



HAL
open science

After 2 years of the COVID-19 pandemic, translating One Health into action is urgent

Thierry Lefrançois, Denis Malvy, Laetitia Atlani-Duault, Daniel Benamouzig,
Pierre-Louis Druais, Yazdan Yazdanpanah, Jean-François Delfraissy, Bruno
Lina

► **To cite this version:**

Thierry Lefrançois, Denis Malvy, Laetitia Atlani-Duault, Daniel Benamouzig, Pierre-Louis Druais, et al.. After 2 years of the COVID-19 pandemic, translating One Health into action is urgent. *The Lancet*, 2023, 401 (10378), pp.789-794. 10.1016/s0140-6736(22)01840-2 . hal-03914066

HAL Id: hal-03914066

<https://hal.science/hal-03914066>

Submitted on 4 Jan 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

The Lancet

After two years of pandemic, translating One Health into action is urgent

--Manuscript Draft--

Manuscript Number: THELANCET-D-22-03141R2
Article Type: Viewpoint
Keywords: One Health, Global Health, Zoonosis, Pandemics, Emergence, Prevention
Corresponding Author: Thierry Lefrancois, CIRAD, Paris, FRANCE

First Author: Thierry Lefrancois,

**Order of Authors: Thierry Lefrancois,
Denis Malvy
Laetitia Atlani-Duault
Daniel Benamouzig
Pierre-Louis Druais
Yazdan Yazdanpanah
Jean-François Delfraissy
Bruno Lina**

Manuscript Region of Origin: FRANCE

Abstract: COVID-19 has highlighted links between the environmental, social, animal and public health determinants that allow pathogen emergence and dissemination. As members of the French national Covid-19 scientific committee, we analysed gaps in the management of the current pandemic and found a crucial role for a comprehensive approach to health. We offer a detailed proposal for an ambitious roadmap to improve One Health approaches at each stage of a pandemic. The roadmap includes developing and monitoring resilient socio-ecosystems, new processes to create intersectoral, multidisciplinary and multi-stakeholder preparedness, early detection systems and crisis management. Additionally, we propose some inspiring perspectives for a worldwide One Health vision: i) upstream reinforcement and operational collaborative research programmes on disease emergence, ii) united regional and worldwide strategies to prevent focal anthropic disease emergence, control the circulation of epidemic-prone infectious organisms and prevent the development of variants potentially harmful to all, iii) a comprehensive One Health training programme for all professionals, decision-makers and the public. In brief, we advocate a more all-encompassing vision of health within a sustainable ecosystem.

Powered by Editorial Manager® and ProduXion Manager® from Aries Systems Corporation

Thierry Lefrançois^{1*}, Denis Malvy^{2,3*}, Laetitia Atlani-Duault^{4,5}, Daniel Benamouzig⁶, Pierre-Louis Druais⁷, Yazdan Yazdanpanah⁸, Jean-François Delfraissy⁹, Bruno Lina^{10,11}.

1. CIRAD, DirBIOS, Montpellier, France.
2. Department of infectious and tropical diseases, University Hospital Pellegrin, Bordeaux, France
3. National Institute for Health and Medical Research (Inserm) UMR 1219, Research Institute for Sustainable Development (IRD) EMR 271, Bordeaux Population Health Research Centre, University of Bordeaux, Bordeaux, France
4. Université Paris Cité, IRD, Ceped, Paris, France
5. Mailman School of Public Health, Columbia University, New York, USA
6. Sciences Po, CNRS. Paris, France
7. General medicine specialist, High Authority of Health, Saint-Denis La Plaine, France
8. ANRS Maladies Infectieuses Emergentes, Inserm, Paris, France
9. CCNE, National Ethical Consultative Committee for life sciences and health, Paris, France
10. HCL, Institut des Agents Infectieux, CNR des virus à transmission respiratoire (dont la grippe), Hôpital de la Croix Rousse, Lyon, France
11. Virpath, Centre International de Recherche en Infectiologie, Université de Lyon Inserm U1111, CNRS UMR 5308, ENS de Lyon, UCBL, Lyon, France

* These authors contributed equally

All the authors are members of the French Covid-19 Scientific Council. Jean François

Delfraissy is the president of the council.

