# Strategic Agenda

V.1.0

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# 5.Purposes of this strategic agenda

PREZODE (PREventing ZOonotic Disease Emergence) is an international initiative that addresses all challenges related to prevention, surveillance, early detection, and rapid response to risks of zoonotic pandemics. This initiative will constitute a scientific and operational framework to coordinate research projects, health networks, and operational activities. With the objective of maximizing the impact of actions against emerging infectious diseases, PREZODE aims to capitalize on past projects and foster synergies with current ones. PREZODE initiated a co-construction process in December 2020 before its launch in January 2021, during the One Planet Summit.

This document is the first strategic agenda of the PREZODE initiative, and is intended to be its research and operational roadmap for the next 10 years. It details the knowledge gaps in research to be filled and the operational activities to be targeted over this timeframe. It also provides a global impact pathway on how PREZODE will contribute to preventing emerging zoonotic diseases and how the impact of the PREZODE initiative will be assessed.

This agenda is the result of a very broad multi-disciplinary participatory consultation, the largest co-design process so far on the prevention of emerging infectious disease risks. It was conducted between January 2021 and June 2022 with the participation of more than 1,800 professionals (i.e., researchers, stakeholders, policy makers) from over 128 countries.

This agenda will evolve dynamically over time. Its first version is based on accumulated scientific knowledge and the operational activities implemented at the time of writing (June 2022). As this topic is rapidly evolving, this agenda will be re-evaluated every two years by the PREZODE Steering Committee and Scientific Advisory Board.

# 6.Intended audience

The target audience for the Strategic Agenda (SA) includes researchers, policy makers, civil society representatives, and any other stakeholders and donors who are interested in or conduct activities related to the fields concerned by One Health (environment, animal health, and public health). These actors share the objective of developing and implementing a joint strategy to prevent the emergence of zoonotic diseases before they spread among human populations, in conjunction with strategies focused on preparedness and response activities (i.e., countermeasures after zoonoses start spreading among human populations). This includes not only the members of the PREZODE initiative, but also the academic/health/NGO/private actors who share these ambitions.

# 7.Executive summaries

Since the early 1970s, more numerous and frequent outbreaks of infectious diseases have been recorded throughout the world. In an increasingly connected world, these outbreaks can turn into global pandemics very quickly. While being prepared for such events is of utmost importance, it is also crucial to model and prevent them. To develop primary prevention strategies, it is of utmost importance to acknowledge that the vast majority of these diseases are zoonoses, i.e., pathogenic agents spilling over from animal species to human populations.

This strategic agenda summarizes the outputs of the large co-design process conducted over 18 months by the PREZODE initiative.

## 7.1. Policy makers

In our highly connected world, spillover events from animals to humans can lead to pandemics within years, or even months. Consequently, preventing the emergence of infectious zoonotic diseases is a top priority, but it requires much-improved international cooperation in assessing, monitoring, and reducing risks of emergence. Prevention strategies save many lives and are far less expensive than controlling infectious disease epidemics. An efficient One Health system is required to prevent zoonotic disease emergence. It should be based on advanced scientific knowledge, efficient monitoring of environmental, animal, and human health, and sustainable control strategies co-designed with stakeholders and local communities. PREZODE is an international initiative that unites countries, research and higher education, health agencies, donors, and international organizations to prevent zoonotic disease emergence. It will deploy academic research and international collaboration in the field via operational actors at the frontlines of outbreaks, in order to envision prevention strategies that reduce emergence risks. The PREZODE initiative will combine:

- A framework for implementing and coordinating research projects, long-term capacity building, and international projects for maximum impact and sustainability. PREZODE will reinforce several surveillance networks, involving local stakeholders to put efficient early warning systems in place.

- A platform for sharing knowledge and data from past, current, and future projects to capitalize on activities worldwide, relying on the international scientific community. PREZODE will scale up and integrate knowledge, innovation, and operational action targeting risk reduction of zoonotic disease emergence across countries at the global scale.

- A resource center for decision-makers to enable public policies that reduce zoonotic disease emergence risks. PREZODE will highlight local examples of ecosystem management strategy that reduce zoonotic emergence risk and encourage economic sustainability. The interoperability of local initiatives promotes balanced, responsible, and resilient socio-ecosystems with greatly lowered infectious disease risks.

## 7.2. Researchers

Many critical research gaps exist. Those concerning the factors driving these zoonoses' emergences need to be addressed quickly, but there is also a crucial caveat regarding the development of integrative prevention strategies. Therefore, many actors desire more transversal academic research regarding the impact of human activities, development of One Health surveillance tools, socio-economic concerns, and interoperability of the data collected. However, to fulfill these actors' needs, this research must also be more translational and connected to those charged with implementing public policies along with ensuring an open science and ethical approach.

PREZODE is based on five pillars; the strategic agenda explores a series of research themes, supporting surveillance, and operational actions for each.

**Pillar 1: Understand the zoonotic risk and risk activities**

- What are zoonotic emergence risks and an interface of risk?
- Who are the players (bugs, hosts, and their environment) and what are the mechanisms in zoonosis emergence?
- What are the main drivers leading to zoonotic disease emergence?
- How can zoonotic disease emergence risks be anticipated?

**Pillar 2: Co-design solutions to reduce the zoonotic risk**

- Using ecosystem conservation to reduce pathogen circulation between wildlife and domestic animals;
- Regulating and tracing activities related to wildlife;
- Innovative livestock management and agriculture systems;
- Design of urban space
- Articulation between all the different approaches and actor engagement

**Pillar 3: Strengthen early warning systems to detect zoonotic risks**

- Assessment of current surveillance systems and practices;
- Context-specific and user-based surveillance systems;
- Innovative surveillance protocols and diagnostic tools;
- Community-based prevention and early warning systems

**Pillar 4: Prototype a global information system for surveillance and early detection**

- Interoperability and sustainability of surveillance systems and global standards;
- Definition of the type of surveillance and objectives of global surveillance, and identification of relevant indicators and data;
- Action plan linked with global surveillance;
- Infrastructures;
- Optimizing efforts to avoid duplication

**Pillar 5 (cross-cutting): Engage stakeholder and co-design One Health networks and policies**

- Community involvement;
- Co-development of health networks and policies through a reinforced dialogue between science, civil society, and policy-makers;
  - Policy engagement and awareness of stakeholders;
  - Dialogue between science, civil society, and policy makers;
  - Co-development and coordination of health networks;
- Promoting One Health approaches and intersectoral collaboration

## 7.3. Donors

Funding is a crucial component of the initiative, as coordinated international investments in One Health are needed. Several considerable gaps must be addressed. First, more transversal mechanisms, i.e., focused on multiple arms of the One Health approach, would mean a more significant impact on the ground. Additionally, the short-term perspective of this funding is problematic for operational activities and academic research in the design and implementation of new primary prevention strategies. Besides research and surveillance activities, cross-cutting dimensions need funding, including:

- capacity building;
- local communities training;
- promoting One Health at schools and universities;
- laboratory capacity building;
- redesigning policy interventions to support One Health;
- data collection, sharing, and analysis.

### PREZODE Theory of change and impact pathway

**IMPACT - PREZODE** aims to support countries and international collaboration in developing innovative and context-based solutions to avoid animal-borne pandemics, while simultaneously ensuring food security and livelihoods for poor communities

**LONG-TERM Outcomes** - These solutions lie in building resilient socio-ecosystems and reducing pressure on biodiversity and environmental health; empowering local communities in the reduction and early detection of emerging risks; better collaboration between sectors and partners from local to global levels; strong political engagement and evidence-based OH policies that maintain ethical practices and equity within countries and across borders.

**MEDIUM-TERM outcomes -** To reach such targets, long-lasting changes are needed, including science-based One Health policies co-developed and implemented by local actors and policy makers and adapted to local contexts; practices which preserve environmental health and reduce emerging risks, co-designed by relevant actors ; collaboration between operational, research, and development agencies and donors at all levels to ensure resource optimization via synergized actions; avoiding redundancy with PREZODE's coordination strategies or other collaborative tools; a constant dialogue between science, society, and policy to ensure One Health measures and strategies are relevant and acceptable , via in-country dialogue platforms.

**ACTION TRACKS** - Reaching such targets would require an integrated approach to health that combines six main action tracks and 24 different types of high-level actions. This approach would enable (1) understanding risks and risk practices (e.g., by looking at the socio-economic and political drivers of emergence and actor interactions) in order to (2) inform co-designed, adapted, and efficient solutions that reduce risks and environmental pressure (e.g., improving land use through design of urban space); (3) strengthening early warning and surveillance systems, building on existing systems, and promoting user-based improvement that relies on a co-designed socio-economical assessment of user needs and constraints; (4) ensuring information sharing and early warning alerts at all geographic scales through system interoperability and international collaboration. All of these objectives will require (5) promoting actor engagement and collaboration through co-designed One Health policies and a permanent dialogue between science-society and the political realm. (6) Ethical practices must be ensured at all levels and sufficient training, including training and trainers, is needed to build up-long term in-country capacities and funding support mechanisms that ensure sustainable actions.

**STRATEGIES** - Such action tracks will be implemented through PREZODE's three main strategies, combining a sound scientific framework, actor engagement, and international collaboration and support with: a scientific and evidence-based reference framework to encourage innovative OH policies; international collaboration and synergies between actions from local to global levels; and technical and financial support of research and development programs that promote PREZODE's desired paradigm shift toward zoonotic risk prevention, via a bottom-up approach.

# 8.Introduction

## 8.1. Emerging zoonotic diseases cause a major health burden

With roughly billion yearly cases and millions of annual deaths, epidemic and endemic zoonoses are among the greatest burdens to human health and livelihoods, causing recurrent and persistent regional health problems worldwide (Karesh et al. 2012, Morens and Fauci 2020). Zoonotic diseases pose a significant threat to global health and security and have caused hundreds of billions of US dollars of economic damage over the past 20 years (Smith *et al.* 2019); this number continues to increase with the current COVID-19 pandemic, estimated to have cost more than US $11.7 trillion as of 2020. Zoonotic agents also represent the largest number of human pathogens (Murray *et al.* 2018), and projections suggest a significant (Anthony *et al.* 2013).

Emergence events require the alignment of multiple drivers and conditions, ranging from reservoir and host distribution to adaptation to humans (Figure 1). Therefore, focusing only on the human link in the transmission chain overlooks the benefit of upstream intervention and the development of prevention strategies that would target the roots of these emergence events (Bernstein et al, 2022).

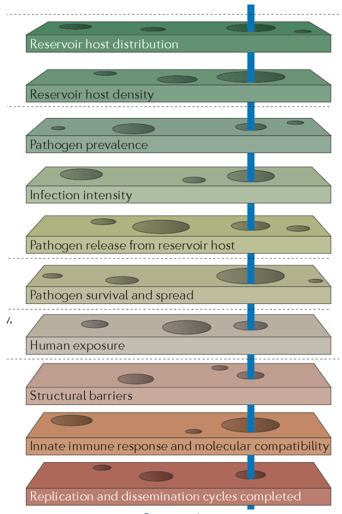


***Figure 1.*** *Set of conditions required to observe zoonosis spillover and creating opportunities to prevent it. From Plowright et al, 2017*

The prevention of pandemic crises requires ambitious scientific and operational programs dedicated to preventing zoonotic disease emergence, ideally before human populations are affected, thus allowing the design of sustainable science-based prevention policies.

## 8.2. A strong link between human activities and emerging zoonotic diseases

Over the past several decades, the world has seen many emerging zoonotic diseases (i.e., those due to newly identified and previously unknown infections, which cause public health problems either locally or internationally), such as COVID-19, avian influenza, SARS, MERS, hantavirus infections, henipavirus infections, West Nile encephalitis, Rift Valley fever, Lyme borreliosis, and leptospirosis, among many others. Their emergence has been strongly linked to changes in host communities that affect the natural dynamics of the pathogen(s) and subsequently allow them to exploit new niches and adapt to new hosts (Gibb *et al.* 2020, IPBES, 2020). In most cases, the underlying causes of new opportunities for zoonotic spillover and propagation are mediated by anthropogenic activities that may create new conditions for transmission and expose their actors to new environments and pathogens. These include changes in land use (e.g. deforestation, urbanization, agricultural practices, habitat homogenization, natural resource extraction, bushmeat hunting), animal production systems (e.g. highly intensive production systems of domestic or wild animals, mixing of traditional backyard and intensive animal production systems, development of free-range production due to societal demand for animal welfare), modern transport and global trade (Smith & Guégan, 2000) as well as increased human outdoor activities due to lifestyle changes. These changes may increase the transmission risk of infectious diseases between animals (enzootic/epizootic), between animals and humans (zoonosis), and from humans to animals (zooanthroponosis leading to the creation of potential reservoirs) in the near future.

Therefore, zoonotic disease emergence and spread do not depend solely on a pathogen's characteristics. Rather, they reflect dynamics across scales within socio-ecosystems, which include humans, biodiversity and evolution, pathogens, and human activities (*Lancet* special series on zoonoses 2012, Morens and Fauci 2020, *Lancet* editorial 2020). While infectious diseases are necessarily caused by infectious agents, disease emergence and spread are also determined by factors related to hosts and vectors, host-environment interactions, and *in situ* human activities and practices (Engering *et al.* 2013).

For example, agricultural activities may impact infectious disease emergence through several mechanisms. First, they can alter important natural habitats, especially in tropical forests, and lead to the loss of ecosystem services and functions (Rockström *et al.* 2009, Venter *et al.* 2016, Weinzettel *et al.* 2018). Second, increases in animals raised for food provide growing opportunities for contact between pathogens and animals (Slingenbergh *et al*. 2018) and between animals and humans. Finally, greater human demand for space and food supply has led to increased contact between humans, wildlife, and domestic animals, thus creating opportunities for interspecies pathogen transmission in new ecological contexts (Craft 2015).

The alteration of biodiversity, which is strongly linked to deforestation and wildlife trade among other elements, is also highly correlated to zoonotic disease emergence (Keesing *et al*. 2010; IPBES, 2020). For example, according to the dilution effect theory, high vertebrate diversity may be associated with low circulation of a given pathogen, as most of these vertebrate species will be dead-end hosts (i.e., unable to become infectious) and will thus "dilute" pathogen transmission (Roche and Guégan 2011). The dilution effect has been proposed to explain the transmission dynamics of several pathogens, including those causing West Nile encephalitis and Lyme disease in the United States, and hantavirus in Europe (Ostfeld and Keesing, 2012). However, the expected decrease in pathogen circulation with higher biodiversity can be outweighed by the "biodiversity paradox" (Hosseini *et al.* 2017) since each vertebrate species will bring its own pathogens into the ecosystem. Therefore, biodiversity conservation could both reduce the transmission of single pathogens and maintain a higher number of circulating pathogens, making it difficult to predict the disease outcomes of biodiversity conservation strategies.

While human activities threatening biodiversity are among the most direct factors driving zoonotic disease emergence, these activities are also contributing to other human health threats such as climate change, which may in turn affect biodiversity as well as animal and human health, thus creating 'vicious circles'. It is therefore more important than ever to synchronize research and set up global synergies between operational agendas against zoonotic disease emergence, climate change, and biodiversity loss in the post COVID-19 era. A key step towards this goal is assessing the costs and benefits of different socio-ecosystems by simultaneously considering agricultural practices, socio-economic activities, local populations' social and economic well-being, various environmental impacts, and emerging disease threats, as suggested for sustainable food production (Clark *et al.* 2019). However, we do not know if the same is true for zoonotic risk reduction (Roche *et al.* 2020). Current scientific literature lacks such information, and this hampers the development of truly transversal programs.

Zoonotic outbreaks have increased over the last 30 years, even after controlling for the confounding effects of reporting (Smith *et al.* 2014, Vourc'h *et al.* 2021). This suggests that incursions by zoonotic pathogens into human populations are increasing, which implies that human behaviors and practices may have reached a threshold in their relationship with nature. Therefore, such emergences need to be better understood at the local and regional levels, as disease control methods (such as therapies and vaccines) are unlikely to prevent increases in zoonotic outbreaks and future pandemics (Dobson *et al.* 2020).

## 8.3. Early detection systems, surveillance strategies, and One Health approaches

No single strategy is expected to be 100% effective in preventing disease emergence; consequently, other safety nets are required to control the spread of unexpected emerging zoonotic diseases. Therefore, a major requirement for the implementation of "scientific evidence-based prevention policies" is to provide robust, cost-effective, and sensitive pathogen surveillance in wild and domestic animals, and install early warning systems for infectious disease outbreaks in animals and humans. This approach allows a rapid response to emerging zoonotic diseases at the source (Zinsstag *et al*. 2020) and thus increases the effectiveness of interventions. It also illuminates trends and changes in the patterns of emerging diseases and helps develop cost-effective multisectoral response plans. However, many surveillance systems fail to capture signals at the intersection between populations of wildlife, domestic animals, and humans early enough to avoid further spread after the first cases of disease appear, and the long-term sustainability of such surveillance creates further difficulties (Bisdorff *et al*. 2016). Passive surveillance of zoonotic diseases has been shown to lead to underreporting and bias, while the high cost of active surveillance via field surveys leads to low spatial and temporal coverage (Hattendorf *et al*. 2017). In addition, the implementation of rapid detection methods, surveillance, and health system infrastructure could be improved at the local level. However, evaluation of the performances and processes of such surveillance systems to implement relevant corrective actions are not systematically performed (Peyre and Goutard, 2022). Surveillance system needs to be tailored based on the socio-economic constraints and needs of local actors who are implementing it (Machalaba et al. 2017). This would reduce the time needed to detect emerging pathogens and increase our ability to implement decisions on both regional and national scales in order to reduce epidemic and pandemic potential (Bird & Mazet 2018). One Health community-based surveillance with actors from the environmental health, animal health, and public health sectors can detect early warning signals of rare events through cross-cutting information exchanges (Guenin *et al*. 2022). An example of this type of exchange is in the case of unusual and/or coinciding cases of animal and human morbidity and mortality.

