Advancing a One Health approach to support the challenge of infectious diseases in Brazil

Workshop report

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The Academy of Medical Sciences

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Contents

Executive summary

The majority of emerging infections originated in animals before crossing species barriers and affecting humans. Zoonotic infections transmitted from animals to humans are becoming more common, likely due to a combination of factors that are increasing the exposure of people to novel or known pathogens present in animal reservoirs. These include changes in land use, agricultural practices, food chains, and deforestation, which reduce animal diversity and bring people into closer contact with animals.

In addition, **climate change** is having a profound impact on the distribution of pathogen-harbouring animals and pathogen-transmitting vectors. It is also triggering extensive migration, changing people's interactions with their environment in ways that affect their exposure to infectious disease.

The **'One Health' approach** recognises the importance of the interplay between animals, humans and the environment, and the mutual interdependence of the health of each. A sustainable existence relies on healthy ecosystems supporting human and animal populations. Disruptions to this balance can have profound short- or long-term consequences for human health.

The One Health approach is inherently **integrated, cross-sectoral and interdisciplinary,** spanning multiple fields of research, including the biology of host–pathogen interactions, the ecology of wider ecosystems, public health, clinical and veterinary medicine, social and economic drivers of human behaviour, and environmental and climate science.

The One Health concept is of particular relevance to Latin America in general and Brazil in particular, given factors such as its high biodiversity, rapid social development and vulnerability to climate change. In March 2023, the UK Academy of Medical Sciences, Brazilian Academy of Sciences and Brazilian National Academy of Medicine jointly convened a workshop in Rio de Janeiro, Brazil, to discuss opportunities to promote a One Health approach to address Brazil's scientific opportunities and gaps, and obstacles to effective implementation.

Following introductory presentations, participants from Brazil and the UK joined breakout groups focused on policy, research, data and community engagement. Discussions highlighted a range of key themes.

The key relevance of One Health to Brazil

Participants concluded the One Health approach is of particular relevance to Brazil, given the immense **biodiversity** of the Amazon region, extensive deforestation linked to natural resource extraction and changing agricultural practices, and environmental sensitivity to the impacts of climate change. These factors are contributing to **increased contact** between people, known and unknown pathogens of animals, providing additional opportunities for **spillovers to people** and transmission between people. Successfully addressing these issues will require an integrated and holistic One Health approach.

Strengths of research in Brazil and international collaborations

Brazil has a **long history** of research on zoonoses and the interplay between the natural world, infectious disease and human activities. Much of this work pre-dates the modern formulation of the One Health concept. It has often been based on **interdisciplinary research interactions and international collaborations.** This strong history provides a firm foundation on which to build additional programmes of One Health research.

Limited adoption of a One Health mindset

Although there is a significant One Health 'movement' in Brazil, participants concluded that the One Health approach has **yet to be fully embedded in the consciousness** of all researchers, policymakers or the public. Research consistent with One Health principles is not always described as such and the relationship to other similar terms, such as planetary health (the dependence of human health on the planet's

natural systems), is not always clear.[1] Participants suggested that clarity is important to ensure **effective communication, political advocacy and public engagement,** and to guide One Health activities.

Understanding drivers of zoonotic disease and potential impacts as key priorities

Participants suggested that a **deeper understanding of the complex mix of factors that drive the emergence and spread of zoonotic disease** should be a key focus of One Health research. Greater input from environmental and social and behavioural scientists was highlighted to be important in this area. Although many data sources exist, they are currently not well connected and there are few incentives to share data; however, building or extending open-access databases, including case studies, could help to address this gap. Further studies on the **impact of prevention and control efforts,** including health economic analyses to generate policy-relevant evidence, were also identified as a priority.

The need for stronger collaboration

Although several research collaborations have been established, participants recognised the need to **strengthen existing interdisciplinary collaborations and build wider partnerships** to strengthen the adoption of the One Health approach. The need to build and strengthen international research partnerships with those in the global South and North was also recognised.

Research funding

It was suggested that, while funding streams are an important enabler of research, **funding systems can also impose barriers to effective interdisciplinary research collaborations.** Conventional funding mechanisms are typically short term and project-based while interdisciplinary collaborations take time to develop and become fully productive. In addition, interdisciplinary funding applications often fare poorly when assessed through conventional discipline-specific peer review and funding panel models.

The workshop highlighted the relevance of One Health to Brazil and showcased multiple examples of notable One Health-related research carried out in Brazil, frequently as part of international collaborations, such as research examples one to three. This provides a **solid foundation on which to build future programmes of One Health-related research.** Key challenges include the need to build greater awareness of the One Health concept among key stakeholders, including the public, to strengthen research collaborations and partnerships with policymakers, and to ensure that funding mechanisms are aligned with the One Health approach.

1. Capon A. Understanding planetary health. Lancet. 2020; **396(10259)**: 1325–1326.

Introduction

The COVID-19 pandemic was the latest illustration of the catastrophic consequences that can follow the transfer of a new infectious agent from an animal host to humans. It is likely that SARS-CoV-2 originated in a wild animal population before infecting people associated with a live-animal market in Wuhan, China. If so, it was the latest in a long line of pathogens that have jumped species and become established in humans – and it is unlikely to be the last.