Abstract

COVID-19 has highlighted links between the environmental, social, animal and public health determinants that allow pathogen emergence and dissemination. As members of the French national Covid-19 scientific committee, we analysed gaps in the management of the current pandemic and found a crucial role for a comprehensive approach to health. We offer a detailed proposal for an ambitious roadmap to improve One Health approaches at each stage of a pandemic. The roadmap includes developing and monitoring resilient socio-ecosystems, new processes to create intersectoral, multidisciplinary and multi-stakeholder preparedness, early detection systems and crisis management. Additionally, we propose some inspiring perspectives for a worldwide One Health vision: i) upstream reinforcement and operational collaborative research programmes on disease emergence, ii) united regional and worldwide strategies to prevent focal anthropic disease emergence, control the circulation of epidemic-prone infectious organisms and prevent the development of variants potentially harmful to all, iii) a comprehensive One Health training programme for all professionals, decision-makers and the public. In brief, we advocate a more all-encompassing vision of health within a sustainable ecosystem.

After two years of pandemic, translating One Health into action is urgent

The world is coping with the health, societal and economic consequences of more than two years of the COVID-19 pandemic. Emerging diseases caused by new pathogens, or re-emerging infectious diseases, appear regularly and their frequency is increasing^{1,2}. Several publications have demonstrated the huge positive cost-benefit of preventing versus managing an emerging infectious disease, especially at global level^{3,4,5}. A paradigm shift is needed to improve pandemic prevention, which will require a global understanding of disease emergence and an integrated One Health approach. Indeed, the environmental, social, economic, ethical and political factors that characterize a social ecosystem and influence the emergence of zoonoses should be considered to control these emergences.

COVID-19 has exposed the disconnection between governmental promotion of the One Health approach in international arenas and the reality on the ground—with the absence of an efficient, comprehensive One Health surveillance system that could have been in place from the onset of the pandemic. As members of the French national scientific committee, appointed in March, 2020 to support governmental efforts in managing the COVID-19 pandemic, we had to grapple with this negative reality. Based on our experience, we propose an ambitious roadmap to prevent and mitigate future pandemic crises, including real-life implementation of intersectoral activities and processes. Our strategy will require a new, worldwide One Health vision that includes ambitious national and international initiatives, as well as One Health education and training.

1/ What have we learnt from the crisis? (Figure 1)

a) The pandemic is a One Health issue

Like around 75% of listed emerging human diseases, COVID-19 is most probably a zoonosis caused by a coronavirus from an animal reservoir. Zoonotic coronaviruses can spread to humans, as observed in the past (OC43 in the 19th century, SARS-CoV-1 in 2003, Mers-CoV in 2011), or today during the COVID-19 pandemic^{6,7}. Beside the pandemic crisis, the lack of an early warning, of early collaboration between stakeholders and the knowledge gap regarding the overall process of SARS-CoV-2 adaptation to new hosts, had two consequences: i) ignorance of the exact mechanisms/factors involved in virus emergence and adaptation steps and, ii) speculation about the origin of the virus behind the pandemic. If COVID-like crises are to be avoided in the future, these knowledge gaps need to be filled to allow the identification and rapid control of zoonotic risks before their introduction in humans. Optimum preparedness will rely on strategies and programmatic plans prepared jointly by scientists, decision-makers and all stakeholders involved in surveillance and early warning. The pandemic highlighted both the interdependence of human health, animal health and environmental health, and the need for an interdisciplinary vision to produce upstream scientific and epidemiological knowledge. Such a strategic One Health^{8,9} approach is only feasible with a comprehensive and multisectoral approach. But despite some successful examples in Rwanda¹⁰ or Senegal, for example, it is still not shared by all, often poorly structured and not operational.

b) An efficient One Health surveillance system is needed

The goal of the One Health strategy is to prevent and control the emergence, re-emergence, or dissemination of zoonotic pathogens^{11,12}. It includes surveillance in animal reservoirs, deciphering factors facilitating emergence¹³ and actions for disease control. In an optimum One health dimension, given that Southeast Asian bat species harbour SARS like-

coronaviruses, coronavirus surveillance¹⁴ should have been triggered with regular biobanking from reservoirs, surveillance of transmission to potentially susceptible animals, or to humans in contact with those animals, and an analysis of the environmental factors favouring transmission (analysis of ecosystems and factors associated with carriage). Action could then have been taken to control the risk through reduced contact between animals, and modified/resilient ecosystems reducing the risk of transmission. The cost of such a mechanism would have to be considered in balance with the potential medium/long-term benefits arising from its use. In addition, the data generated and the genetic resources collected would have to be shared and used beyond national, or even regional, public health strategies. Control also requires an understanding of all factors allowing pathogens to cross the species barrier. In addition to modified eco-systems and virus molecular evolution that can trigger cross-species transmission, biological surveillance should also include how host responses influence virus evolution, to help identify relevant evolutionary drivers responsible for changes that bring the virus to the edge of dissemination in humans.

