

Zoonotic Diseases: Impacts on Animal, Human, and Public Health

AUTHORS DETAIL

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Abstract

Zoonotic infections create serious risks to public health, animal welfare, and the global economy because they are spread from animals to humans. Nonetheless, there is evidence that zoonotic outbreaks including COVID-19 are becoming more frequent and intense. This chapter examines the vital connections among human, animal, and environmental health in order to shed light on the factors that might contribute to the emergence and spread of zoonotic diseases. Moreover, these also include habitat destruction, climate change, globalization, and agricultural intensification. Furthermore, a wide spectrum of zoonotic disease from bacterial and viral infections to parasitic and fungal conditions are covered in this chapter along with their implications for agriculture, human populations, and animal health. Further, the philosophy of One Health is highlighted as a key foundation for lowering the risks of zoonotic illnesses. Communication between the human and animal health sectors facilitates the monitoring, identification, and management of disease. The chapter also highlights the need of early diagnosis, timely intervention, and clear communication in preventing and controlling zoonotic outbreaks. In summary, maintaining public health and ensuring a sustainable future depend on comprehending the complex causes of zoonotic diseases and implementing a One Health strategy.

Keywords: Zoonotic Diseases, One Health, Public Health, Animal Health, Environmental Health, Emerging Infectious Diseases

1. Introduction to Zoonotic Diseases

Zoonosis is a natural negative relationship from wild or free-ranging animals to humans through direct or indirect contact. In many developing nations, there is limited integration of zoonotic disease surveillance between human and veterinary medicine within the One Health framework (Shanbehzadeh et al., 2022). Between 1990–2000 and 2000–2010, the global rise in zoonotic diseases was recorded at 22% and 21%, respectively (Tazerji et al., 2022). The One Health concept, which focuses on improving human, animal, and environmental health, is gaining importance for controlling emerging and zoonotic infections

at national, regional, and global levels. Since these diseases traverse the animal-human-ecosystem interface, isolated studies of diseases in the environment or a single host species may be insufficient, necessitating further research (Singh et al., 2024).

Apart from the health burden, the global economic ramifications of pandemics and emerging infectious diseases could be catastrophic which leading to reduced international trade, travel, and tourism. With increasing global connectivity through trade and travel, emerging infectious diseases pose significant risks by requiring collaboration among health ministries and institutions focused on health, agriculture, trade, and the environment (Kelly et al., 2020). The One Health strategy offers substantial opportunities to mitigate the impact of emerging diseases and prevent future outbreaks through enhanced understanding, knowledge sharing, and coordination (Okesanya et al., 2023). This chapter will explore the significance of the One Health approach in understanding zoonotic virus transmission routes at the human-animal-environment interface and improving overall health outcomes for humans and animals (Shaheen, 2022).

Over the past decade, zoonotic diseases have incurred over \$20 billion in direct costs and \$200 billion in indirect costs globally. Additionally, the loss of more than 25% of the original forest cover due to increased interactions between humans, domestic animals, and wildlife has exacerbated this issue (Lawler et al., 2021). Human activities have significantly altered or destroyed over 75% of terrestrial and 66% of marine ecosystems through intensifying the spread of infectious diseases. These disruptions contribute to an estimated 20% global loss in animal production and have serious implications for food security (Godde et al., 2021).

Zoonoses, which are infectious diseases transmissible between animals and humans, account for approximately 75% of emerging and re-emerging disease pathogens (Nomi et al., 2012). Of these, 60% originate from domestic and wild animals, and 80% are associated with bioterrorism concerns (Subedi et al., 2024). Over the past 20 years, the world has experienced numerous zoonotic outbreaks, including Ebola virus disease, salmonellosis, Marburg disease, rabies, anthrax, and COVID-19. Some of these diseases, such as Ebola and anthrax, are prone to recurring outbreaks, while others, like COVID-19, have triggered global pandemics (Morens and Fauci, 2020). The increasing spillover of emerging diseases highlights the interconnectedness of humans, animals, and ecosystems, necessitating a multisectoral approach like One Health to manage these health threats (Mahajan et al., 2024).

