

One Health: Historical Evolution, Core Principles, and Applications in Global Health

Georgios Mouchtouris, Eleni Jelastopulu

Abstract

The One Health approach is a critical framework for addressing global health challenges, recognizing the inextricable link between human, animal, and environmental health. This review goes beyond a mere summary to critically analyze the historical development of that approach, from the observations of Rudolf Virchow and Calvin Schwabe to its institutionalization by the quadripartite alliance of WHO, OIE, FAO and UNEP.

The novelty of the study lies in its focus on the key pillars of the approach, interdisciplinary collaboration, systems thinking, information sharing, capacity building, resource integration and research, as foundations for effective responses to zoonoses, antimicrobial resistance (AMR), food security and the impacts of climate change. Recognizing that One Health is not just an option, but a necessity for global security, the review critically identifies obstacles. These include institutional silos, inadequate funding, cultural differences, and limited political will. To overcome these challenges, it is recommended to strengthen political commitment, expand education, and leverage digital tools to improve surveillance. The success of One Health requires systematic reforms and continued investment in building resilient systems.

Key words: *One Health; zoonoses; antimicrobial resistance; climate change; interdisciplinary collaboration*

INTRODUCTION

Traditionally, health has been understood through an anthropocentric lens, focusing primarily on medical care and disease prevention in human populations. However, growing awareness of the complexity of ecosystems and the dynamics of pathogenic microorganisms has highlighted the deep and inseparable connections between the health of humans, animals, and the environments they inhabit [1]. In this context, the concept of “One Health” has emerged as a key paradigm. It promotes a collaborative, multisectoral, and interdisciplinary

approach to addressing health challenges that arise at the interface of these three domains [2].

One Health is not the only interdisciplinary approach that recognizes the connection between health and ecosystems. The related frameworks of EcoHealth and Planetary Health, although originating from different epistemological starting points, share the common goal of addressing global challenges [3,4]. While EcoHealth has historically focused on socio-ecological interactions at the local level, and Planetary Health provides the broader macro-vision of the preservation of the planet’s natural systems as a prerequisite for human civilization [5], One Health emerges as the quintessential operational framework. This review, focusing on critical analysis and proposed solutions for integrating and addressing operational barriers to One Health,

Department of Public Health, Epidemiology and Quality of Life, School of Medicine, University of Patras, Greece

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confirms its central position as the practical mechanism for coordinating actions (WHO, OIE, FAO, UNEP) against common threats, such as zoonoses and antimicrobial resistance (AMR) [5].

The recognition of this interdependence is not new. In the 19th century, Rudolf Virchow, the German physician and founder of pathological anatomy, emphasized the coexistence of human and animal health. He coined the phrase *Ars veterinaria, medicina comparativa* (veterinary art, comparative medicine) and identified zoonoses as diseases common to both humans and animals [6]. Nevertheless, the formal adoption of One Health as a framework - and its promotion as a global strategy - stems from the pressing need to address modern health challenges in a coordinated way.

These challenges are both numerous and interconnected. Globalization, population growth, deforestation, intensification of agriculture, livestock farming, and climate change all contribute to the emergence and re-emergence of infectious diseases [7]. Approximately 75% of new and re-emerging infectious diseases in humans are of zoonotic origin [8]. Major outbreaks of zoonoses - including SARS, H1N1, avian influenza, MERS, Ebola, and COVID-19 - underscore the urgent need for surveillance and prevention systems that integrate environmental and animal health perspectives.

Beyond zoonoses, antimicrobial resistance (AMR) poses another global threat that transcends the human sector. The widespread and often indiscriminate use of antibiotics in medicine, livestock production, and even agriculture accelerates the development of resistant microbes that spread across humans, animals, and ecosystems, thereby complicating the treatment of common infections [9]. Tackling AMR requires coordinated action across sectors, in line with the One Health approach.

Food security and climate change are also central to this framework, as both directly and interactively affect the health of living beings. Ensuring safe and sufficient food for a growing global population depends on healthy animal production systems, disease prevention in livestock, and the preservation of ecosystems [10]. At the same time, climate change is changing the geographical distribution of disease vectors (e.g., mosquitoes, ticks), affecting the productivity of agriculture and livestock, and increasing the frequency and severity of extreme weather events, with direct impacts on human and animal health [11].

