Matière
à débattre & décider

# Emergence of infectious diseases

## Risks and issues for societies

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# 5. Surveillance of emerging diseases: challenges and contradictions

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**Are we now on the brink of a fourth global epidemiological upheaval?** The first, which took place in the Neolithic era, was associated with the domestication of animals and the establishment of larger permanent human settlements. The next two upheavals were linked to urbanization and commercial trade and led to "microbial unifications", one beginning in the fifth century in Eurasia, the other starting in the fifteenth century in the New World. Pandemic influenzas, viral haemorrhagic fevers in animals and humans, and antimicrobial resistance are, rightly or wrongly, emerging or feared 'microbial storms' induced by a broad range of environmental and socioeconomic factors and increasingly frequent and intense contacts between humans and animals. In this context, it has become necessary to assess all of the factors involved in epidemiological dynamics, including not only biological factors (which all too often are the only factors considered) but also economic, social and environmental factors, and particularly the decline of biodiversity. Moreover, surveillance and control systems must be developed based on risk assessments integrating human and social dynamics, including the cost-effectiveness of these systems and how they are perceived and accepted by livestock farmers, health professionals, and society as a whole.

While the International Commission on Stratigraphy (International Union of Geological Sciences) has not officially validated the term 'Anthropocene', it is increasingly being used by researchers and the media to describe a period where, "for two generations, humanity has become a geological force on a global scale, altering human and ecosystem health[51]" (Steffen *et al.*, 2015). In animal health, profound changes in livestock farming practices in many regions of the world, combining genetic standardization with high domestic animal densities, and in parallel the destruction of natural habitats in certain areas, could lead to the emergence and spread of new diseases. This Anthropocene era may also be linked to a sixth mass extinction of animal and plant species (Ceballos *et al.*, 2015; Kolbert, 2015), one much more rapid than past extinctions and with a major impact on biodiversity that could play a role in the occurrence of infectious events.

51. The starting point of the Anthropocene is a particular topic of debate: while some authors consider it to have begun with the Industrial Revolution, others wish to go back to the Neolithic era, or even earlier (Lewis and Maslin, 2015).

Two major and opposing trends have been shaping the evolution of infectious diseases over the past two decades:

– First, United Nations international agency programmes, particularly the public health objectives of the Millennium Development Goals (Dye, 2014), and animal health programmes focusing on strengthening veterinary services (OIE[52]), alongside research institutions and centres are contributing to a reduction in the incidence of certain diseases (even eradication, as for rinderpest[53]) and the strengthening of public and veterinary health systems, although results continue to vary significantly across regions and diseases.
– Second, environmental, climatic and zootechnical changes and the internationalization of goods and trade are favouring the emergence, spread and maintenance of new human, animal and zoonotic diseases. These disturbances also are inducing increased interference and interactions between 'epidemiological compartments', meaning between human groups, domestic and wild animal populations, and the environment. Lastly, the development of antimicrobial resistance is now leading some authors to sound the alarm on the risks of what could be a public health 'time bomb'.

This has led to the development and strengthening of management capacities, namely the surveillance and control of infectious diseases. More efficient health surveillance is deemed indispensable to react swiftly to an emergence, but also to measure the effectiveness of control measures implemented (for example, vaccinations). It is difficult to anticipate abrupt outbreaks of infectious diseases, although monitoring certain biological and non-biological determinants (human behaviour, social events) of diseases and health statuses can warn of the risk of emergence (Olson *et al.*, 2015). The outbreaks, epizootics and epidemics of bluetongue, a ruminant disease in northern Europe, Ebola fever in West Africa, and the H5N1 strain of highly pathogenic avian influenza, etc. were not anticipated. Nor was the emergence of AIDS, which can be considered as a true black swan (Paté-Cornell, 2012), meaning that the emergence of the HIV virus from the equatorial forest was a completely unforeseen event (see below).