Factors driving the rise of zoonotic diseases include exponential growth in livestock and human populations, urbanization, habitat destruction, changes in farming systems, and close interactions between wildlife and domestic animals (Jori et al., 2021). The globalization of animal trade, antimicrobial resistance, and climate change further exacerbate these risks. Improper land use, overexploitation of natural resources, and environmental degradation are coupled with floods, droughts, and habitat fragmentation, which reduce biodiversity and amplify interactions between disease vectors and hosts, thereby increasing the likelihood of disease spillover. Antimicrobial resistance, arising from the misuse of antibiotics in livestock, complicates the treatment of infections, while environmental pollution facilitates the transmission of diseases via air, water, and soil (Endale et al., 2023).

2. Types of Zoonotic Diseases

Numerous pathogens like bacteria, viruses, parasites, fungus, and prions cause zoonotic illnesses that are infections which can spread from animals to humans. These diseases are classified into groups based on the agents that cause or spread through direct contact, ingestion, or vectors like insects. Ebola, Lyme disease, rabies, and anthrax are some examples (Sonnie, 2022). According to an estimate, 60% of human diseases originates from animals and 75% of newly discovered infections being zoonotic and these zoonotic infections pose serious public health concerns (Shaheen, 2022).

2.1 Viral Zoonosis

Animal-to-human infectious diseases referred as viral zoonosis that pose a serious risk to public health across the world. However, COVID-19, Ebola and rabies are examples that produces extensive epidemics and pandemics (Nnaji et al., 2021). Direct contact with sick animals can exposure to body fluids or these diseases can also spread vectors including ticks and mosquitoes. Moreover, many illness reoccur due to a significant impact on the development of human behavior, societal variables and environmental changes (Alshaya, 2022). Furthermore, RNA viruses pose a significant threat to emerging diseases because of their rapid adaptability which is a big challenge. Control strategies and preventive have examples such as developments in prophylactics treatments and diagnostics (Nguyen et al., 2020). The mechanism of viral zoonotic diseases expressed in fig. 1.