## 8.4. The One Health landscape for zoonoses

### *Institutionalization of One Health*

Zoonoses and their associated risk factors illustrate the interdependence of human health, the animal world (domestic and wild), and environmental health. Over the past several decades, different actors and scientific fields have developed a holistic and transdisciplinary approach to health in response to zoonotic diseases. UN agencies have adopted the One Health approach, which embodies health collaboration at the human-animal-ecosystem intersection. Since 2021, the Quadripartite alliance (involving the WHO, WOAH, FAO, and UNEP) has been active, and is currently the closest thing to an "institutional face" of One Health.
Under the impetus of France and Germany, the Quadripartite launched the One Health High Level Expert Panel (OHHLEP) on 17 and 18 May 2021, which aims to produce policy recommendations on the prevention of and response to future health crises and inform citizens about the issues at stake. The OHHLEPP's first priority was to develop a One Health definition with consensus across sectors that is inclusive and relevant for a global audience (OHHLEPP *et al*. 2022).

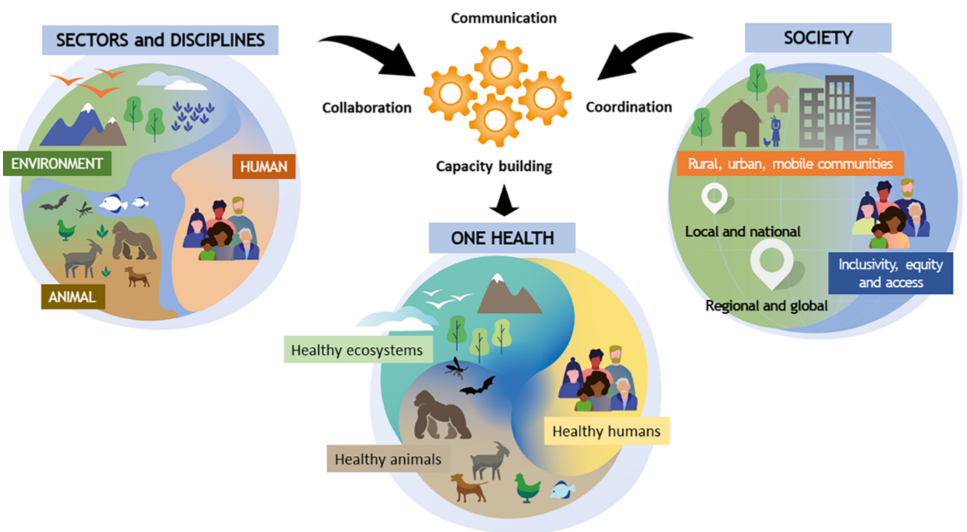


***Figure 2.*** *One Health toward a sustainable healthy future as developed by the OHHLEP. From OHHLEP et al, 2022*

This new definition is based on several fundamental principles such as equity, inclusivity, equal access, parity, socioecological equilibrium, stewardship, and transdisciplinary (see "Key definitions" in appendixes).

As a first concrete joint action, the quadripartite published recently the first One Health joint plan of action. This plan on One Health provides a set of activities to create a framework to integrate systems and capacity so that we can collectively better prevent, predict, detect, and respond to health threats. Ultimately, this initiative seeks to improve the health of humans, animals, plants, and the environment, while contributing to sustainable development. The PREZODE strategic agenda is presenting possible synergies with this plan.

### *International initiatives*

Over the past 15 years, international One Health initiatives have focused on capacity building, surveillance systems at the human-livestock interface, and mapping hotspots of disease emergence (Laury *et al.* in prep.). However, numerous key activities have been neglected, such as disease emergence prevention strategies, stakeholder engagement, consideration of the environment/biodiversity dimension for risk reduction in the pre-emergence phase, and early detection at the human-animal interface.

In the light of a significant worldwide increase in One Health initiatives to address the relationships between human health, animal health, and the state of the ecosystems on which humans and animals depend, a systematic and comprehensive overview of what is actually being done is sorely lacking. An initial bibliometric analysis revealing these weaknesses is described below, together with a synopsis of national and international funding.

A meta-analysis based on 2,430 search results (Khan *et al.* 2018) identified 100 One Health networks (86 formed since 2005) in Asia, Africa, and Europe. Most networks (64%) operated at national or regional levels, but not across regions or continents (only 2% operated in all three regions concerned). One third of One Health networks addressed only human and animal health without taking into account the environmental and sociological components that are usually the Achilles' heel of these initiatives. Seventy-height networks involved academic bodies and/or governmental entities. The private sector was involved in only 23 networks; community groups were involved in only 10. Only four networks from emerging countries collaborated and 15 provided information on monitoring and evaluation. Overall, the majority of One Health networks have made efforts to support communication, collaboration, information sharing, and capacity building; however, they have suffered from weak stakeholder representation, insufficient or deficient monitoring in terms of sampling strategy, lack of evaluation structures, and potential duplication between local and regional actions. One Health networks' functioning could benefit from collaborations and environmental studies led by low- and middle-income countries (LMICs), an essential yet often missing pillar of One Health.

## 8.5. Scope of PREZODE: the need for a paradigm shift

Although the vast majority of emerging infectious diseases in humans are zoonotic in origin, current dogma focuses on post-spillover responses to best limit spread among humans, rather than preventing spillover at the source.
As infectious agents know no borders, preventing the emergence of zoonotic diseases must be inclusive and requires international collaboration. However, one size does not fit all: the prevention of zoonotic disease emergence must be based on the concerns and needs of local communities and frontline actors. Co-construction and two-way capacity building are fundamental principles to integrating local specificities, raising awareness, and generating strong, sustained commitment.

Public policies to prevent disease emergence are efficient when they are science-based. Research on zoonosis emergence as well as policies and impact analysis is essential to better enable the world to deal with zoonotic risks.

Preventing zoonotic disease emergence is a cross-sectoral issue that encompasses many challenges, such as biodiversity loss, agricultural development, land use, and climate change, as well as human behaviors and exposure (wildlife trade or the encroachment of people or livestock on natural habitats).

Through a co-constructive and bottom-up approach, the PREZODE initiative aims to develop evidence on zoonosis emergence that supports the implementation of prevention and epidemiological surveillance strategies. This approach can, in turn, mitigate the likelihood of future pandemics. To reach this goal, the initiative utilizes an integrated, interdisciplinary, and cross-sectoral approach involving human, animal, and environmental health actors in research, policy-making, and fieldwork at local, regional, and global levels. The environmental, societal, economic, ethical, and political factors that characterize a socio-ecosystem influence the emergence of zoonotic diseases. In this context, PREZODE's objective is to understand the drivers and risk factors associated with zoonotic disease emergence, the underlying ecological and epidemiological mechanisms, and how to detect and mitigate these events as early as possible. The emergence factors are numerous and will be considered in the context of global changes (cf. section 9.2.). The PREZODE initiative will seek to foster systems-based approaches in order to better integrate processes both locally and globally. Understanding complex local interactions and their further integration at a larger scale may avoid the misattribution of observed patterns to global variables.

The PREZODE initiative will conduct research on the pre-emergence and emergence phases (Figure 3) with a clear focus on prevention strategies developed through a participative approach both with and by local actors. Research activities will focus on the emergence risks linked to local and global changes, the development of sustainable prevention strategies through livestock and/or ecosystem management, and the development of early warning systems at all geographic scales.

The PREZODE initiative will also conduct research on policy analysis in term of cost-benefit and impact analysis and understanding of mechanisms that could help to translate the outputs on spillover science into practical policy.

Via a One Health approach, the PREZODE initiative aims to develop a research framework to understand the macro processes and drivers that lead to zoonosis emergence within a context of global changes. This will be conducted by studying the ecology and evolutionary history of pathogens and hosts, as well as the socio-environmental mechanisms that bring humans and animals together. Doing so will enable strategies that aim to minimize human exposure to zoonotic pathogens and, ultimately, foster the prevention of zoonotic disease emergence.

To achieve its goals, the PREZODE initiative will focus on:

- zoonotic pathogens that could emerge (because of characteristics such as host shifts or antibiotic resistance, increased pathogen circulation within ecosystems, and/or the human-animal interface where they circulate),
- Zoonotic pathogens that have already emerged (e.g, COVID, MERS-COV, animal influenza),
- Zoonotic pathogen that could re-emerge (e.g., Ebola, Rift Valley Fever).

All types of pathogens circulating worldwide will be addressed. This includes pathogens from wildlife and domestic animals in both terrestrial and aquatic environments. Similarly, all of the different transmission pathways between animal species and human populations (e.g., through vectors, food, environment, direct contact with infected animals, etc.) will be considered.

### *What is not in the scope of the PREZODE Initiative?*

All processes **related to the post-emergence phase of pathogens in human populations**, as well as approaches that aim to improve the epidemiological response (such as the development of vaccines and drugs, improvement of contact tracing, and isolation), fall outside of the scope of the PREZODE initiative. However, studies and pre- and post-emergence surveillance require significant synergy and complementarity between them, as do approaches toward prevention, preparedness, and response like the development of innovative diagnostic solutions or integrated data systems.

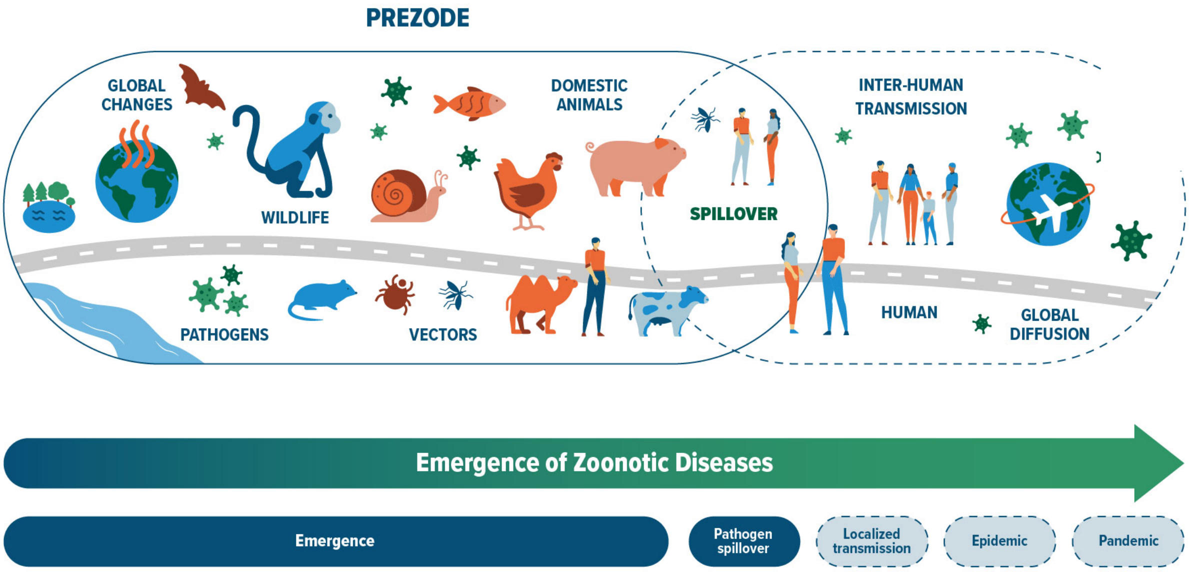


***Figure 3.*** *The need for a change in paradigm: Towards prevention and bottom-up approaches – Figure modified from "Zoonoses, ces maladies qui nous lient aux animaux » (1st Edition). Vourc'h G., Moutou F., Morand S., and Jourdain E. (2021) Editions Quae.*

## 8.6. The five pillars of PREZODE

To support international organizations and countries across the globe in preventing zoonotic disease emergence and spread, particularly in low-income countries, PREZODE will develop a framework shift to envision innovative prevention strategies, on the basis of five pillars:

- **Pillar 1**: Understand the zoonotic risk and risk activities
- **Pillar 2**: Co-design solutions to reduce the zoonotic risk
- **Pillar 3**: Strengthen early warning systems to detect zoonotic risks
- **Pillar 4**: Prototype a global information system for surveillance and early detection
- **Pillar 5** (cross-cutting): Engage stakeholders and co-design One Health networks and policies

Syntheses of the research and operational needs of each pillar are detailed in sections 12 and 13.

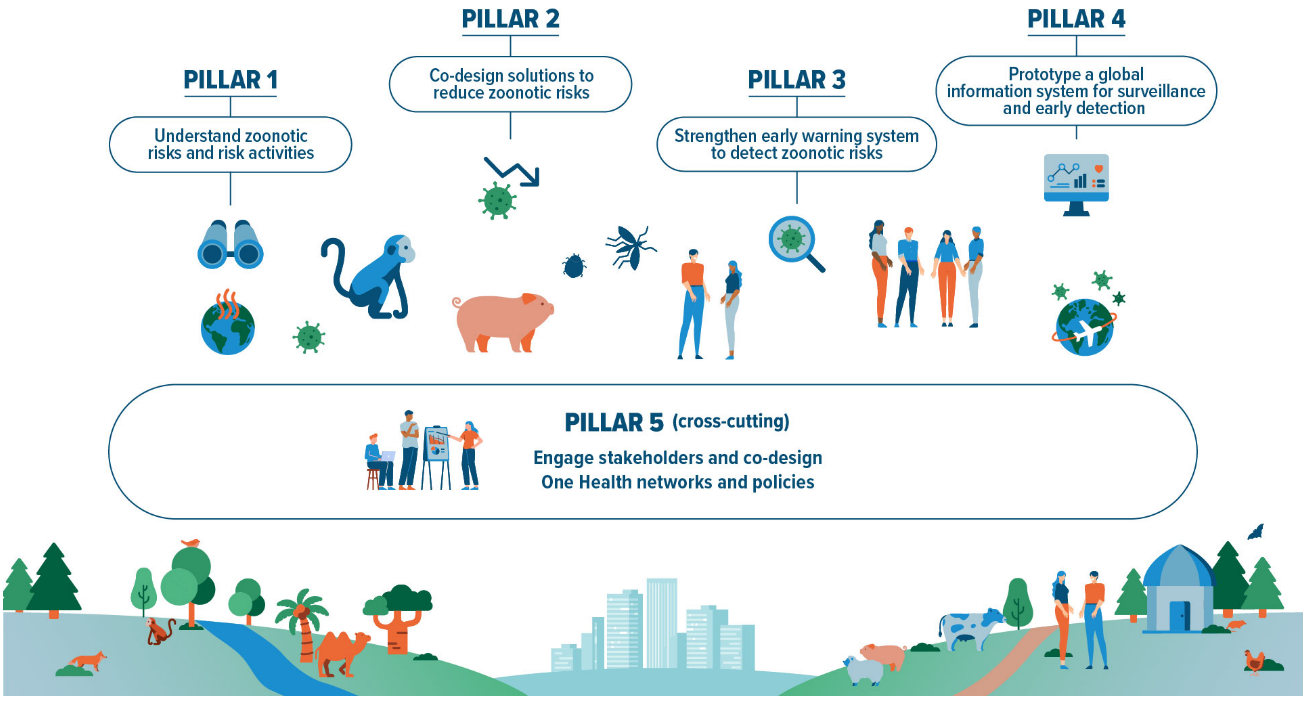


***Figure 4.*** *The five pillars of the PREZODE Initiative.*

# 9.Methods for co-designing PREZODE's strategic agenda

One of the PREZODE initiative's main ambitions is a co-construction process that engages all stakeholders involved in the prevention of emerging risks. These stakeholders include health professionals (from the animal, human, and environmental sectors), researchers, field operators, and decision makers from both the private and public sectors at all geographic scales. This co-construction approach is required to define the initiative's mission and visions and the generic scientific framework, knowledge gaps, and operational needs, adapted to all regions of the world. It is also needed to further implementation methods and impact pathways in each region.

The PREZODE co-construction approach was implemented through a series of regional and international workshops that required (1) identifying key participants, (2) organizing online workshops, (3) an exhaustive synthesis of ideas, and (4) a transparent review and validation process (Figure 4).


***Figure 5.*** *PREZODE co-construction steps*

## 9.1. Identification of key scientists and stakeholders

The first step identified key stakeholders and scientists relevant to the different co-construction workshops (regional and international).

For the regional workshops, the aim was to ensure the representation of key regional and national actors from the academic, government, and private sectors of international organizations at the co-construction workshops. Therefore, we first invited these key actors; they subsequently identified other relevant actors through a snowball approach (Sadler *et al.* 2010) and were asked to forward the invitations to those identified. The invited participants were relevant local and international stakeholders from the animal, human, and environmental health sectors who deal with preventing zoonosis emergence. They included decision makers, researchers, field operators (from NGOS and the private and public sectors), governmental institutions, and academic fields. They were identified through the PREZODE network, namely via regional focal points and the PREZODE internal team. The PREZODE internal team sent more than 1,500 invitations to regional workshops.

For the international scientific workshops, the aim was to ensure the international scientific community of experts' representation in the scope of PREZODE. We first conducted a bibliometric analysis to identify scientists who contributed significantly to zoonotic disease emergence prevention in the past 10 years. These scientists then identified other relevant participants through a snowball approach (as with the regional workshops). Invited participants were asked to forward the invitations to other relevant actors in their networks. Scientists from the regional workshops were also invited.

