Infectious diseases have been appearing at an average rate of one every 14 to 16 months since the mid-20th century.

Human health suffers from a simplistic view of biodiversity

Philippe Grandcolas,
Research Professor at the French National, Centre for Scientific Research (CNRS), Deputy Director of CNRS Ecology and Environment,
Gudrun Bornette,
Research Professor at the CNRS, Scientific Delegate for Health Ecology, CNRS Ecology and Environment.

KEY POINTS

In contemporary societies, the living world is sometimes seen as a source of direct aggression: this animal is venomous or harmful, that plant is allergenic. It is vital to deconstruct stereotypes about biodiversity, to understand how it functions and interacts in order to correct the damage of human activity on ecosystems, which are sources of numerous pathologies. As there is no simple solution for engineering daily life alongside plant and animal species, we must look at how to optimise the co-benefits.

Our Western societies often imagine nature as a wilderness that would not be a good place to live. On the flipside of this concept is the idea of a domesticated nature, presumed tamed and under control, with our cultivated plants and farm animals. In this somewhat dualistic vision, the first is the source of many ills, while the second enables us to live in good health. Our cultural perceptions of biodiversity dwell on stereotypes of nature as a wilderness distanced from humans, yet we are actually stakeholders in ordinary biodiversity [1].

This cultural perception has also been reinforced by the scientific community. In the 20th century, the development of the life sciences and modern medicine meant that research focused on what a few model organisms had in common with humans, mainly in the laboratory. Organisms such as drosophila, zebrafish and mice have become biological models, or even analogues of humans, uprooted from the natural environment in which they previously lived.

The result has been extraordinary advances in knowledge but also, at times, something of a divorce from the problems of nature. As a result, the wildness (in the sense of "non-domesticated") and the extraordinary diversity of the living world have been erased or given negative connotations in popular representations, except in terms of distant and exotic species (tropical forests, large African mammals, etc.). At present, health issues in tropical and equatorial countries, which bring into focus the fundamental relationships between wild fauna – and flora – and public health (in zoonoses like malaria, Ebola, Zika and chikungunya), seem to be far removed from our concerns, even for some members of the scientific community. The countries of the global North do not always pay enough attention to these issues, which people often associate with poverty and a lack of healthcare infrastructure, whereas the problem is more complex.

Very recently, in 1986, science defined the word and concept of biodiversity in order to reignite interest in the study of differences between individuals, species or ecosystems. By studying biodiversity we can tackle subjects such as human health from new angles, in particular using the "One Health" and "Planetary Health" approaches (*see article* The diversity of concepts that lie behind the word "nature" *in this issue*). We now have a clearer understanding of how the health of ecosystems, domestic animals and cultivated plants are all linked to human health [2].

Fragmented natural spaces

Our impact on habitats and the species that inhabit them is considerable. Firstly, we are fragmenting habitats, particularly through urban sprawl and the expansion of farmland, meaning humans can easily move in and out of ecosystems and settle extremely close to wild organisms. Caught in the trap of a partitioned natural world, animals are increasingly coming into contact with humans, who regard them at best as pets and at worst as pests. This close proximity to potential reservoir animals can lead to the evolution of pathogens that may transfer between animal species (wild and/or domestic) and to humans. These processes significantly increase the circulation of zoonotic infectious diseases and can even cause the emergence of new diseases. New diseases have been appearing at an average rate of one every 14 to 16 months since the mid-20th century, a rate that is accelerating as human and animal mobility increases considerably across the planet's surface [3]. Ebola virus disease in Africa is a tragic example, with epidemics of this particularly morbid and deadly virus emerging in recently deforested areas, or following the consumption of bushmeat or contact with bats, which are reservoirs for the virus [4].

Our propensity to overexploit certain poached, domestic or peridomestic animal species[1] also brings us into closer contact with reservoir animals. Through actions that bring together species not normally found together in the wild – e.g. trafficking or displacement of domestic and wild animals whose health has been poorly assessed, destruction of natural habitats leading to increased contact between species, capture and domestication of wild animals – we cause further contact with potential sources of infectious agents and of zoonotic disease.

Climate change and the transport of exotic species, which may be potential or known reservoirs or vectors, are giving rise to new issues linked to cohabitation. In mainland France, these include the coypu, which is a known reservoir of leptospirosis since 1886 in Europe, and the tiger mosquito, the vector of dengue fever, which arrived at the end of the 20th century. More recently, in late 2023, exotic ticks of the *Hyalomma* genus, carriers of the Crimean-Congo haemorrhagic fever (CCHF) virus[2], were identified on cattle farms in the south of France; early cases had already been identified in Spain in 2013.

