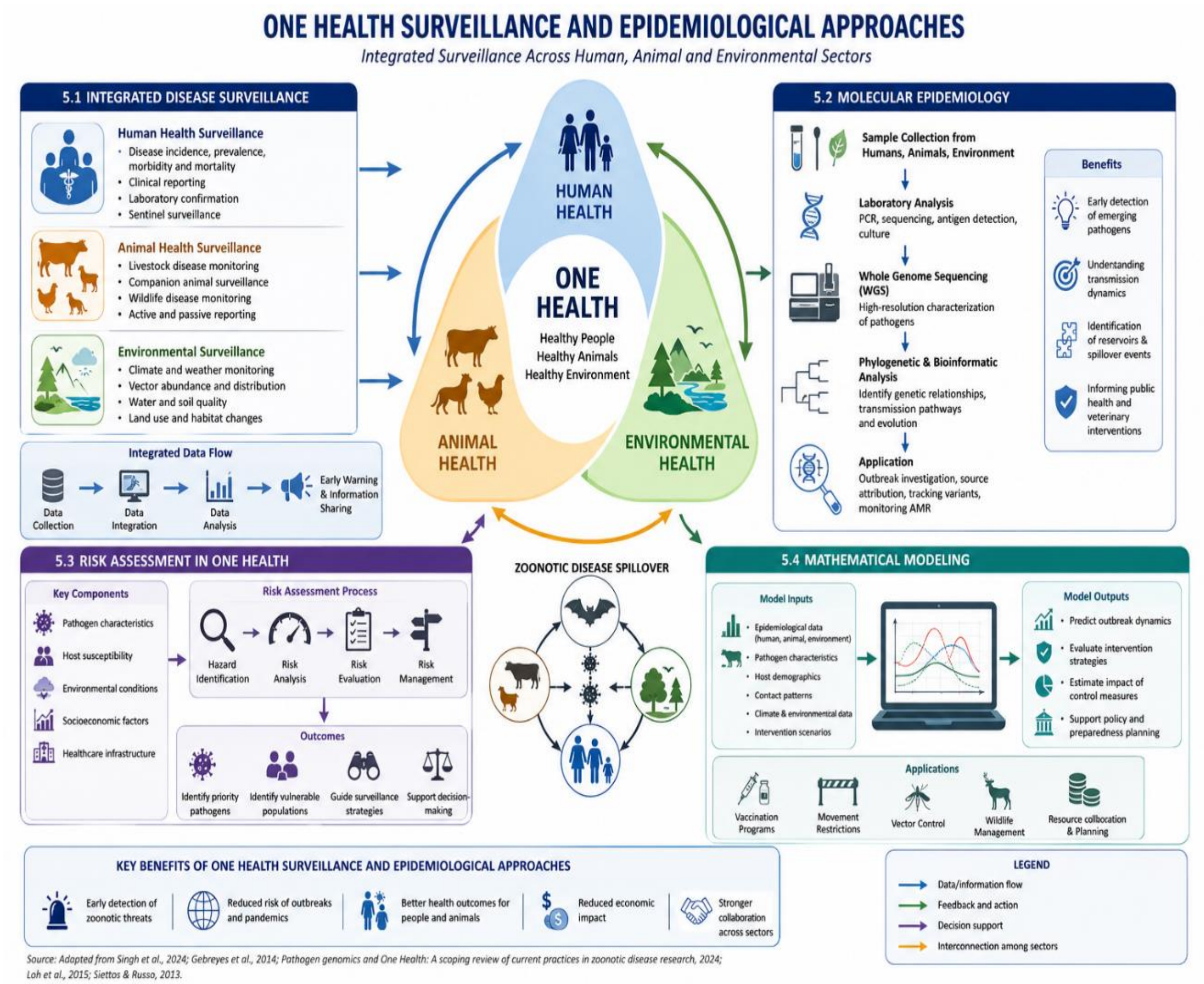

Figure 3: One Health Surveillance and Epidemiological Approaches

5.1 Integrated Disease Surveillance

Integrated surveillance involves the systematic collection, analysis, interpretation, and dissemination of health data from multiple sources. Human health surveillance systems monitor disease incidence, prevalence, morbidity, and mortality, while veterinary surveillance programs track disease occurrence in livestock,

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companion animals, and wildlife populations (Singh et al., 2024). Environmental surveillance examines ecological factors that influence disease transmission, including climate variables, water quality, vector abundance, and habitat changes (Gebreyes et al., 2014). The integration of these surveillance systems enables earlier detection of emerging zoonotic threats. For example, monitoring influenza viruses in wild birds and poultry populations can provide early warning of strains with pandemic potential before widespread human transmission occurs. Similarly, surveillance of bat populations can help identify novel coronaviruses and other viral pathogens that may pose future risks.