Even today the COVID-19 emergence process remains unexplained. However, a comprehensive holistic One Health programme would have provided data on virus ecology, evolution, mechanisms involved in the acquisition of virulence factors (including furin or polybasic cleavage sites) and adaptive molecular traits. Surveillance would also have facilitated control and preventive measures, such as appropriate farming processes and prevention through restricted culling strategies. An optimized surveillance system capable of providing early and robust data on a new pathogen will rely on three pillars: i) virus surveillance and detection in wildlife ecosystems, ii) identification of potential intermediate hosts (in wildlife and livestock) and factors favouring transmission (including adaptive processes) and, iii) early detection of asymptomatic or symptomatic infections in exposed humans.

c) The risks of reverse transmissions between humans and animals

Like other zoonotic pathogens, SARS-CoV-2 is capable of “reverse” infection (retro-zoonosis), particularly, but not only, in mustelid mammals¹⁵ or in deer and hamsters^{16,17}. So far, the human SARS-CoV-2 virus has been detected in 23 animal species in 35 countries¹⁸ and the figures are increasing. During retro-zoonosis, viruses may accumulate mutations leading to changes in different genes, with the potential acquisition of severity and/or immunity escape factors. It has been speculated that the Omicron variant may have emerged after retro-zoonosis¹⁹. This understanding of potential evolutionary processes through reverse virus zoonosis and their consequences is part of the One Health strategy that needs to be addressed for each emergence (e.g., Monkeypox virus, see annex).

2/ Developing an ambitious roadmap for each step of a pandemic crisis

a) Going beyond past and current One Health projects and strategic plans

Much is being done to develop One Health approaches. More than just a concept, One Health is a strategy long used in research and surveillance in numerous zoonosis projects, mostly implemented in specific emergence and re-emergence zones (Ebola, Mers-CoV, avian influenza, Nipah virus, vector diseases, rabies, etc.), or regionally by setting up One Health surveillance networks (One Health Indian Ocean, or Segal One Health). Some large multiregional projects (e.g., Predict20) have implemented large-scale virus surveillance in the environment.

Beyond these research initiatives, true political awareness has recently emerged worldwide, with some symbolic declarations, including those from the G7 (4th June 2021) and G20 (5-6 September 2021) health ministers. The COVID-19 pandemic has also triggered some institutional One Health strategies. A “One Health High Level Expert Panel” (OHHLEP) was created in May 2021 with responsibility for “gathering, analysing, passing on and giving greater visibility to the scientific information available on the links between human, animal and environmental health”. The aim was to assist policymakers and international organizations in preventing and responding to future health crises. They published a new inclusive definition of One Health encouraging intersectoral, but also interdisciplinary and multi-stakeholder approaches^{21,22}. Several One Health operationalization plans have also been developed, such as the Quadripartite (WHO, FAO, WOA and UNEP) One Health Action Plan “Working together for the health of humans, animals, plants and the environment”²³ and the One Health Operationalization Framework proposed by the World Bank²⁴.

However, while declarations and action plans provided by each stakeholder in their own sector are a prerequisite for any change, they are not enough. Although the human health sector and agencies are well funded, they are not versed in the One Health concept taking an intersectoral approach. Conversely, this global understanding is more advanced in the ecology and animal health sectors, though it is poorly funded and still very theoretical there. These funding and commitment hurdles must be addressed to increase our capacity to respond to epidemics and pandemics. We consider that action plans must incorporate a solid long-term research programme rather than merely providing short-lived epidemiological data from a One Health surveillance system outsourced to Northern countries. Concrete and sustained surveillance and prevention actions are needed on all scales, together with education, training and behavioural changes. These ambitious research projects must be co-constructed with all the actors required for a One Health action plan, including local communities. It should be embedded in national plans with national stakeholders, not as

external/international studies. This local empowerment is a prerequisite for programme implementation on a national and regional scale.

b) Targeted health prevention means developing resilient socio-ecological systems

This objective entails certain knowledge prerequisites, notably an understanding of biodiversity-agriculture-food-health links, the notion of interdisciplinary data-sharing and the development of comprehensive indicators, including some from the human sciences. With such common and shared knowledge upstream of an emerging risk, economically viable and accepted socio-ecological systems can be jointly constructed with characteristics detrimental to long-term disease emergence, offering greater resilience to health crises.