## Epidemiologic rupture or transition?

> *"Global disease burden has continued to shift away from communicable to non-communicable diseases and from premature death to years lived with disability. In sub-Saharan Africa, however, many communicable, maternal, neonatal, and nutritional disorders remain the dominant causes of disease burden."* (Murray *et al.*, 2012)

**Alongside global changes,** including upheavals in terms of land use and globalization, biodiversity's role in health is discussed in Chapter 1 by Serge Morand. He examines

52. OIE PVS Pathway, http://www.oie.int/en/support-to-oie-members/pvs-pathway/
53. http://www.oie.int/en/for-the-media/press-releases/detail/article/no-more-deaths-from-rinderpest/

the ambivalent role of biodiversity loss, which research indicates may favour or hinder emergence. However, according to the author there is a confusion of scale in numerous studies, i.e., between actual emergence (e.g., primary transmission between a reservoir and a host) and spread (role of movements, globalization of trade). More broadly, there is a need to clearly distinguish between the potential emergence of pathogens (detected through analyses, monitoring, etc.) and the emergence of a disease in its clinical and epidemiological forms. Many questions remain with regard to the relationship between biodiversity loss and disease. However, a recent meta-analysis (Civitello *et al.*, 2015) suggests that the maintenance of biological diversity reduces disease risks. If this is the case, health, and its corollary, health protection, could be added to the list of ecosystem services provided by biodiversity.

The role of wildlife, which is frequently associated with emergences (avian influenza and wild birds; Ebola and bats and great apes; SARS and bats and civets), probably should be qualified (Tompkins *et al.*, 2015). Furthermore, certain diseases also impact amphibians, birds and mammals (Grogan *et al.*, 2014). For example, the Ebola virus disease had devastating consequences for great ape conservation plans in Central Africa (Bermejo *et al.*, 2006); white-nose syndrome decimated bat colonies in the United States (Boyles *et al.*, 2011), which could lead to major farm losses due to the positive role played by bats in relation to crop pests; canine distemper (a disease of domestic dogs) infected lions in East Africa (Viana *et al.*, 2015); bovine tuberculosis, an animal disease transmissible to humans (zoonosis), affects cats and other species in southern Africa (de Garine-Wichatitisky *et al.*, 2013); rabies and canine distemper (Gordon *et al.*, 2015) affect Ethiopian wolves, considered an endangered species (red list) by the International Union for Conservation of Nature (IUCN). Wildlife conservation policies should more fully consider these risks of infection in keeping with the "One Health" concept, which advocates for a global approach to human, animal and environmental health. More specifically, better defined research and surveillance strategies are needed at the interface between wildlife and domestic animals (Wiethoelter *et al.*, 2015).

We propose to distinguish between epidemiological, global, major and above all infectious and parasitic ruptures (or upheavals, or shocks) – of which there have been three since the first during the Neolithic agricultural revolution 11,000 to 12,000 years ago – and epidemiologic transitions, which pertain rather to recent, modern transformations of societies in terms of demographics, technologies, and health (shift from infectious diseases to chronic, degenerative diseases) and which are continuing with the economic development of societies (Table 2).

Over the past two centuries, numerous countries experienced a significant drop in mortality combined with a considerable increase in life expectancy as they developed. In terms of public health disease burden, chronic diseases (generally non-infectious) have replaced acute infectious diseases. There are several reasons for this: improved hygiene and care, vaccinations and antibiotic treatments, biosecurity on farms, improved nutrition and food security. However, urbanization, more sedentary lifestyles, dietary changes, etc. accompany these transitions towards primarily non-infectious and chronic pathologies.

**Table 2. Epidemiologic ruptures and transitions: a preliminary typology**

| | Epidemiologic ruptures (or upheavals or shocks) | Epidemiologic transitions |
|---|---|---|
| Periods | Neolithic (agricultural revolution), fifth century (Africa-Asia including Europe) then fifteenth century (New World) | Since the end of the 19th century |
| Geography | Regions (Middle East, China, etc.), continents | Countries undergoing demographic and economic transitions; achieved for developed countries, underway for middle-income countries and emerging economies (BRICS) |
| Mode | Gradual (domestication) or brutal (colonization of the New World). Also "exchanges" (e.g., syphilis) towards Europe | Gradual over several generations |
| Diseases | Wide spread of infectious diseases (microbial pools, new viruses for immunologically naive populations) | Move from parasitic, infectious diseases to chronic, degenerative diseases |
| Impacts | Major impact on societies (e.g., epidemiologic shock on the Americas) | Increased life expectancy |
| Present day | *Potential rupture? Consequence of climatic, ecological and therapeutic changes (antibiotic resistance)* | *Epidemiologic transitions continuing in middle-income countries and emerging economies: towards a globalization of health?* |