5.2 Molecular Epidemiology

Advances in molecular biology have transformed epidemiological investigations. Molecular epidemiology uses genetic and genomic tools to characterize pathogens, identify transmission pathways, and track disease outbreaks. Whole-genome sequencing has become particularly valuable in understanding the evolution and spread of zoonotic pathogens (Pathogen genomics and One Health: A scoping review of current practices in zoonotic disease research, 2024). During the COVID-19 pandemic, genomic surveillance enabled researchers to identify viral variants, monitor transmission dynamics, and assess the effectiveness of public health interventions. Similar approaches have been applied to avian influenza, Ebola virus disease, and antimicrobial-resistant bacterial infections. Molecular epidemiology also facilitates the identification of pathogen reservoirs and spillover events. By comparing genetic sequences from human and animal isolates, researchers can determine evolutionary relationships and infer transmission pathways between species.

5.3 Risk Assessment in One Health

Risk assessment is an essential component of One Health epidemiology. It involves evaluating the likelihood and consequences of disease emergence, transmission, and spread. Risk assessments guide decision-making by identifying priority pathogens, vulnerable populations, and critical intervention points (Loh et al., 2015). One Health risk assessments typically consider multiple factors, including pathogen characteristics, host susceptibility, environmental conditions, socioeconomic determinants, and healthcare infrastructure. These assessments support the development of targeted surveillance strategies and resource allocation.

5.4 Mathematical Modeling

Mathematical and computational models play an increasingly important role in zoonotic disease epidemiology. Models can simulate disease transmission dynamics, evaluate intervention strategies, and predict outbreak trajectories. By incorporating data from human, animal, and environmental systems, One Health models provide a more comprehensive understanding of disease ecology (Siettos & Russo, 2013). Modeling studies have been used extensively to assess the impact of vaccination programs, movement restrictions, vector control measures, and wildlife management interventions. Such tools support evidence-based policymaking and emergency preparedness planning.

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Table 3: Core Components of the One Health Framework

One Health Component	Objective	Activities	Expected Outcome	References
Human Health Surveillance	Early case detection	Clinical reporting, diagnostics	Reduced outbreaks	(WHO, 2022)
Animal Health Surveillance	Monitor livestock and wildlife diseases	Veterinary surveillance	Early spillover detection	(Gebreyes et al., 2014)
Environmental Monitoring	Detect ecological risk factors	Water, soil, vector monitoring	Reduced environmental transmission	(Singh et al., 2024)
Molecular Epidemiology	Track pathogen evolution	Whole genome sequencing	Improved outbreak tracing	(Chazya et al., 2025)
Risk Assessment	Identify emerging threats	Risk modeling	Better preparedness	(Loh et al., 2015)
Mathematical Modeling	Predict outbreaks	Disease transmission models	Improved intervention planning	(Siettos & Russo, 2013)
Community Engagement	Improve awareness	Public education	Better prevention practices	(Chazya et al., 2025)
Antimicrobial Stewardship	Reduce AMR	Rational antibiotic use	Lower antimicrobial resistance	(Salkeld et al., 2023)
Intersectoral Collaboration	Coordinate stakeholders	Human-veterinary-environmental partnerships	Effective disease control	(Zinsstag et al., 2018)
Policy and Governance	Strengthen One Health implementation	National One Health policies	Sustainable disease prevention	Di Guardo, 2025)

6. Antimicrobial Resistance and One Health

Antimicrobial resistance (AMR) is one of the most pressing global health challenges and exemplifies the need for a One Health approach. AMR occurs when microorganisms develop the ability to survive exposure to antimicrobial agents that were previously effective against them. Resistant pathogens can spread among humans, animals, and the environment, creating a complex public health problem.