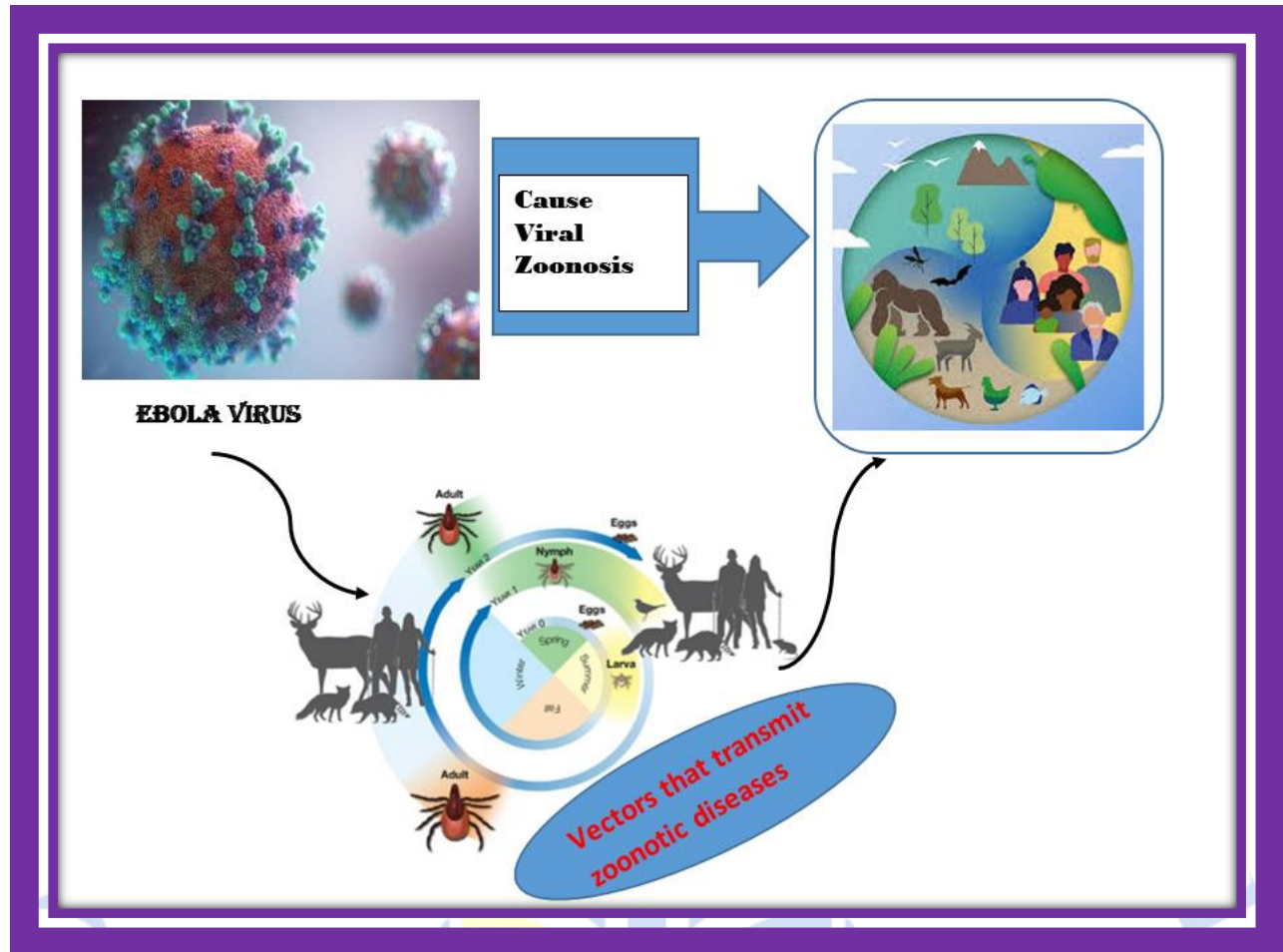


Fig. 1 Representation of Viral Zoonotic diseases

2.2 Bacterial Zoonosis

Human-animal contagious diseases are also termed bacterial zoonosis that are present in serious threats to public health. In different areas, few examples are common including Leptospirosis, brucellosis, and anthrax (Shaheen, 2022). Domestic animals including dogs carry the bacterial zoonosis such as pasteurellosis, campylobacteriosis and Lyme borreliosis (Fig.2). However, these infections are considered as possible biological warfare agents. These outbreaks often go unreported although their effect which highlights the need for improved public awareness and surveillance (Ifedinezi et al., 2024).

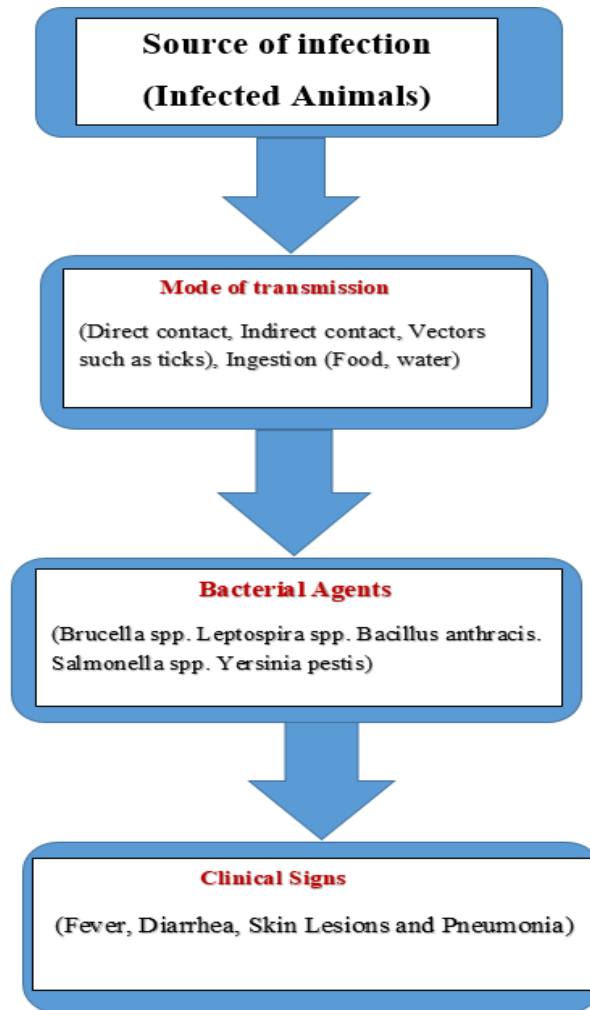


Fig .2 Representation of Bacterial Zoonosis

2.3. Fungal Zoonosis

Fungal zoonosis is also infectious diseases which give serious health concerns to humans and animals by frequently go unnoticed. Furthermore, severe systemic ailments such as aspergillosis, candidiasis and cryptococcosis as well as superficial skin infections like dermatophytoses are included in this illness. Whereas certain fungi including Sporothrix in the epidemiology of fungal zoonosis that is sketched in fig. 3 and