The risk of 'zoonotic' spread of pathogens – transmission from other animals to humans – is becoming ever greater, due to the changing nature of interactions between humans, animals and the vectors that ferry pathogens between them. Many factors are driving this change, including the movement of people into previously sparsely inhabited areas, land use changes and urbanisation, and the impacts of climate change on people, pathogens and vectors. The complex interplay between these factors is affecting people's exposure to known pathogens and creating new risks for the 'spillover' of novel pathogens from animals to humans.

The interconnectedness of human health, animals and the environment is the central tenet of the **'One Health'** approach. One Health is an interdisciplinary, integrated approach that simultaneously aims to optimise the health of humans, animals and ecosystems. By focusing on the connections between humans, animals and the environment, One Health can address the full spectrum of infectious disease control, detection, prevention, preparedness, response and management.

The One Health approach is of particular relevance to Brazil. The country is a **biodiversity 'hotspot'** but also one in which deforestation and changing land use is having a profound effect on fragile ecosystems. These changes will have global consequences for the climate, which will in turn have further impacts on natural systems.

To take stock of these issues and their implications for research and policy, in March 2023, the Academy of Medical Sciences, the Brazilian National Academy of Medicine and the Brazilian Academy of Science jointly organised a two-day workshop in Rio de Janeiro. The workshop included a series of scene-setting talks and presentations on specific examples of One Health research in Brazil, while breakout groups discussed potential future options for research, policy, data and community engagement.

Global context

To set the scene, Professor Janice Zanella, Brazilian Agricultural Research Corporation (EMBRAPA), provided a summary of the global, regional and national One Health policy context.

The One Health concept was initially promoted by a tripartite partnership between the World Health Organization (WHO), the UN Food and Agriculture Organization (FAO) and the Office Internationale des Epizooties (OIE, now the World Organization for Animal Health). In 2021, the UN Environment Programme (UNEP) joined this collaboration, creating the **'Quadripartite Alliance'.**

Following a call for experts in April 2021, a **One Health High-Level Expert Panel (OHHLEP)** was launched in May 2021 with 21 members from all regions. Its mission is to carry out policy-relevant scientific assessments on emerging health crises at the human–animal–ecosystem interface, and to provide guidance on the development of a long-term strategic approach to zoonotic prevention. It also contributes to the global One Health research agenda and, when invited, offers technical advice to countries.

OHHLEP has developed a consensus definition of One Health:

"One Health is an integrated, unifying approach that aims to sustainably balance and optimise the health of people, animals and ecosystems. It recognises the health of humans, domestic and wild animals, plants, and the wider environment (including ecosystems) are closely linked and interdependent. The approach mobilises 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 clean water, energy and air, safe and nutritious food, taking action on climate change, and contributing to sustainable development."

This definition is based on five principles:

- Equity between sectors and disciplines
- Sociopolitical parity – all voices are heard
- Socioecological equilibrium
- Stewardship and responsibility for the future
- Transdisciplinarity

Rather than placing humans at the centre, this model emphasises the importance of maintaining balance in order to benefit humans, animals and ecosystems equally – **'cosmocentrism'** rather than anthropocentrism. This conceptualisation of One Health extends its original meaning, which had a more restricted focus on the human–animal interface, and has some similarities with concepts such as planetary health.

To implement the model, OHHLEP has developed a **joint plan of action for 2022–2026.**[2]
A complementary **theory of change** has also been produced, which outlines the pathways through which positive change can be achieved.[3] These two outputs share a common impact statement:

"A world better able to prevent, predict, detect, and respond to health threats and improve the health of humans, animals, plants, and the environment while contributing to sustainable development."

2. World Health Organization, Food and Agriculture Organization of the United Nations, World Organisation for Animal Health & United Nations Environment Programme. One health joint plan of action (2022-2026): working together for the health of humans, animals, plants and the environment. 2022. Available at: https://www.who.int/publications/i/item/9789240059139
3. One Health High Level Expert Panel (OHHLEP). One Health Theory of Change. 2022. Available at: https://www.who.int/publications/m/item/one-health-theory-of-change

The theory of change adopts a longer-term perspective than the joint plan of action and the steps needed to achieve end goals. The joint plan of action was endorsed at the G7 Ministers Meeting in Germany in May 2022 and has also received the backing of the G20 group of nations.[4,5]

In the pandemic context, the One Health approach provides a greater focus on pathogen spillover, providing earlier warning than human health-based surveillance. The ultimate goal is to reduce both the likelihood of spillovers and their consequences, through enhanced prevention and preparedness.

Globally, many One Health networks have been established, but comparatively few in low- and middle-income countries, and environmental aspects are often not included.[6] The Pan-American Health Organization (PAHO) and Pan American Center for Foot-and-Mouth Disease and Veterinary Public Health (PANAFTOSA) - a Pan-American organisation focusing on veterinary health - published a One Health policy document in 2021.[7] Specifically in Brazil, an interdepartmental working group has been established, led by the Ministry of Health, to co-ordinate activities across national networks and institutions. A national One Health plan is being developed, focusing initially on intrasectoral mapping of activities before moving onto intersectoral mapping.

Professor Aileen Marty FCAP, Florida International University, US, reminded participants that the One Health perspective needed to include microbes and the microenvironment as well as the macroenvironment. While humans, animals and the environment are interconnected, the microbial world is an important factor in all three, shaping and responding to physical and biological environments.