Industrial livestock farming: A hotbed for pathogens

Domestic livestock farms pose a problem because they act as a bridge between wild reservoir species and humans. For example, on small farms in Asia, the Nipah virus was transmitted from fruit bats to pigs foraging under the trees where they roost, then from the pigs to humans. Intensive farming also exerts problematic selective pressures on pathogens: by cramming genetically identical and weakened pigs or chickens into vast farms, we are selecting particularly virulent pathogens from wild reservoirs. Poultry farms, which account for a massive 71% of the world's bird biomass, allow virulent variants of the avian flu virus to persist because the host being killed or becoming very sick does not prevent transmission given the extreme proximity that the animals live in. Virtually all mutations that cause H5N1 to become virulent in birds since it was first observed in China in 1996 have appeared in livestock birds [5]. These variants of an avian flu virus that mutated in poultry farms are now invading the world, killing wild bird colonies and their marine mammal neighbours, as demonstrated recently by the high mortality of gannets and elephant seals. They are now infecting dairy cows in the United States, with a potentially different mode of transmission. For now, this variant has a very limited affect on humans, only causing conjunctivitis, but other variants of H5N1 found in Asia appear to be less harmless. It seems that this disease of avian origin has not yet been transmitted from one human to another, but it does appear to be transmissible between members of the same species in other mammals.

With little or no knowledge of the concepts and theories of ecology, or any understanding of interactions with biodiversity, we often perceive the living world as a direct source of aggression and hold a simplistic view of biodiversity: this animal is venomous or harmful, that plant is allergenic. The list of potential threats is as long as biodiversity is vast. The way we live today, in megacities, in fact only makes us more fragile. We can see this with the issue of respiratory allergies to pollen, which are on the increase in urban areas due to exposure to pollution and earlier or more intense pollen production due to climate change. This problem may be exacerbated by the choice of particular ornamental species in urban areas, such as the plane tree, and reinforced in rural or peri-urban areas where allergenic exotic species have been introduced with crops, as in the case of ragweed with American clover seed.

In terms of exposure, our problems are therefore evolving in tandem with the biodiversity crisis and its main drivers, which have been categorised by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). Habitat loss and urbanisation, combined with climate change and increased global circulation of organisms, are leading to new artificially constructed environments that are conducive to the establishment of opportunistic organisms and numerous pathologies. Multiple pollutants, both in our food and in the air, mean multiple exposures, which exacerbate our sensitivity. Finally, our horticultural, agricultural and forestry practices increase our exposure to exotic species that have been introduced deliberately (ornamental species) or unintentionally (alongside crops, stowaways in our transport systems). When studying our exposure, we must also take into account how food chains amplify or transform the issue. The quantity of a given product in the environment is not the only important indicator; our behaviour, the type of product and its availability also come into play, as does the magnifying effect of increased concentration through build-up in organisms linked to each other within food chains [6]. This process of biomagnification is classically associated with lipophilic substances such as DDT[3] but is now beginning to be considered for substances bound to proteins, such as some PFAS[4] [7].

The risk of depleted or unbalanced microbiota

The human body is also home to its own biodiversity, known as the microbiota, with the gut microbiota being one example. Its composition and behaviour depend on our relationship with the environment and in particular our diet [8]. Two kilograms of bacteria from more than a hundred species occupy our bodies, in colossal numbers that exceed our own cells, i.e. 30,000 billion. Studies of microbiology and human health are only just beginning to understand how dietary factors, such as the importance of fibre or fermented products, or the harmful effects of pesticides, affect the health of the microbiota. Numerous problems such as gastrointestinal diseases, psychiatric disorders, degenerative diseases and cancer can disproportionately affect us when our microbiota is unbalanced, depleted or invaded by a given microorganism. We would therefore exert less pressure on both our internal and external environments by adopting a balanced diet made up of

seasonal vegetables and fruit as well as fermented products, all distributed via short channels and grown without pesticides.

This means we need to rethink our relationship with biodiversity to understand that we are part of it and linked to it in a highly complex way, if only through our food, the ecosystems of production and our microbiota. Wild and domesticated species are neither angels nor demons. They are part of our environment, interacting with each other, reproducing, dispersing and evolving with each generation.

The way we interact with them must take account of these essential properties of living organisms [9]. If certain species become problematic for us, we must not stimulate their reproduction or dispersal through poor management. For example, killing local badgers that are reservoirs for bovine tuberculosis stimulates the dispersal of badgers from neighbouring areas that come to occupy empty territories, increasing the probability of their contamination by infected wild or domestic animals; killing foxes gives rodents more free roam to transmit *Borrelia* bacteria and Lyme disease to us via ticks that live on them as parasites and that can also bite us. We should also avoid exerting inappropriate pressures that can favour the selection of undesirable genetic characteristics, whether this be the virulence of an influenza virus or antibiotic resistance in bacteria present on industrial farms, or through spraying contaminated effluents or bacteriostatic inputs (e.g. glyphosate) across open fields.

