



Health, Science, and Sustainability: A Multidisciplinary Review of Disease Dynamics, Therapeutic Advances, and Environmental Challenges

Muhammad Akram^{1*}, Mohammed Khudhair Hasan², Hind A. Abdulghafoor³, Fahad Said Khan⁴, Fethi Ahmet Ozdemir⁵, Gawel Sołowski⁵, Jauher Bin Ali⁶

¹Department of Eastern Medicine, Government College University Faisalabad-Pakistan

²Al Manara College for Medical Sciences, Maysan, Iraq

³Department of Pathology and Forensic Medicine, University of Fallujah, Iraq

⁴Department of Eastern Medicine, University of Poonch Rawalakot, Azad Jammu and Kashmir, Pakistan

⁵Department of Molecular Biology and Genetics, Faculty of Science and Art, Bingol University, Bingol, 1200, Türkiye

⁶ESST-HS/University of Sousse Sime Laboratory (ENSIT)/University of Tunis

*Email corresponding author's: makram_0451@yahoo.com

Received:6/12/2025

Accepted:19/12/2025

Published:1/1/2026

Abstract

Health dynamics and environmental sustainability are deeply interlinked. Recent years have seen rapid shifts in disease patterns from pandemics like COVID-19 to rising chronic conditions driven by globalization, urbanization, and climate change. At the same time, technology is advancing in medicine: novel therapeutics, diagnostics, and AI are transforming prevention and care. Environmental factors such as pollution, land use, and climate shifts influence disease emergence and exacerbate health risks. This review integrates multiple fields to examine how diseases spread and evolve, the latest in treatments and biomedical innovations, and the environmental challenges that threaten health and ecosystem balance. We summarize key trends in epidemiology and modelling, highlight breakthroughs in therapy and diagnostics, and explore sustainability issues like fertilizer use and climate impacts. Experiments and public data ranging from WHO climate studies to OurWorldInData analyses are used to illustrate these themes. The goal is to provide a clear, human-centered synthesis of complex topics for a broad audience.

Keywords: *disease dynamics, vaccines, antibiotics, climate change, One Health, nanotechnology, antibiotic resistance, sustainability.*

Doi : <https://doi.org/10.64943/ljacs.2026.010101>

INTRODUCTION

Human health does not exist in isolation. Infectious and chronic diseases are influenced by the world around us: climate, ecology, and our social systems. Over the past century, improved sanitation, vaccines, and antibiotics dramatically cut disease deaths, but new threats have emerged. In the 21st century, we have faced pandemics (COVID-19, H1N1, etc.), surges in chronic illnesses, and growing drug resistance. At the same time, advances in science and technology such as targeted drugs, immunotherapy, artificial intelligence (AI) and nanotechnology are revolutionizing how we prevent, diagnose, and treat illness [1]. This review brings together disease dynamics, medical innovation, and environmental sustainability. We draw on published studies and public datasets to explore how diseases spread and change, what therapies are emerging, and how environmental changes (pollution, climate) affect health. The aim is a broad, human-readable survey that covers the latest data and concepts from multiple disciplines.

Disease Dynamics and Epidemiology

Diseases spread through populations via complex pathways. Early models of epidemics, such as the SIR (Susceptible-Infectious-Recovered) framework, group people by health status to predict outbreaks. In the SIR model, individuals move from being susceptible to infected to recovered over time (Figure 1). This simple structure can be expanded to include births, deaths, different age groups, or

hospitalizations [2]. Such compartmental models quickly offer insight into outbreaks, and more detailed agent-based models add individual behaviors. Model equations use parameters like contact rates and infectious periods to simulate how fast a disease might grow. While real epidemics involve many factors, even basic models help plan interventions (e.g. vaccinate 20% of people, or impose social distancing) by showing the possible impact on transmission.



Figure 1. The SIR epidemic model groups a population into Susceptible, Infectious, and Recovered states. People move from being susceptible to infected and then to recovered (or immune). This simple model captures core epidemic dynamics and can be expanded (e.g. adding vaccination or hospitalization compartments).

Modern disease surveillance and modelling combine multiple data streams. For instance, COVID-19 highlighted how rapid testing, contact tracing, and genomics feed into models that estimate viral spread [3]. Incorporating real-world data (mobile phone mobility, hospital use, climate factors) refines predictions [3]. However, uncertainty remains high without good data: as one expert notes, gaps in climate and health monitoring have real impacts on outbreak preparedness [4]. Globally, 60% of emerging infectious diseases in people originated from animals [5]. Urbanization, deforestation, and wildlife trade create new risks of “spillover” infections, as we saw with COVID-19. Climate change also shifts disease patterns: warmer, wetter weather expands mosquito habitats and triggers outbreaks of malaria, dengue, and other vector-borne diseases [5]. Overall, understanding and predicting disease requires a “One Health” approach linking humans, animals, and environment [5].