A certain number of levers and monitoring systems could be deployed locally, in liaison with national and supranational bodies. Environmental intelligence sites (sentinel sites) and operational monitoring of prevention initiatives (living labs) can help to build socio-ecological systems that respect pre-established specifications. This work calls for combined environmental and ecology research programmes, incorporating stakeholders responsible for the health of a territory, based on a pre-defined policy and identification of a risk for emerging diseases.

c) Preparedness and early detection should structure One Health action plans

A list of pathogens to be monitored should be jointly decided and updated by all the stakeholders. Corresponding indicators and innovative tools combining surveillance and alert should then be developed, and research programmes addressing the relevant emergence and transmission issues should be implemented. In the event of detection, these initiatives should be rapidly reinforced and the surveillance upgraded to provide all relevant data for risk assessment and management.

This can be facilitated by a rapprochement between the reference laboratories of Health and Agriculture ministries through joint funding or dual trusteeship. This would simplify the rapid mobilization and early response of animal health and human health experts at the very outset of health crises. Reference laboratories with more holistic expertise in real-life surveillance activities (e.g., surveillance of emerging zoonotic infectious diseases, syndromic surveillance), such as the current WAHO collaborative centres, could also be established. Embedded national or regional surveillance platforms could be set up with high-level diagnostic, sequencing, pathogen discovery and surveillance capabilities. Emergence surveillance gaps at the human health/animal health interface need to be identified, with a redefinition of monitoring and management responsibilities. For instance, pathogens or diseases with a public health impact can circulate on livestock farms or in arthropod vectors without falling under the direct responsibility of a Ministry of Agriculture, as they are not categorized, such as swine flu virus infection, surveillance of H5N8 avian influenza in humans, or Crimean-Congo Haemorrhagic Fever virus circulation in animals.

A One Health inter-ministerial scientific platform with governance at the highest political level in each country could identify, analyse and update major local risks involving emerging pathogens in the environment, in animals, or in humans and could share that information with all stakeholders and develop control strategies.

d) Predefined One Health structures and task forces should drive crisis management and use all diagnostic and control capabilities

A rapid decision-making process with robust institutionalized support is essential to ensure that rapid responses agreed by different socio-economic actors and political decision-makers are actually implemented. Priority should therefore be given to developing an operational “alert-decision” model, based on sound and acknowledged science and a multidisciplinary evaluation including the social sciences. The early reporting of abnormal and severe clinical presentations without any known aetiology (including imported diseases) requires hospital resources, ranging from infectious diseases, infection control specialists and microbiologists to resuscitation experts. In addition, rapid and innovative disease information reporting, with feedback on case monitoring to a large community, will ease the diagnostic process.

From the early days of an emergence, administrative and regulatory hurdles will have to be removed to mobilize all relevant lab resources regardless of their affiliation (i.e., veterinary laboratories) to allow diagnostics and research. Indeed, multisectoral laboratories will need to work together for sample handling and sharing of material, results and techniques. Such field collaboration developed between hospital, animal health and wildlife/environment professionals, and between institutional surveillance and research platforms, will include using common platforms for laboratory testing, metagenomics, sequencing and all relevant diagnostic techniques. Implementing these operational recommendations at each step of a pandemic will require strong political will in each country to overcome the usual sectoral work, habits and rules. Active local and international communities, together with civil society mobilization, could thus become a game changer, as observed for climate change.

3/ Inspiring new perspectives for a worldwide health vision

a) Improving surveillance and prevention by reinforcing both upstream and operational research

Research programmes should rely on multidisciplinary, multisectoral and multi-professional international projects with a focus on novel approaches to environmental/ecological genomics (open-minded detection of pathogens circulating in reservoirs and vectors, molecular identification of viruses with zoonotic potential)^{25,26}, modelling, artificial intelligence and social science studies.