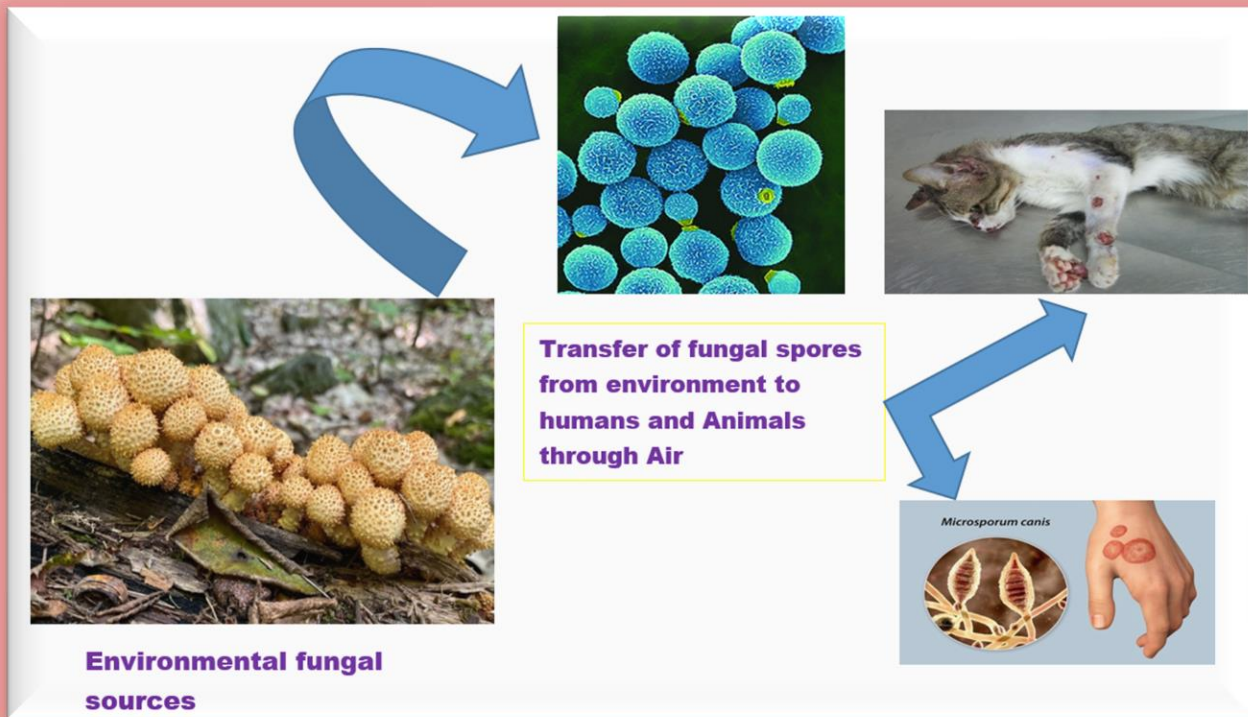


Fig. 3 Epidemiology of fungal zoonosis

brasiliensis and *Microsporium canis* can obtain by the environment which directly affect public health by animal-to-human transmission (Bongomin & Fayemiwo, 2021).

3. Transmission and Host Dynamics

Humanity continues to grapple with pandemics and the challenges posed by emerging and re-emerging diseases, many of which originate in animals although optimism prevailed in the 1970s regarding the eradication of infectious diseases (Makam and Matsa, 2021). Pathogens affecting animals not only lead to zoonotic diseases in humans but also have detrimental effects on livestock and wildlife health. Multi-host pathogens are capable of infecting various hosts that impact livestock farmers' livelihoods, national economies, and ecosystems through wildlife die-offs. Molecular epidemiology tools, such as whole-genome sequencing (WGS) and pulsed-field gel electrophoresis (PFGE) are revolutionizing the tracking and management of these pathogens by enhancing outbreak investigations and surveillance systems (Nomi et al., 2012). These challenges are exacerbated by factors such as land development, globalization, and climate change. Intensive agricultural practices further aggravate infectious diseases in livestock due to the high concentration of animals in limited spaces (Hayek, 2022). Similarly, wildlife populations, especially those of conservation concern, face heightened risks of infection due to habitat loss and exposure to pathogens from more abundant hosts. Increased human populations and expanding land use have intensified interactions between humans, wildlife, and domestic animals are creating more opportunities for pathogen transmission (Mishra et al., 2021).