This article provides a comprehensive overview of the One Health framework. It first examines the historical

evolution of the concept, followed by an analysis of its main principles and pillars. Examples of its application in tackling major global health challenges are then presented. Finally, the article discusses the barriers to the widespread implementation of One Health and explores future prospects for strengthening international cooperation toward sustainable health for all.

Historical evolution of the term “One Health”

Ancient Perceptions and Early Observations

Since ancient times, people have been aware of the close relationship between their health and the environment, including animals. As early as the time of Hippocrates (c. 460–370 BC), observations on the influence of water, air, and soil on human health were central. Similar perceptions existed in other ancient cultures, such as India and China, where the health of domestic animals was considered an integral part of the community well-being [6]. Epidemics seemingly linked to animals or environmental conditions (e.g., plague, rabies) reinforced these perceptions and led to practices resembling One Health principles, such as isolating sick animals or avoiding contaminated areas.

The Pioneers of Science and the Emergence of Comparative Medicine

The 19th century was pivotal in advancing scientific understanding of the interconnectedness of health. Rudolf Virchow (1821–1902), a German physician and pathologist, was one of the first to explicitly link human and animal medicine. He used the term “zoonoses” to describe diseases that can be transmitted between animals and humans, and was a proponent of the *Ars veterinaria, medicina comparativa* (veterinary art, comparative medicine). Virchow argued that there were no strict boundaries between human and veterinary medicine and that progress in one field enriched the other [6]. His studies on the life cycle of *Trichinella* and the role of animals in the chain of disease transmission are characteristic examples of his visionary approach [12].

At the same time, Louis Pasteur (1822–1895) advanced microbiology and developed vaccines for rabies and anthrax - diseases affecting both humans and animals - thereby reinforcing the link between public health and veterinary medicine. Similarly, Robert Koch (1843–1910), through his work on *Mycobacterium tuberculosis*, emphasized the need for broader perspectives in understanding and managing infectious diseases.

The Emergence of One Medicine and Calvin Schwabe

In the mid-20th century, the concept of interconnected health was revived with renewed emphasis. James H. Steele, the first veterinarian employed at the U.S. Centers for Disease Control and Prevention (CDC), played a key role in establishing the Veterinary Public Health Division in 1947, recognizing the critical contribution of veterinary medicine to public health [13].

The idea of *One Medicine*, however, is most closely associated with Calvin Schwabe (1927–2006), an American veterinarian and epidemiologist. In 1964, Schwabe published his groundbreaking book *Veterinary Medicine and Human Health*, in which he argued that human and veterinary medicine should function as a single discipline, given their shared principles of pathology, epidemiology, and public health [12]. He emphasized that most human diseases have animal counterparts or origins and called for joint education and collaboration between physicians and veterinarians. Schwabe's work laid the intellectual foundation for the modern concept of One Health.

From One Medicine to One Health: The Extension to the Environment

While *One Medicine* primarily focused on human–animal health collaboration, increasing environmental awareness and recognition of ecosystem dynamics led to a broader *One Health* framework.

2004 - The Manhattan Principles on “One World, One Health”: Emerging from a Wildlife Conservation Society (WCS) conference in New York, these principles formally acknowledged the indivisible links between human, animal, and environmental health. They outlined 12 core recommendations for interdisciplinary collaboration in disease surveillance, prevention, and control [14]. The 2003 SARS outbreak - an archetypal zoonosis with global consequences - underscored the urgency of this perspective.

2008 - The Tripartite Partnership: Recognizing the complexity of global health risks, the World Health Organization (WHO), World Organisation for Animal Health (OIE; now the World Organization for Animal Health), and the Food and Agriculture Organization (FAO) formalized their collaboration. This “Tripartite” aimed to address challenges at the human–animal–ecosystem interface, with particular focus on zoonoses and antimicrobial resistance [15].

2010 - The Berlin Principles on One Health: During a conference in Berlin, guiding principles for One Health

were developed, emphasizing international cooperation, data sharing, integrated surveillance, and the incorporation of One Health into research and education.

Consolidation of One Health in the 21st Century and the One Health Joint Plan of Action

In the early decades of the 21st century, the rising frequency of infectious disease outbreaks, including avian influenza H5N1, MERS, Ebola, Zika, and most notably, COVID-19, together with escalating antimicrobial resistance and climate change impacts, reinforced the need for a globally recognized One Health approach.

The COVID-19 pandemic, a probably zoonotic disease with profound socio-economic consequences, acted as a catalyst for fully incorporating the environmental dimension into health frameworks. This development led to the expansion of the original tripartite into a quadripartite alliance, with the United Nations Environment Programme (UNEP) joining the WHO, the OIE, and the FAO.