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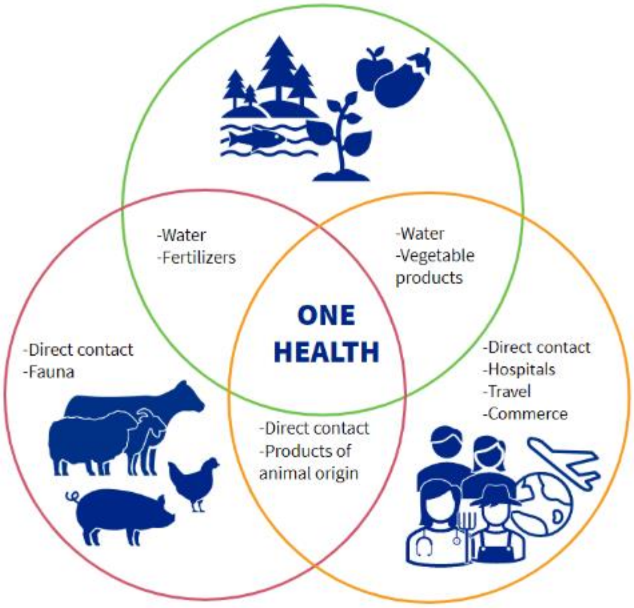

Figure 4: Spreading processes of resistant bacteria at the human-animal-environment interface

6.1 Drivers of Antimicrobial Resistance

The emergence and spread of AMR are driven by multiple factors. In human medicine, inappropriate prescribing practices, self-medication, and incomplete treatment courses contribute to resistance development. In veterinary medicine, antimicrobials are used for disease treatment, prevention, and, in some regions, growth promotion. Environmental contamination from pharmaceutical manufacturing, agricultural runoff, and wastewater further contributes to the dissemination of resistant microorganisms (Integrated surveillance systems for antibiotic resistance in a One Health context: A scoping review, 2023). These interconnected pathways highlight the importance of coordinated action across sectors. Resistant bacteria originating in livestock can infect humans through direct contact, food consumption, or environmental exposure. Similarly, resistant pathogens from healthcare settings may contaminate environmental systems and affect animal populations.

6.2 Epidemiological Significance of AMR

The epidemiology of AMR extends beyond individual healthcare settings. Resistant organisms can spread globally through travel, trade, food supply chains, and migratory wildlife. Examples of zoonotic resistant pathogens include methicillin-resistant *Staphylococcus aureus* (MRSA), multidrug-resistant *Salmonella* species,
resistant *Campylobacter* strains, and extended-spectrum beta-lactamase-producing Enterobacteriaceae (Gebreyes et al., 2014). AMR increases healthcare costs, prolongs illness, complicates treatment, and contributes to mortality. The World Bank and international health organizations have warned that unchecked resistance could undermine decades of medical progress.

6.3 One Health Strategies for AMR Control

Effective AMR control requires integrated surveillance systems that monitor antimicrobial use and resistance patterns across human, veterinary, and environmental sectors. Key interventions include:

- Promoting responsible antimicrobial use.
- Strengthening infection prevention and control measures.
- Expanding vaccination programs.
- Enhancing laboratory capacity.
- Improving environmental management.

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- Supporting research into alternative therapies and diagnostics.

A One Health framework ensures that interventions implemented in one sector do not inadvertently increase risks in another (Integrated surveillance systems for antibiotic resistance in a One Health context: A scoping review, 2023).

7. Challenges in Implementing One Health Approaches

Despite widespread recognition of its importance, implementing the One Health approach remains challenging due to several interconnected factors that limit its effectiveness in addressing zoonotic diseases at a global scale. One of the major barriers is institutional fragmentation, where human health, animal health, and environmental sectors often function independently under separate governance structures, funding systems, and surveillance networks, which weakens coordination and delays timely responses to emerging disease threats (Constructing a One Health governance architecture: A systematic review and analysis of governance mechanisms for One Health, 2024). Resource limitations further compound this issue, particularly in low- and middle-income countries where shortages of trained professionals, diagnostic laboratories, field surveillance capacity, and financial investment restrict the ability to develop and sustain integrated One Health programs despite a high burden of zoonotic diseases (Gebreyes et al., 2014). In addition, data sharing barriers significantly hinder progress, as effective One Health surveillance depends on the rapid exchange of information across sectors and national borders; however, legal restrictions, incompatible databases, institutional reluctance, and inconsistent reporting systems often prevent seamless integration of human, animal, and environmental health data (Integrating One Health Into Health Systems: A systematic review and narrative synthesis of implementation challenges, opportunities and strategic directions, 2026). Workforce capacity is another critical challenge, as many education and training systems still operate in disciplinary silos rather than promoting interdisciplinary skills, resulting in a shortage of professionals capable of working effectively across medical, veterinary, and environmental fields (Review on progress, challenges, and recommendations for implementing the One Health approach in the Eastern Mediterranean Region, 2025). Political and policy challenges also play an important role, since sustained governmental commitment is required to prioritize long-term disease prevention strategies, yet competing national interests and short-term policy priorities often limit investment in integrated surveillance and preparedness systems (WHO analysis finds 1,843 public health events in Africa between 2001 and 2022, 2022). Finally, climate and environmental uncertainty adds further complexity, as ongoing climate change continues to alter ecosystems, affecting the distribution of hosts, vectors, and pathogens in ways that are difficult to predict, thereby requiring flexible and adaptive surveillance systems capable of responding to rapidly changing ecological conditions (Zinsstag et al., 2018).