Understanding disease transmission within populations requires an analysis of the infection transmission rate that is commonly expressed as $b = g \times K_b = g \times K$, where b is the transmission rate, g is the likelihood of transmission per contact, and K is the contact rate (Chorawala et al., 2024). This formula is often represented through contact networks that visualize connections between individuals or groups, with nodes signifying individuals and edges indicating potential transmission pathways. Not all contacts lead to disease transmission but making the contact network a subset of the overall transmission network. Estimating g is challenging, so researchers focus on quantifying contact networks as conduits for disease spread (Wang et al., 2023).

Contact structures in populations are influenced by behaviors such as social interactions, migration, dispersal, and social systems which drive the spatial and temporal concentration of hosts. In social species, group living comes with the cost of increased pathogen transmission (Stockmaier et al., 2021). Furthermore, its relationship with infection susceptibility remains complex and unresolved while sociality can influence health outcomes by affecting disease risk. Mathematical models such as dynamic disease models are instrumental in studying disease dynamics, enabling researchers to explore ethically or logistically challenging questions, estimate epidemiological parameters, and evaluate disease control strategies (Cuadros et al., 2024).

Dynamic disease models, including Susceptible–Infectious–Removed (SIR) models, track population changes over time among susceptible, infected, and removed individuals. Traditional SIR models often assume homogeneous contact structures within groups are overlooking population and individual-level heterogeneities, such as super spreaders who drive a majority of transmission events (Poulin, 2021). Network modeling, originally popularized for studying sexually transmitted diseases and later applied during the 2003 SARS outbreak that incorporates heterogeneous contact structures by providing valuable insights into targeted interventions for specific population members. These models range from compartmental SIR models to lattice-based systems, with their applicability determined by the research question, data quality, and required outputs (Nardini et al., 2021).

Network models, while effective for human populations, have been underutilized in studying wildlife and livestock disease dynamics. Their application offers opportunities to address knowledge gaps, particularly regarding the unique contact structures of animal populations (Ross et al., 2023). This chapter explores the integration of animal contact data with network modeling and emphasizing its growing importance in understanding pathogen transmission among wildlife and livestock. It highlights the heterogeneous contact patterns in animal population mismatches between behavioral contact networks and pathogen transmission, and avenues for advancing research in this domain to increase the adoption of network approaches (Wooster et al., 2024).

Table. 1 Impacts on Animal Health and Agriculture

Category	Details	References
Global Awareness	Increased awareness of diseases due to potential for bioterrorism or agro-terrorism	(Shankar et al., 2020)
Select Agent	55 disease agents listed. Excludes plant pathogens, 36 are zoonotic or animal-specific pathogens	(Varela et al., 2020)
World Organization for Animal Health (OIE)	118 notifiable diseases identified. It Includes diseases infecting multiple species or specific animals (e.g., cattle, poultry, fish and mollusks)	(Lane et al., 2022)
Characteristics of High-Risk Diseases	High transmissibility Potential to spread across borders Significant socio-economic and public health impacts	(Vallée, 2023)
Impacts on Animal health	Substantial risks to animal health, trade and public health	(Clemmons et al., 2021)

Numerous reviews have explored the impact of livestock and poultry infectious diseases and zoonosis by addressing topics such as disease burden, economic implications, epidemiology and their roles in pro-poor policies. However, reviewing the diverse characteristics of animal diseases within a single manuscript is challenging due to the wide range of affected hosts, transmission methods, ease of spread, and differing economic and geographic impacts (White & Razgour, 2020). For example, an outbreak of exotic Newcastle disease may severely affect households in low-income endemic regions reliant on eggs for

nutrition and income but may have negligible direct impact on households in high-income settings where such effects are mitigated by alternative food sources. Conversely, in high-income settings, the costs associated with controlling and recovering from an outbreak can heavily burden producers, local communities, and regulatory authorities, even if individual households are minimally affected (Waage et al., 2022).