Molecular and cellular interactions between human host tissues and viruses, bacteria or other pathogens dictate whether a pathogen will be able to establish an infection, cause disease and be transmitted to others, highlighting the critical importance of understanding host–pathogen interactions.

Professor Marty also noted **climate change** is having a profound impact on the interactions between humans, animals and the environment, in multiple ways. The risks associated with more than half of known pathogens are increased by climate change, while increasing exposures are leading to a greater risk of spillover of new pathogens from animals to humans.[8]

Complex life-cycles are vulnerable to disruption, affecting the human–pathogen–environment equilibrium. As well as human acquisition of novel pathogens, spillback to animals provides opportunities for further viral evolution before transmission back to humans. This may explain the origins of the omicron variant of SARS-CoV-2, for example, which may have accumulated mutations in mice before infecting humans.[9]

Taking this holistic and multilevel view of pathogens and their interactions with humans, concluded Professor Marty, will be important for breaking the cycles of neglect and panic that currently characterise pandemic preparedness and response.

4. https://www.gov.uk/government/news/g7-health-ministers-unite-to-protect-world-from-another-pandemic
5. https://www.woah.org/en/g20-ministers-of-health-reaffirm-the-urgent-need-to-address-global-health-under-a-one-health-approach/
6. Mwatondo A, Rahman-Shepherd A, Hollmann L *et al. A global analysis of One Health Networks and the proliferation of One Health collaborations.* Lancet. 2023;**401(10376)**:605-616. doi: 10.1016/S0140-6736(22)01596-3.
7. https://www.paho.org/en/documents/ce168r11-one-health-comprehensive-approach-addressing-health-threats-human-animal
8. Mora C, McKenzie T, Gaw IM *et al. Over half of known human pathogenic diseases can be aggravated by climate change. Nat Clim Chang.* 2022;**12(9)**:869-875. doi: 10.1038/s41558-022-01426-1.
9. Wei C, Shan KJ, Wang W *et al. Evidence for a mouse origin of the SARS-CoV-2 Omicron variant. J Genet Genomics.* 2021;**48(12)**:1111-1121. doi: 10.1016/j.jgg.2021.12.003.

One Health in Brazil

Focusing on national collaborations, Dr Liliane Carneiro, Evandro Chagas Institute, discussed One Health activities in Brazil. She suggested there has been a long history of One Health research in Brazil and South America more generally, even before the concept was fully developed globally.[10]

Many initiatives have been 'bottom-up' community-focused disease control projects. Examples include the LEISHNAO BRAZIL educational initiative for control of leishmaniasis, as well as more general One Health days. Region-wide, a notable success story has been the multidisciplinary collaboration on rabies control. Dog-mediated rabies in humans has been reduced by over 99% in Latin America. In 2021, the ECOHA interdisciplinary One Health network was launched in Brazil, with a particular focus on aquatic environments.

One Health is of particular relevance to the **Amazon region.** It is extremely biodiverse but subject to significant land use changes, including mining and agriculture, leading to extensive deforestation and driving significant social changes, including migration and urbanisation. The Amazon's relatively constant hot and humid climate is also conducive to the spread of infections, particularly vector-borne diseases.

There is some evidence outbreaks of several vector-borne diseases are becoming more common. For example, malaria outbreaks are on the rise in indigenous and mining areas.[11] Agricultural practices in the Amazon region also bring people into contact with disease-carrying vectors. Several yellow fever outbreaks have occurred in recent years, alongside cases of other infections such as toxoplasmosis.

Dr Carneiro suggested a complex mix of social, economic and environmental factors are all interacting to drive changing patterns of disease. To encourage a more interdisciplinary and intersectoral approach to these changes, a **'onehealthbrasil' network** has been established to connect those with an interest in this area.[12]

South America is the world's most urbanised region (accounting for the percentage of populations living in cities), and the urban environment creates an additional range of opportunities for infectious diseases to spread. **Dr Tamara Leite Cortez** described the work carried out by the **PAHO/WHO Collaborating Centre for Training and Research in Urban Zoonoses**, based in Sao Paolo. It received its first designation in 1994 and is currently nearing the end of its seventh designation, which ends in 2023; it has applied for an eight designation for the period 2023–2027.

Its key function is protecting public health through surveillance. Its eight divisions are supported by two laboratories, with capacity for diagnosis using human, animal and environmental samples. Its activities include surveillance and characterisation of animal species within the urban environment and assessing the risk to health. It is also engaged in the surveillance, prevention and control of zoonotic diseases. Other activities include advising on the control of feral animals, inspection of veterinary facilities, and advising local authorities on households where large numbers of animals are being kept.

The Collaborating Centre also supports regional PAHO activities related to the surveillance and control of urban zoonoses. It provides specialist technical training to other countries in the region and contributes to technical document development. It also contributes to research on zoonoses and disease vectors.