However, bacteria, viruses and parasites continue to exist, and infectious diseases are particularly pernicious in the Global South, in both human and animal populations. For animal diseases, there is considerable geographic diversity, with sharply contrasting situations between developed countries, countries in transition and middle-income countries, and the poorest countries, principally in Africa, which are the most dependent on livestock farming and most at risk from a health perspective (Perry *et al.*, 2013). Consequently, we also could apply the concept of epidemiologic transition, initially developed in public health,[54] to animal health, and say that there are transitions between an ensemble of parasitic and infectious diseases predominating in traditional systems and a pathology related to livestock intensification.

A study (Jones *et al.*, 2013) shows that agricultural intensification and environmental changes – and the evolution of the link between the two – are correlated with the risk of emerging zoonoses. Some authors suggest that micro-organisms may also play a role in the development of important chronic diseases in developed countries and those in

54. The concept of epidemiologic transition was proposed by Omran (1971).

**Box 2. Pathocenosis**

The concept of pathocenosis – based on the notion of biocenosis but applied to a community of diseases – proposed by Grmek in 1969 aims to provide a logical framework to analyse these transitions and disease emergence. A recurring but controversial theme in epidemiology linked to this concept is that each pathogenic agent occupies an ecological niche, and its elimination leaves room for new pathogens. According to Lloyd-Smith (2013), the elimination of a pathogen leads to a vacant niche that could be re-invaded by the original pathogen. However, if other pathogens attempt to move in, other factors intervene in a dialectic of competition and evolutionary adaption without necessarily leading to the emergence of a new disease.

transition, for example heart diseases, cancers and diabetes (Rosenthal, 2015). The use of antibiotics is rising sharply in livestock farming worldwide, causing the development of transmissible resistance in bacteria affecting humans. Van Boeckel *et al.* (2015) estimate that antimicrobial consumption will increase by 67% by 2030, linked particularly to the growing demand for meat products in middle-income countries. Given the major risks posed by this surging and uncontrolled use of antibiotics in animal production and health, as well as in individual medicine, self-medication and public health, coupled with weak new product development, Woolhouse *et al.* (2015) liken antimicrobial resistance to climate change and suggest that an intergovernmental group similar to the Intergovernmental Panel on Climate Change (GIEC) should be created.

Will the history of infectious diseases soon come to an end with the latest upheavals correlated with a massive loss of biodiversity? Or are we going through a new epidemiological rupture (new viruses jumping the species barrier and causing new diseases in first epidemic and then endemic forms; antimicrobial resistance)? Or is it the case that epidemiologic transitions are continuing in public and animal health, varying with the economic situations of countries? Influenza viruses, responsible for animal and human influenza, could contribute to this discussion; new strains appear regularly, sometimes jumping the species barrier between birds and mammals, including humans, and causing epizootics or epidemics or even panzootics and pandemics.

## What ever happened to the seventh pandemic?

*"Massive deadly epidemics have disappeared. They have been replaced by just one: the proliferation of humans themselves." Cool Memories 1980–1985*, Jean Baudrillard, 1987

A POSSIBLE INFLUENZA PANDEMIC was reported in the sixteenth century in Europe and Africa. The twentieth century witnessed the Spanish influenza pandemic of 1918–1919