In 2021, this Quadripartite collaboration launched the *One Health Joint Plan of Action (2022–2026)*, providing a comprehensive framework for global, national, and local implementation of One Health. The plan emphasizes six priority areas: 1. Strengthening capacities for the One Health approach, 2. Addressing emerging and re-emerging zoonoses, 3. Addressing antimicrobial resistance, 4. Promoting food safety, 5. Managing environmental health and 6. Addressing climate change [2].

In conclusion, from antiquity to the present day, there has been a growing understanding of the interdependence among human health, animal health, and ecosystems. This is also the springboard for a unified response to the health challenges that have arisen to date and that will arise in the future.

Key Pillars and Principles of the One Health Approach

The One Health approach is a structured strategic framework grounded in specific pillars and principles. These principles guide collaborative actions required to effectively address the complex health challenges that affect humans, animals, and the environment [2]. The main pillars and principles are outlined below.

Multidisciplinary and interdisciplinary collaboration

A key pillar of the One Health approach is multidisciplinary and interdisciplinary collaboration [16]. In practice, this requires experts from human medicine, vet-

erinary medicine, environmental sciences, agriculture, public health, and related disciplines to work together in addressing emerging challenges. Such cooperation must be systematic and structured across international, national, and local levels [17] and includes:

- **Shared understanding of the problems:** Health crises such as epidemics should be analyzed collaboratively by different scientific fields, rather than through a single disciplinary lens.
- **Development of common strategies:** Solutions should emerge from the joint expertise of all relevant disciplines.
- **Cross-sectoral working groups:** Networks and structures must be established to ensure regular communication and collaboration.

Holistic and Systemic Approach

The One Health approach emphasizes a holistic and systemic perspective [6], recognizing that human, animal, and environmental health form a single interconnected system. For example, changes in animal health inevitably affect human and environmental health. This principle entails:

- **Recognizing interdependencies:** Understanding how drivers such as climate change, intensive livestock farming, and deforestation contribute to disease emergence.
- **Addressing root causes:** Identifying and mitigating sources of pathogens or risks within animal and environmental domains, rather than focusing solely on treating human disease outcomes [1].
- **Preventive action:** Prioritizing prevention of infectious diseases through awareness of risks arising from human–animal–environment interactions.

Communication and Information Sharing

Effective communication and sharing of information are one of the most important prerequisites for the success of One Health [17]. Timely collection, analysis, and dissemination of data on animal health, environmental changes, and human disease trends are essential. This includes:

- **Integrated surveillance systems:** Coordinated monitoring of zoonoses, antimicrobial resistance, and environmental indicators to enable rapid response.
- **Data sharing:** Ensuring data collected are accessible and usable across all sectors and stakeholders.
- **Transparent and timely communication:** Establishing protocols for communication among authorities, stakeholders, and the public, especially during crises.

Capacity Development and Training

Building professional capacity is vital for the effective implementation of One Health. Authorities should design training programs that prepare professionals in medicine, veterinary medicine, and environmental sciences to apply One Health principles in practice [6]. This includes:

- **Interdisciplinary study programs:** Integrating One Health concepts into academic curricula (e.g., medical, veterinary, and environmental schools).
- **Continuing education and training:** Offering life-long learning opportunities to update knowledge in line with new developments.
- **Investment in human resources:** Recruiting and supporting professionals with expertise in the One Health approach.

Resource Sharing and Sustainability

Another equally important pillar of the One Health approach is the sharing of resources (financial, human, and material) to develop sustainable practices in the implementation of One Health [2]. This includes:

- **Joint financing and investment:** Coordinating policies for funding interdisciplinary programs and initiatives.
- **Development of sustainable practices:** Promoting measures such as improved zoonotic risk management or sustainable water use that protect both human and ecosystem health.
- **Political commitment:** Ensuring that national governments and international organizations demonstrate the political will to translate One Health strategies into actionable policies.

Research and innovation

Finally, the final pillar of the One Health approach is research and innovation [16]. Implementing One Health in practice requires continuous investigation of new potential threats to public health, as well as research to find new, innovative practices that facilitate and make the implementation of One Health more feasible at the international level. This implies:

- **Interdisciplinary research:** Designing studies that integrate methods from medicine, veterinary science, ecology, epidemiology, and microbiology.
- **Development of new technologies:** Creating diagnostic tools, vaccines, treatments, and surveillance systems.
- **Translation of research into policy and practice:**

Ensuring research findings are effectively converted into real-world policies and interventions.