8. Future Directions and Recommendations

The increasing frequency of zoonotic disease outbreaks highlights the urgent need for strengthened One Health initiatives worldwide, particularly through the development of more robust and integrated surveillance systems capable of simultaneously monitoring human, animal, and environmental health indicators; governments should prioritize investment in digital health infrastructure and emerging technologies such as artificial intelligence, remote sensing, and genomic sequencing to improve early warning systems and outbreak detection capabilities (Emerging and re-emerging zoonotic viral diseases in Southeast Asia: One Health challenge, 2023). In parallel, expanding interdisciplinary collaboration is essential, bringing together physicians, veterinarians, ecologists, epidemiologists, microbiologists, environmental scientists, and social scientists to develop more comprehensive and effective solutions to complex zoonotic disease challenges that cannot be addressed by any single discipline alone (One Health Day 2023 collection, 2023). Enhancing community engagement is also critical, as public

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ISSN: (e) 3007-1607 (p) 3007-1593

awareness and participation play a key role in disease prevention by improving understanding of zoonotic risks, promoting safer behaviors, and supporting grassroots disease reporting and surveillance efforts in both rural and urban settings (Chazya et al., 2025). Improving wildlife monitoring should be a core component of global preparedness strategies, as systematic surveillance of wildlife populations can provide early indicators of emerging pathogens and potential spillover events before they reach human populations (Mapping the zoonotic niche of Ebola virus disease in Africa, 2014). Addressing environmental drivers of disease emergence is equally important, with policies focused on reducing deforestation, conserving biodiversity, promoting sustainable agricultural practices, and mitigating climate change serving as fundamental tools for reducing opportunities for pathogen spillover at the human–animal–environment interface (Global evidence synthesis on land-use change and zoonotic risks, 2026; Environmental degradation as a recipe for emerging viral diseases: Implications for global health, 2026). Strengthening global cooperation remains indispensable, as zoonotic diseases transcend national borders and require coordinated action among international organizations, governments, research institutions, and non-governmental organizations to ensure timely data sharing, coordinated response efforts, and unified global preparedness strategies (Allen et al., 2017). Finally, sustained investment in research and innovation is crucial for advancing understanding of pathogen ecology, host–pathogen interactions, and transmission dynamics, while emerging technologies such as metagenomics, artificial intelligence, and predictive modeling offer powerful tools to enhance surveillance systems, improve risk assessment, and strengthen overall One Health capacity for preventing future outbreaks (Siettos & Russo, 2013; Pathogen genomics and One Health: A scoping review of current practices in zoonotic disease research, 2024).

9. Conclusion

Zoonotic diseases represent one of the most significant public health challenges of the modern era. The increasing interconnectedness of human, animal, and environmental systems has created unprecedented opportunities for pathogen emergence and transmission. Recent outbreaks, including COVID-19, Ebola virus disease, avian influenza, and other zoonotic infections, demonstrate the profound health, social, and economic consequences of emerging infectious diseases. The One Health framework provides a comprehensive approach for addressing these challenges by recognizing the interdependence of human, animal, and environmental health. Through integrated surveillance, interdisciplinary collaboration, risk assessment, and coordinated intervention strategies, One Health enhances the capacity to prevent, detect, and respond to zoonotic disease threats. Numerous factors, including land-use change, wildlife trade, agricultural intensification, urbanization, globalization, climate change, and antimicrobial resistance shape the epidemiology of zoonotic diseases. Addressing these drivers requires collaboration across sectors and disciplines. Traditional approaches that focus exclusively on human health are insufficient to manage the complex ecological and social determinants of disease emergence. Future efforts should prioritize the development of robust surveillance systems, the expansion of interdisciplinary education and training, investment in research and innovation, the enhancement of community engagement, and the strengthening of international cooperation. By embracing One Health principles, societies can improve global health security, reduce the burden of zoonotic diseases, and build resilience against future pandemics. Ultimately, the prevention and control of zoonotic diseases depend on recognizing that the health of people, animals, and ecosystems is inseparable. A coordinated One Health approach offers the most effective pathway toward sustainable disease prevention and a healthier future for all.

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