caused by the H1N1 virus (over 40 million dead); the 1957 Asian influenza caused by the H2N2 virus (1 to 4 million dead); and the Hong Kong flu in 1968 caused by the H3N2 virus (1 to 2 million dead). The appearance in the twenty-first century of the panzootic and zoonotic H5N1 avian influenza revived the threat of a major pandemic. The H5N1 virus, a strain highly pathogenic for birds, is transmitted to humans with very high rates of case fatality (mortality/morbidity) but with thus far very low overall mortality. However, due to the genetic plasticity of influenza viruses and the possibility of recombination with other strains, researchers, experts and international agencies rapidly launched a pandemic risk alert. H1N1 influenza A (H1N1pdm09), which emerged in 2009, had a pandemic character in terms of geography and contagiousness but its mortality rates cannot be compared to the pandemics of the twentieth century. As mortality linked to the influenza virus is mainly due to secondary infections (Jamieson *et al.*, 2013), improved hygiene and care of flu patients has certainly contributed to the overall reduction in mortality during the last pandemics. However, given the weakness of health systems in some countries and the unpredictability of certain highly pathogenic strains (for example, H7N9 in China, which is proving to be weakly pathogenic in birds but highly pathogenic in people), it would be unwise to let down our guard.

While some authors[55] consider that the emergence of highly pathogenic H5N1 avian influenza overall led, in terms of public health, to "much ado about nothing", it should be noted that the disease had major direct and indirect socioeconomic impacts on livestock farms in countries of the Global South (Alders *et al.*, 2014). These impacts are linked to the disease itself, but also to the responses of different stakeholders in the poultry sector, to consumers, and to the measures taken by governments. H5N1 is now endemic in many Asian countries and in Egypt, and since 2015 has re-emerged in Africa with serious consequences for poultry value chains. Some authors argue that we will never again be faced with a devastating influenza pandemic due to effective early warning and surveillance programs, better care for patients and secondary infections, etc. However, given the recent multiplication of bird and pig zoonotic strains, particularly in China where livestock farming conditions facilitate the spread and genetic evolution of these viruses, and the economic and health risks for the least developed countries, continued vigilance is necessary (Von Dobschuetz *et al.*, 2014). Bluetongue disease and Ebola haemorrhagic fever, which never should have left their natural areas – respectively the inter-tropical region and the forest of Central Africa – should incite us to be cautious in terms of projections.

For Brender and Gilbert (Chapter 2), WHO actually emerged as an international organization by restructuring itself through the management of a pandemic, influenza A(H1N1)pdm09, and of the pandemic risk of H5N1 avian influenza. This crisis made it possible to strengthen links between health sectors and start developing the 'One Health' approach (Pfeiffer *et al.*,

55. "It is not necessary to set fire to the planet due to some zoonotic infection, nor to spend billions of euros, nor to create a governmental crisis; ultimately it is 'much ado about nothing'". Raoult, 2015.

2013). In animal health, this panzootic had a positive effect on the overall strengthening of veterinary capacities in many countries through programmes and projects financed and implemented by international agencies and donors. These avian influenza epizootics led animal health sector managers to further develop dialogue with livestock farmers (Alders *et al.*, 2014).

Recently, WHO was sharply criticized for its management of the ongoing Ebola epidemic in West Africa. An expert report dated 7 July 2015 emphasizes that the organization indeed failed to "provide an urgent public health response to a grave epidemic" (Maurice, 2015). Twenty-some recommendations have been proposed to re-establish "WHO as the lead guardian of global public health". Among these recommendations is a proposal to strengthen GOARN,[56] a global outbreak alert and response network. Jeremy Farrar, the Director of Wellcome Trust, vigorously supports this idea and emphasizes that this mechanism "should be truly independent, outside any political influence" (Maurice, 2015).

The management of infectious diseases at the international level requires robust and interconnected international agencies. The One Health paradigm ratified by OIE and United Nations agencies (FAO, WHO, UNICEF), which postulates that the epidemiological dynamics and interplay of actors conditioning the health of animal and human populations should be studied in their ecological, socioeconomic and political context at the interface of human health, animal health and ecosystem health, should facilitate this management.

The real or imagined consequences of an epidemic or epizootic, fear of a pandemic, media coverage and the hype that can follow must be held up against the reality of health and epidemiological data (morbidity, mortality, and lethality rates, economic and social impacts) by a broad range of medical scientists working in both animal and public health.

## The Horseman on the Roof

> *"What?" said the young man, "You don't know? Where are you from? It's cholera. It is the finest case of Asiatic cholera that has ever been seen! Go there one more time," he said, holding the vial. "Trust me, I am a doctor."*
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> *The Horseman on the Roof,* Jean Giono, 1951.