Therapeutic Advances and Biomedical Innovations

As diseases evolve, medical science advances to meet them. Antibiotics remain lifesaving but resistance is rising due to overuse. The “Golden Age” of antibiotics (1940s–1960s) saw most classes developed (penicillins, tetracyclines, etc.) (Figure 2). These drugs dramatically cut many infectious disease deaths. For example, early sulfonamide antibiotics introduced in the 1930s reduced scarlet fever death rates by about 65% and maternal death by about 36%. However, since the 1970s pharmaceutical R&D shifted away from antibiotics, slowing new discoveries [6]. Recent efforts focus on targeted uses: large-scale trials in Africa showed that giving azithromycin to children twice a year cut child mortality by about 15%. This illustrates that even existing antibiotics, used cleverly, can save lives. But new strategies (e.g. phage therapy, novel antibacterials) are needed too [6].

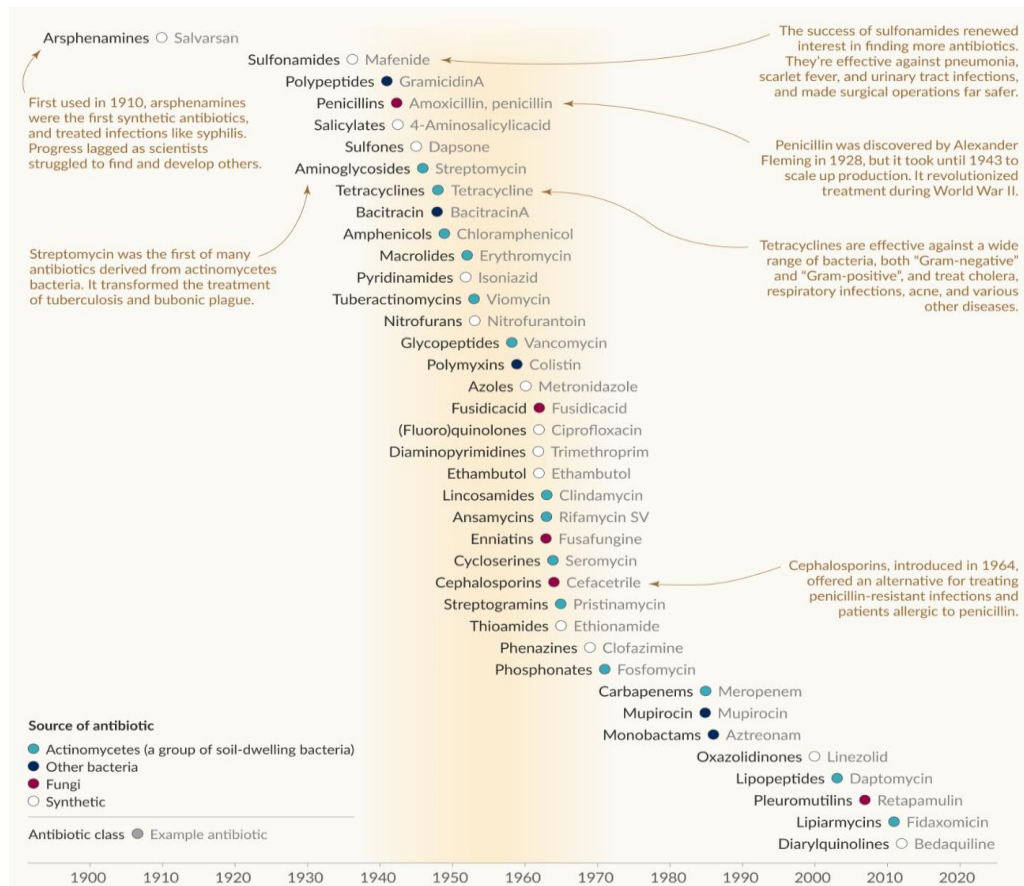
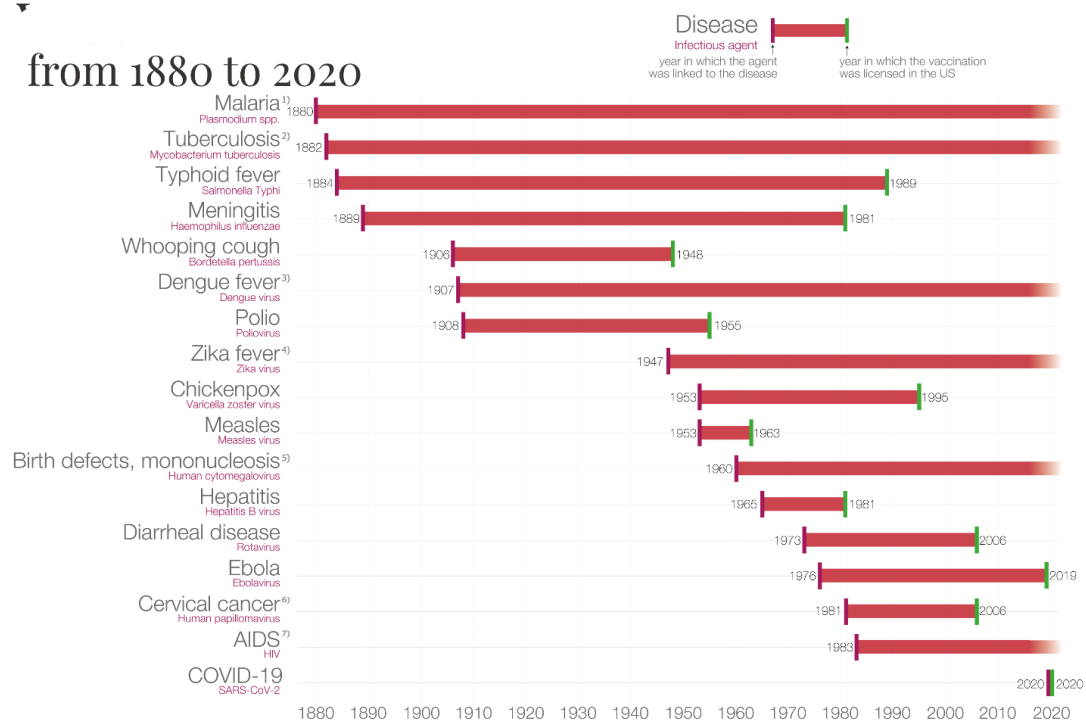