Such combined research approaches will, i) accelerate control and prevention through the acquisition of basic knowledge in a coordinated manner, including on origins and adaptation mechanisms; ii) strengthen sustained infrastructures and networks, allowing the coordinated collection of data for modelling and implementing a response strategy; iii) boost innovative public health strategies, or early development of innovative countermeasures, to mitigate the impact of emerging epidemic events (diagnostics, vaccines, therapies, behaviour). International operational research initiatives, such as Prezode²⁷, are thus needed to implement robust co-constructed One Health programmes, along with surveillance programmes and networks worldwide, with all the necessary stakeholders. Ambitious research projects targeting large-scale surveillance in the environment will need bottom-up co-construction, local empowerment and true interactions between research and decisionmaking. They will have to consider the Nagoya protocol²⁸. Overcoming hurdles related to this protocol will require international collaboration and mutual trust, and will have to be endorsed by policy-makers^{29,30,31}.

b) Developing a worldwide comprehensive and united vision of health

Diseases inherent to globalization cannot be controlled on a single-country basis^{32,33}. International institutions, including WHO, need to evolve to cope with the global challenges raised by global health and One Health. The effort must be focused on major emergence zones and be developed on a regional scale to have a global impact. Specific areas of Africa and Southeast Asia are the epicentres of emerging and epidemic-prone infectious diseases. 'Recognized hot zones' or 'evolving zones' for emergence need to be identified, listed and published based on factors such as agricultural/human encroachment into wildlife habitats, increasingly intensified livestock/poultry systems, live animal markets, poor biosecurity and the emergence of megacities with poor hygiene/infection prevention management systems.

In addition, implementing One Health approaches with countries less advanced in health management will need to be backed by sustained twinning programmes to improve diagnostic, sequencing, surveillance and public health capacities (see annex). On a regional scale, neighbouring countries share the same risks, the same socio-economic and political constraints and must develop regional One Health strategies^{34,35} to develop shared expertise, laboratories and platforms, especially in limited-resource settings. The existing One Health regional health networks need to be further developed, with a focus on pandemic prevention and preparedness. This means solving the major issues related to critical animal diseases and natural disasters that impact food sustainability and security, and undermine population resilience.

Whatever the scale, a sustained political will and understanding of the One Health approach is mandatory and should be demonstrated by leader countries together with international organizations, with a long-term view and not only at the onset of a crisis. This means longterm financial guarantees provided by international communities through different mechanisms, including World Bank funding.

d) Ensuring adequate education and training for One Health

Implementing One Health and global health concepts will take time to produce operational effects. Training initiatives are needed to abolish boundaries between sectors³⁶. For all One Health professions (veterinarians, clinicians, pharmacists, biologists and ecologists), the jointly constructed concept should be included in the curriculum of each discipline in its initial training. This common training should be widely available, based on transversal teaching modules involving multi-disciplinary expertise and combining public health, human and social sciences, the health of populations, territories and the environment, and research. This would subsequently foster collaboration among professionals. One Health awareness campaigns, continuous training for decision-makers, teachers and members of civil society will lead to a population-based shared culture. This education should be provided early in the school curriculum to induce behavioural changes, as observed for global warming. This specific training will develop transversal skills needed to grasp the One Health concept, such as complex thinking, systems thinking and suitability for multidisciplinary collaboration capacity.

e) A paradigm shift is needed

Health continues to be largely viewed through the limited prism of human diseases. WHO clearly defines health as being “a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity”. Environmental protection, animal health and the sustainable health of a territory are not part of this definition. For a more embracing vision of health, we need to rethink how we approach the One Health concept by more effectively integrating the environment, thereby gaining an overall grasp of the health of all living organisms in a given ecosystem.

The One Health concept goes well beyond preventing health crises and is closely linked to a holistic vision of health and to the links existing between health, environmental quality, climate, food and agriculture, and biodiversity. Recent papers^{37,38}, and less recent but major ones^{1,39,40,41}, have demonstrated and reinforced the link between climate change, biodiversity crises and emerging zoonotic diseases. One Health comprises the challenging “grasped by all” and “shared by all” societal objectives. They need to be addressed at global level to fulfil sustainable development goals, together with global empowerment.

Acknowledgments

We thank all members of the French Covid-19 Scientific Council for their contribution to the advice on One Health published on 8 February 2022 on the French Ministry of Health website. Available in French at https://solidaritesante.gouv.fr/IMG/pdf/contribution_conseil_scientifique_8_fevrier_2022_one_health.pdf

We thank Patricia Doucet and Delphine Guard-Lavastre (CIRAD) for the illustration.