## 9.2. PREZODE co-construction workshops

To co-construct the initiative, regional workshops were organized in order to 1) define a common vision of the initiative, its main objectives, expected impacts, and obstacles; 2) identify relevant actors and needed changes in practices; and 3) identify the activities to implement to promote such changes (research, operational, capacity, and policy needs). We then identified the main research and operational needs through a literature review of international reports[1] . Finally, during the international scientific workshops, more than 160 international scientific experts (identified using bibliometric analysis and selected from regional workshops) completed the list of research gaps identified from international reports and the regional workshops.

### *Regional workshops*

These workshops had specific objectives and deliverables that were iterative from workshop to workshop. This iterative co-construction method is based on the principles of the theory of change, which consists of identifying expected impacts, necessary actions and changes, and the actors involved in these changes (Blundo Canto *et al.,* 2020).

[1] Biodiversity in post-covid cross-sectoral challenges, EKLIPSE (2021); Nature, biodiversity and health: an overview of interconnections. WHO (2021); Report of the scientific task force on preventing pandemics at the source, Harvard (2021); Situation analysis on the roles and risks of wildlife in the emergence of human infectious diseases. Kock., R. and Caceres-Escobar, H. (2022); Workshop Report on Biodiversity and Pandemics of the Intergovernmental Platform on Biodiversity and Ecosystem Services. IPBES (2020); Tripartite guide on zoonosis; The 2021 report of the Lancet Countdown on health and climate change (2021) Lancet, The Natural Environment and Health in Africa, Smithsonian Institution, (2021)

Regional workshops following a standardized participatory method (adaptation of IMPRESS ex ante [Blundo Canto *et al.*, 2020] and ASIRPA [Colinet *et al.*, 2014] methods at a large international scale) were implemented in 10 regions of the world defined on the basis of regional similarities in their socio-economic profiles, ecosystems, and zoonosis emergence risk:

- Central Africa
- Europe
- Indian Ocean
- Latin America and the Caribbean
- Northern Africa/Middle East
- Southern Asia
- Southeast Asia/East Asia and the Pacific
- Southern and Eastern Africa
- USA/Canada
- Western Africa

Workshop participants aimed to 1) define a common vision of the initiative and its main objectives, expected impacts, and obstacles; 2) identify the relevant actors and the changes in practices needed; and 3) identify activities that would promote such changes.

These steps led to the identification of impact pathways, which consist of identifying problems and needed changes as well as the actors essential to implement the intervention. Examining these impact pathways led to the identification of the research gaps and operational needs.

Regional workshops took place online. Participants' input was collected via digital sticky notes and discussion (oral and chat). Workshop facilitators were international researchers from different institutions, regional focal points involved in constructing PREZODE, and researchers from the internal PREZODE team. Through regular meetings, they actively participated in implementing the method used in the workshops and inviting participants in their networks. They received a briefing on the methodology few weeks before the workshops.

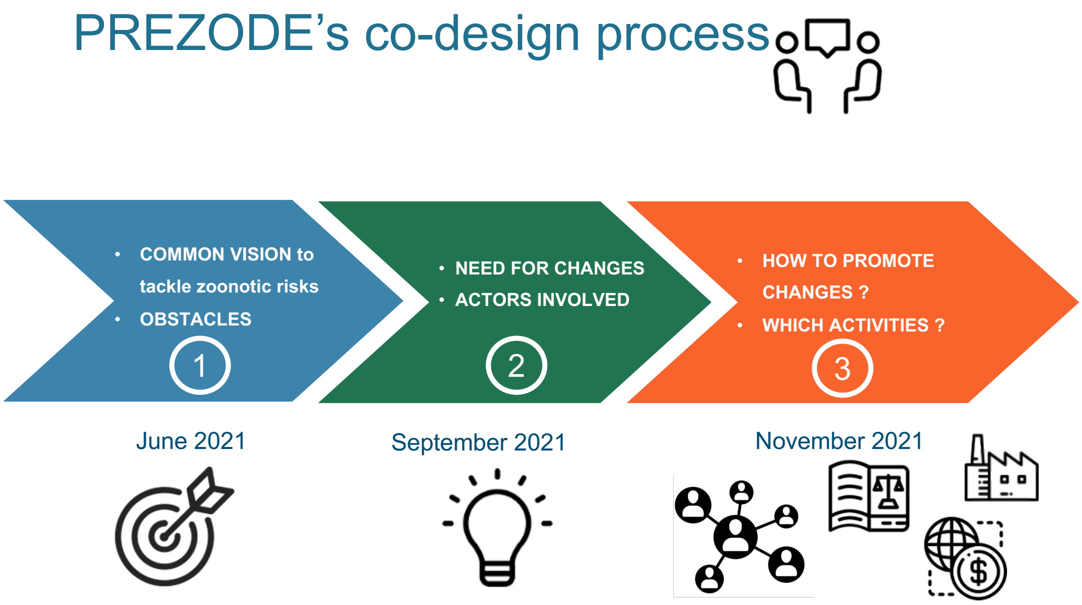


***Figure 6.*** *The 3-step PREZODE co-design process for regional workshops based on the theory of change*

### *International scientific workshops*

The two scientific workshops were intended to co-construct the PREZODE strategic agenda's scientific base by identifying and building a research plan across PREZODE's five pillars. As with the regional workshops, international workshops were hosted online and participants' input was collected via digital sticky notes and discussion (oral and chat). International researchers from different institutions and researchers from the internal PREZODE team facilitated the workshops.

The international workshop was organized into two sessions (Figure 6). During the first session, participants were asked to share research gaps and operational needs related to the five pillars. As a result, 756 research gaps and operational needs were identified. For the second session, these research gaps and operational needs were synthesized and categorized into three themes:

1. Wildlife, biodiversity, and land use in a changing climate
2. Livestock, production schemes, and animal-based food systems
3. Urbanization: green cities and human demographic development

Participants were asked to brainstorm imaginary projects based on these three themes using the research gaps and operational needs identified during the first session. The objectives were a transversal approach identifying possible links between pillars.

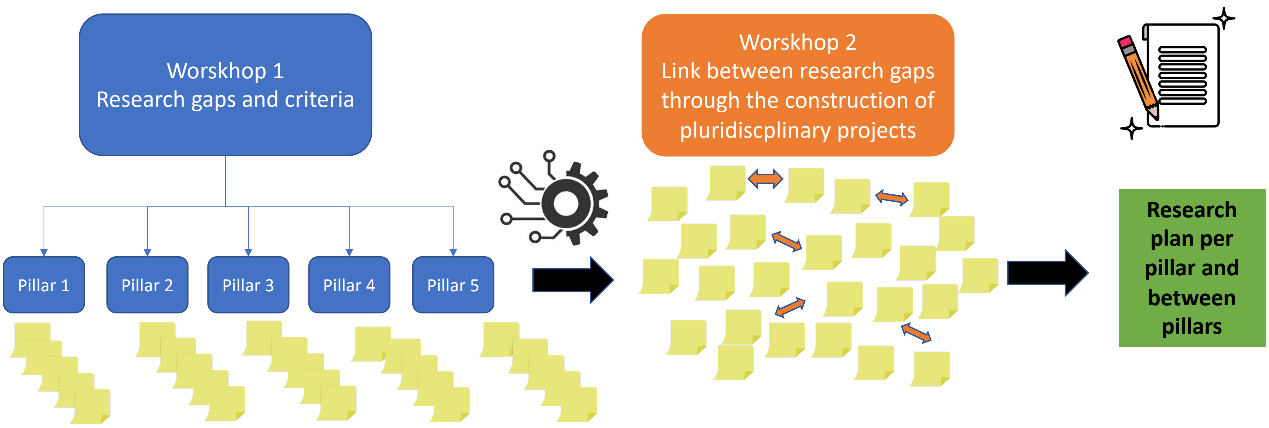


***Figure 7.*** *International scientific workshops process*

## 9.3. Data collection, analysis, and synthesis of ideas

Approximately 1,800 contributors (i.e., persons that registered or participated to one of the workshops) from 128 countries were identified throughout the workshops. In addition to the international scale of this process, participants/actors represented different sectors, bringing intersectorality to the co-construction process. Participants' contact data (email addresses, names, institution of origin) were anonymized so only the number of participants per type of sector was documented, in compliance with the General Data Protection Regulation. Participants were informed that their contributions were recorded, anonymized, and analyzed as aggregated data to draft the strategic agenda of the initiative. They could access their contributions or request to be deleted from the database at any time. They also retained rights to rectify, refuse, and limit the use of their contributions.

1527 workshops outputs were gathered in a unique database and categorized by thematic areas and pillars. Data from all the workshops were compiled in an Excel database prior to analysis ( https://doi.org/10.7910/DVN/2EB8AM ) . The research gaps and operational needs that participants shared were aggregated through an exacting review of the workshop recordings. 152 comments were deleted because a lack of clear information. For the sake of transparency, the chronological order of the comments has been respected. To ease synthesis, the data were sorted out per pillar and placed into 10 categories:

- Understanding ecosystems and disease emergence
- Predictive methods
- Surveillance systems and participatory approaches
- Data management
- Gender equality, diversity, and inclusion;
- Innovative diagnostic methods

- Community engagement and inclusion
- Indicators and impacts
- Framework
- Science and policy interface

Research gaps and operational needs were extracted from this database and synthesized into this agenda.

## 9.4. Review and validation

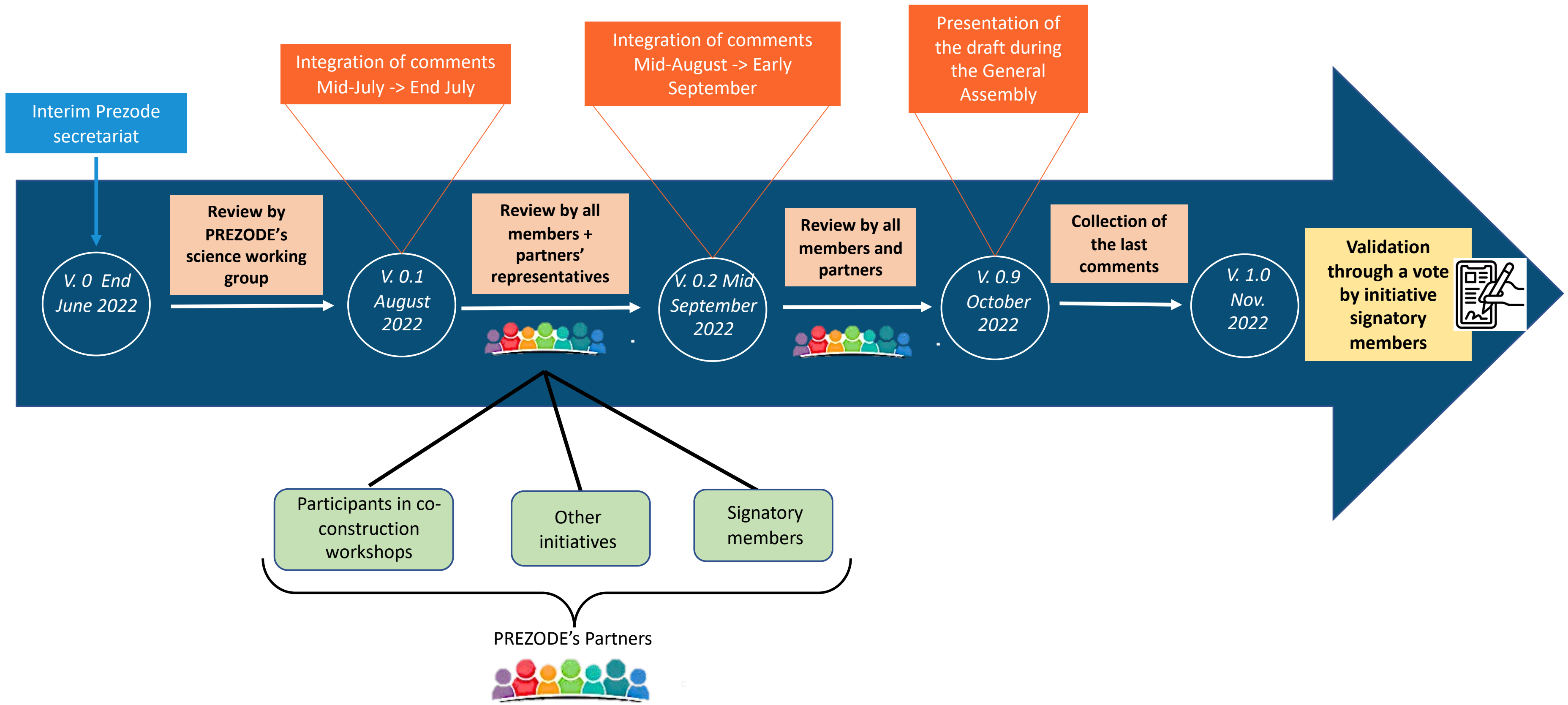


*Figure 8. Review and validation process of the strategic agenda*

The results of the synthesis of the workshop outputs are first presented in the section "Vision and Mission of the PREZODE Initiative", then addressed by pillar in subsequent sections.

# 10. Vision, Mission, and Guiding Principles of the PREZODE Initiative

The following sections were developed based on the outputs from the regional workshops, in which participants were asked to define a common vision of the initiative and its main objectives, expected impacts, and obstacles.

## 10.1. Long-term vision of PREZODE

PREZODE envisions a world where:

The risk of new zoonotic pandemics is reduced and healthy populations are in tune with a healthy planet, recognizing that human, animal, and environmental health are truly linked.

Current trends in increasing zoonosis risk associated with encroachment on natural habitats, intensification of livestock production, and wildlife trade and consumption have been reversed. Infectious disease risks have been reduced, while the food system and healthy, affordable diets remain resilient.

Public policies and market and trade mechanisms worldwide promote sustainable land management practices and develop for food security alternatives that encourage sustainable coexistence between agriculture and other forms of land use by humans and wildlife.

## 10.2. By 2030

PREZODE has helped reduce the upward trend of emerging zoonoses through preventive actions designed jointly with all relevant stakeholders.

PREZODE has fostered efficient early warning systems for detection and rapid actions to counter emerging diseases on all geographical scales. These early warning systems have been jointly developed through a One Health approach and, consequently, are interoperable and involve all stakeholders and communities, which increases awareness.

PREZODE has promoted developing scientific methodologies to characterize innovative strategies for managing societies and their ecosystems. Such methodologies limit the emergence risks and make societies and ecosystems more resilient to the zoonotic disease emergence while ensuring food security.

PREZODE has developed and promoted synergies with regional and international initiatives focusing on the prevention of zoonotic diseases and/or their drivers (i.e., global changes).

## 10.3. Mission

To achieve this vision by 2030, the global community must unite in establishing sustainable prevention strategies for zoonotic diseases. We are only as safe as the weakest link in the global One Health system; hence, such a mission must be coordinated, participated in, and agreed upon at the international level.

PREZODE aims to improve the identification of drivers and understanding of the mechanisms that lead to zoonotic disease emergence in complex socio-ecosystems. This improvement would help in identifying the main biological, ecological, and socio-economic drivers that influence emergence risks and human societies' response capacities.

PREZODE will strengthen effective engagement and integrate local people's knowledge, innovation, capacity building, and operational actions to jointly reduce risk and rapidly detect the emergence of zoonotic diseases on all geographical scales.

It will deploy academic research and cross-sectoral collaboration in the field, and engage operational actors on the frontlines of epidemics in evaluating strategies to prevent emerging risks.

The PREZODE initiative will combine:
- An integrated health and scientific framework for the implementation and coordination of research programs, surveillance networks, and operational projects, aiming for maximum impact.
- A platform for sharing knowledge from past, current, and future projects or programs and capitalizing on activities in different regions of the world.
- A resource center for decision-makers to enable public policies aimed at reducing zoonotic disease emergence risks.

## 12.4. PREZODE’s guiding principles

The PREZODE initiative identified a set of values to guide the initiative implementation by all the members. The initiative’s principles aim for a common vision of PREZODE's implementation.

**Cooperation and co-construction**: The PREZODE initiative is built on synergies and partnerships between members and stakeholders. It aims to shift the paradigm via an international multi-disciplinary scope and design process that acknowledge different ideas and contexts. The PREZODE initiative emphasizes cooperation and supporting member efforts as essential to addressing zoonotic disease emergence challenges.

**Transparency**: The PREZODE initiative is built on collaboration and transparency is expected between members, stakeholders, and beneficiaries. Projects, actions, experiences, and knowledge aims must be shared on a common platform for the benefit of all.

**Inclusiveness and diversity**: The PREZODE initiative aims to enhance both aspects at every level. Only by a wide and inclusive representation will a wider vision arise as well as a focus on local challenges and adapted solutions. The PREZODE initiative supports participatory approaches to ensure empowerment of the communities in developing innovative and comprehensive solutions and their adoption.

**Gender equality**: The PREZODE initiative takes gender equity and gender-sensitive perspectives into consideration. Both are key drivers of the initiative's success.

# 11. Synthesis of research gaps and operational needs per pillar

The following sections synthesize the outputs from the co-design process for each pillar. Themes that are transversal across pillars will be described in section 13. The numbers used as references provide unique identifiers for the corresponding outputs in the co-designed database. These outputs have been organized by the topics identified by the writing committee.
The research and operational needs described below constitute an exhaustive list by workshop participants to prevent zoonotic disease emergence, which is PREZODE's main goal. Not all activities identified will necessarily be implemented by the PREZODE initiative.