Figure 2. Timeline of antibiotic drug class discoveries in the 20th century. Most antibiotics (tetracyclines, penicillins, etc.) were found between the 1940s and 1960s ("Golden Age"); few new classes emerged after the 1970s. Source: Our World in Data.

Vaccines are another key tool. After Jenner's cowpox vaccine in 1796, progress was slow until germ theory (late 1800s) enabled many modern vaccines [6]. Over the 20th century, vaccines for smallpox, polio, measles, and more have saved millions. Technological advances now let us design vaccines faster: genomic sequencing and AI allow rapid identification of targets, and mRNA platforms can be updated in months (as seen in the COVID-19 vaccine race) [6]. For instance, Figure 3 shows how quickly recent vaccines have followed disease discovery. Data also demonstrate vaccine power: smallpox was eradicated by 1980 through concerted vaccination efforts, and diseases like diphtheria and polio have seen >90% decline in cases after vaccines [6].

Beyond antimicrobials and vaccines, precision medicine is advancing. Nanotechnology is enabling targeted drug delivery: nanoparticles can carry chemotherapy directly to tumors with fewer side effects. Imaging technologies now resolve single molecules, improving diagnostics. AI and machine learning are being applied to medical data: they help interpret complex imaging (MRI, CT) and predict disease risk from genetics [1]. For example, AI algorithms can scan radiology images for early cancer signs more quickly than humans. By combining AI with nanotech, personalized treatment plans and diagnostics are emerging [1]. Integrating these fields promises more effective, individualized care. At the same time, it raises ethical issues (privacy, bias) and technical challenges (data quality, interpretability) that researchers must address [2].

Non-drug therapies are also notable: immunotherapy uses the body's immune system to fight cancer (e.g. checkpoint inhibitors), and gene therapy can correct genetic disorders. Digital health (telemedicine, wearables) has expanded access during the pandemic. These innovations reflect a broader trend: medicine is becoming more precise, data-driven, and connected. However, equitable access remains a problem: advanced treatments are often expensive, and global health spending varies widely [6] (Figure 7).



1) - 2016 vaccine RTS,S undergoing pilot trials in select countries after being approved by European regulators in 2015.
 2) - The only approved vaccine is bacilli Calmette-Guérin (BCG), developed in 1921 but its efficacy in adults is variable. Other tuberculosis vaccines are currently in development.
 3) - 2016 partially effective vaccine CYD-TDV, sold under the brand name Dengvaxia.
 4) - Successful first human clinical trials of a vaccine against the virus in 2016. Only in 2016 did the WHO issue statements of concern about the Zika virus' links to Guillain-Barré Syndrome (GBS) and microcephaly.
 5) - A number of vaccine candidates are under investigation.
 6) - Not all cervical cancers are caused by the HPV virus and the HPV vaccine can protect against other cancers caused by the HPV virus.
 7) - 2009 efficacy findings for vaccine candidate RV 144 has shown some promise. In stage III human trials.