4. Human Health Risks and Public Health Implications

Diseases that can be transmitted between animals and humans, known as zoonotic diseases, pose a significant and increasing risk to global public health. The global spread of SARS-CoV-2, the virus responsible for COVID-19 and is an especially striking and high-profile example (Anand et al., 2021). The estimated economic damage, health impacts, and mortality caused by COVID-19 in the United States alone amount to approximately \$16 trillion. Although the precise origin of the outbreak remains uncertain because it is widely believed to have resulted from the transmission of disease from wildlife to humans either directly through contact or consumption or via a domesticated animal intermediary (Zhou et al., 2022).

The study draws on four public health justifications to support these policies: promoting overall benefits, resolving collective action challenges related to health, preventing harm and safeguarding rights, and achieving distributive justice. Each justification is sufficient independently, meaning one can endorse a policy without subscribing to all four arguments (Congiu and Moscati, 2022). While this chapter primarily advocates for the permissibility of such measures as the arguments could also support the claim that governments are obligated to implement a mix of these policies to fulfill their duty to protect public health. First, it concentrates on government interventions rather than individual actions to change production patterns, despite ongoing debates about individual responsibilities in large-scale collective action problems. Second, it targets policies aimed at producers of intensive agriculture rather than consumers, based on skepticism about the sufficiency of demand-side interventions to address the health risks (Bryant et al., 2024). Third, it assumes that the proposed policies would be effective, leaving the evaluation of specific measures and their contextual effects to future studies. Fourth, the study does not propose a specific systemic alternative to current production practices while advocating for subsidies for ASF alternatives as exploring alternative food systems is beyond its scope (Tadic, 2024). The risk of zoonotic diseases is deeply rooted in human-animal interactions, with domestication dating back to the Neolithic period likely giving rise to diseases like measles and smallpox. In the past century, zoonotic diseases have caused major outbreaks, including Spanish flu, HIV, Ebola, SARS, MERS, and H1N1 swine flu, with COVID-19 being the most impactful modern zoonotic event. However, the emergence of new zoonotic pandemics is inevitable (Bhatia et al., 2024).

The dynamic operates in three primary ways increased disease transmission due to the density and genetic uniformity of animals in intensive farming operations, and the disruption of traditional farming economies by the creation of novel species assemblages through human encroachment on natural ecosystems, which contributes to wildlife trade and consumption (Rayfield et al., 2023). The intensification of animal agriculture is a global issue, as exemplified by rapid land-use changes and deforestation for agricultural expansion in nations like Brazil and China. Addressing this challenge requires federal government intervention because zoonotic disease risks cannot be effectively managed without regulatory measures (Li et al., 2021).

5. Control, Prevention, and the One Health Approach

The One Health concept combines the fields of environmental, animal, and human health to become more widely acknowledged for successful method of managing zoonotic illnesses such as Q fever and rabies. However, a strong emphasis on multi-sectoral cooperation is placed by this strategy which includes cooperative risk assessment, surveillance, and action (Cheng et al., 2024). Especially when it comes to putting biosecurity measures into place at the farm, regional, and national levels then veterinary epidemiology is essential in disease prevention and control (Verma et al., 2024). Animal health authorities should be involved in preparedness and response activities for emerging and exotic zoonotic illnesses, which should encompass the prevention, readiness, response, and recovery continuum. Import restrictions and biosecurity are examples of prevention tactics, whereas situational awareness, research, and training are examples of readiness (Sami and Chun, 2024).

Conclusion

The critical relationships of people, animals, and the environment led to the spread of zoonotic illnesses, and still pose serious problems for economies and public health across the world. New diseases emergence such as SARS-CoV-2 emphasizes how urgently a coordinated and all-encompassing approach is required to successfully combat these dangers. Furthermore, One Health approach is required to manage zoonotic diseases. Moreover, this method enables a more comprehensive understanding of the different elements impacting the beginning and development of illness through the integration of environmental, animal,

and human health. Developing and implementing effective preventative and control measures requires close collaboration between scientists, politicians, and communities. In order to lessen the impact of zoonotic diseases, it is crucial to fund observation and study, create public health systems, and encourage ecologically friendly agricultural practices. Reducing the likelihood of future outbreaks requires addressing the underlying drivers of disease development, such as deforestation, habitat degradation, and extensive livestock husbandry. Ultimately, zoonotic disease management and prevention necessitate an integrated approach that emphasizes the interconnectedness of all living things. We can work together to create a more sustainable and healthful future for both people and animals.

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