## 11.1. Pillar 1: Understand the zoonotic risk and risk activities

### *THEME 1: What is a zoonotic emergence risk and an interface of risk?*

In order to address the issue of zoonotic disease emergence risk and risk interfaces, it is first and foremost crucial to define and understand some concepts. Besides a few definitions warranted in this context, such as "outbreak", "zoonosis", "interface of risk"[2], and "risk areas"[3], there is a clear need for tools and criteria to better define these concepts in order to help prevent zoonoses and find solutions[4]. For instance, the decision criteria for what makes a threat serious enough to warrant alerting international authorities and what constitutes a Public Health Emergency of International Concern (PHEIC)[5]. Tools are also needed to assess the emergence risk and transmission of unknown pathogens[6].

### *THEME 2: Who are the players and what are the mechanisms (the bugs, hosts, and environments) in zoonosis emergence?*

A first challenge lies in discovering new potential zoonotic agents, and evaluating their zoonotic potential, putative hosts, and vectors[7]. This requires combining empirical, experimental, and modeling approaches[8] based on genomic, ecological, environmental, and epidemiological data.

A second challenge concerns analyzing the underlying processes of circulation among animals and the passage of pathogens between animals and humans[9]. This includes a variety of eco-evolutionary processes. First, this facilitation can be the result of different population dynamics phenomena[10], such as geographical distribution[11], immunity interaction of hosts and pathogens, and landscape-dependent variations[12]. Moreover, this spillover can be also the result of interaction between individual specificities and population processes, such as microbiomes, host behavior, the adaptive capacities of hosts and reservoirs[13], eco-epidemiological factors (environmental persistence, shedding, dynamics)[14], and the evolution[15] of pathogens (within and between hosts, populations, and species; recombination potential) that lead, for example, to antimicrobial resistance (AMR). This knowledge about eco-evolutionary processes' impact should enable us to better quantify human-animal contacts[16] and transmission networks[17]. It should also allow us to better understand host-pathogen interactions and highlight the mechanisms at the origin of pathogenicity, resistance, host specificity[18], and facilitating host shifts[19].

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[2] 1090, 1093, 1116
[3] 1093, 1107
[4] 404
[5] 652
[6] 1120, 1303
[7] 1088, 1226, 1303
[8] 1054, 1081
[9] 629
[10] 1366, 1373, 1434, 1513
[11] 1245
[12] 1105, 1405
[13] 1061, 1108, 1270, 1322, 1465, 1506, 1516
[14] 622, 1115
[15] 1076, 1233, 1418
[16] 1265
[17] 1062
[18] 1056, 1059, 1436
[19] 619, 620, 1191, 1306

A third challenge is to better understand the relationships between biodiversity loss and zoonotic hazards. Improved knowledge of how spatial and temporal scales or different geographical contexts[20] may affect these relationships[21] is needed.

Other potentially influential factors in circulation of pathogens must also be considered. For biotic factors, these should include coinfections[22], host-microbiome pathogen interactions[23], and AMR[24]; for abiotic factors, land use[25], deforestation, and climate change[26] should be considered.

The focus should be on geographic contexts with high likely risk of zoonotic spillover and transmission to humans (wildlife-human-livestock intersections)[27], such as areas with high rates of deforestation, livestock farming[28], urban areas[29], and territories where significant biological invasion is occurring. These emerging "hotspots" have been carefully characterized through quantitative indicators, which requires developing a standardized and accepted methodology.

## *THEME 3: What are the main drivers of zoonotic disease emergence?*

Identifying the main drivers includes assessing and characterizing the footprint of human activities such as:

- agriculture[30]
- food habits and consumption[31]
- population density[32] and urbanization[33]
- land use[34] and habitat fragmentation/deforestation[35]
- trade[36], international exchanges[37], and regional/global connectivity[38]

[20] 1251
[21] 1256
[22] 1058, 1233, 1458
[23] 634, 1083, 1527
[24] 631, 638, 639
[25] 1251
[26] 1322
[27] 1492, 1514, 1520
[28] 1417
[29] 1414, 1515
[30] 640, 641, 642, 640, 1469, 1495, 1500
[31] 653, 646, 1317, 1495, 1500
[32] 637, 1063, 1482
[33] 636, 644, 1102, 1463, 1499, 1515, 1517, 1526
[34] 1074, 1108, 1471
[35] 428, 1498, 1501
[36] 643, 1249, 1249b
[37] 1102
[38] 1063, 1482

These activities need to be carefully characterized in terms of their impact on biodiversity[39], pathogen spillover[40], pathogen transmission dynamics[41], level of host exposure[42], emergence risk at the human-animal interface[43], vector and host distribution[44], and vectorial capacity[45].

Climate and environmental changes are two other important factors. Extreme events and natural disasters like floods, severe drought, storms, and fires[46] need to be taken into account, as do more gradual changes in temperature or precipitation and extreme scenarios that may impact disease emergence[47]. Regarding environmental changes, there is a need to compare different areas with a graduation in ecosystem structures and address potential regional biases[48].
Nevertheless, the complexity of ecological communities requires study beyond pooling various forms of habitat "destruction" or "degradation", as these factors can have non-linear, contrasted effects on ecological interactions[49]. This should facilitate the design of health indicators[50] to monitor local ecosystems cross-sectionally.

### *THEME 4: How can we anticipate the risks of zoonotic disease emergence and decrease spillover likelihood?*

With regard to successfully anticipating zoonotic disease emergence risks, the main research gaps concern detecting pathogens in their hosts or environment[51] and implementing efficient surveillance[52]. Specifically, there is a need to identify reservoirs of multi-host pathogens (through the use of innovative non-invasive field diagnostic tools), improve surveillance[53], classify and quantify these reservoirs' epidemiological role, quantify the role of the human-animal contact network, and share challenges in surveillance and outbreak data between public health and veterinary entities in order to improve early detection[54] (for instance, through the development of mobile apps).
Pathogen transmission routes at different scales, geographical areas, and time periods should be studied[55]. Wildlife (including that at the center of illegal trade) has been highlighted as a priority for surveillance efforts to anticipate disease emergence risks[56], similarly, wastewater monitoring could

[39] 632, 645, 1102, 1129, 1251, 1256, 1350, 1499
[40] 1050, 1117, 1370, 1499
[41] 1070, 1409, 1290, 1489
[42] 1463
[43] 1064, 1319, 1392
[44] 1052, 1065, 1074, 1224, 1257, 1014, 1065, 1208
[45] 1505
[46] 1075
[47] 1052
[48] 1229, 1278
[49] 73, 1091, 1370, 1302
[50] 73, 1091, 1302, 1370
[51] 627, 647, 1265, 1341
[52] 426, 1249, 1253, 1265
[53] 1253
[54] 1091, 1265, 1348
[55] 648, 650, 651, 1096, 1201, 1202, 1359
[56] 1068, 1249, 1272, 1437

enable early threat detection[57]. Past exposure data (e.g., serological tests) could be used to develop predictive systems and approaches that are flexible, iterative, and collaborative across disciplines and scales[58]. Assessing the cost of pandemics will help fund efforts to prevent them[59].

## 11.2. Pillar 2: Co-design solutions to reduce the zoonotic risk

### *THEME 1. Mitigating spillover through ecosystem conservation*

Since zoonotic disease emergence is strongly connected to ecosystem alteration, reducing pathogen circulation in wildlife (and therefore, spillover probability) relies heavily on promoting ecosystem conservation or restoration as a long-term prevention strategy[60].

First of all, it is important to note that wildlife is not a risk for human health per se [61], but processes such as changes in land use and the wildlife trade mean wild animals' ever-increasing proximity to human populations and domestic animals may transform this hazard into a risk (Hosseini et al, 2017). To circumvent this, it would be very useful to evaluate the efficacy of ecosystem conservation/restoration strategies (ecological corridors, hotspot biodiversity, etc.) in reducing microbe circulation[62], and also characterize both their direct[63] and indirect[64] consequences on other socio-economic dimensions.
A complementary approach would be to evaluate the negative impact of the non-implementation of ecosystem conservation strategies transversally[65]. These negative impacts will obviously impact biodiversity[66] and could be evaluated by quantifying the price and cost of biodiversity or determining the monetary value of biodiversity management and surveillance [67], beyond any protection such methods may confer against zoonotic pathogens. These strategies would be implemented through different landscape management strategies[68] that may also limit wildlife-human contacts[69], possibly through buffer zones and/or agroecological practices[70], but the cultural norms of populations living near areas of circulating pathogens[71] must be considered to facilitate adherence. The agricultural sector could be reimbursed for productivity losses if it shifts its focus and practices[72].

[57] 1302
[58] 1237, 1357
[59] 1428
[60] 60, 722, 723, 738, 799, 800, 801, 817, 1206, 1230, 1362
[61] 733
[62] 21, 1109, 1266, 1331, 1498
[63] 143, 241, 306
[64] 604, 1348
[65] 421
[66] 753
[67] 783, 807
[68] 368, 582, 749, 750, 1501
[69] 718, 720, 796, 1192, 1297, 1492
[70] 713
[71] 807

Implementing such strategies to improve ecosystem resilience[73] may be facilitated through innovative business models[74] and incentives[75], but is not straightforward. For example, actors' awareness of the consequences of deforestation must be improved[76], and shared responsibilities must be delineated[77]. Moreover, since deforestation is also linked to agriculture, landscape management strategy development has to consider the importance of cultivated farmland[78] in order to ensure food security. Forest habitat degradation can also result from extreme events such as storms or wildfires. To this extent, it is crucial to consider the social and anthropological origins of deforestation, as well as forests' economic value to local populations[79]. Thus, involving local stakeholders and communities[80], possibly through incentives[81], is crucial to developing the bottom-up approach required to trigger political commitment[82]. This step is pivotal to developing supportive policies and legislation[83], as well as efficient training programs. On practical aspects, conservation umbrella organizations[84] could implement ecosystem conservation and restoration programs to prevent zoonoses with governmental support. Such actions could be supported operationally by funding NGOs that protect wildlife[85].

### *THEME 2. Regulating and tracing commercial and non-commercial activities related to wildlife*

Beyond the propagation of pathogens inside ecosystems, the interface between wildlife and humans can take many forms. It is therefore important to regulate and trace the commercial interests related to wildlife, including bushmeat consumption, trade, farming, tourism, and hunting.

To this extent, it is obvious that the hierarchical relationships of activities[86] and different intermediate actors[87] need to be better characterized. This is especially true for wildlife farming[88], whose role in zoonosis emergence is still unclear. Overall, it is recommended that wildlife-related commercial activities (such as bear farming, animal breeding for entertainment purposes, and the

[73] 232
[74] 324
[75] 419
[76] 240, 734, 752
[77] 788
[78] 253, 420, 739
[79] 546, 603
[80] 184, 270
[81] 419
[82] 189
[83] 54
[84] 55
[85] 152, 558
[86] 719, 1192
[87] 5, 29
[88] 717

bushmeat, exotic pet, and fur trades) be reduced or suppressed, especially wildlife trade[89] and markets, which require much greater regulation[90]. This consideration is especially important and should be enforced for activities that do not profit local and Indigenous communities[91]. Nevertheless, economic considerations related to these regulations must be addressed to avoid increases in illegal hunting and trade[92]. The aim is to develop alternatives to risk-generating activities like poaching through law enforcement and/or economic incentives[93].

### *THEME 3. Innovative systems of livestock management and agriculture*

While wildlife is a source of spillover (and also a victim, as in the case of AMR), livestock is as a tipping point for human exposure. Therefore, it is crucial to envision new, innovative systems of animal production that could reduce emergence risk across all potentially relevant farming systems (agriculture, plantations, intensification, aquaculture, etc.).

Clearly, livestock production needs new strategies that promote mixed farming to decrease microbe circulation[94], but must also precisely quantify these strategies' efficacy in order to estimate long-term economic impacts. This approach will certainly have a cost[95] that must be offset to ensure production systems' sustainability, whether these systems are organic[96] or not[97]. Therefore, responsible livestock management has to be viable[98], and penalizing irresponsible management could create indirect incentives[99]. This implies a clear definition of each actor's responsibilities. A 3R strategy (reduction-refinement-replacement, initially adopted to decrease the use of animals in experiments) for responsible farming could be developed[100] to reduce the need for animal products[101] while ensuring food security and avoiding detrimental consequences for social cohesion[102]. Quantifying the space agriculture and livestock need is also important in designing management strategies that limit encroachment[103].

[89] 774, 780, 803, 804, 805, 806, 808, 812, 1249
[90] 778, 797
[91] 802
[92] 234, 813

[93] 206, 791
[94] 714, 1424, 1426, 1485, 1486, 1523
[95] 1474, 1475, 1518
[96] 392, 716, 748
[97] 754, 755, 815
[98] 729, 757,758, 761, 762, 763, 765, 766, 767, 768
[99] 760
[100] 751
[101] 770, 771,772, 773
[102] 731
[103] 755,756, 798

It is also important to increase monitoring and control measures in livestock facilities. This means quantifying biosecurity measures' efficiency[104]. It also means sustainably ensuring antibiotic availability as needed[105], while reducing antibiotic consumption[106] and vaccinating susceptible host species when possible[107]; this approach could also facilitate livestock trade[108] and reduce the economic costs of biosecurity and preventive measures. The entire supply chain[109], including contact with animals[110], must also be examined not only to better understand the chain of emergence events[111], but also to optimize livestock production systems[112] to produce greater yields with smaller facilities.

Integrative animal health regulations (i.e., those which consider food security, zoonosis emergence risk, and animal well-being) are therefore needed[113]. These regulations could rely on promoting agroecology (via a One Health approach[114]) through public-private partnerships. To this extent, it is important not to penalize producers who have developed responsible farming practices and continue to report new cases of zoonotic disease by compensating them for emergence events[115].

### *THEME 4. Urban planning*

It is also important to reduce the emergence risk in the most densely populated areas. To this extent, urban areas represent an important potential interface for the emergence and propagation of zoonoses and should be designed with such a risk in mind.

This increasingly important topic has been little studied and requires more fundamental research[116], including on peri-urban areas[117]. While identifying risk areas is important[118], green spaces in urban areas could decrease spillover risks[119]. However, it is important to guarantee this strategy would not

[104] 715, 769, 1427, 1429, 1449, 1453
[105] 810
[106] 809
[107] 793
[108] 819
[109] 790, 1452
[110] 1192, 1297
[111] 1469
[112] 1467
[113] 742
[114] 814
[115] 795
[116] 1461
[117] 1464
[118] 1430
[119] 1459

actually have an inverse effect[120]. Modeling urban management[121] to avoid creating risk areas[122] (such as suitable habitats for vectors) could be a valuable first step in developing such a strategy[123].

Finally, human risk behaviors must be considered, especially those concerning green space use[124] and domestic animals in those areas[125], as individual societies' perceptions of urban fauna vary widely[126]. It is also crucial to account for the significant fluctuation in interactions between humans, animals, and the environment[127].

### *THEME 5. Articulation between all different approaches and actor engagement*

Finally, a coherent strategy must articulate these different approaches and combine them with reinforced One Health surveillance networks[128] through a standardized data structure[129], and must adopt a risk-based approach to turn these prevention strategies[130] into an efficient safety net.

Interactions between different strategies regarding the trade-off between food demand, poverty reduction, and prevention strategies[131] will be envisioned. The key is to go beyond a single-problem/single-solution approach[132] via a transversal evaluation of the impacts of interventions[133]; this would enable shared costs[134] and include all actors in a bottom-up approach[135] to reduce contact between wildlife, humans, and pathogens[136].

[120] 1416, 1499, 1504, 1517
[121] 1524
[122] 1481
[123] 1460
[124] 1471
[125] 1192
[126] 1490
[127] 1473
[128] 205, 784, 1071
[129] 1094
[130] 1267
[131] 1432
[132] 730, 735
[133] 1223
[134] 789
[135] 207
[136] 203

## 11.3. Pillar 3: Strengthen early warning systems

### *THEME 1. Assessment of current surveillance systems and practices*

There is a clear need to evaluate current epidemiological and environmental surveillance systems' effectiveness[137], methods and tools[138], and socio-economic impacts[139]. Regarding the socio-economic aspect, innovative methods[140] and indicators[141] to assess economic feasibility and efficiency are essential. This would help determine whether a surveillance system is useful for a particular animal/public health challenge, by supporting the achievement of the goals of the animal/public health program and the data collection objectives (proof of concept[142]). Any evaluation of surveillance systems should take the potential heterogeneity of stakeholders' engagement[143] into account, especially interactions between the different sectors involved in One Health[144].

### *THEME 2. Context-specific and user-based surveillance systems*

Implementing efficient surveillance systems requires that all stakeholders involved have been identified and recognized[145]. Stakeholders' risk perception and needs, knowledge, and practices regarding zoonotic disease emergence must be understood[146]. Considering and characterizing these needs and expectations, including any socio-economic incentives in terms of surveillance systems benefits[147], is also essential to ensure a user-based system approach. Co-building surveillance systems through both bottom-up and top-down approaches seems essential to their sustainability. Finally, understanding the environmental[148] and epidemiological contexts[149] in which surveillance systems are developed is necessary to designing tailored surveillance systems.