Author contributions

All the authors participated in writing the paper (original draft, review and editing)

TL, DM, BL, JFD were involved in the conceptualization, supervision and validation.

TL, DM, BL, worked on the figure.

The authors declare no conflict of interest

Funding: none

Figure



Figure: Transmission of zoonotic diseases

Stages involved in a pandemic crisis, from the initial circulation of pathogens within wild fauna and the natural environment, to the global dissemination after large-scale human-to-human transmission. Anthropological factors lead to changes in pathogen circulation and to increased contacts with new animal species, including domestic ones, which can induce spillover, with possible transmission to humans. The COVID-19 pandemic highlights the risk of reverse zoonoses, due to intensive circulation of SARS-CoV-2 in humans, transmission to new animal species, and circulation within some that have proven to be highly susceptible (hamsters, minks, and wild-tailed deer), with possible transmission of a mutated virus to humans. New variants can also emerge from circulation within humans.

References

1. Jones KE, Patel NG, Levy MA, Storeygard A, Balk D, Gittleman JL, Daszak P. Global trends in emerging infectious diseases. *Nature*. 2008; 451: 990-3.
2. Marani M, Katul GG, Pan WK, Parolari AJ. Intensity and frequency of extreme novel epidemics. *Proc Natl Acad Sci U S A*. 2021;118: e2105482118.
3. Bernstein AS, Ando AW, Loch-Temzelides T, Vale MM, Li BV, Li H, Busch J, Chapman CA, Kinnaird M, Nowak K, Castro MC, Zambrana-Torrel C, Ahumada JA, Xiao L, Roehrdanz P, Kaufman L, Hannah L, Daszak P, Pimm SL, Dobson AP. The costs and benefits of primary prevention of zoonotic pandemics. *Sci Adv*. 2022; 8: eabl4183
4. Dobson AP, Pimm SL, Hannah L, Kaufman L, Ahumada JA, Ando AW, Bernstein A, Busch J, Daszak P, Engelmann J, Kinnaird MF, Li BV, Loch-Temzelides T, Lovejoy T, Nowak K, Roehrdanz PR, Vale MM. Ecology and economics for pandemic prevention. *Science*. 2020; 369: 379-381.
5. IPBES (2020) Workshop Report on Biodiversity and Pandemics of the Intergovernmental Platform on Biodiversity and Ecosystem Services. Daszak, P., das Neves, C., Amuasi, J., Hayman, D., Kuiken, T., Roche, B., Zambrana-Torrel, C., Buss, P., Dundarova, H., Feferholtz, Y., Földvári, G., Igbinsola, E., Junglen, S., Liu, Q., Suzan, G., Uhart, M., Wannous, C., Woolaston, K., Mosig Reidl, P., O'Brien, K., Pascual, U., Stoett, P., Li, H., Ngo, H. T., IPBES secretariat, Bonn, Germany, https://ipbes.net/sites/default/files/2020-12/IPBES%20Workshop%20on%20Biodiversity%20and%20Pandemics%20Report_0.pdf
6. Pekar, JE, Magee A, Parker E, Moshiri N, Izhikevich, K, Havens JL, Gangavarapu, K, Malpica Serrano LM., Crits-Christoph A, Matteson NL, Zeller M, Levy JI, Wang JC, Hughes S, Lee J, Park H, Park MS, Ching Zi Yan K, Tzer Pin Lin R, Wertheim JO. The molecular epidemiology of multiple zoonotic origins of SARS-CoV-2 *Science*. 2022. 377, (6609), 960-9667.
7. Worobey M, Levy JI, Malpica Serrano LM, Crits-Christoph A, Pekar JE, Goldstein SA, Rasmussen AL, Kraemer MUG, Newman C, Koopmans MPG, Suchard MA, Wertheim JO, Lemey P, Robertson DL, Garry RF, Holmes EC, Rambaut A, Andersen KG. The Huanan seafood market in Wuhan was the epicenter of Covid-19 Pandemic. *Science*, 2022. 377 (6609), 951-959.8.