**The "plague" in Athens in 430 BC** was a major epidemic in ancient Greece. It has been the subject of discussion in recent years among doctors, microbiologists, epidemiologists, paleo-pathologists and other experts who debate the origin and etiology of this disease. *A priori* from Ethiopia, this infectious disease, characterized by a gastrointestinal haemorrhagic-like fever, could have been typhus, influenza, a viral haemorrhagic fever like Rift Valley fever or, some argue, even Ebola (Olson *et al.*, 1996). Animal mortality was

56. http://www.who.int/ihr/alert_and_response/outbreak-network/en/. At the end of 2014, CIRAD offered GOARN its expertise in the fields of ecology, epidemiology and veterinarian sciences for certain zoonoses.

reported during the same period. The events are recounted by the Greek politician and historian Thucydides (fifth century BC), who considered that fear and panic both disrupted Greek society at the time and amplified the spread and consequences of this disease.

The destructive nature of fear is without doubt a signature of the plagues which have since taken societies by surprise: the black plague (*Yersinia pestis*) in medieval times, AIDS in the 1980s, pandemic influenzas and Ebola virus today. The cholera epidemics of the nineteenth century in Europe and North America share several similarities with the ongoing Ebola epidemic in West Africa: inadequate health services, populations' fear and beliefs about the means of contamination, riots, unrest and suspicion of the medical community (Sheard, 2014). While Ebola killed fewer people during the epidemic in West Africa (since 2014) than many endemic diseases like malaria or measles during the same period of time, it had an amplifying effect on other diseases (e.g., malaria) and more broadly on health (for example, refusal to go maternity clinics for fear of contamination; Hessou, 2014). More broadly, for Ebola, the public health crisis was transformed into a multi-sectoral crisis affecting people's food security and livelihoods and national economies while threatening the geopolitical stability of the region (FAO-CIRAD, 2015).

Against this backdrop, to act more effectively on the chains of transmission, the cooperation of sociologists and anthropologists would have been warranted from the start of field interventions during the Ebola epidemic in Guinea, Liberia and Sierra Leone (Chandler *et al.*, 2015; Brown *et al.*, 2015). More broadly, an understanding of epidemics, surveillance and disease control can benefit from multidisciplinary approaches that do not limit themselves to biological and medical sciences (Stärk and Morgan, 2015).

## Black swans and perfect storms

> *"What complicates everything is that which does not exist works hard to make everyone believe otherwise."*
>
> *Vendredi ou les limbes du Pacifique*, Michel Tournier, 1966

BLACK SWAN AND PERFECT STORM ARE TWO BUZZWORDS in the English-language press, which often uses them as shorthand to describe financial and weather-related disasters. In probability theory, they refer respectively to a 'rare event' (black swan[57]) which can have wide ranging consequences if it occurs, and to a convergence of apparently unrelated, rare circumstances that drastically aggravate a situation (perfect storm, or 'worst-case scenario').

The emergence of an animal pathogen with zoonotic potential can be a rare event in terms of probability. An example is the zoonotic form of Ebola, with the original animal-

57. Referring to black swans which had been assumed to be non-existent in Europe until they were discovered in Australia. The use of the term 'black swan' was proposed by the philosopher Nassim N. Taleb in the field of finance.

to-human transmission for the index case being a rare event (Pigott *et al.*, 2014). The subsequent human-to-human spread, facilitated by weak health systems and ineffective international coordination, can cause, as shown by the epidemic still underway in January 2016 in West Africa. Highly localized outbreaks of vector-borne diseases (the first case of West Nile fever on the American continent in the Bronx Zoo in New York in 1999; Lanciotti *et al.*, 1999), a new influenza strain on a livestock farm (Baudon *et al.*, 2014), or a disease emerging in wildlife (Wiethoelter *et al.*, 2015) may also be considered as rare events. The wide spread of an emerging pathogen in a new socioeconomic system (Ebola in West Africa), and the risk of an antibiotic resistance 'pandemic', can be seen as perfect microbial storms underway or in the making. This notion of a perfect storm converges with the concept of emergence in its first, philosophical definition, namely, "the whole is greater than the sum of its parts".[58]

## Can a black swan or perfect storm be predicted?

Paté-Cornell (2012) argues that while the attack on the twin towers of the World Trade Center in New York on 11 September 2001 was not a black swan – there were warning signals that could have been analysed – the emergence of AIDS in the 1980s truly was one, as was the Ebola haemorrhagic fever outbreak in West Africa in 2014 (Osterholm *et al.*, 2015).