### *THEME 3. Innovation in surveillance protocols and diagnostic tools*

The protocols and tools currently in use are insufficient to face future threats. This is especially true for integrated surveillance protocols (those in use across sectors), which need to be standardized and carefully adapted to field conditions and local contexts[150]. There is also a clear need for more

[137] 674, 675, 688, 690, 691, 693, 699, 701, 707, 1148, 1196, 1219, 1252, 1267, 1496, 1509
[138] 256, 610, 682, 692, 693, 694, 698, 1131, 1267
[139] 225, 483, 604, 661, 1355
[140] 225, 388, 484, 1135, 1136, 1144, 1148, 1149, 1236, 1249, 1314, 1336, 1349, 1377, 1483, 1509
[141] 1091, 1095
[142] 1252, 1276
[143] 661, 667, 686, 706
[144] 666, 667, 695, 705, 1122, 1125, 1219
[145] 401, 595, 1079, 1097, 1131, 1295
[146] 204, 208, 396, 1094, 1185, 1195, 1355
[147] 59, 204, 208, 225, 362, 382, 396, 401, 406, 427, 595, 662, 1194, 1195
[148] 21, 426, 661, 688, 708, 1122, 1125
[149] 21, 426, 593, 688, 1091, 1122, 1125, 1131, 1232
[150] 2, 3, 4, 256, 363, 367, 370, 396, 511, 690, 701, 1039, 1071, 1094, 1173, 1183, 1450, 1511, 542

effective, non-invasive, real-time, standardized diagnostic tools[151], especially for wildlife, as well as an improved capacity to build laboratories for pathogen diagnosis and characterization[152]. Innovative and integrated surveillance systems based on the One Health approach (such as community participatory disease surveillance and those based on risk-based, syndromic analysis, wildlife, vectors, or proxy measures such as mortality or wastewater[153]) and tools to detect rare health events[154] must also be developed.

[151] 107, 112, 116, 657, 692, 1232, 1238, 1246, 1247, 1271, 1339, 1478, 1263
[152] 255, 594, 1013, 1383, 1011, 1012, 1013, 1014
[153] 659, 1095, 1097, 1122, 1132, 1133, 1155, 1196, 1199, 1211, 1267, 1302, 1343, 1344, 1425, 1456, 1508
[154] 1199, 1316

## 11.4. Pillar 4: Prototype a global information system for surveillance and early detection

*THEME 1: Interoperability and sustainability of surveillance systems and global standards*

Developing efficient and locally tailored surveillance systems based on innovative, standardized tools is crucial. Current threats are clearly distributed internationally, which emphasizes the need for rapid or even real-time interoperability of data sharing. This would enable: simultaneous shared mapping of human and animal diseases and the anticipation of links between both types of diseases; the development of tools such as artificial intelligence models, digital tools, and apps[155]; and the ability to share genomic data[156]. It is therefore crucial to improve the interoperability of local existing surveillance systems, i.e., the ability of one surveillance system to work with another, while exploring the capabilities of both without extra user effort.

Workshop participants cited the need to share, exchange, and reuse methods and tools related to risk identification[157] and ensure that surveillance systems communicate[158], share, and integrate common procedures, nomenclature, ontologies, taxonomies, standards, and plans[159] as well as data[160] to assess risks at different spatio-temporal scales. To ensure this interoperability, there is a need to harmonize samples, establish common standards for sample submission, and share information about tests and results[161]. This requires coordinated surveillance and diagnostic protocols[162][163] and reliable point-of-care diagnostics[164].
Establishing international working groups is essential to this process [165]. Data harmonization would rely on integrating surveillance systems at all geographic scales[166] and alignment with international protocols[167].

These exchanges of data between countries, organizations, and levels require global standards. This corresponds specifically to harmonized quality standards of diagnostics tools and their validation[168],

[155] 689, 696, 878, 879, 880, 881, 884
[156] 832
[157] 858
[158] 507, 571, 659, 671, 695, 703, 705, 1396, 1466
[159] 173, 507, 549, 659, 671, 673, 693, 694, 695, 703, 705, 1396, 1411, 1466
[160] 659, 668, 671, 673, 695, 703, 705, 1168, 1344, 1353, 1396, 1411, 1454, 1466, 1484
[161] 1106
[162] 174
[163] 485, 698
[164] 864
[165] 96
[166] 1285
[167] 16
[168] 863, 865, 866

a new common data format [169], and the standardization and interoperability of different data streams[170].

Emerging infections are a perpetual concern. Therefore, it is crucial to develop sustainable disease surveillance and response systems[171]. This requires long-term financial and technical support[172] at national, regional, and global levels. Generating surveillance research outputs that inform policy development and decision-making is also necessary[173]. Finally, improving information flows (bottom-up and top-down[174]) within and between these surveillance systems and to provide evidence that surveillance is feasible effective, and better than the existing system (proof of concept).

### *THEME 2: Definition of the type of surveillance and objectives of global surveillance; identification of relevant indicators and data*

Building global standards and global surveillance systems requires clearly identifying surveillance objectives and relevant indicators and data to establish links between the information shared and outbreaks[175]. Scientists must reflect on the needs behind data sharing and global standards: what kind of data do we need? For whom? What kind of database is needed?[176].
Several research needs are related to these questions:

- how to promote surveillance based on metagenomic data[177];
- how to move beyond hazard detection and hazard-predictive mapping toward integrative epidemiological models of disease risks[178];
- how to prioritize which pathogens to monitor[179] and
- how to evaluate event-based surveillance (which permits browsing circulating pathogens) as a complement to targeted (risk-based) surveillance[180].

These relevant indicators also depend on economic analyses and determining return on investment for programs that reduce environmental changes that exacerbate pandemic risks[181], and how to develop cost-effective One Health surveillance systems[182].

[169] 31
[170] 1022
[171] 660, 692, 706, 710, 1144, 1180, 1313, 1512
[172] 346, 419, 543, 669, 1165, 1193, 1234, 1263
[173] 483, 484, 507, 709, 1276
[174] 175, 211, 372, 401, 406, 515, 611, 658, 667
[175] 665, 666, 821
[176] 610, 702
[177] 1179, 828, 830, 831
[178] 1175
[179] 1177
[180] 823
[181] 1212
[182] 1136

Once these indicators are established, they need to be compared to assess different approaches (strengths, weaknesses, practicability, costs, etc.) in order[183] to evaluate and monitor surveillance systems[184].

### *THEME 3: Action plan linked with global surveillance*

The link between surveillance and action plans, driven by the question of how to transform the global surveillance system into operational actions[185], must be better defined. Concerning early warning systems, research gaps exist in reacting to alarms triggered by surveillance[186]. A quick response to zoonotic disease emergence requires operational local, regional, and national action plans linked to this surveillance[187]. Thus, One Health platforms could be used as regular consultation points to discuss these plans and development priorities[188].
Participants aspire to co-construct these plans with researchers and policy makers in order to establish a well-founded contingency plan for emerging diseases[189].

### *THEME 4: Strengthen infrastructures to operationalize global surveillance systems*

Infrastructures are needed to operationalize global system surveillance. Workshop participants have proposed assessing existing infrastructures, namely national One Health data collection capabilities[190] and reference labs in hotspot countries[191], to map actors of wildlife sampling[192] and sample shipping[193]. The aim is to understand countries' data collection and sharing needs, as well as the innovations and changes in practices necessary to overcome the capacitive and logistical issues hindering the surveillance of emerging zoonotic diseases[194].
Globally, long-term investment in One Health surveillance[195] and surveillance tools[196] is needed. Participants have proposed establishing One Health observatories supported by international organizations[197] or regional bodies that include One Health experts[198].

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[183] 119
[184] 1509
[185] 1289
[186] 843
[187] 861
[188] 441
[189] 507
[190] 1423
[191] 867
[192] 3,4
[193] 256
[194] 1314
[195] 891, 1234
[196] 370
[197] 300
[198] 78

More specifically, it is necessary to invest in infrastructures of sample collection and analysis to enable rapid, accessible diagnostics[199], especially for emerging pathogens[200] and in emergencies[201]. Infrastructures must be able to collect and ship samples and utilize mobility grants for human resource exchanges[202]. Some participants have proposed establishing a network that includes non-governmental actors and promotes public-private partnerships to collect and send these samples[203]. Concerning laboratory infrastructures, laboratories could share equipment[204] and exchanges between human and veterinary laboratories could be facilitated[205]. Participants have proposed supporting regional laboratories[206] and creating national laboratories[207] for analyzing samples on-site in each country[208].

Finally, digital infrastructure and transition[209] are needed to enable rapid, efficient data sharing[210].

### *THEME 5: Optimization of efforts to avoid duplication*

The effectiveness and strength of international surveillance systems lies in optimizing efforts and avoiding duplication. This implies first mapping the existing surveillance systems from different sectors and establishing links both between them and their actors. by using and improving present networks[211] in order to learn from and build on existing systems[212]. Improved One Health surveillance systems also require better intra- and intersectoral collaboration[213] through harmonized One Health system networks and information systems[214]. Centralized databases that enable researchers to search for projects by location and pathogen to assess possible collaborations could facilitate intrasectoral collaboration[215]. On the other hand, intersectoral collaboration would involve strengthening international networks between laboratories in the human, animal, environmental, and agricultural health sectors[216], starting with mapping existing laboratory networks[217]; this would facilitate international diagnostic collaborations by (i) harmonizing and exchanging sampling

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[199] 107, 835 868, 869, 870, 871, 1247, 1420, 1450, 1478
[200] 833
[201] 108
[202] 346
[203] 230
[204] 84
[205] 82, 86, 98, 487
[206] 557, 594
[207] 99
[208] 112, 488
[209] 882
[210] 390
[211] 1219, 522, 523, 592, 292, 299
[212] 325
[213] 1158, 4, 217, 541
[214] 399
[215] 1010, 3, 18
[216] 344
[217] 77, 255, 323, 398, 465, 540

methods[218], (ii) optimizing laboratory resources between sectors[219] and (iii) optimizing the use of capacities[220]. Centralized databases would also help in monitoring the impact of surveillance[221].

## 11.5. Pillar 5: Engage stakeholder and co-design One Health networks and policies

### *THEME 1. Community involvement*

Zoonotic disease prevention is a continuous challenge, and there is an urgent need to engage communities on the frontlines of emergence events in research projects to assess and reduce zoonotic risk (pillars 1 and 2) and detect emerging events quickly through community-based surveillance systems (pillar 3). A first step is to define relevant communities (e.g., local actors, civil society, smallholders), their respective roles, and their interactions[222] by mapping key players.

A second step is to identify tools that foster community involvement.

For disease surveillance, workshop participants expressed the need to develop community-based systems and build community and citizen trust. This includes understanding the stakeholders' motivations for engaging in surveillance[223]; training (including participatory training) all stakeholders from local to international levels, including citizens and community health workers[224]; developing innovative tools to improve risk communication[225]; disseminating communication tools[226]; education and awareness[227]; and strengthening community-based alert systems[228]. Identifying and using incentives for actors to report diseases[229] has also been proposed, especially for smallholder farmers who need social guarantees[230] and professionals who communicate risks to local populations[231].

Inclusion in the very early stages of research and development project design[232] is a key element of community engagement. An example of this would be a regional pool of reviewers that integrates local and regional expertise[233] to review projects in development.

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[218] 1151, 434, 607
[219] 243, 244
[220] 825
[221] 842
[222] 5
[223] 230, 372, 594, 667, 672, 684, 179, 185, 211, 225, 230, 658, 682, 1138, 1167, 1169, 1194, 1325, 1381, 1394, 1441, 1462
[224] 49, 50, 179, 233, 242, 250, 422, 425, 500, 575, 595, 679, 686, 1274, 1285, 1462
[225] 62, 114, 211, 225, 242, 250, 252, 372, 1285, 1286
[226] 242, 250, 372, 515, 1097
[227] 114, 515, 658, 663, 678, 679, 686, 1285
[228] 57, 334, 362, 595, 614, 670, 672, 682, 685, 686, 1060, 1097, 1150, 1167, 1194, 1441, 1462
[229] 59, 211, 237, 362, 1194, 1325, 1442
[230] 137, 204
[231] 482
[232] 64, 210, 227
[233] 95, 193

Communities should also be included throughout the project via participatory approaches (e.g., focus group discussions[234]) and research findings[235] by making them understandable by all.
To motivate researchers to integrate these activities, donors should require stakeholders' consultation and engagement in their project calls[236] and should prioritize projects (including outreach activities) that create links between stakeholders and enhance communication among them[237], by integrating social science expertise[238]. Coupled with reinforced training and communication on zoonotic disease risk management capacity[239] (cf. section 13.1), such an approach will also help overcome community mistrust by limiting miscommunication and fake news[240].

Finally, community engagement is critical to implementing sustainable solutions to zoonotic disease emergence, such as promoting community-based management of conservation areas through supportive policies, legislation, and investment[241]. We must also find solutions to ensure that the benefits of sustainable options are distributed equitably or valued in these communities[242].

## *THEME 2. Co-development of health networks and policies through the reinforcement of the dialogue between science, civil society, and policy makers*

### Political engagement and awareness of stakeholders

Stakeholder engagement and commitment is critical to building sustainable and fair global surveillance systems[243]. This is reflected in the need to share surveillance data, and therefore in how to promote, encourage, and even reward data sharing[244]. It also underlines the need to investigate and communicate the value of sharing data (with cost-benefit analyses on whether to share surveillance data conducted by, for example, external partners such as NGOs or international organizations[245]). When combined with demonstrated benefits of the surveillance systems approach[246], this latter example would also help motivate policy makers to increase funding for global surveillance systems[247]. Finally, local stakeholders' engagement and bottom-up approaches could

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[234] 156
[235] 70
[236] 126
[237] 141, 277
[238] 89, 198, 199, 282
[239] 37
[240] 197, 212, 215, 245
[241] 53, 54, 55, 58
[242] 225
[243] 1124, 1140, 890
[244] 706, 1423
[245] 147
[246] 845
[247] 1174

improve coordination between countries on surveillance, but this has yet to be demonstrated (proof of concept and added value)[248].

### Dialogue between science, civil society, and policy makers

A key transversal point is a constant dialogue between science and society[249] through co-designed solutions involving all actors[250] in order to improve local populations' involvement and acceptance [251]. Indeed, it is necessary to consider local context to involve actors and sustain their engagement[252] by representing them at the national and regional levels[253]. The multidimensional complexity of each local context (culture, beliefs, social representations, knowledge, and practices) must be taken into account in order to build interventions adapted to local contexts[254]. Through the use of co-construction tools, interventions can be adapted to different elements, such as language[255], communication practices and tools[256], perception and representation of epidemics[257], knowledge of zoonoses[258], and different local customs[259] like eating habits[260].

While this dialogue must take place between scientists and stakeholders[261], it also needs to involve policy makers[262], especially regarding economic dimensions[263]. Connecting these strategies to sustainable policies and funding from the outset would engage actors in zoonosis prevention[264] and enable the development of efficient policies[265].

Missing in this dialogue is the quantification of the impact[266] of prevention strategies[267], and of not implementing them[268]. There is a clear and repeated need to develop economic and impact indicators of zoonotic emergence risks[269]; these could also be qualitative if categorized by risk levels[270].

[248] 182, 228
[249] 1027
[250] 1150
[251] 231
[252] 1139, 1160, 1292, 1381
[253] 38
[254] 1268, 1283, 1296, 1400
[255] 1045
[256] 1046, 1047, 1048, 1399
[257] 1116, 1118
[258] 1187
[259] 1231, 1355
[260] 1470, 1472, 1480, 1495
[261] 1031
[262] 1005, 1029, 1032
[263] 41, 1030
[264] 1182
[265] 1184, 1304, 1310, 1305
[266] 109
[267] 1275
[268] 1085
[269] 391, 724, 759, 764, 1034, 1099, 1198, 1205, 1213, 1243, 1340, 1408, 1410, 1412
[270] 787

Different approaches could be used to this end, from modeling techniques to geographic/botanical approaches[271]. These indicators must consider the whole range of zoonotic pathogens[272], not just individual ones. These indicators could be pivotal to funding that incentivizes these strategies[273] and/or identifying penalties for high-risk activities[274]. This could help engage the private sector's[275] understanding of its activities' roles in zoonotic emergence risk[276]. Such indicators could be developed and validated at pilot sites to calibrate their use in the field[277].

### Co-development and coordination of One Health networks

Another key point is co-building and validating health networks to develop integrated surveillance systems with all stakeholders, including citizens, through both bottom-up[278] and top-down[279] approaches. This relies squarely on understanding and strengthening existing One Health systems in order to promote relevant and effective intersectoral collaboration[280]. The needs and constraints of all stakeholders[281], from local to national levels, must be considered to ensure their engagement and acceptance.

These One Health networks need to be coordinated[282] to avoid redundant efforts for researchers, stakeholders, and policy makers alike. Such coordination could facilitate the translation towards policies, a dynamic process that will require regular updates[283], especially in the context of evolving risks[284]. This improved coordination will also place actors in their respective roles, possibly at different spatial scales[285] and with differing levels of responsibility[286].