Together, these pillars form a unified framework for addressing health crises in a comprehensive and sustainable manner. By integrating collaboration, systemic thinking, communication, training, resource-sharing, and research, the One Health approach provides a robust pathway to managing current and future health challenges.

Applications of One Health to Global Health Challenges

The One Health approach goes beyond theory, serving as a practical framework for addressing many of the major health challenges of the 21st century [6]. Its applications span zoonoses, antimicrobial resistance, food security, and environmental health.

Zoonoses and Emerging Pathogens

One of the main areas where One Health is applied is in the management of zoonoses. It is estimated that three out of four new or re-emerging diseases in humans are of zoonotic origin [8]. Their emergence is driven by globalization, closer human–wildlife interactions, climate change, agricultural expansion, and intensive livestock farming [18]. One Health contributes to controlling zoonoses through:

- **Integrated surveillance:** Cross-species monitoring of pathogens (e.g., influenza, rabies, Ebola) enables early detection and rapid response [2].
- **Joint response actions:** Coordinated interventions by physicians, veterinarians, and environmental experts—for example, in the eradication of rinderpest [19].
- **Risk reduction at interfaces:** Regulating wildlife trade, improving farm practices, and engaging local communities to prevent spillovers [20]. The COVID-19 pandemic highlighted the critical importance of such measures [21].

Antimicrobial Resistance (AMR)

Antimicrobial resistance (AMR) is one of the most important threats to public health, making it increasingly difficult to treat common diseases [22]. It arises from the misuse of antibiotics in human medicine, livestock production, and environmental contamination [23]. The One Health approach addresses AMR by:

- **Coordinated reduction strategies:** National action plans for rational antibiotic use in humans, animals, and aquaculture [9].

- **Integrated surveillance:** Monitoring resistance and antimicrobial use across humans, animals, and ecosystems (e.g., wastewater, soil, aquatic ecosystems) [24].
- **Hygiene and biosecurity:** Strengthening hygiene and biosecurity in hospitals, clinics, livestock farms, and communities can reduce the need for antibiotics [25]. This process includes personal and public hygiene measures as well as primary prevention measures such as vaccination of both humans and animals.
- **Alternatives to antibiotics:** Development of vaccines, probiotics, and phage therapy [26].

Food Safety and Security

Food security concerns access by all people to safe, sufficient, and nutritious food. However, food security is directly affected by animal and environmental health [10]. There are animal diseases, such as swine fever and avian influenza, which can wipe out entire livestock populations, leading to serious food shortages and economic losses. At the same time, there are foodborne diseases that pose a significant threat to public health. One Health strengthens food systems through:

- **Disease prevention in livestock:** Vaccination, biosecurity, and surveillance to safeguard production [27].
- **Control of foodborne diseases:** Cooperation between veterinary services and food safety and public health authorities to monitor pathogens (e.g., *Salmonella*, *Campylobacter*) in the food chain, from initial production to consumption [28].
- **Hygiene standards:** Enforcing food safety practices from production to consumption.
- **Environmental safeguards:** Protecting soil and water quality to reduce contamination risks.

Environmental Health and Climate Change

Environmental health is now an integral part of the One Health approach, as changes in ecosystems have direct and widespread consequences for human health [2]. In addition, climate change, biodiversity loss, deforestation, pollution, and urbanization create fertile ground for the emergence and spread of infectious diseases. One Health addresses these challenges through:

- **Ecological risk assessment:** Studying how land use, habitat loss, and vector dynamics affect disease transmission [11].
- **Climate adaptation:** Monitoring vector-borne dis-

eases, managing water, and protecting vulnerable populations [29].

- **Biodiversity Protection:** Recognizing the role of healthy biodiversity as a “moderator” of diseases and promoting conservation to reduce pathogen spread [7].
- **Environmental Pollution Management:** Coordinated efforts to reduce pollution (air, water, soil) that affects both human and animal health, as well as its contribution to antimicrobial resistance [24].
- **Promoting Sustainable Systems:** Encouraging practices in agriculture, livestock, and fisheries that are environmentally friendly, minimize the carbon footprint, and protect the health of ecosystems in the long term.