OurWorldinData.org - Research and data to make progress against the world's largest problems.

Licensed under CC-BY by the author Max Roser

Figure 3 Vaccination development timeline. Each bar shows years between identifying a pathogen (purple) and licencing its vaccine (green). Notice that in recent decades this lag has shortened (e.g. rotavirus, COVID-19) thanks to better science and technology.

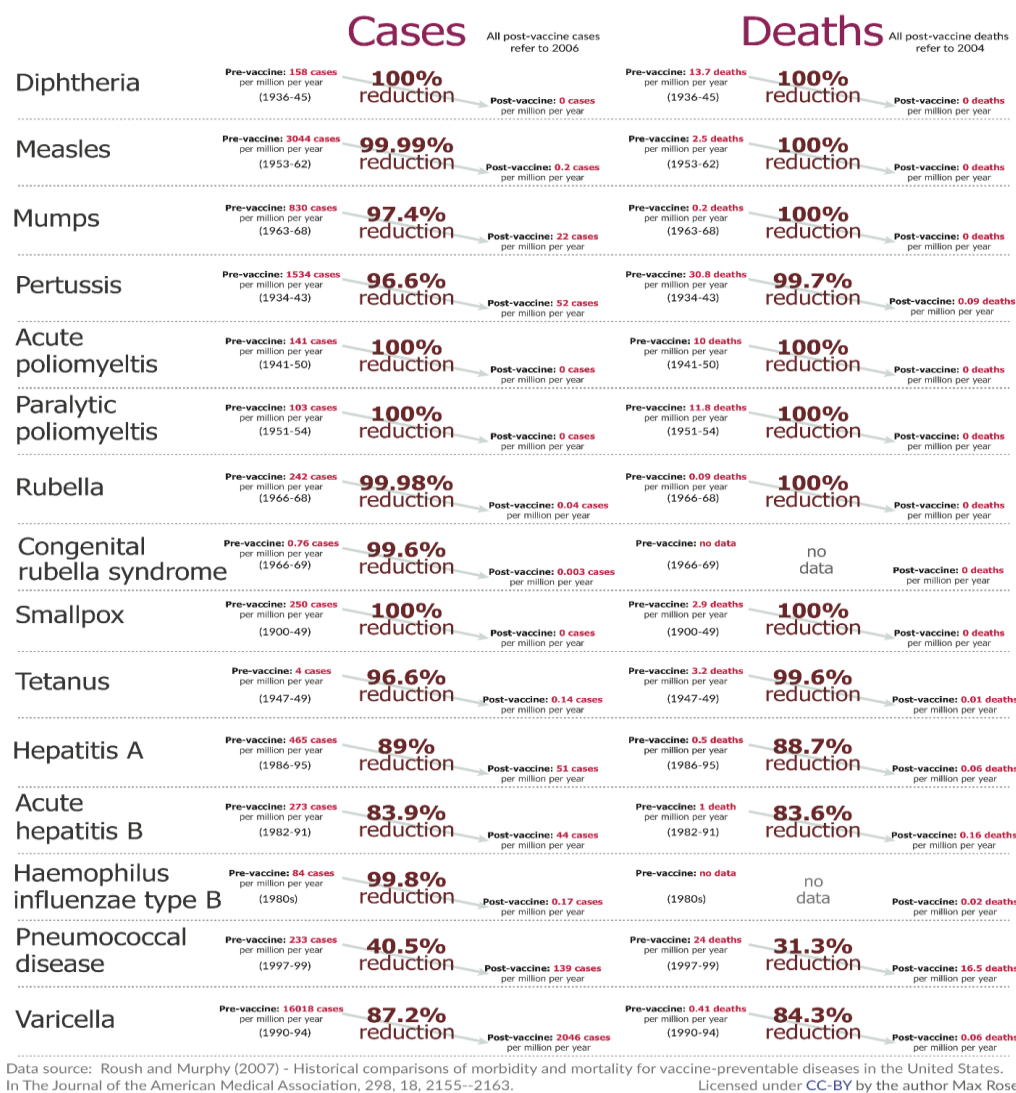


Figure 4. Vaccine impact on public health in the US. The chart compares disease incidence and mortality before and after vaccine introduction for multiple diseases. Vaccination achieved near-total elimination (100% reductions) for diseases like smallpox and diphtheria, and very large declines in measles, polio, and others.