[271] 428
[272] 726
[273] 415,811
[274] 567, 782, 785, 786
[275] 219, 400, 704
[276] 381
[277] 732
[278] 57, 511, 595, 610, 614, 670, 672, 685, 687, 1079, 1091, 1094, 1097, 1134, 1150, 1167, 1185, 1195, 1276, 1325, 1355, 1379, 1381, 1383
[279] 507, 610, 611, 665, 666, 668, 671, 676, 685, 687, 689, 694, 696, 699, 703, 1079, 1091, 1095, 1122, 1286
[280] 507, 611, 659, 665, 666, 668, 671, 672, 676, 685, 695, 696, 703, 705, 1097, 1138, 1144, 1150, 1155, 1158, 1161, 1168, 1185, 1193, 1265, 1276, 1285, 1286, 1394, 1415, 1444
[281] 511, 595, 610, 614, 692, 693, 1039, 1060, 1071, 1094, 1122, 1132, 1134, 1155, 1185, 1195, 1325, 1355, 1379, 1383, 1442
[282] 1104, 1121, 1259
[283] 1072, 1033, 1051, 1154, 1361
[284] 725
[285] 1079, 259, 292, 315, 1042, 1157
[286] 371

Scientists' role regarding policy development and implementation of interventions must be clarified [287] with all actors [288]. This clarification is also required to develop more efficient[289] (i.e., better coordinated) and inclusive[290] science, especially in LMICs, which may lead[291] to effective solutions[292]. To do so, it is important to better communicate research[293], especially to stakeholders and decision makers, in order to help them develop relevant policies[294].

To this end, there is a clear need to improve scientific communication[295] through relevant materials[296] and media involvement[297]. Information overload must be avoided without masking complexity[298] and communication must be specifically tailored to each actor[299]. This approach must also be adopted for each kind of prevention strategy[300]. Communities' feedback on communication[301] will also help develop a culture of health and biodiversity and measure the impact on economic activities[302].

### *THEME 3. Promoting One Health approaches and intersectoral collaboration*

Promoting and practicing One Health approaches on all geographic scales to secure stakeholders' engagement is required to develop transdisciplinary intersectoral collaboration. Promoting these approaches relies on training (cf. section 13.1) and One Health infrastructure creation. At the local level, this requires human resources for technical services[303].
At the national level, several relevant ideas have been identified. These include: a scientific committee and a national secretariat (e.g., a One Health observatory of emergence[304]) that promote the One Health concept to politicians and ministries[305]; governmental mechanisms for One Health collaborations[306]; and a national One Health program for zoonoses[307]. As a concrete action, an such

[287] 196
[288] 239, 1375
[289] 999, 1000, 1020
[290] 1145
[291] 1002
[292] 1028
[293] 1057, 356, 1009
[294] 1003, 1004, 1006
[295] 1024, 1114
[296] 114
[297] 201, 429, 600
[298] 215
[299] 269, 449, 454, 461, 482, 606
[300] 286, 518, 520,535,562, 727, 1001, 1446
[301] 1239
[302] 216
[303] 934
[304] 94
[305] 7, 8
[306] 87, 165, 166
[307] 91, 267, 930

as the "National Conference on One Health" has also been proposed[308], as has the need to include preparedness and prevention plans in government plans and laws[309].
At the global level, a One Health institute has been cited as a need[310]. Coordinating One Health actions at this scale should rely on regional platforms[311] and accessible information-sharing platforms and tools, such as a website that maps planetary health[312]. A high impact interdisciplinary health journal[313] and global organizations that urge governments toward a global approach are ways to encourage pluri-disciplinarity[314]. A final important point highlighted by participants is the need to draw inspiration from LMICs' best prevention practices[315].

# 12. Ethics, sustainability, policies and implementation framework

The research gaps and operational needs described above point to the need for an international framework for designing prevention strategies[316]. This framework could be standardized[317] by identifying common rules and patterns in emerging infectious diseases[318] and could be adapted on a local scale[319]. Feedback from local initiatives based on the One Health approach's three pillars is also essential[320].

## 12.1. Strengthen country capacity to implement OH approaches for zoonoses risk prevention

### *Local community engagement and training*

The need for more accessible training and workshops has been consistently cited by PREZODE workshop participants[321], especially regarding communicating strategic necessities to local

[308] 79
[309] 271
[310] 69
[311] 88
[312] 105
[313] 110
[314] 162
[315] 128
[316] 778
[317] 781
[318] 1338; 1369; 1318; 1200; 1207; 1242; 1248; 1364
[319] 563, 1107, 1424, 649
[320] 1018, 1019
[321] 148, 149, 150, 1082, 574, 580, 1016, 1044, 1082, 1273

communities, strengthening communities' skills in surveillance, prevention[322], and data management[323], and raising stakeholder awareness[324]. It is therefore important not only to develop joint training between livestock and wildlife professionals, health[325] and medical professionals[326], and ecologists on prevention strategies, but also to adopt a modeling approach[327] to set the same standards internationally, especially in low-income countries [328]. This educational approach[329] could also be supported by wildlife professionals (such as "nature patrols"[330] and/or former hunters[331]) and serve as a basis for onsite explanation to different actors of the benefits of changing practices[332], including private sector actors[333]. All training of this nature should consider gender dynamics[334]., Identifying available tools and online resources[335] and leveraging funds to address shortcomings[336] are necessary to making training materials accessible to local communities.

### *Promoting One Health at schools and universities*

Educational training needs regarding science, research, and One Health approaches have also been identified in schools[337] and universities[338]. These needs could be addressed through transdisciplinary programs that include ecosystem health courses and non-academic actors[339]. Solutions to develop these programs have been identified, such as the creation of an academic co-design training platform[340], experience sharing between universities[341], and partial coverage of academic training costs[342].

### *Laboratory capacity building*

To develop efficient laboratory networks at the national and local levels, laboratory staff and technicians need regular training in the technologies and tools for zoonotic disease diagnosis[343] and

[322] 497, 580, 1274
[323] 1021
[324] 266, 247, 214, 187
[325] 49, 51, 56, 570, 939, 958
[326] 417, 957
[327] 1037
[328] 35, 1216
[329] 130, 249, 303, 1103
[330] 85
[331] 180
[332] 177
[333] 424
[334] 1281
[335] 586
[336] 151
[337] 11, 130, 409, 564, 573, 902, 920
[338] 573
[339] 278, 586, 587, 589, 590
[340] 44
[341] 591
[342] 133
[343] 500

diagnostic surveillance methods[344], including recently developed ones. However, developing these networks also relies on joint capacity-building programs that strengthen and coordinate regional and national laboratory facilities[345]; in terms of capacity[346], laboratories must be harmonized between sectors[347], as should the procedures and reagents to be used[348]. For example, workshop participants suggested that non-commercial reagents should be available. In addition, reference laboratories should be identified in hotspot countries[349] and quality assurance measures such as ring trials should be established.

## 12.2. Funding and sustainability

There is a clear need to increase funding[350], especially at a national scale[351], to meet national priorities and ensure their sustainability[352]. Governmental investors could create incentives for such strategies[353]. More funding would benefit several areas; for example, many unanswered questions remain about the fundamental science of pathogen life cycles, transmission, and the links between biodiversity and zoonosis emergence[354], among others. Translational research that renders scientific findings into practical solutions also needs more financial support. Increased funding of prevention strategies should also aim to ensure sustainable interventions[355], with such examples as conservation areas[356] and sustainable approaches[357].

It bears mentioning that the return on investment of programs focused on horizontal approaches[358] is expected to be significant; while still to be calculated[359], such a strategy is expected to be more efficient (for public health indicators) than purely vertical programs.

## 12.3. Data collection, sharing, and analysis

[344] 1462
[345] 77, 82, 84, 98, 243, 284, 323, 398, 465, 505, 540, 594, 1016, 1151, 1286
[346] 434, 556
[347] 344, 607
[348] 1013
[349] 867
[350] 1051, 373, 794, 1036, 1345
[351] 1089
[352] 1397
[353] 237
[354] 1293, 1295, 1376, 1451
[355] 792
[356] 53, 202
[357] 792
[358] 1280
[359] 1428

The theme of data and their analysis was intensively discussed. With regard to data collection, there is a clear demand to improve standardized diagnostic methodologies and tools for monitoring diseases and pathogens in wildlife, livestock, and the environment[360], and consequently for strengthening laboratory capacity building[361]. This is especially true for wildlife[362], which is not closely monitored due to the difficulty in accessing samples; this reality may in turn limit the detection and reporting of diseases. Moreover, access needs to be sustainable and could be based on various wildlife stakeholders' engagement (hunters, conservation NGOs, governmental services, etc.)

Questions about data quality and type were also raised[363], and there is also a clear present need for longitudinal research[364]. Genomic data collection is also in high demand[365], especially in low-income countries where genomic capacities are relatively rare.
The value of data collection must be enhanced[366] to engage all field actors in improving data quality. This is also linked to improving some data criteria's meaning and contextual adaptation[367]. Finally, data accessibility[368] and interoperability must be reinforced by adopting the FAIR data approach[369].

Data sharing is a pressing need, achievable through open data and transparent communication[370]. It requires, for one, the development of open-source platforms based on existing monitoring systems through interoperable systems[371] and supported by key stakeholders[372]. This development must nevertheless operate through agreements[373] and ensure electronic traceability[374] to fulfill Nagoya protocol requirements. This should be discussed first at a national scale[375] but based on international standards[376], particularly GDPR (General Data Protection Regulation) legislation[377]. Data interoperability and exchange require new rules of data and sample sharing[378], as well as laboratories and staff sharing[379].

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[360] 172, 1097, 1247, 1271, 1339
[361] 1286
[362] 1339
[363] 1189
[364] 1434; 1070; 1489; 1115; 1397
[365] 1241, 1110
[366] 1394
[367] 1195, 1185, 1138
[368] 1265
[369] 1170, 1225, 1339
[370] 873, 875, 876, 1178, 1222, 1378, 170, 171
[371] 1367
[372] 320, 342
[373] 183, 690, 700, 1141, 1443, 1457
[374] 885
[375] 1503
[376] 1227, 1476
[377] 887, 888, 1222
[378] 1390, 17
[379] 505

To facilitate this sharing, the objectives and consequences of this procedure[380](why and how can data be shared globally and between sectors? What data can be shared?) must be carefully identified[381]. From a practical perspective, this includes developing and implementing digital data platforms[382] and related operating procedures for data sharing[383] that all stakeholders can access. This requires clarifying data sharing purposes[384], such as data users' needs, the quality of shared data, and the ecosystem of actors involved in data collection, management, analysis, and use.

An intersectoral data sharing process relies on balancing capabilities, capacities, and resource allocation across sectors to conduct surveillance and information sharing[385]. Existing networks should be used to share data between sectors, which involves mapping existing surveillance systems and networks[386]. Cross-sectoral cooperation and collaboration is essential to global monitoring systems[387] and involves the creation or improvement of data sharing platforms[388]. These platforms would support international central databases (including global virome or serology databases[389]) and be co-constructed between sectors and disciplines[390] to be accessible by local- to central-level users[391]. This approach would also help make existing data accessible[392] and clarify reciprocal consequences between sectors, e.g., food safety and food production[393]. Finally, this raises questions about how to centralize different reporting systems (mandatory vs. voluntary, indicator based-surveillance vs. event based-surveillance vs. news, social media)[394] and connect multiple surveillance data sources to global One Health systems[395].

These data can be therefore used to generate generic and flexible predictive models for understanding disease transmission dynamics, especially in LMICs[396]. Workshop participants also consistently emphasized the importance of adapting existing models to other diseases[397]. Current zoonosis prediction models must be sophisticated enough[398] to integrate heterogeneous data (different types and scales of data) so that different topics, from field data to molecular determinants

[380] 848, 1077, 1222
[381] 263
[382] 390, 430, 478, 543, 689, 700, 1041, 1344
[383] 3, 4, 173, 175, 549, 542, 1141, 1219
[384] 263, 610, 1183, 1415, 1454, 1484
[385] 1193
[386] 1219
[387] 1156, 1324
[388] 874, 1040, 1235
[389] 1023
[390] 1010, 93, 302
[391] 1055, 1478
[392] 18, 47
[393] 862
[394] 1128
[395] 1168, 1353, 1454
[396] 1159, 1161, 1216
[397] 1214; 1338; 1369; 1318; 1200; 1207; 1242; 1248; 1364
[398] 1161

to risk prediction, can be addressed irrespective of pathogen, host, or location[399]. These models should integrate primary data (e.g., health statistics and pathogen attributes[400]), contextual data (e.g., risk factors), climate and deforestation data (to develop innovative surveillance methodology), and historical data (how much does past emergence predict future emergence?[401]). Artificial intelligence techniques are of interest for discovering novel potential vectors and/or hosts (based on known relationships) for a given pathogen or identifying less likely hosts/vectors (arguably equally useful for prioritizing risk-mitigating actions[402]). There is also a need to gather more or new field data through well-planned longitudinal studies[403], such as repeatedly sampling specific populations (wildlife, for example) in hotspots, high-risk areas (for example, at the land-water interface[404]), or areas with limited data over time in order to understand temporal variations in risk[405], seasonality, and climate change effects on transmission dynamics. Participants pointed out the importance of implementing research in multi-sectoral frameworks[406]. They also prioritized adopting socio-cultural approaches[407] essential to assessing risk behaviors and understanding the complete disease ecosystem.

## 12.4. Ethics and policies

### *Ethical guidelines*

Ethics are obviously a key component of any international protocols, and two main areas have been identified. First, concerns abound regarding the lack of ethical guidelines[408] related to subjects such as biological material access through the Nagoya protocol[409], laboratory safety procedures[410], or the implementation of important biosecurity measures generally used only in large-scale intensive livestock facilities[411]. Ethical considerations are also central to the development of official[412] and cross-sectoral (public, private, or third-party) partnerships to build trust and ensure that data confidentiality is maintained.

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[400] 1258, 1260
[401] 1096, 1068, 1201
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[403] 1434, 1070, 1489, 1115, 1397
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[405] 1078
[406] 1043, 447
[407] 1118, 1185, 1131, 1231, 1101, 1262
[408] 140, 204, 664, 1142, 1145, 1146, 1180, 1381
[409] 1457
[410] 728
[411] 1419
[412] 173, 208, 230

### *Inclusion of minorities and gender aspects*

The second axis concerns the social dimension of preventing zoonotic disease emergence, especially for the minorities and stigmatized communities[413] who are among the first to suffer from emergent zoonoses. Since zoonotic disease emergence prevention may be based on ecosystem[414] and/or livestock production system management, it is important to consider the impact of these management strategies on other areas[415]. This is especially true regarding animal welfare[416], and the development of sustainable and equitable agriculture[417] that ensures sustainable food security[418] while reducing the climate impact of farming[419].

### *Sample and data sharing*

Concerning sample sharing, participants advocate establishing common standards for sample submission and sharing information on tests and results[420], as well as implementing the WOAH code for sampling[421]. Permits for wildlife sampling procedures should be centralized nationally[422]. An agreement on sample transportation is also needed[423].

These legal and ethical rules demand ensuring and facilitating ethical agreements on data collection, use, and sharing according to current agreements such as the Nagoya protocol[424]. It also implies a wider reflection on governance mechanisms for One Health collaborations[425] and potential intervention strategies.

### *Policies*

PREZODE is an international initiative deeply rooted in producing scientific knowledge linked closely to each regional or national context, as well as in implementing operational prevention strategies through careful co-design at local pilot sites. To this extent, the activities developed by PREZODE will be instrumental in providing robust cost-benefits analyses that could guide public policy on zoonosis prevention. These well-informed policies, based on both up-to-date scientific knowledge and prevention strategies implemented locally by a large variety of actors, would therefore be applied

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[416] 775, 776, 777
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[420] 1106
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[423] 17, 172, 173, 175, 542
[424] 1141, 1457, 183, 298, 321
[425] 387

more sustainably. These interactions between policymakers, scientists, and operational actors will also be analyzed inside the initiative to identify potential obstacles.

# 13. Evaluation of the impact

This strategic agenda has been developed using the ex-ante Impact Evaluation, which is based on the Theory of Change (Blundo-Canto *et al.* 2020; Joly *et al.* 2015). This method permits a global impact pathway for PREZODE with stakeholders in order to identify the steps required to achieve the initiative's global vision (impact) (Figure 8). The approach requires considering the contribution of other initiatives operating in the same landscape and also contributing to similar impact. Therefore, PREZODE's global impact pathway is strategically linked to and aligned with the One Health Joint Plan of Action (OH-JPA) initiative. The OH-JPA initiative supports implementing a coordinated One Health approach at regional, national, and global levels by strengthening collaboration, communication, capacity building, and coordination across all sectors that address health concerns at the human-animal-plant-environment interface. The contribution of such other initiatives could be assessed as part of PREZODE's international collaboration strategy, either based on their own impact evaluation programs or by working in synergy via the impact evaluation framework PREZODE proposes.