The applications of One Health extend across zoonoses, AMR, food security, and environmental health, offering a coherent and effective response to global challenges. Its success depends on sustained interdisciplinary collaboration and the integration of One Health principles into policies and practices worldwide.

Challenges in Implementing One Health

Although the One Health approach is necessary due to its potential benefits for global health, its implementation in practice faces considerable obstacles. These challenges are multifaceted and multifactorial, covering institutional, educational, financial, and cultural areas [6,16].

Institutional and Sectoral Isolation

A major barrier is institutional fragmentation, often described as a “silo mentality.” Government agencies, academic disciplines, and professional sectors are traditionally organized into separate structures, each with its own budget, legislation, and mandate. This separation hampers cross-sectoral collaboration, joint decision-making, and information sharing [17].

Inadequate and Unsustainable Financing

Another critical challenge is the lack of stable funding. Many One Health initiatives rely on short-term, project-based programs without long-term financial commitment from national budgets. Preventive actions, such as vaccination campaigns or zoonotic disease surveillance, are often undervalued compared to emergency responses, despite being more cost-effective in the long run [2].

Disciplinary and Cultural Differences

Differences in professional culture also pose significant difficulties. Physicians, veterinarians, and environmental scientists often approach health problems with distinct methodologies, priorities, and even terminologies [1]. These divergences can create misunderstandings, weaken communication, and hinder collaboration. The absence of harmonized surveillance protocols and common data-sharing platforms exacerbates these barriers.

Lack of Political Will and Commitment

Finally, One Health initiatives frequently suffer from insufficient political support. Without strong leadership and sustained commitment at both national and international levels, actions remain fragmented and ineffective. Recognizing One Health as an integral component of global health security is essential for its successful implementation [6].

In summary, the challenges of institutional silos, unstable financing, disciplinary divides, and weak political will represent major barriers to One Health implementation. Overcoming these obstacles requires systemic reforms, sustained investment, and stronger integration of One Health into public policy agendas.

Future Perspectives and Recommendations for One Health

The One Health approach is an imperative to address current and future public health challenges. However, its successful implementation requires coordinated efforts across all levels of governance, from local authorities to international organizations [1].

Strengthening Political Commitment

A key priority is the recognition of One Health as a central strategy for national and global health security. Achieving this requires stronger political will, long-term commitment, and the development of unified, interdisciplinary action plans that integrate human, animal, and environmental health [2].

Expanding Education and Training

Embedding One Health principles in education is crucial for shaping future professionals. Medical, veterinary, and environmental science curricula should be revised to foster a holistic understanding of health interconnections and to emphasize interdisciplinary collaboration [6, 16].

Leveraging Digital Tools for Data Sharing

Digital innovation can play a transformative role in improving epidemiological surveillance. The development of platforms and applications that enable secure, real-time data exchange across sectors will enhance the capacity for early detection and rapid response, while respecting data privacy [17].

Promoting Research and Innovation

Finally, sustained investment in research is essential to advance One Health goals. Priority areas include studying human–animal–environment interactions, developing new diagnostic tools, vaccines, and treatments, and translating scientific insights into practical solutions for global health. Continuous adaptation to evolving conditions is critical for long-term resilience [1].

CONCLUSIONS

The One Health approach has become a cornerstone for addressing global health challenges by recognizing the interdependence of human, animal, and environmental health. From its roots in the work of Rudolf Virchow and Calvin Schwabe to its formalization in the Manhattan and Berlin Principles, One Health has evolved into a unified framework for tackling complex threats.

Its core pillars - interdisciplinary collaboration, systemic thinking, information sharing, capacity-building, resource integration, and research - provide the tools for addressing zoonoses, antimicrobial resistance, food security, and climate-related health risks. The COVID-19 pandemic further highlighted its necessity, accelerating global cooperation through the Quadripartite alliance of WHO, OIE, FAO, and UNEP.

Nevertheless, barriers such as institutional silos, insufficient funding, disciplinary differences, and limited political will continue to hinder progress. Overcoming these obstacles requires sustained investment, stronger governance, digital innovation, and expanded education and training. Ultimately, One Health is not optional but essential for building resilient systems and ensuring a sustainable future for all life on the planet.

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both authors read and approved the final version of the manuscript.

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Corresponding author:

Eleni Jelastopulu
Department of Public Health, Epidemiology and Quality
of Life, School of Medicine, University of Patras, Greece
Tel.: +30 2610969878, +30 6977624636
E-mail: jelasto@upatras.gr