10. Pettan-Brewer C, Martins AF, de Abreu DPB *et al. From the Approach to the Concept: One Health in Latin America-Experiences and Perspectives in Brazil, Chile, and Colombia.* Front Public Health. 2021;**9**:687110. doi: 10.3389/fpubh.2021.687110.
11. Castro MC, Peterka C. *Malaria is increasing in Indigenous and artisanal mining areas in the Brazilian Amazon.* Nat Med. 2023 Mar 27. doi: 10.1038/s41591-023-02280-0.
12. https://onehealthbrasil.com

Viral infections

Research example one

Among the most significant infectious diseases in Brazil are those caused by **arboviruses,** which include dengue, chikungunya and yellow fever. **Dr Livia Caricio Martins** described some of the history of arbovirus research, particularly at the Evandro Chagas Institute, which has been conducting research in the Amazon region for more than 85 years.

Arboviruses are mostly zoonotic. They can occur in rural and urban settings, and can lead to reinfection of animals from humans ('reverse zoonosis'). Climate change is altering the epidemiology of disease, affecting vector density, vector diversity and viral replication.

Arbovirus circulation is being affected by different factors in different settings. Key human activities affecting exposure have included new road building, including the trans-Amazon highway, large-scale mining activities and hydroelectric constructions. Since 1954, more than 17,000 arbovirus isolates have been studied, covering 212 different types of virus, of which 175 were detected for the first time in Brazil, 115 were new to science, and 36 were associated with human disease and 6 were associated with outbreaks/epidemics.

In the 1970s, serological studies identified a large increase in arbovirus exposure as the trans-Amazon highway was constructed.[13] Similarly, studies in the late 2000s found a high prevalence of arbovirus antibodies in populations living close to the road. Other studies have examined exposure in cities along highways, such as Novo Progresso and Trairão, and genotyped circulating strains of dengue virus.[14] Conditions are ideal for virus circulation among populations with low immunity.

Studies of insects and animals around new roads in Serra Norte, Pará state, identified multiple viruses, including several previously unknown.[15] A study in Carajás Mineral Province is now analysing the presence of arboviruses in human, animal and vector populations, including local inhabitants and migrants.

Metagenomic approaches are now enabling the diversity of arbovirus species to be investigated in more depth. West Nile virus has been identified in Brazil, as well as novel viruses such as Tapirapé virus and negeviruses, and insect-specific viruses.[16,17,18,19] Outbreaks of Oropouche fever have also been detected.[20]

Dr Caricio Martins suggested that disruption of ancient ecosystems is creating conditions that favour the spread of arboviruses.[21] The current unsustainable development taking place in the Amazon could have potentially long-term implications for the wider ecosystem and ultimately the health of humans.

13. Pinheiro FP, Bensabath G, Andrade AH *et al. Infectious diseases along Brazil's trans-amazon highway: surveillance and research.* Bull Pan Am Health Organ. 1974;**8(2)**:111-22.
14. Nunes MR, Barbosa TF, Casseb LM *et al. [Arbovirus eco-epidemiology in the area affected by the Cuiabá-Santarém Highway (BR-163), Pará State, Brazil].* Cad Saude Publica. 2009;**25(12)**:2583-602. doi: 10.1590/s0102-311x2009001200006.
15. Rosa A, Rosa J, Hervé J *et al. Arboviruses in Serra Norte, Carajás region, Pará, Brazil.* 1992. Sociedade Brasileira para o Progresso da Ciência. Available at: https://patua.iec.gov.br/items/54c95e3e-0677-41bd-a7b1-d308500be7cd
16. Martins LC, Silva EVPD, Casseb LMN *et al. First isolation of West Nile virus in Brazil. Mem Inst Oswaldo Cruz.* 2019 Jan 17;114:e180332. doi: 10.1590/0074-02760180332.
17. Rodrigues DS, Medeiros DB, Rodrigues SG *et al. Pacui Virus, Rio Preto da Eva Virus, and Tapirape Virus, Three Distinct Viruses within the Family Bunyaviridae.* Genome Announc. 2014;**2(6)**:e00923-14. doi: 10.1128/genomeA.00923-14.
18. da Silva Ribeiro AC, Martins LC, da Silva SP *et al. Negeviruses isolated from mosquitoes in the Brazilian Amazon.* Virol J. 2022;19(1):17. doi: 10.1186/s12985-022-01743-z.
19. Nunes MR, Silva SP, Carvalho VL *et al. Emergence of new insect-restrictive viruses in the Amazon region.* Genome Announc. 2015 Mar 19;**3(2)**:e00131-15. doi: 10.1128/genomeA.00131-15.
20. Azevedo RS, Nunes MR, Chiang JO *et al. Reemergence of Oropouche fever, northern Brazil.* Emerg Infect Dis. 2007 Jun;**13(6)**:912-5. doi: 10.3201/eid1306.061114.
21. Vasconcelos PF, Travassos da Rosa AP *et al. Inadequate management of natural ecosystem in the Brazilian Amazon region results in the emergence and reemergence of arboviruses.* Cad Saude Publica. 2001;17 Suppl:155-64. doi: 10.1590/s0102-311x2001000700025.