Environmental Health and Sustainability Challenges

Human health and the environment form a feedback loop. Climate change, pollution, and land use can worsen health and lead to new diseases [7]. For example, WHO warns that climate change is a “threat multiplier” for health. Rising global temperatures and extreme weather already cause heat stress, floods, and food insecurity. WHO estimates an extra 250,000 deaths per year (2030–2050) from malnutrition, malaria, diarrhea, and heat stress due to climate change [5]. Moreover, climate shifts alter where diseases occur: warmer temperatures allow mosquitoes (malaria, dengue) and ticks (Lyme) to survive in new regions [7]. One study noted that by 2030–2050, vector-borne diseases will rise, especially affecting low-income countries [7]. In essence, environmental change can spark health crises, from direct (heatstroke, injuries in storms) to indirect (vector spread, crop failure, pollution).

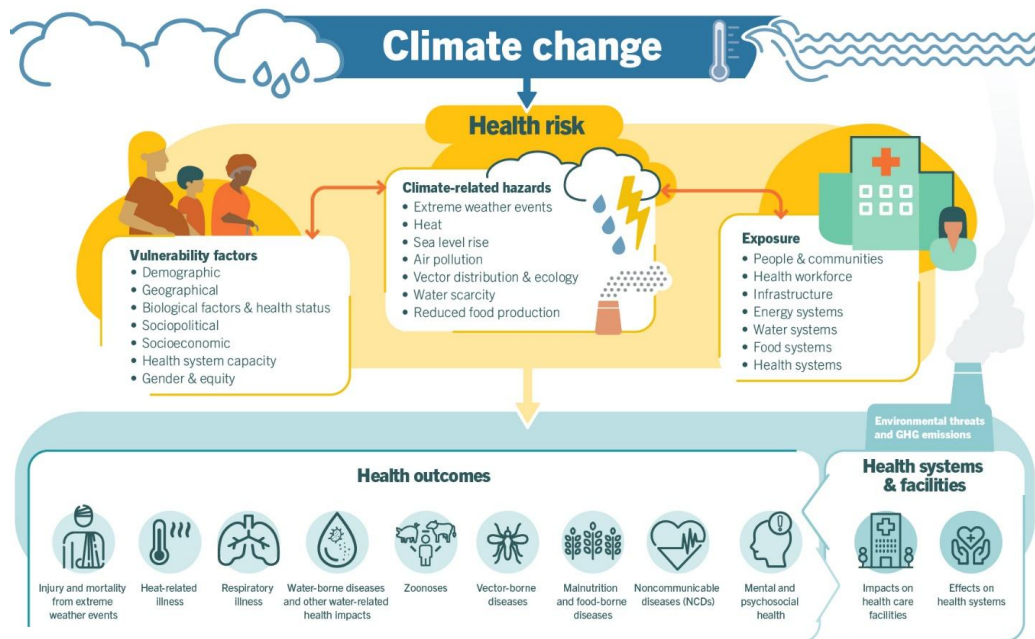


Figure 5. Health impacts of climate change. This WHO infographic illustrates climate-related hazards (heatwaves, floods, air pollution) and how they translate into health risks (injury, malnutrition, respiratory disease, etc.). Climate change affects everything from food systems to infection patterns, making it harder to protect health [5].

Pollution and land use are also critical. Industrial and agricultural chemicals can contaminate water, air, and soil, causing disease. For instance, the overuse of nitrogen and phosphorus fertilizers has doubled global food production but at an ecological cost [6]. Our World in Data reports that nearly two-thirds of applied nitrogen fertilizer is not taken up by crops and runs into ecosystems as pollutant. This excess fertilizer leads to water pollution (eutrophication) and greenhouse gas emissions. Figure 6 shows that countries like China, India, and the USA generate the largest total nitrogen pollution, while small nations may have very high per-hectare waste [6]. Managing fertilizer use is thus a sustainability and public health challenge: reducing pollution without sacrificing yield is a key research goal.