8. Osterhaus ADME, Vanlangendonck C, Barbeschi M, Brusckhe CJM, Christensen R, Daszak P, de Groot F, Doherty P, Drury P, Gmacz S, Hamilton K, Hart J, Katz R, Longuet C, McLeay J, Morelli G, Schlundt J, Smith T, Suri S, Umali K, van Aken J, Wagenaar JA. Make science evolve into a One Health approach to improve health and security: a white paper. *One Health Outlook*. 2020; 2: 6.
9. Zinsstag J, Schelling E, Waltner-Toews D, Whittaker M, Tanner M, coordinateurs. ONE HEALTH, UNE SEULE SANTÉ Théorie et pratique des approches intégrées de la santé. 2020. Ed Quae
10. Nyatanyi T, Wilkes M, McDermott H, Serge N, Gafarasi I, Mudakikwa A, Kinani JF, Rukelibuga J, Omolo J, Mupfasoni D, Kabaja A, Nyamusore J, Nziza J, Hakizimana JL, Kamugisha J, Nkunda R, Kibuuk R, Rugigana E, Farmer P, Cotton P, Binagwaho A. Implementing One Health as an integrated approach to health in Rwanda. *BMJ Global Health* 2017;2: e000121.
11. de Garine-Wichatitsky M, Binot A, Morand S, Kock R, Roger F, Wilcox BA, Caron A. Will the COVID-19 crisis trigger a One Health coming-of-age? *Lancet Planet Health*. 2020; 4: e377-e378
12. Gibbs EP. The evolution of One Health: a decade of progress and challenges for the future. *Vet Rec*. 2014; 174: 85-91
13. Taylor LH, Latham SM, Woolhouse ME. Risk factors for human disease emergence. *Philos Trans R Soc Lond B Biol Sci*. 2001; 356: 983-9.
14. Delaune D, Hul V, Karlsson EA, Hassanin A, Ou TP, Baidaliuk A, Gámbaro F, Prot M, Tu VT, Chea S, Keatts L, Mazet J, Johnson CK, Buchy P, Dussart P, Goldstein T, Simon-Lorière E, Duong V. A novel SARS-CoV-2 related coronavirus in bats from Cambodia. *Nat Commun*. 2021; 12: 6563.
15. Goraichuk IV, Arefiev V, Stegnyy BT, Gerilovych AP. Zoonotic and Reverse Zoonotic Transmissibility of SARS-CoV-2. *Virus Res*. 2021; 302:198473.
16. Pickering B, Lung O, Maguire F, Kruczkiewicz P, Kotwa JD, Buchanan T, Gagnier M, Guthrie JM, Jardine CM, Marchand-Austin A, Massé A, McClinchey H, Nirmalarajah K, Aftanas P, Blais- Savoie J, Chee H-Y, Chien E, Yim W, Banete A, Griffin BD, Yip L, Goolia M, Suderman M, Pinette M, Smith G, Sullivan D, Rudar J, Adey E, Nebroski M, Goyette G, Finzi A, Laroche G, Ariana A, Vahkal B, Côté M, McGeer AJ, Nituch L, Mubareka S, Bowman J. Highly divergent white-tailed deer SARS-CoV-2 with potential deer-to-human transmission. 2022 Preprint bioRxiv 2022.02.22.481551; doi: <https://doi.org/10.1101/2022.02.22.481551>
17. Yen HL, Sit THC, Brackman CJ, Chuk SSS, Gu H, Tam KWS, Law PYT, Leung GM, Peiris M, Poon LLM. Transmission of SARS-CoV-2 delta variant (AY.127) from pet hamsters to humans, leading to onward human-to-human transmission: a case study *The Lancet*. 2022, 399: 1070-1078
18. OIE. SARS-Cov-2 in animals – Situation Report 13, 31/05/2022 available at <https://www.woah.org/fr/document/sars-cov-2-in-animals-situation-report-13/>
19. Wei C, Shan KJ, Wang W, Zhang S, Huan Q, Qian W. Evidence for a mouse origin of the SARS-CoV-2 Omicron variant. *J Genet Genomics*. 2021; 48: 1111-1121.
20. PREDICT Consortium. Advancing Global Health Security at the Frontiers of Disease Emergence. One Health Institute, University of California, Davis, December 2020, 596 pp. Available at <https://ohi.vetmed.ucdavis.edu/programs-projects/predict-project>
21. Tripartite and UNEP support OHHLEP's definition of "One Health" Joint Tripartite (FAO, OIE, WHO) and UNEP Statement. 1 December 2021. Available at <https://www.who.int/news/item/01-12-2021-tripartite-and-unep-support-ohhleps-definition-of-one-health>