Research example two

Professor Fernando Spilki, Universidade Feevale, described the application of genomic and metagenomic approaches to provide more insights into virus epidemiology in Brazil. Contamination of water became a headline issue in 2016, when US Olympic rowers suffered enteric infections. Studies identified high levels of multiple enteric viruses around Olympic venues.[22] Earlier studies had found enteric virus contamination in up to a quarter of tap water samples from schools in southern Brazil and links between rainfall patterns and viral load in untreated water samples and cases of gastroenteritis.[23,24] More recently, wastewater surveillance has been applied to SARS-CoV-2, shedding light on links between environmental parameters, detection of SARS-CoV-2 and case numbers.[25]

Genomic approaches have also been applied within the veterinary sector, identifying teschoviruses and other viral pathogens causing a polioencephalomyelitis outbreak in pigs and in environmental samples around pig farms.[26,27]

Metagenomic approaches enable a much richer picture of the diversity of viruses in environmental samples to be determined. They also facilitate the identification and characterisation of novel viruses, including husavirus in southern Brazil.[28]

During the COVID-19 pandemic, national genomic surveillance of SARS-CoV-2 was introduced in Brazil, providing information on the spread of variants.[29] The extent of genomic surveillance for other priority pathogens varies considerably. Some important data has been generated on chikungunya virus and dengue virus.[30,31]

Brazil is also part of a UK Health Security Agency (UKHSA) international collaboration, the **New Variant Assessment Platform,** which is strengthening genomic surveillance infrastructure to identify and track new SARS-CoV-2 variants in nine countries.[32]

Continuing the viral theme, **Professor Giliane Trindade,** Federal University of Minas Gerais, provided an overview of the ecoepidemiology of emerging infectious diseases in Brazil. Globally, multiple factors are driving the emergence of zoonotic diseases, including increasing demand for animal protein, unsustainable agricultural expansion, exploitation of natural resources, increased exploitation of wildlife, increased travel, changes in food supply chains and climate change. Brazil is affected by all these factors.[33]

22. Staggemeier R, Heck TMS, Demoliner M *et al. Enteric viruses and adenovirus diversity in waters from 2016 Olympic venues.* Sci Total Environ. 2017;**586**:304-312. doi: 10.1016/j.scitotenv.2017.01.223.
23. Kluge M, Fleck JD, Soliman MC *et al. Human adenovirus (HAdV), human enterovirus (hEV), and genogroup A rotavirus (GARV) in tap water in southern Brazil.* J Water Health. 2014;**12(3)**:526-32. doi: 10.2166/wh.2014.202.
24. Rodrigues MT, Henzel A, Staggemeier R *et al. Human adenovirus spread, rainfalls, and the occurrence of gastroenteritis cases in a Brazilian basin.* Environ Monit Assess. 2015;**187(11)**:720. doi: 10.1007/s10661-015-4917-4.
25. Martins RM, Carvalho T, Bittar C *et al. Long-Term Wastewater Surveillance for SARS-CoV-2: One-Year Study in Brazil.* Viruses. 2022;**14(11)**:2333. doi: 10.3390/v14112333.
26. Hammerschmitt ME, de Almeida PR, de Cecco BS *et al. Swine polioencephalomyelitis in Brazil: identification of Teschovirus A, Sapelovirus A, and Enterovirus G in a farm from Southern Brazil.* Braz J Microbiol. 2021;**52(3)**:1617-1622. doi: 10.1007/s42770-021-00509-z.
27. Souza FG, Gularte JS, Demoliner M *et al. Teschovirus and other swine and human enteric viruses in Brazilian watersheds impacted by swine husbandry.* Braz J Microbiol. 2020;**51(2)**:711-717. doi: 10.1007/s42770-019-00197-w.
28. Demoliner M, Filippi M, Gularte JS *et al. Genome of a husavirus from Southern Brazil.* Rev Inst Med Trop Sao Paulo. 2023;**65**:e5. doi: 10.1590/S1678-9946202365005.
29. Menezes D, Fonseca PLC, de Araújo JLF, Souza RP. *SARS-CoV-2 Genomic Surveillance in Brazil: A Systematic Review with Scientometric Analysis. Viruses.* 2022;**14(12)**:2715. doi: 10.3390/v14122715.
30. Souza UJB, Santos RND, Giovanetti M *et al. Genomic Epidemiology Reveals the Circulation of the Chikungunya Virus East/Central/South African Lineage in Tocantins State, North Brazil.* Viruses. 2022;**14(10)**:2311. doi: 10.3390/v14102311.
31. de Jesus JG, Dutra KR, Sales FCDS *et al. Genomic detection of a virus lineage replacement event of dengue virusserotype 2 in Brazil, 2019.* Mem Inst Oswaldo Cruz. 2020;**115**:e190423. doi: 10.1590/0074-02760190423.
32. UK Health Security Agency (UKHSA). *UKHSA expands support to help countries identify emerging variants.* 23 May 2022. https://www.gov.uk/government/news/ukhsa-expands-support-to-help-countries-identify-emerging-variants
33. Nava A, Shimabukuro JS, Chmura AA, Luz SLB. *The Impact of Global Environmental Changes on Infectious Disease Emergence with a Focus on Risks for Brazil.* ILAR J. 2017;**58(3)**:393-400. doi: 10.1093/ilar/ilx034.

As well as pristine forest environments and urban environments dominated by people, habitats in Brazil are increasingly being shared by animals and humans, providing new opportunities for viruses to emerge and spread. One example is **vaccinia virus,** which circulates in cattle but is increasingly the source of zoonotic infections through a range of routes, including direct contact with cattle, through contaminated dairy products, or through wild-animal intermediary hosts.[34] In the Mangabeiras urban park in Belo Horizonte, which connects to pristine forest, vaccinia virus was detected in both domestic dogs and wild coatis.[35] It has also recently been detected in local rats.