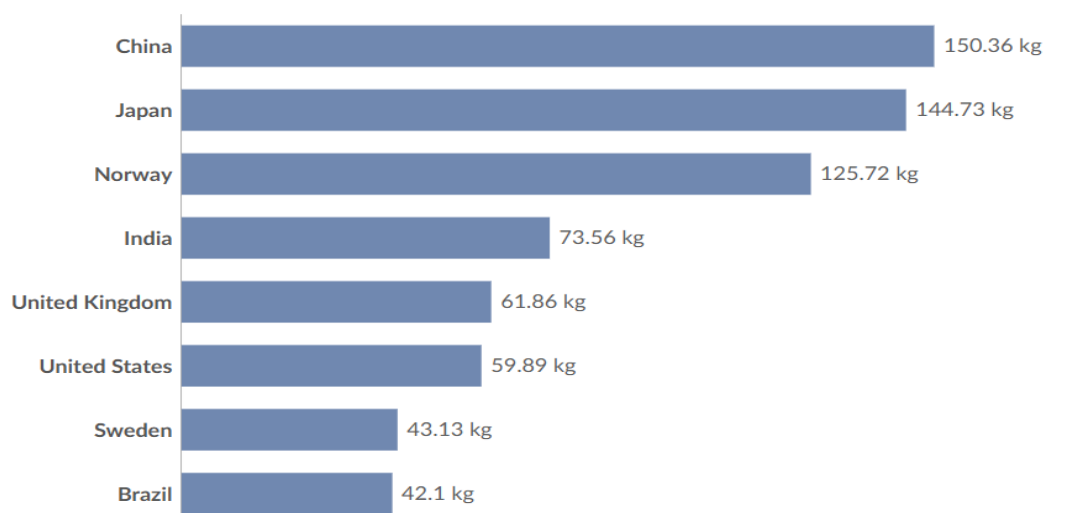


Figure 6. Excess nitrogen fertilizer application by country. Left: excess nitrogen per hectare of cropland (kg/ha). High-income and intensive farming countries produce much excess nitrogen, polluting water and air. Source: Our World in Data.

Deforestation and habitat loss compound issues. When wild areas are cleared for agriculture or development, wildlife contact with humans increases. This can introduce novel pathogens (zoonoses)

into human populations. For example, land-use change is linked to malaria surges in some regions. One Health approaches recognize these connections: human health, animal health, and ecosystem health must be balanced to prevent disease emergence [5]. The WHO notes that 75% of new pathogens in the last 30 years originated in animals. Environmental stressors like climate change and pollution thus not only harm current health, they create new disease risks. Sustainable practices reducing emissions, preserving biodiversity, and using cleaner agriculture have co-benefits for health [7].

Air quality is another concern. Burning fossil fuels produces fine particulate matter and ozone, which cause lung disease, heart disease, and early death. The Lancet's Global Burden of Disease study (2019 data) shows ambient air pollution is one of the top global risk factors, causing over 4 million premature deaths per year. Similarly, contaminated water leads to diarrheal illnesses and epidemics. Over 2 billion people lack safe drinking water, and diseases like cholera can spread rapidly under climate stress [6].

Nutrition and food systems tie in as well. Climate affects crop yields and nutritional value. Increasing CO₂ and heat reduce protein and mineral content in staples, worsening undernutrition. The WHO warns that climate change could cause 529,000 additional malnutrition-related deaths by 2050 [7]. Sustainable agriculture (e.g. biofertilizers, crop diversification) can improve resilience. For instance, studies have shown biofertilization (using beneficial microbes) can boost plant growth while cutting chemical inputs [8]. This approach reduces pollution and can slow climate change. In animal farming, reducing antibiotic overuse (e.g. better hygiene instead) lowers the rise of resistant bacteria [9].

Health Economics and Access

Health is also shaped by economics and infrastructure. Richer countries generally spend more per person on healthcare. Figure 7 maps total health expenditure per capita (adjusted for purchasing power). High-income countries (USA, Europe) spend thousands of dollars per person, while poorer countries may spend only a few hundred [10]. This gap affects outcomes: vaccination rates, chronic disease management, and preventive services are often lower where spending is low. WHO's data show underinvestment in health is a major barrier to global goals like universal coverage.