Preserving and limiting human intrusion into the living space of wild species is a way of both protecting biodiversity and limiting the circulation of pathogens in the environment and in humans. Understanding the power of biodiversity through these dynamic mechanisms will enable us to support the processes that are beneficial to us and to restrict or even block those that are seriously damaging. This means it is essential to severely restrict the fragmentation of natural ecosystems and our propensity to disperse organisms, whether intentionally or unintentionally, in order to prevent biological invasions by potentially pathogenic organisms or vectors of pathogens. If we do not, we will be condemned to constantly fighting against them, with the tiger mosquito being a case in point in France today. Similarly, it is crucial for us to review our model of intensive meat production in factory farms raising genetically similar, immunocompromised animals, which are veritable hotbeds of pathogens, if we do not want the result to be yet more pandemics.

The way we live alongside ordinary plant and animal biodiversity in our megacities must be engineered as effectively as possible, without giving it total freedom to evolve or constantly intervening. The cost of this kind of management is significant, but the benefits are even greater. Innovations such as these can be developed and explored in partnership with local stakeholders in long-term socio-ecological research sites[5] (such as the "workshop zones" run by the CNRS), and by using nature-based solutions, as promoted by the SOLU-BIOD national research programme[6] [4]. ■

1. Many zoonoses are transmitted by peridomestic animals, which are animals that live near or visit human habitats: cat scratch disease, ringworm, rabies, etc.
2. See Santé publique France documents: https://www.santepubliquefrance.fr/docs/elements-d-information-et-de-prevention-sur-la-fievre-hemorragique-de-crimee-congo and https://www.santepubliquefrance.fr/les-actualites/2024/fievre-hemorragique-de-crimee-congo-adopter-les-bons-gestes-pour-se-proteger-des-piqures-de-tiques.
3. Insecticide banned in North America and Europe, but still used to combat vector-borne diseases in many countries.
4. Perfluoroalkyl and polyfluoroalkyl substances, known as PFAS or "forever chemicals", are a group of several thousand chemical compounds, including two herbicides currently authorised in France (diflufenican, flufenacet).
5. Interdisciplinary research network on socio-ecosystems and the environment in relation to societal issues. (Editor's note.)
6. https://www.pepr-solubiod.fr/

REFERENCES

[1] P. Grandcolas, C. Marc. *Tout comprendre (ou presque) sur la biodiversité*. Paris: CNRS Éditions, 2023.

[2] D. Destoumieux-Garzón, P. Mavingui, G. Boetsch, J. Boissier, F. Darriet, P. Duboz *et al.* The one health concept: 10 years old and a long road ahead. *Frontiers in Veterinary Science*, 2018, vol. 5, no. 14. Online: https://doi.org/10.3389/fvets.2018.00014

[3] P. Daszak, C. das Neves, J. Amuasi, D. Hayman, T. Kuiken, B. Roche *et al. IPBES Workshop Report on Biodiversity and Pandemics of the Intergovernmental Platform on Biodiversity and Ecosystem Services*. Bonn (Germany): IPBES secretariat, 2020. Online: DOI:10.5281/zenodo.4147317

[4] J. Olivero, J. E. Fa, R. Real, A. L. Márquez, M. A. Farfán, J. M. Vargas *et al.* Recent loss of closed forests is associated with Ebola virus disease outbreaks. *Scientific Reports*, 2017, vol. 7, no. 14291. Online: https://doi.org/10.1038/s41598-017-14727-9

[5] K. Kupferschmidt. From bad to worse: How the avian flu must change before it can trigger a human pandemic. *Science*, 2023, vol. 380, no. 6640. Online: https://doi.org/10.1126/science.adi1013

[6] INSERM. *Pesticides et effets sur la santé : Nouvelles données*. Montrouge: EDP Sciences, coll. Collective expertise, 2021. Online: https://www.inserm.fr/expertise-collective/pesticides-et-sante-nouvelles-donnees-2021/

[7] C. Morrissey, C. Fritsch, K. Fremlin, W. Adams, K. Borgå, M. Brinkmann *et al.* Advancing exposure assessment approaches to improve wildlife risk assessment. *Integrated Environmental Assessment & Management*, 2024, vol. 20, no. 3: p. 674-698. Online: https://doi.org/10.1002/ieam.4743

[8] P. Testard-Vaillant and editorial staff. Les pouvoirs méconnus du microbiote, peuple de nos intestins. *CNRS Le Journal*, 18 August 2022. Online: https://le-journal.cnrs.fr/articles/les-pouvoirs-meconnus-du-microbiote-peuple-de-nos-intestins

[9] M. Hossaert, X. Le Roux. Revising our way to programme and support research to tackle the scientific issues of nature-based solutions: the case of France institutions. *In* EGU23, The 25th EGU General Assembly, 23-28 April, Vienna (Austria). Conference Abstracts, May 2023: p. EGU-16964. Online: https://ui.adsabs.harvard.edu/abs/2023EGUGA..2516964H/abstract

THE AUTHORS DECLARE NO TIES OR CONFLICTS OF INTEREST WITH REGARD TO THE CONTENT OF THIS ARTICLE.