In addition, screening of wild coatis identified spillback of the newly emerged zeta variant of SARS-CoV-2, as well as SARS-CoV-2 antibodies in half of the animals tested.[36] Professor Trindade concluded by stressing the importance of better understanding the natural history of pathogens and the ecological dynamics of human infection, as well as strengthening of relationships across sectors and with policymakers.

34. Oliveira JS, Figueiredo PO, Costa GB *et al. Vaccinia Virus Natural Infections in Brazil: The Good, the Bad, and the Ugly.* Viruses. 2017;**9(11)**:340. doi: 10.3390/v9110340.
35. Costa GB, Ribeiro de Almeida L, Cerqueira AGR *et al. Vaccinia Virus among Domestic Dogs and Wild Coatis, Brazil, 2013-2015.* Emerg Infect Dis. 2018;**24(12)**:2338-2342. doi: 10.3201/eid2412.171584.
36. Stoffella-Dutra AG, de Campos BH, Bastos E Silva PH *et al. SARS-CoV-2 Spillback to Wild Coatis in Sylvatic-Urban Hotspot, Brazil.* Emerg Infect Dis. 2023 Mar;**29(3)**:664-667. doi: 10.3201/eid2903.221339.

Parasite infections

Research example three

Professor Miriam Tendler, Fundacao Oswaldo Cruz (Fiocruz), described how the development of a new vaccine against **schistosome and *Fasciola hepatica* (liver fluke) infections** had considered both human and veterinary applications. The work has also highlighted the importance of international collaborations.

In the 1980s, **Sm14,** a fatty acid-binding protein, was identified as a potential target for vaccine development for schistosomiasis. In collaboration with colleagues in Germany, homologues of Sm14 were found in other parasite species, while a further collaboration enabled a molecular structure of Sm14 to be determined, facilitating structure–activity relationship studies.

A public–private partnership was developed to support commercialisation of the vaccine, supported by a Brazilian funding agency. Following encouraging preclinical results, GMP-quality material was prepared in collaboration with Cornell University in the US to facilitate a phase I trial carried out at Fiocruz.[37] Additional international partnerships have supported a phase IIa trial in Senegal and scale-up of production facilities for a phase III trial.

Sm14 is a protein essential to many parasites. Results demonstrating cross-protective efficacy against *F. hepatica* in a mouse model generated great global interest, as it is the main helminth disease of cattle and responsible for huge economic losses each year.[38] A separate formulation with a different adjuvant has been developed for the veterinary market.

Professor Andre Luiz Rodrigues Roque described work carried out to understand transmission of ***Trypanosoma cruzi*** to humans and the role of wild-animal hosts. Although based on an integrated cross-disciplinary approach, Professor Roque suggested that, while carrying out such studies, he had not actively considered them to fall under the 'One Health' umbrella.

T. cruzi is a protozoan parasite responsible for **Chagas disease,** which has affected populations in South America for centuries. It is a multi-host parasite that infects humans through different routes, including via insect vectors. Vector control has led to a fall in incidence, although oral transmission via exposure to wild-animal faeces has led to a growing number of outbreaks. In Navagentes, for example, opossums are the wild-animal reservoir but 50% of domestic dogs showed evidence of infection, and contamination of sugar cane led to human cases.[39]

Around 40% of cases of Chagas disease occur in the Amazon region. Agricultural practices tend to attract vectors, particularly at harvest time, increasing exposures and risk of transmission.

Transmission patterns are heavily dependent on local contexts. In Cachoeira do Arari, for example, seroprevalence is high in dogs, although they are not a reservoir for human infection. Reduction in the local diversity and abundance of mammals was associated with higher parasitaemia in small wild mammals and higher exposure of dogs to infection.[40] Monitoring of canine seroprevalence is a possible approach for surveillance, providing an indication of risks for human disease.

37. Santini-Oliveira M, Coler RN, Parra J *et al. Schistosomiasis vaccine candidate Sm14/GLA-SE: Phase 1 safety and immunogenicity clinical trial in healthy, male adults.* Vaccine. 2016;**34(4)**:586-594. doi: 10.1016/j.vaccine.2015.10.027.
38. Tendler M, Brito CA, Vilar MM *et al. A Schistosoma mansoni fatty acid-binding protein, Sm14, is the potential basis of a dual-purpose anti-helminth vaccine.* Proc Natl Acad Sci U S A. 1996 Jan 9;**93(1)**:269-73. doi: 10.1073/pnas.93.1.269.
39. Roque AL, Xavier SC, da Rocha MG *et al. Trypanosoma cruzi transmission cycle among wild and domestic mammals in three areas of orally transmitted Chagas disease outbreaks.* Am J Trop Med Hyg. 2008;**79(5)**:742-9.
40. Xavier SC, Roque AL, Lima Vdos S *et al. Lower richness of small wild mammal species and chagas disease risk.* PLoS Negl Trop Dis. 2012;**6(5)**:e1647. doi: 10.1371/journal.pntd.0001647.