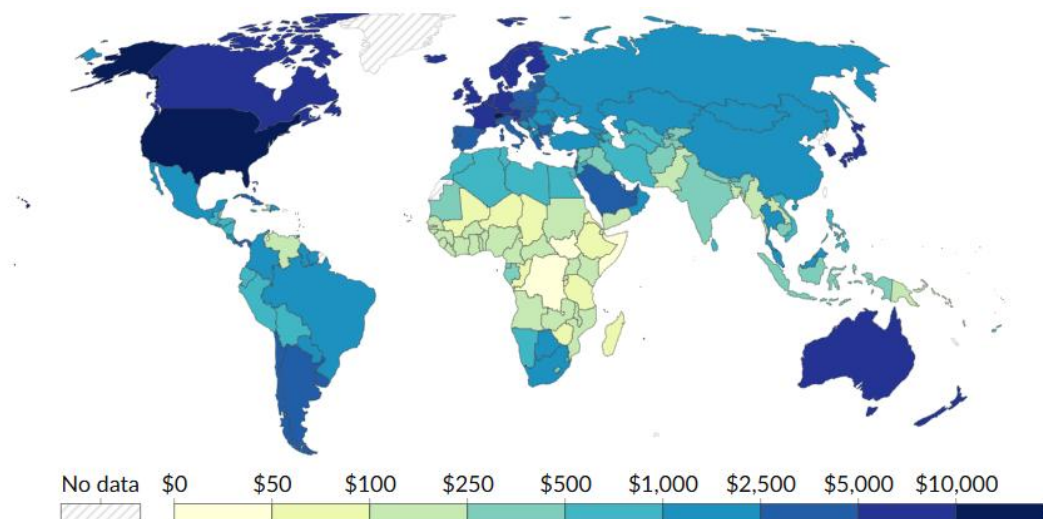


Figure 7 Global health spending per person (current international dollars). Wealthy nations invest far more in healthcare, while many developing countries spend much less. (Data from WHO/World Bank, via Our World in Data.)

Disparities in access translate to health inequalities. For example, during COVID-19 the vaccine rollout was swift in rich regions but delayed in poor countries, prolonging the pandemic for all. Similarly, new therapies like cancer immunotherapy or biologics may be unaffordable to many. Global trends in cardiovascular disease show that high-risk lifestyles (smoking, poor diet) are increasing in low- and middle-income countries, raising future disease burdens [11]. Mental health is also emerging as a

critical public health issue, especially after the stress of the pandemic [12]. Investments in education, clean environments, and primary care can improve these outcomes at scale.

On the positive side, international data sharing has improved. Organizations like WHO and research networks provide open data on outbreaks, climate, and pollution. Publicly available analyses (e.g. from data portals, UN, academic projects) have guided policy. For instance, the UN Foundation uses climate and health data to advocate interventions [13]. Similarly, open-data projects show how vaccination and health spending correlate with life expectancy, guiding public health priorities. Continued investment in data (e.g. more weather stations, epidemiological labs) is crucial for preparedness [14, 15].

CONCLUSIONS

Health, science, and sustainability are interconnected in complex ways. Disease dynamics now reflect global travel, climate change, and ecological disruption. At the same time, science and technology provide powerful new tools: advanced modeling, vaccines, antibiotics (when used wisely), and AI-driven medicine. The challenge is to harness these advances responsibly and equitably, while addressing environmental harms that threaten health. Climate change, pollution, and unsustainable practices can undo decades of health progress if unchecked.

A multidisciplinary, One-Health approach is essential. Public health must coordinate with environmental policy, agriculture, and technology innovation. For example, reducing greenhouse emissions not only slows warming but also cuts pollution-related illnesses. Regulating antibiotic use in farming preserves these drugs for human medicine. Climate adaptation (better cooling, flood control) saves lives now. Moreover, emerging fields like AI in medicine should be coupled with efforts to bridge the digital divide, so benefits reach all people. In research, combining data (climate records, genetic data, case reports) with global collaboration will improve forecasts and responses to health threats.

Ultimately, safeguarding health in the coming decades requires both scientific progress and sustainability. By integrating public health measures, cutting-edge therapies, and environmental stewardship, societies can build resilience. As WHO emphasizes, addressing climate and health together will yield “very large gains for health” (reduced air pollution, better nutrition, cleaner environments). Similarly, new medical technologies must be developed with sustainability and equity in mind. This review highlights that the path to a healthier future lies at the crossroads of biology, medicine, and ecology.

REFERENCES

1. Ibrahim, H. K. (2024, May 30). From Nanotech to AI: The Cutting-Edge Technologies shaping the future of medicine. <https://aaasjournals.com/index.php/ajapas/article/view/810>
2. Technical Explainer: Infectious disease transmission models. (2025, January 6). CFA: Modeling and Forecasting. <https://www.cdc.gov/cfa-modeling-and-forecasting/about/explainer-transmission-models.html>
3. Lee, M., Choi, H., & Lee, C. H. (2025). A novel framework for inferring dynamic infectious disease transmission with graph attention: a COVID-19 case study in Korea. *BMC Public Health*, 25(1). <https://doi.org/10.1186/s12889-025-23059-7>
4. Trust, W. (2025, June 18). Tracking the health effects of climate change around the world. Wellcome. <https://wellcome.org/insights/articles/tracking-health-effects-climate-change-around-world>
5. World Health Organization: WHO. (2023, October 12). Climate change. <https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health>
6. Total health spending per person. (2025, July 3). Our World in Data. <https://ourworldindata.org/grapher/annual-healthcare-expenditure-per-capita>
7. Sanchez Bao, P. (2023, November 29). Ahead of COP28 Health Day: Addressing the growing threat of vector-borne diseases due to climate change. United Nations Foundation. <https://unfoundation.org/what-we-do/issues/global-health/global-health-resource-center-2/ahead-of-cop28-health-day-addressing-the-growing-threat-of-vector-borne-diseases-due-to-climate-change/>