22. Adisasmito WB, Almuhairei S, Behravesh CB, Bilivogui P, Bukachi SA, et al. (2022) One Health: A new definition for a sustainable and healthy future. *PLoS Pathog* 18: e1010537.
23. One Health Joint Plan of Action. Working together for the health of humans, animals, plants and the environment. Available at <https://www.woah.org/app/uploads/2022/04/ohjoint-plan-of-action-summary.pdf>
24. Berthe FC, Bouley T, Karesh WB, Le Gall F, Machalaba C, Plante C, Seifman R. Operational framework for strengthening human, animal and environmental public health systems at their interface (English). Washington, D.C.: World Bank Group. Available at <http://documents.worldbank.org/curated/en/703711517234402168/Operationalframework-for-strengthening-human-animal-and-environmental-public-health-systems-attheir-interface>
25. Mollentze N, Babayan SA, Streicker DG. Identifying and prioritizing potential human-infecting viruses from their genome sequences. *PLoS Biol.* 2021; 19: e3001390.
26. Wardeh M, Baylis M, Blagrove MSC. Predicting mammalian hosts in which novel coronaviruses can be generated. *Nat Commun.* 2021; 12: 780
27. Peyre M, Vourc'h G, Lefrançois T, Martin-Prevel Y, Soussana JF, Roche B. PREZODE: preventing zoonotic disease emergence. *Lancet.* 2021, 397: 792-793. <https://prezode.org/>
28. The Nagoya Protocol on Access and Benefit-sharing. Available at <https://www.cbd.int/abs/>
29. Lajaunie C and Morand S. Nagoya Protocol and Infectious Diseases: Hindrance or Opportunity? *Front. Public Health* 2020. 8:238.
30. Mueni Katee S and Keambou Tiambo C. Discussing the Drawbacks of the Implementation of Access and Benefit Sharing of the Nagoya Protocol Following the COVID-19 Pandemic. 2021. *Front. Public Health* 9:639581.
31. Ho CW-L. Operationalizing "One Health" as "One Digital Health" Through a Global Framework That Emphasizes Fair and Equitable Sharing of Benefits From the Use of Artificial Intelligence and Related Digital Technologies. *Front. Public Health.* 2022. 10:768977.
32. Coker RJ, Hunter BM, Rudge JW, Liverani M, Hanvoravongchai P. Emerging infectious diseases in Southeast Asia: regional challenges to control. *Lancet* 2011; 377: 599–609
33. Nay O, Barré-Sinoussi F. Bridging the gap between science and policy in global health governance. *Lancet Glob Health.* 2022; 10: e322-e323.
34. Jakab Z, Selbie D, Squires N, Mustafa S, Saikat S. Building the evidence base for global health policy: the need to strengthen institutional networks, geographical representation and global collaboration. *BMJ Glob Health.* 2021; 6: e006852.
35. Aarestrup FM, Bonten M, Koopmans M. Pandemics. One Health preparedness for the next. *The Lancet Regional Health - Europe* 2021; 9: 100210
36. Montgomery M and Baitchman E. A call for One Health Education [version 1]. *MedEdPublish* 2020, 9: 281
37. Carlson CJ, Alberty GF, Merow C, Trisos CH, Zipfel CM, Eskew EA, Olival KJ, Ross N, Bansal S. Climate change increases cross-species viral transmission risk. *Nature.* 2022 Apr 28 doi: 10.1038/s41586-022-04788-w.
38. Holmes EC. COVID-19-lessons for zoonotic disease. *Science.* 2022; 375: 1114-1115.
39. Allen T, Murray KA, Zambrana-Torrel C, Morse SS, Rondinini C, Di Marco M, Breit N, Olival KJ, Daszak P. Global hotspots and correlates of emerging zoonotic diseases. *Nature communications.* 2017; 8: 1124
40. Daszak P, Cunningham AA, Hyatt AD. Emerging infectious diseases of wildlife--threats to biodiversity and human health. *Science.* 2000; 287: 443-9.
41. Karesh WB, Dobson A, Lloyd-Smith JO, Lubroth J, Dixon MA, Bennett M, Aldrich S, Harrington T, Formenty P, Loh EH, Machalaba CC, Thomas MJ, Heymann DL. Ecology of zoonoses: natural and unnatural histories. *Lancet.* 2012; 380: 1936-45.