In Belém, by contrast, collection and transport of acai fruit in baskets is a key risk factor for transmission, while in Abaetetuba, changes in land use are playing a more important role.[41,42] These examples highlight the importance of understanding behavioural and economic drivers, as well as biological factors, that could provide additional opportunities for disease transmission. Risk of disease will vary by location, and risk-mapping approaches are being developed that integrate multiple factors, to inform prioritisation of Chagas disease control and response efforts.[43]

Box 1: The building blocks approach

Paolo Ferrinho, Instituto de Higiene e Medicina Tropical, Lisbon, Portugal, outlined how the 'building blocks' approach used for health systems strengthening could be applied to One Health systems.

The systems approach is designed to encourage co-ordinated development and action across different sectors. The building blocks concept has been developed by the WHO to provide a framework for health systems strengthening, with six building blocks identified: leadership and governance; financing; workforce; products and technology; information and research; and service delivery.

A World Bank report advocated for the building blocks approach for the development of One Health interventions, its building blocks being: governance; stakeholders, roles and responsibilities; resources (financial and people); communication and information; and technical infrastructure.

The One Health joint plan of action does not explicitly refer to building blocks, but Professor Ferrinho identified an implicit building blocks framework comprising: governance; stakeholder and community engagement; implementation; monitoring and evaluation; and resource mobilisation.

Professor Ferrinho concluded that combining these frameworks could provide a consensus integrated building block framework to guide the development of One Health systems.

Box 2: Environmental dimensions

Dr Patricia Fernanda Do Pinho, Instituto de Pesquisa da Amazonia (IPAM), summarised how climate change is affecting people in the Amazon region.

The Intergovernmental Panel on Climate Change (IPCC) has identified significant implications for the Amazon region from climate change, particularly in water and climate regulation, which are likely to have major impacts on health and welfare.

Health falls within an IPCC category of 'non-economic loss and damage' and efforts have been made to quantify this loss and damage, mostly from floods but potentially also from droughts. The impacts of extreme events and changing patterns of disease are mostly being felt by indigenous populations. Based on 30 years of data, estimated economic losses are low but social costs are high, with up to a million people affected.

As Dr Do Pinho pointed out, the populations affected are highly vulnerable, with little capacity to respond to changing contexts, little insurance, no early warning systems and minimal government support. She suggested that intersectoral collaboration will be required to address these inequities, while global support will be needed to tackle the wider issue of climate justice – that those at highest risk of its impact made the least contribution to climate change.

41. Xavier SC, Roque AL, Bilac D *et al. Distantiae transmission of Trypanosoma cruzi: a new epidemiological feature of acute Chagas disease in Brazil.* PLoS Negl Trop Dis. 2014;**8(5)**:e2878. doi: 10.1371/journal.pntd.0002878.
42. Roque AL, Xavier SC, Gerhardt M *et al. Trypanosoma cruzi among wild and domestic mammals in different areas of the Abaetetuba municipality (Pará State, Brazil), an endemic Chagas disease transmission area.* Vet Parasitol. 2013;**193(1-3)**:71-7. doi: 10.1016/j.vetpar.2012.11.028.
43. Teixera M, Xavier S, Roque AL *et al. Applying fuzzy model to map vulnerability areas of Trypanosoma cruzi transmission. In: Models and methods for supporting decision-making in human health and environment protection* (Eds: Bouza CN, de Mello FL, Negreiros MJ). 2016. Chapter 7, pp.85-101. Nova Science Publishers, Inc.

Breakout sessions and emerging themes

Following introductory presentations, participants joined breakout groups to discuss key issues and potential ways forward. Breakout groups individually focused on either policy, research, data or community engagement, and discussed the current state of play, gaps and challenges, and examples of successful cross-sectoral collaborations (Annexe 1). These discussions highlighted a number of key themes:

The key relevance of One Health to Brazil

Brazil's rich biodiversity, sociocultural diversity and inequality, and history of environmental exploitation generate a **complex web of interactions** affecting human, animal and environmental health, stressing the need for One Health approaches.

Key issues include the existence of **multiple vector-borne pathogens and strong potential for zoonotic transmission** of known and novel pathogens. Many factors are influencing exposure of people to pathogens, including changing land use, particularly deforestation for agriculture and natural resource extraction, climate change impacts, and large-scale migration and urbanisation, creating new opportunities for transfer of novel pathogens to humans and spread of known vector-borne diseases.

All these factors are contributing to a highly dynamic context, and one that demands a One Health approach.

Strengths of research in Brazil and international collaborations

Given the importance of these issues, **Brazil has developed a strong strand of One Health research,** with extensive national and international interdisciplinary networks. Research on infectious diseases and zoonoses is a particular strength, with multiple high-quality outputs being generated through Brazilian-led research and international collaborations.

This existing research presence and international networks provide Brazil with an opportunity to play a leading role in One Health research, to inform national and global policymaking. Although some state and national One Health initiatives have been launched, it was felt that there was considerable potential to strengthen links between research and policymaking in Brazil, and to encourage a 'health in all policies' approach.

Limited adoption of a One Health mindset

Among the challenges to be addressed, participants concluded the **One Health concept is not yet fully embedded in researcher, policymaker or public consciousness**, in Brazil. The same can be said for arrangements at institutional level and for research funding.