Major virus detection campaigns (USAID PREDICT-1 followed by PREDICT-2[59] which will also explore possible determinants more deeply) in ecosystems considered to be hotspots of biodiversity – and consequently of viruses (South-east Asia, Central Africa) – and the metagenomic analysis of the biodiversity of viromes are not analogous to surveillance, but rather a snapshot of a community of pathogens at a specific point in time. Yet will these viruses jump the species barrier, locate a receptive host community and foster the emergence of a disease? The exploration of these 'viral loads', as well as of environmental and human behaviour parameters within ecosystems, could help define priorities for the surveillance of pathologies.

Current research is not adequately addressing the complexity and interdependence of the environmental, biological, economic and social dimension of pathogen emergence. This is considerably limiting our capacity to anticipate, prevent and respond to the emergence of infectious diseases. However, prediction and simulation models are becoming increasingly sophisticated (Heesterbeek *et al.*, 2015). They combine the spatial and temporal dimensions of population-based, individual-based, social (contact networks), economic, etc. mathematical models, but they should be handled with caution: "All models are wrong, but some are useful" (Box, 1976). This underscores the need to

58. http://plato.stanford.edu/entries/properties-emergent/

59. http://www.usaid.gov/what-we-do/global-health/pandemic-influenza-and-other-emerging-threats/programs

better communicate the limits of these models to decision makers and health managers, especially with regard to one type of modelling, risk analysis.

Risk analysis, which does not consist in predicting events, but rather in understanding the probability of possible scenarios, is a probabilistic modelling tool – unlike the scenario planning method described by Patrick Zylberman in Chapter 3 – developed in the veterinary and then medical fields, and which should be consolidated, particularly with regard to its communication component. Indeed, too few tangible studies on the communication of risk have been conducted (Figuié and Fournier, 2008). Risk analysis involves both scientists, who estimate and assess risks and propose alternative scenarios to mitigate these risks, and managers in charge of developing control strategies. A lack of effective communication between these stakeholders, as well as with the general public and the media, limits the relevance and effectiveness of these models and fuels confusion and misunderstanding about the risks involved.

For certain diseases such as influenza, the prediction of the occurrence of a new strain seems unrealistic given current knowledge about mutations and recombinations of influenza viruses and the tools available.[60] Surveillance systems capable of detecting rare events and the precursors of these events are needed. They require innovative methods to detect and identify an unusual event capable of generating epidemics or epizootics. Syndromic surveillance, non-specific surveillance based on the collection of data that can be outside the medical field,[61] could enable the early detection of emergences or the warning signs of emergence. These approaches also are being studied to warn of the risk of an imminent terrorist attack.[62]

## Surveillance at all costs?

*"Hidden diseases are the most difficult to treat."*

Chinese proverb

Health surveillance is a field that requires input from a wide range of disciplines: pathology, epidemiology, microbiology-immunology, sociology, economics, anthropology, modelling, ecology, communication sciences, etc. It is not the prerogative of epidemiologists alone, who contribute to the definition and evaluation of surveillance systems through methodological input (samples, statistical and epidemiological analyses) and the proposal of new collection, analysis and assessment methods (Goutard *et al.*, 2012; Vergne *et al.*, 2012; Collineau *et al.*,

60. In time, the Chaos Theory (modelling of deterministic chaotic systems) could nevertheless be an interesting method (https://www.ncbi.nim.nih.gov/pmc/articles/PMC2465602/). Tools have also been developed to assess the pandemic potential of the H7N9 strain and other influenza viruses (https://doi.org/10.1017/S0950268815001570).