8. Bhardwaj, D., Ansari, M.W., Sahoo, R.K. et al. Biofertilizers function as key player in sustainable agriculture by improving soil fertility, plant tolerance and crop productivity. *Microb Cell Fact* 13, 66 (2014). <https://doi.org/10.1186/1475-2859-13-66>
9. Manyi-Loh, C., Mamphweli, S., Meyer, E., & Okoh, A. (2018). Antibiotic Use in Agriculture and Its Consequential Resistance in Environmental Sources: Potential Public Health Implications. *Molecules*, 23(4), 795. <https://doi.org/10.3390/molecules23040795>
10. Rahman, M. M., & Riad, F. M. (2024). Impact of health expenditure on universal health coverage (UHC) (composite index): Global evidence. *BMC Public Health*, 24(1), 1-15
11. Roth, G. A., et al. (2020). Global burden of 87 risk factors in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. *The Lancet*, 396(10267), 1223-1249.
12. COVID-19 Mental Disorders Collaborators. (2021). Global prevalence and burden of depressive and anxiety disorders in 204 countries and territories in 2020 due to the COVID-19 pandemic. *The Lancet*, 398(10312), 1700-1712.
13. Balatbat, C., Mundaca Shah, C., & Oppenheim, B. (2025). Pandemic Risk Assessment and its Intersection with Climate Change: Needs, Opportunities, and Design Considerations. Washington, DC: National Academy of Medicine / United Nations Foundation.
14. Bedford, J., Enria, D., Giesecke, J., Heymann, D. L., Ihekweazu, C., Kobinger, G., ... & WHO Strategic and Technical Advisory Group for Infectious Hazards. (2019). Living with risk: COVID-19 and the future of health security. *The Lancet*, 395(10240), 1846-1848.
15. Labrique, A. B., Wadhwani, C., Williams, K. A., Lamptey, P., Hesp, C., Luk, R., & Aerts, A. (2018). Best practices in scaling digital health in low and middle income countries. *Globalization and Health*, 14(1), 103.

الصحة والعلوم والاستدامة: مراجعة متعددة التخصصات لديناميات الأمراض والتطورات العلاجية والتحديات البيئية

الملخص

ترتبط ديناميات الصحة والاستدامة البيئية ارتباطًا وثيقًا. شهدت السنوات الأخيرة تحولات سريعة في أنماط الأمراض، من جوائح مثل كوفيد-19 إلى تزايد الأمراض المزمنة نتيجة للعولمة والتوسع الحضري وتغير المناخ. في الوقت نفسه، يشهد الطب تقدمًا تكنولوجيًا متسارعًا، حيث تُحدث العلاجات والتشخيصات الحديثة والذكاء الاصطناعي نقلة نوعية في الوقاية والرعاية. تؤثر العوامل البيئية، كالتلوث واستخدام الأراضي والتغيرات المناخية، على ظهور الأمراض وتفاقم المخاطر الصحية. تدمج هذه المراجعة مجالات متعددة لدراسة كيفية انتشار الأمراض وتطورها، وأحدث العلاجات والابتكارات الطبية الحيوية، والتحديات البيئية التي تهدد الصحة وتوازن النظام البيئي. نلخص الاتجاهات الرئيسية في علم الأوبئة والنمذجة، ونسلط الضوء على الإنجازات في العلاج والتشخيص، ونستكشف قضايا الاستدامة مثل استخدام الأسمدة وتأثيرات المناخ. تُستخدم التجارب والبيانات العامة، بدءًا من دراسات منظمة الصحة العالمية حول المناخ وصولًا إلى تحليلات OurWorldInData، لتوضيح هذه المحاور. الهدف هو تقديم عرض واضح ومُبسّط للمواضيع المعقدة، مُوجّه لجمهورٍ واسع.

الكلمات المفتاحية: ديناميكيات الأمراض، اللقاحات، المضادات الحيوية، تغير المناخ، الصحة الواحدة، تقنية النانو، مقاومة المضادات الحيوية، الاستدامة.