## 13.1. PREZODE global impact pathway

The co-designed workshops have enabled identification of PREZODE's global ambition (**impact**) (Figure 8):

“Working with countries and with other initiatives to develop innovative and context-based solutions for avoiding animal-borne pandemics, while ensuring food security and livelihoods for the poorest communities”

This global ambition was translated into **six long-term outcomes** to be achieved by **2040**:

- **Long-term outcome 1:** building resilient socio-ecosystems while reducing pressure on biodiversity and environmental health
- **Long-term outcome 2:** improving early detection and surveillance networks - from local to global levels
- **Long-term outcome 3:** empowering local communities and national stakeholders in the reduction and early detection of emerging risks
- **Long-term outcome 4:** strengthening collaboration and trust between sectors, levels, and types of partners on all geographic scales
- **Long-term outcome 5:** ensuring political engagement and the development of evidence-based One Health policies

- **Long-term outcome 6:** ensuring ethical practices that consider equity, countries' development needs, and sharing results and recommendations

To reach these long-term outcomes, **seven medium-term outcomes** were identified and should be achieved by **2030**:

- **Medium-term outcome 1:** co-development and implementation by local and policy actors of One Health policies, operational from local to global levels and adapted to local contexts' constraints and needs
- **Medium-term outcome 2:** design and implementation of sustainable prevention strategies through the collaboration of relevant actors from the different sectors (animal, health, and environment) at local and global levels, with better understanding and management of risks
- **Medium-term outcome 3:** coordinating agency funding to ensure co-funding of activities and financial synergy through PREZODE
- **Medium-term outcome 4:** maintaining a permanent science-society-policy dialogue to ensure relevance and acceptability of the One Health measures and strategies through in-country dialogue platforms
- **Medium-term outcome 5:** ensuring permanent feedback and dialogue between researchers, development actors, and project participants
- **Medium-term outcome 6:** building (inter)national policies with on science-based evidence and a collaborative approach
- **Medium-term outcome 7:** coordinating researchers' and development actors' actions with the PREZODE coordination platform or other collaboration tools

To achieve these expected medium-term outcomes, PREZODE is built around **six action tracks** associated with implementing several high-level actions. These action tracks are the thematic pillars of PREZODE:

Reaching these targets requires an integrated approach to health that combines six main action tracks and 24 different types of high-level actions to (1) understand risk and risk activities in order to inform the co-design of adapted and efficient solutions to reduce the risks and reduce pressure on the environment (e.g., by looking at the socio-economic and politic drivers of emergence and actors' interactions); (2) strengthening early warning and surveillance systems, building on existing systems, and promoting user-based improvement through co-design and socio-economic assessment of user needs and constraints (e.g., improving land use through design of urban space); (3) ensuring the sharing of information and early warning alerts from the local to global levels through system inter-operability and international collaboration (4). These strategies will require encouraging actors' engagement and collaboration through a co-designed process of One Health policies and permanent dialogue between science-society and the political realm (5); they also require ensuring ethical practices at all levels and training (including trainers) sufficient to develop long-term in-country capacities and funding support mechanisms that guarantee actions remain sustainable (6).

These tracks and their high-level actions are mapped out across **three pathways of change**. These pathways represent the areas where PREZODE has the greatest capacity to spur sustainable and significant changes towards expected medium- and long-term outcomes. This approach contributes to the desired impact by combining sound scientific frameworks, actor engagement, and international collaboration and support:

- **Pathway of change 1:** A referential, scientific, and operational framework adapted to specific contexts to prevent emerging risks, following a One Health approach and co-developed through a bottom-up method
- **Pathway of change 2:** International and multi-sectoral collaboration to facilitate decision-making and enable relevant public policies to coordinate and synergize actions at the local and international levels
- **Pathway of change 3:** A support mechanism and framework for research and/or development programs, projects on emerging risk prevention (e.g., coordination of funding)

The global PREZODE initiative impact pathway presented here (Figure 8) is a dynamic tool that will need to evolve as the initiative develops and any other relevant needs are identified. It is important to note that an impact pathway is not linear; the results of activities might contribute to different types of changes, which may in turn enable reaching more than one target. Additionally, there will likely be feedback effects that warrant recalibrating the activities. Moreover, multiple steps might be required to reach the outcomes identified here; these could include intermediate activities and results to be produced between primary/secondary or tertiary outcomes.

## 13.2. Detailed/specific impact pathway and monitoring and evaluation process

In addition to this global impact pathway, detailed impact pathways and evaluation indicators will be developed based on the outputs of the co-design process of the initiative. These will subsequently need review both at the national level and within the framework of further development and implementation of the initiative's activities. Specific pathways will be developed for the three expected strategies of the initiative and the five scientific pillars, and will be required at the national level for each country involved in PREZODE activities. More specific pathways may be required and developed according to need.

## 13.3. Bibliometric analysis for impact evaluation

A bibliometric analysis will be conducted in 2022 to identify the scientific landscape in which PREZODE will develop its activities. This analysis will be repeated in five to 10 years to understand how this landscape is evolving over time.
The specific objectives of this analysis will be to:

1. Understand how institutions and researchers collaborate: which academic fields are working together? Who is working with whom?
2. Understand how inter-disciplinary and inter-sectorial research is financed
3. Assess the number of projects focusing on zoonotic risk prevention that implement bottom-up approaches

## 13.4. Monitoring and evaluation logical framework

A set of indicators will be defined based on this global impact pathway and, subsequently, on the detailed impact pathways.
Globally and specifically relevant indicators based on existing grids such as Sustainable Development Goals (SDGs) and the Globally Harmonized System (GHS) will need to be identified to assess the initiative's impact on each target set and its global vision. Specific indicators could be defined according to need and the availability of measurement data.
Performance indicators will be defined to measure the outputs (results) and the outcomes (changes) in line with the activities implemented as part of the initiative; these indicators will be based on existing evaluation protocols (e.g., the One Health evaluation grid from the Network for Evaluation of One Health [NEOH]], collaboration performance indicators, surveillance evaluation tools such as Survtool, etc.). The PREZODE Impact and Evaluation working group will review existing indicators and evaluation tools to identify the most relevant and practical ones. Specific indicators could be defined as needed at the onset of a specific activity to ensure that its performance can be monitored over time. Such work could address the indicators used to assess risk levels or return on investment and be initiated with international organizations of the quadripartite alliance.

PREZODE will support projects/programs under the PREZODE endorsement process or led by PREZODE members in their impact evaluation strategy and implementation. PREZODE could also support other initiatives in developing impact evaluation strategies, using a similar framework to streamline the global assessment of each initiative contribution to reach comparable targets.

## 13.5. Impact and evaluation working group

An Impact and Evaluation Working Group will be launched as part of PREZODE governance. This group will continue impact evaluation, monitoring, and evaluation at the scale of the initiative. It will also develop precise impact pathways and detailed logical frameworks for monitoring and evaluation that will enable review of the initiative's performance over time. This group could provide support to members and other initiatives attempting to build synergies or develop their own impact evaluation strategies.

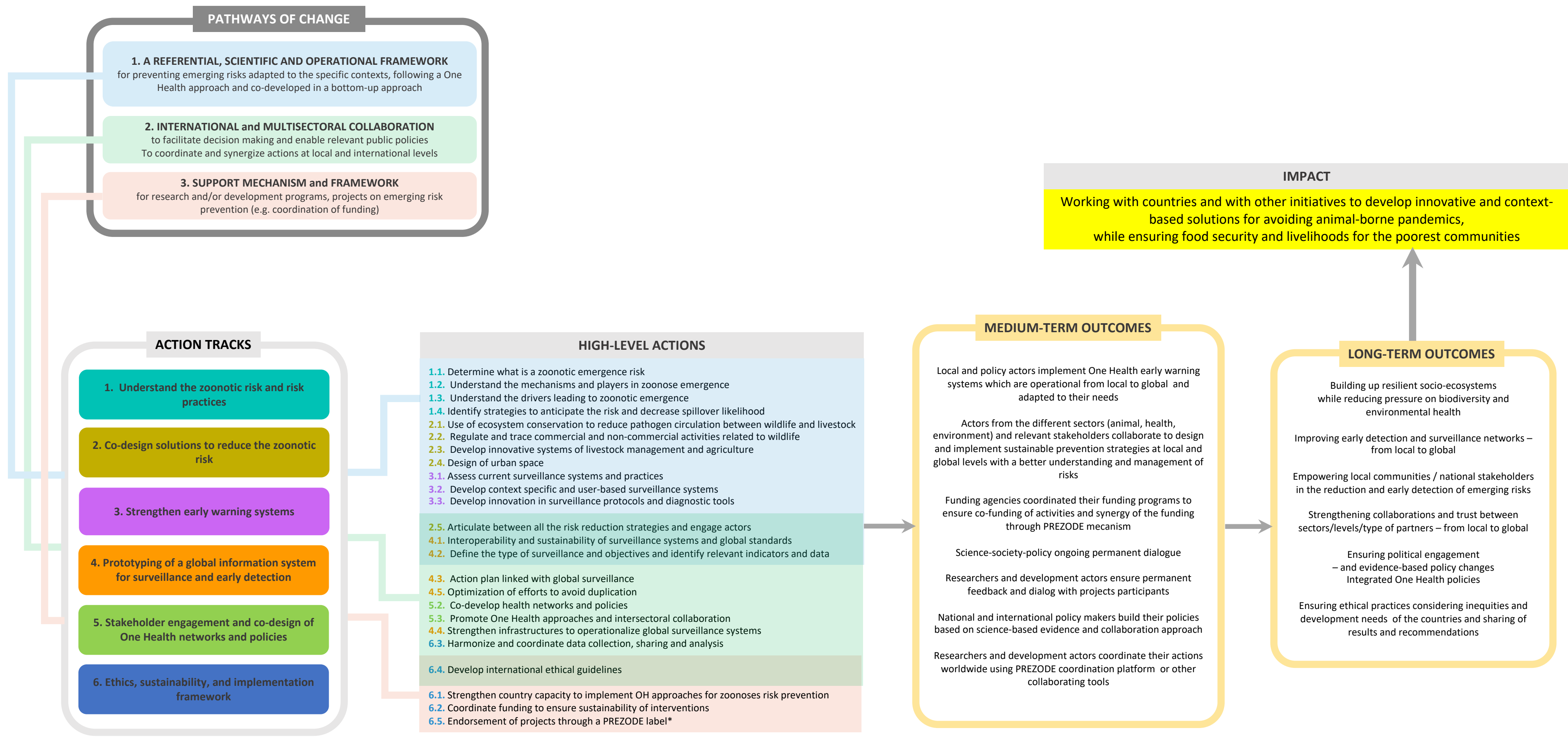


***Figure 9.*** *PREZODE initiative global impact pathway adapted from the OH-JPA impact pathway*

# 14. Key elements of the PREZODE Initiative implementation

## 14.1. Partnership and cooperation approach

As of the date of submission of the first PREZODE strategic agenda, 164 institutional members and 12 countries have declared their support for the initiative. This includes 119 academic organizations and 33 NGOs or enterprises.

PREZODE aims to respect all members and the diversity of their opinions. It also supports the principle of equity among the members, no matter their financial contribution capacity or geographical origin.

## 14.2. Governance

PREZODE members agree on Terms of Reference (ToRs) describing the governance of PREZODE and its functioning. Any legal entity or group of organizations conducting or willing to conduct activities related to the One Health approach can apply for PREZODE membership. PREZODE membership is not legally binding and does not imply any financial commitment. Countries and organizations applying for membership are first required to sign an online declaration of intent (https://prezode.org/Get-involved ).

The initiative is governed by 3 main bodies:

1. The General Assembly (GA), with one representative per PREZODE member, reviews and adopts the strategy and the deliverables of the initiative based on proposals elaborated by the Steering Committee.
2. Elected by colleges of the GA, the Steering Committee (SC) proposes a strategy and time-bound deliverables to the GA and oversees the implementation of the initiative. A portion of the SC members represents PREZODE's world regions.
3. The Donor Committee (DC) gathers representatives of public and private donors who allocate funds to PREZODE-related projects and programs. It mobilizes resources in support of the initiative and secures funds committed to research and operational activities.

These three bodies are supported by the Secretariat (S), which coordinates and implements the day-to-day activities of the PREZODE initiative, and by two additional advisory bodies:

- An independent Scientific Advisory Board (SAB), which provides scientific and technical recommendations to the SC and GA;

- An independent Ethics Committee (EC), which advises on ethical, biosafety, and biosecurity issues in the field of emerging zoonotic disease prevention, as well as on any ethical issue connected to PREZODE membership and activities.

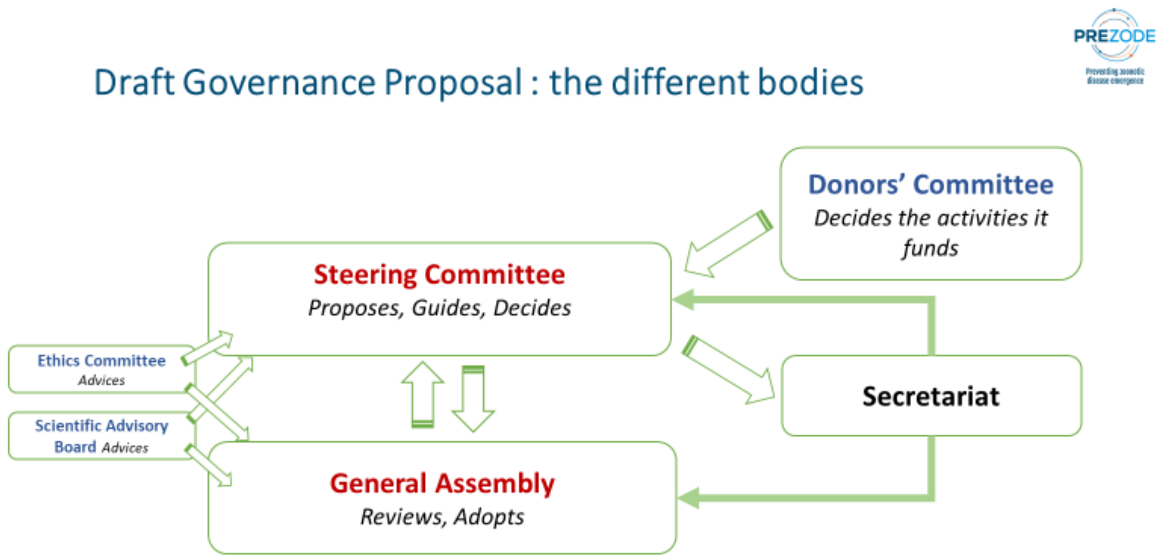


***Figure 10.*** *PREZODE's governance scheme*

Members are asked to vote on these initial ToRs at the first meeting of the General Assembly (GA). However, updates on the ToRs may be discussed during the next GA meeting at the initiative of the GA President or the Steering Committee chair.

## 14.3. Endorsement process for projects, programs, and initiatives

*What do we mean by a PREZODE endorsement scheme and why do we want to build it?*

In order to foster synergies between current and future activities[426], the PREZODE community has proposed developing a formal endorsement scheme. Inclusion or eligibility criteria and a formal application process (cf. Section How) will be defined to ensure that the different

426 **Terminology used in this document**

- **Activity: actions conducted by** a person or group – either through projects, programs or initiatives
- **Project:** an individual or collaborative enterprise that is carefully planned to achieve a particular aim; a sequence of tasks that must be completed to reach a given outcome. Specific with a defined time line
- **Program**: a set of related measures or activities with specific long-term goal(s). Programs might define the framework of open call for projects. Longer time line - larger portfolio of projects
- **Initiatives**: a new attempt to achieve a goal or solve a problem, or a new method for doing this. Initiatives often set global agendas and direction, and can support programs as well as projects, directly or indirectly. They also drive long term transformative processes, visions and goals; often initiatives will turn into programs

projects, programs, and initiatives under this scheme coordinate their actions. Any activity can apply to join this scheme, including those outside PREZODE's direct funding.

### *How are activities endorsed?*

To enter the endorsement process, all projects, programs, and initiatives at any geographic scale would have to meet **all** criteria below, which address objectives and values (in line with PREZODE values and strategic agenda). Entrants must also adhere to fundamental safeguarding principles, such as respect for human rights, animal ethics, livelihood, and the environment. Finally, entrants must not have any intention to alter or negatively impact biosecurity.

**Criteria:**

1. Contribute to the prevention of zoonotic disease emergence.
2. Consider aspects related to gender equality, diversity, ethics, and open science
3. Aim to contribute to at least one Sustainable Development Goal
4. Aim to launch actions in the fields of research, innovation, education, or development projects that will improve or better knowledge sharing on emergence risks, zoonotic disease spread, and surveillance and mitigation actions.
5. Promote One Health as an integrated, unifying approach.
6. Encourage sharing relevant information, results, and innovations, ideally through a common platform, to improve knowledge and ensure the future empowerment of local and international communities.
7. Encourage evidence-based policy development and/or recommendations using a bottom-up approach whenever possible and relevant.
8. Take an inclusive approach whenever possible to engage with relevant actors at all geographic levels to ensure actions are relevant and acceptable.

### *What are the benefits for endorsed projects, programs, and initiatives?*

As part of the PREZODE **community**, endorsed projects, programs, and initiatives would **be recognized for embracing** the principles, **values, and goals, including collaboration and synergy between activities,** promoting PREZODE paradigm change to prevent next pandemics. In addition to granting greater visibility to activities, endorsement will facilitate international interaction and ensure deeper impacts.

# 15. Synchronization with the One Health Joint Plan of Action

It is crucial to acknowledge that the PREZODE initiative's goals are shared by other medium and large One Health projects. Consequently, aligning with existing regional and international frameworks can also encourage the sustainability of a national multisectoral One Health approach against zoonotic disease emergence. Therefore, most countries work within one or more frameworks that require coordination across sectors and disciplines.

Given the context of a fluctuating environment experiencing rapid growth, the "Synergy" section of the first version of PREZODE's strategic agenda focuses on the potential support PREZODE can bring to the **quadripartite One Health Joint Plan of Action** (OH JPA)**.** Future versions will develop synergies with frameworks like the Convention on Biological Diversity (CBD), the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), and the United Nations Framework Convention on Climate Change (UNFCCC).