Research is not always labelled as One Health even when it clearly meets One Health criteria. In addition, the **scope of the term** can cause confusion, and its relationship with other concepts, such as planetary health, is not always clear.

Participants noted clarity is important in order to support **political advocacy and to mobilise public support.** It was argued that effective, targeted communication to key stakeholder groups is needed, using appropriate language. In addition, approaches such as economic analyses could be important to generate additional policy-relevant data and to support greater policymaker engagement. It was suggested that there could be a role for national academies in engagement with policymakers and other key stakeholders.

Participants also suggested One Health could be built into **medical school education** and other university courses. Researcher capacity building and training could also help to build the national skills base in One Health-related research.

Understanding drivers of zoonotic disease and potential impacts as key priorities

Participants suggested that a deeper understanding of **the complex mix of factors that drive the emergence and spread of zoonotic disease** should be a key focus of One Health research. It was felt that research on biological factors was reasonably well integrated, but the environmental dimension could be strengthened. The potential for more input from the social and behavioural sciences was also highlighted.

Multiple types of **surveillance data** are collected but data are not always easy to access and analyse, with a range of data formats used. Data from the private sector, including the animal industry, can be particularly hard to access. Proposed solutions included incentives to encourage data sharing, or sanctions when important data are not shared, and the development of new data platforms to collate and integrate data from multiple sources across different sectors.

There may also be opportunities to identify and exploit **'dark data' sources** – data that are routinely collected but not analysed for One Health purposes. The importance of data standards was also highlighted. Routine georeferencing, for example, can facilitate spatial analyses. Participants also highlighted the potential of rapid diagnostics and genomic technology to generate detailed information on pathogen numbers and types.

A deeper understanding of the drivers of zoonotic disease can underpin the development of **prevention and control efforts.** Participants identified research on the benefits of disease prevention and control as an additional research priority, particularly **quantification of health and economic benefits** to inform policymaker engagement. This will require additional data in areas such as disease burdens as well as economic modelling studies, and the development of appropriate metrics on environmental impacts.

The need for stronger collaboration

Attendees argued that **stronger collaborations and partnerships** are required with policymakers, public health structures, and the public. As well as more interdisciplinary collaboration within research, it was suggested that stronger links are needed between the research community and policymakers, and greater engagement with public audiences and civil society organisations (CSOs). Efforts could also be made to bring private sector organisations into research partnerships.

It was concluded there is a need to join up surveillance/data collection, investigation and analysis, and public health/policy response, to create **'data for action' cycles.** This will require more effective sharing of data as well as interoperative data systems spanning different domains. Although there are many sources of data relevant to One Health in Brazil, it can be challenging to access and analyse different data collected by different organisations using different data formats. Stronger linkages could also be forged between public health laboratories in different states.

It was also suggested that the public, particularly **indigenous peoples**, should be more involved in One Health research activities, helping to shape the research agenda, contributing to research activities such as surveillance, and receiving feedback on the findings of research. This will help such groups take action in response to new research findings, and also better enable them to advocate for One Health approaches and sustainable development more generally. Furthermore, indigenous groups can be an important source of knowledge on the natural world.

Participants noted that time is needed to spend **building trust** with indigenous communities. Training in effective community engagement could be more strongly emphasised in public health and other courses.

Ensuring research funding is a facilitator

Research funding systems can be both an enabler of One Health research but also impose obstacles to effective interdisciplinary research collaborations. Conventional funding approaches are typically short term and project-based, which is not an ideal way to support interdisciplinary collaborations, which typically take time to develop and become most productive.

In addition, participants suggested that interdisciplinary funding applications are often difficult to assess through traditional grant-giving mechanisms. The discipline-specific model of peer review and a funding panel is not well suited to the kind of interdisciplinary programmes that characterise the One Health approach.

Conclusion

The workshop identified a range of reasons why the One Health concept is of particular significance to Brazil. Through the Quadripartite Alliance, global frameworks are being established to promote One Health approaches. Brazil is taking steps to develop One Health policy, establishing structures to promote cross-sectoral collaboration.

With its expertise and track record in infectious disease, the Brazilian research community is well placed to provide major inputs into the adoption and implementation of One Health policy within the country. This will require further strengthening of interdisciplinary and cross-sectoral collaborations, including stronger partnerships with policymakers, and further development of international partnerships, potentially with the global South as well as the global North.

Despite much progress in the control of infectious disease in Brazil, the country remains vulnerable to resurgent outbreaks of known pathogens and the emergence of novel pathogens of public health concern. The One Health approach potentially provides the mindset and tools to develop an integrated perspective on the factors underlying the origins and spread of infections, laying the ground for more effective prevention and outbreak responses in the future.

Annexes

Annexe 1: Workshop steering committee

Both the early scoping work and development of the workshop were informed by a wide range of experts from different countries and sectors.

Co-chairs

Professor Marcello Barcinski, Professor, Federal University of Rio de Janeiro, Academia Nacional de Medicina (ANM)

Professor Alison Holmes OBE FMedSci, Professor of Infectious Diseases and the Director NIHR Health Protection Research Unit, Imperial College London

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Professor Patricia Bozza, Vice-President for the Rio de Janeiro Region, Academia Brasileira de Ciências (ABC), Brazil

Annexe 2: Participant list

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