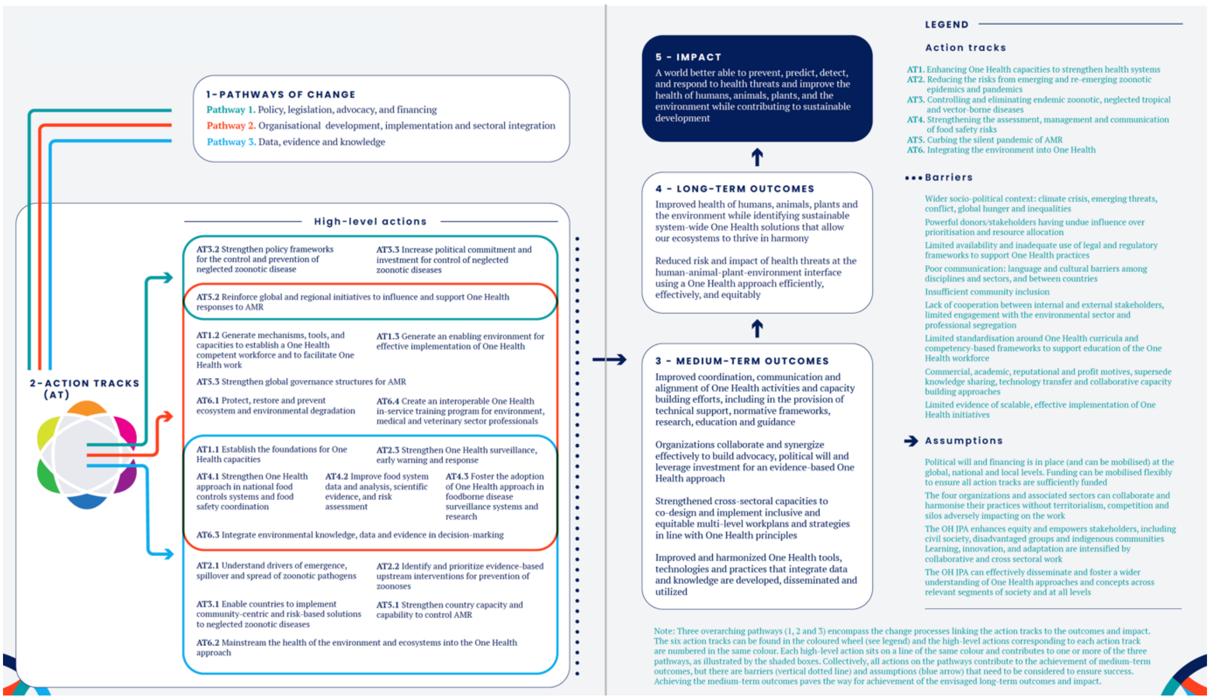


***Figure 11.*** *Overview of the theory of change for the OH-JPA*

Even though the PREZODE initiative is focused on zoonotic diseases and the OH-JPA more broadly address all health threats that OH actions might cover, both plans rely on the same vision and operational objectives. These similarities underscore the need to pursue evidence-based One Health strategies (Pillars 1, 2, 3, and 4) through investment in research, including

local communities (Pillar 5, Theme 1), and a reinforced dialogue between science and policy (Pillar 5, Theme 2).
To this extent, we identified practices common to both action tracks (AT) 1, 2, 3, and 6 of the OH-JPA and those identified during PREZODE co-design workshops. Action tracks 4 and 5, respectively addressing food safety risks and the relatively unnoticed spread of antimicrobial resistance, are not in the center of PREZODE's scope, even though by-product synergies will inevitably emerge during its development.

- **Action track 1: Enhancing One Health capacities to strengthen health systems**

In AT1, specific actions have been proposed, including developing a One Health legal framework and coordination system and building capacity. These actions are completely in line with Pillar 5 activities concerning promoting One Health approaches in intersectoral collaboration, co-development/coordination of health networks, and One Health transversal needs concerning ethics and capacity building. To this extent, the PREZODE co-design workshops and the more than 1,600 actors in 125 countries who participated over 18 months, represent one of the largest and most diverse One Health communities that could create sort of network coordination.

- **Action track 2: Reducing the risks from emerging and re-emerging zoonotic epidemics and pandemics**

In its AT2, the OH-JPA highlights the need to understand the drivers of the emergence, spillover, and spread of zoonotic pathogens (Action 2.1); PREZODE's strategic agenda addresses this need in Pillar 1 and highlights data use priorities (sampling, interoperability, sharing, etc.) in its transversal needs section. Action 2.2 focuses on identifying and prioritizing targeted, evidence-based upstream interventions to prevent the emergence, spillover, and spread of zoonotic pathogens; this action fully addresses the activities of Pillar 2 of PREZODE, in which the objective is to build sustainable strategies that reduce zoonotic emergence risks by constructing resilient socio-ecosystems that incorporate Indigenous people's knowledge. Through this approach, PREZODE aims to understand emergence drivers in order to build comprehensive and resilient strategies based on scientific data and community knowledge.
Action 2.3 aims to ensure the timely detection of zoonotic (re-)emergence through sustainable and targeted One Health surveillance systems in order to establish triggers for action and develop evidence-based decision support tools. To this extent, the PREZODE initiative will contribute to the implementation of global OH surveillance by developing global data management systems, standardized OH surveillance methodologies (Pillar 4), and early warning systems (Pillar 3); these elements are mentioned specifically in actions 2.3.1 and 2.3.4 within the context of a knowledge and data sharing platform. PREZODE will also contribute to the global effort to establish predictive epidemic intelligence systems (as cited in actions 2.3.5, 2.3.7, and 2.3.8) through a focus on innovative pathogen detection at the

pre-emergence or emergence phases, as well as pathogen emergence frameworks or forecasts. Indeed, timely zoonosis detection can be achieved through a One Health strategy as well as shared knowledge and state of the art prevention technologies.

- **Action track 3: Controlling and eliminating neglected endemic zoonotic tropical and vector-borne diseases**

Even though Action Track 3 of the OH-JPA is primarily concerned with controlling and eliminating endemic zoonotic diseases, while PREZODE focuses on preventing emerging ones, we have identified some synergies on this track. These include promoting communication on zoonotic risk and community engagement, and are central to pillar 5 of PREZODE.
AT3 also emphasizes the need for integrated multisectoral training, much as PREZODE's transversal needs section encourages via a participatory approach; this has already been implemented in the construction of PREZODE.
Finally, action 3.2 focuses on implementing practical measures to strengthen policy frameworks at all levels and is directly linked to pillars 3 and 4, which focus on surveillance systems at the local, national, and global levels and implementing efficient and integrative surveillance at all scales. The control and elimination of zoonoses also relies on community engagement and a stronger policy framework, achieved through practical measures and multisectoral training.

- **Action track 6: Integrating the environment into the One Health approach**

AT6 has synergies with PREZODE pillars 1 and 2, as we included the environment in our understanding of emergence drivers and consider the role environmental management plays in mitigating emergence risks. Indeed, the environment is key to the One Health approach, and only by acknowledging and understanding its interdependence on animal and human health can we truly achieve an integral vision to mitigate zoonosis (re-)emergence.

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# 17. Appendixes

## 17.1. Key definitions

This section defines the main concepts in this document in alphabetical order.

A

**antimicrobial resistance (AMR)** - microbial resistance to antimicrobials is a natural phenomenon but is exacerbated by their inappropriate use in human and animal medicine. AMR arises when disease-causing organisms evolve to become resistant and survive the medicines used to treat them.

**Anthropozoonosis:** infection or disease that primarily affects other animals but can be naturally transmitted to humans (with the reservoir host being the other animal, e.g., human rabies from domestic dogs) (IUCN, 2021).

B

**Bayesian statistics** - a theory in the field of statistics in which the evidence about the true state of the world is expressed in terms of 'degrees of belief'. Find more information on the site of the International Society for Bayesian Analysis

**benefit-cost ratio** - a ratio that attempts to summarize overall value for money; value of benefits divided by value of costs

C

**collaboration** - a working practice where individuals/groups work together towards a common purpose to achieve mutual goals

**co-construction** - co-developing solutions with all the actors who can be involved

D

**direct contact -** transmission of pathogens through contact with saliva, blood, urine, mucous, feces, or other body fluids (e.g., rabies, ebola)

**disease** - Arthur Kleinman shaped the concepts of illness and disease. Disease is regarded as a natural phenomenon (etic view)

**Disease outbreaks:** those with pandemic potential have a zoonotic origin, caused by a pathogen spilling over from animals into humans and occurrence of disease cases in excess of normally expected.

E

**emergence and re-emergence (WHO):** Emerging infectious diseases are those due to newly identified and previously unknown infectious agents, which cause public health concern or problems either locally or internationally. Re-emerging infectious diseases are those due to the reappearance and increase of infections which are known, but had formerly fallen to levels so low that they were no longer considered a public health problem.

**emic** - a framework for social analysis which is rooted in the ideologies of local communities, wherein the perspective is internal and perceptional

**empirical** - based on or verifiable by observation or experience rather than theory or pure logic

**endemic** - describes a disease regularly found in a certain area

**Eco Health** - a community of practice which includes systemic, participatory approaches to understanding and recognizes the inextricable linkages between the health of humans and animals and their environment within the social context and tries to demonstrate such linkages using integrated scientific studies

**Epidemic**: an increase, often sudden, in the number of cases of a disease in a particular area

**epidemiology** - the study of the distribution and determinants of health-related states or events (including disease), and the application of this study to the control of diseases and other health problems

**etic** - a framework for social analysis which is based on the ideologies of professionals outside of the local communities, such that the perspective is external and observational

**Enzootic and Epizootic**: An epizootic is defined as an outbreak of disease in which there is an unusually large number of cases, whereas an enzootic refers to a low level of disease that is constantly present in an animal population

F

**Focus Group Discussion** - a qualitative method that engages a small number of people in a focused discussion

**food safety** - the science of providing safe, high-quality food along the chain from production through transformation, storage, and marketing all the way to consumption of food

**Foodborne transmission** - transmission via milk, meat, eggs, fruits, vegetables contaminated by a pathogenic agent from an animal or human or environmental source (e.g., salmonellosis, brucellosis) or human/animal recombinant bugs (e.g., *E. coli*O104:H4)

H

**health economics** - a branch of economics concerned with issues related to efficiency, effectiveness, value and behavior in the production and consumption of health and healthcare

**Host:** a living organism, which is capable of supporting a microorganism or parasite in its body or cells. and may harbor a disease

I

**illness** - Arthur Kleinman shaped the concepts of illness and disease. Illness is conceptualized as a cultural construction (emic view) of not feeling well

**Indirect contact** - coming into contact with areas where animals live and roam, or objects or surfaces that have been contaminated with germs (e.g., Q fever [*Coxiella* burnetii], influenza, coronaviruses).

**Infectious agent**: a microbial organism (virus, bacterium), parasite or prion causing infection or infectious diseases

**integration** - bringing together smaller components into a single system that functions as one

**interdisciplinarity** - a process which involves combining two or more academic disciplines into one activity (e.g., a research project) in order to create something new by crossing boundaries and thinking across them

**interviews** - a popular method of gathering qualitative information. They provide a way of generating empirical data by asking people to talk about their lives and experiences

K

**KAP studies** - a rapid appraisal method called knowledge, attitude and practice (KAP) study

L

**Livestock facilities:** feedlots, pens, confinement buildings, and other types of systems designed to house livestock in a productive manner

M

**mathematical model** - a description of a system using mathematical concepts and language

**meat inspection** - examination of meat intended for human consumption to ensure that it is wholesome and free from diseases that might be transmitted from the animal to humans; may include examination of the living animal and/or the carcass

N

**nature-based solutions** - actions to protect, sustainably manage, and restore natural and modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits

O

**observations** - one of the most important methods used during qualitative data collection
**One Health:** an integrated and unified approach that aims to sustainably balance and optimize the health of people, animals, and ecosystems. It recognizes the health of humans, domestic and wild animals, plants, and the wider environment (including ecosystems) are closely linked and interdependent. This approach mobilizes multiple sectors, disciplines, and communities at varying levels of society to work together to foster well-being and tackle threats to health and ecosystems, while addressing the collective need for healthy food, water, energy, and air, taking action on climate change and contributing to sustainable development (OHHLEP, 2022).

P

**Pandemic**: an epidemic occurring in multiple continents or worldwide, or over a very wide area, crossing international boundaries and usually affecting a large number of people
**Pathogen**: an organism causing pathological dysfunction (disease) to its host
**pathogen spillover** - an event occurring when a reservoir population with a high pathogen prevalence comes into contact with a novel host population. The pathogen is transmitted from the reservoir population and may or may not be transmitted within the host population.
**planetary health -** an inter-disciplinary approach that addresses the interconnections between the processes of environmental change and their impacts on human health and well-being, at scale. This approach builds on the ecological framing of planetary boundaries and supports the UN Sustainable Development Goals and the Paris Climate Change Agreement.
**pluralistic** - a condition or system in which two or more states, for example, groups, principles or sources of authority, coexist
**Preparedness:** ex ante actions that help mitigate losses when a disease outbreak occurs. It includes strengthening the capacities and capabilities at community, country, regional, and global levels to prevent, detect, contain, and respond to the spread of disease, mitigating economic and social impacts.
**Prevention** encompasses the systems, policies, and procedures with participation to determine, assess, avoid, mitigate, and reduce public health threats and risks. This definition captures interventions needed to mitigate risk and reduce the likelihood or consequences of spillover events at the human, animal, or ecosystem interfaces. Such interventions frequently reside within agriculture, food, or environmental sectors, highlighting the importance of a multi-sectoral One Health approach. However, routine health systems strengthening initiatives can also be included under the definition of PPR, as prevention and preparedness

are often best supported through health systems strengthening, rather than by setting up separate structures.

Q

**qualitative methods** - qualitative research is a broad methodological approach encompassing many research methods. Qualitative methods examine the why and how of decision making, not just what, where, when, or who, and have a strong basis in the field of sociology and anthropology

R

**reservoir host -** a host in which an infectious agent can be maintained and from which this agent can be transmitted to other hosts.

**Response:** ex post actions taken in response to a disease outbreak to reduce its economic, social and health consequences or impacts

**risk analysis** - a science-based, structured, transparent method used to identify and assess factors that may jeopardize the success of a project or achievement of a goal; includes three components: risk assessment, risk management and risk communication

S

**socio-ecosystems -** A coherent system of biophysical and social factors that regularly interact together

**stakeholder** - a party that has an interest in an enterprise

**Spillover infection**: an infection from a reservoir host, that results in infection in another species, a dead-end infection with no onward transmission or a stuttering chain of limited transmission in another the new host species or secondary epidemiological cycles that can be quite extensive but usually burn out, and inclusive of single events which lead to pathogen spread and independent circulation in another species (Plowright et al., 2017).

**surveillance** - systematic, continuous or repeated, measurement, collection, collation, analysis, interpretation and timely dissemination of health-related data from defined populations to the relevant stakeholders to ensure risk mitigation actions.

**syndrome** - a group of symptoms that together are characteristic of a specific disorder or disease

T

**transdisciplinarity** - the process through which scientists enter into dialogue and mutual learning with societal stakeholders, such that science becomes part of societal processes, contributes explicit and negotiable values and norms in society and science, and attributes meaning to knowledge for societal problem solving

V

**Vector**: an animal (vertebrate or invertebrate) which is essential important for carrying and transmitting of an infectious agent to another living species over space and time (e.g., *Anopheles* mosquitoes and the *Plasmodium falciparum* malaria agent)

**vector-borne pathogen** - a pathogenic agent transmitted by the bite of an arthropod vector like ticks, mosquitoes, flies, flea, biting midges, lice, and bedbugs (e.g., yellow fever, bubonic plague, West Nile encephalitis, Lyme disease, Rift Valley fever)

W

**waterborne transmission** - transmission by drinking or coming in contact with water that has been contaminated by an infected animal or human (e.g., amoebae, Hepatitis E virus, leptospirosis, Schistosoma)

**Wildlife**: for the purposes of considering human-animal disease risk, this report defines "wildlife" as vertebrate animals including all feral animals, captive wild animals, and wild animals, as proposed by the WOAH (World Organization for Animal Health).

**Wildlife farming**: in the context of the wild animal, plant, and fungi trades, this term designates modes of management and production that are distinct from "wild-sourcing" or "ranching", with breeding, propagation, and raising taking place in controlled conditions.

Z

**zoonosis** - any disease or infection that is naturally transmissible from between vertebrate animals (animal reservoir) to and humans (WHO, 2020b); either directly (via contact or aerosol) or indirectly (via food, fomite or vector [usually arthropod])

**zoonotic pathogen -** a pathogen that is maintained in a non-human animal reservoir and is capable of infecting and causing disease in humans

## 17.2. List of abbreviations

**AMR:** Antimicrobial resistance
**CBD :** Convention on Biological Diversity
**CIRAD:** Centre de coopération Internationale en Recherche Agronomique pour le Développement
**CITES:** Convention on International Trade in Endangered Species of Wild Fauna and Flora
**COVID-19:** Coronavirus Disease
**FAIR:** Findability, Accessibility, Interoperability, and Reusability
**FAO:** Food and Agriculture Organization of the United Nations
**GDPR:** General Data Protection Regulation
**INRAE:** Institut National de la Recherche pour l'Agriculture, l'Alimentation et l'Environnement
**IRD:** Institut de Recherche pour le Développement
**KAP:** Knowledge, Attitude, and Practice
**LMIC:** Low- or Middle-Income Country
**MERS:** Middle East Respiratory Syndrome
**NEOH: Network for Evaluation of One Health**
**NGO:** Non-Governmental Organization
**OH:** One Health
**OHHLEP:** One Health High Level Expert Panel
**OH-JPA:** One Health Joint Plan of Action
**PREZODE**: PREventing ZOonotic Disease Emergence
**SA:** strategic agenda
**SARS:** Severe Acute Respiratory Syndrome
**UNEP:** United Nations Environment Programme
**UNFCC:** United Nations Framework Convention on Climate Change
**WOAH:** World Organization for Animal Health
**WHO:** World Health Organization