61. Triple-S guidelines on syndromic surveillance: www.syndromicsurveillance.eu/Triple-S_guidleines.pdf.

62. American CDC: http://emergency.cdc.gov/bioterrorism/).

2013; Delabouglise *et al.*, 2015). A surveillance system based only on laboratories and information systems, which are now very powerful but rely on equipment that is expensive to obtain and maintain, cannot be sustainable, particularly in the difficult socioeconomic context of countries in the Global South. The key issue remains access to the field and to 'epidemiological units', which are individuals or groups of animals or people, for the collection at the source of health information and samples in sufficient quantities and quality and on a regular basis to be able to derive elements for monitoring and alerts. It is also clear that the information which is compiled and analysed must be regularly provided back to system stakeholders for the system to operate in an optimal manner. Innovations in this field, particularly in the least developed countries and the most isolated regions, are critical (Goutard *et al.*, 2015). These include in particular participatory approaches which rely, in animal health, on the knowledge of livestock farmers, for example.

Surveillance leads to action. In animal health, this involves vaccination, treatment, and quarantine measures, as well as slaughtering and controlling animal movements, etc. If these interventions have negative or adverse effects, this reduces the effectiveness of surveillance and the involvement of stakeholders, or induces the emergence of parallel systems. The actual (in the case of slaughtering) or feared (dissension within social networks) risks of sanctions following the suspicion of animal or zoonotic diseases do not encourage livestock farmers to report suspicions or become part of a surveillance network. Alongside a top-down approach, in which no consultation process is involved, it may be interesting to use participatory approaches developed in the social sciences. This would enable discussions, communication, negotiations and a sharing of knowledge in order to lead to the joint identification of priorities and socially acceptable solutions. Participatory surveillance thus could certainly supplement a surveillance system by addressing the shortfalls identified by evaluation processes. These approaches also render it possible to avoid surveillance systems that stigmatize farmers. They made it possible to identify the last outbreaks of rinderpest before the disease was eradicated from the planet (see inset 2).

In the big data era, weak signals can be detected and identified within a huge mass of data to alert, anticipate (Olson *et al.*, 2015) and contribute to non-specific syndromic surveillance. For animals in the Global South, however, we are dealing rather with small data, although the extraordinary coverage of mobile networks holds some promise for the potential to collect data that could be used in a surveillance framework in collaboration with livestock farmers. Numerous recent initiatives in this area in public and animal health and through One Health approaches for the surveillance of zoonoses confirm the value of this tool. However, digital surveillance raises a certain number of confidentiality and ethical questions given that mechanisms guaranteeing the rights of citizens (for example, data protection and freedom of information) are currently lacking in numerous countries.

The evaluation of surveillance systems is essential for their improvement (Calba *et al.*, 2015). Beyond technical elements (efficiency of data transmission), such evaluations must consider economic issues – what are the benefits, what utility can be drawn from a

system which is by definition long-term in nature, how can it be measured? – as well as social, even psychological questions regarding the populations involved, whether in public health or animal health for livestock farmers and animal sector actors. Surveillance can effectively lead to ostracism and stigmatization for target populations whether in human health (for example, the start of the AIDS epidemic) or animal health (the identification of a herd with tuberculosis, or an industry infected by a pathogen, can have significant social consequences). For wildlife, an effective surveillance system can have indirect consequences for traditional hunters and the bush meat supply chain.

## Broadening the battlefield

> *"But in all frankness, how long can we maintain the wall separating the department of biology from the departments of law and political science?"*
>
> *Sapiens: A Brief History of Humankind*, Yuval Noah Harari, 2015

While the Global North is broadly protected from the incursion and spread of known pathogens thanks to effective health systems, the Global South is more exposed and less equipped to fight epidemics and epizootics, and especially endemic and enzootic diseases, whether recognized or neglected. Global attention is focused on emerging diseases, but neglected diseases – meaning ones neglected by public authorities, donors, the scientific community, and the private sector – affecting vulnerable populations in the Global South have major medical, economic and social impacts. The 17 tropical diseases and a subgroup of eight zoonoses the WHO considers neglected are also neglected in terms of surveillance. The official, ratified extension of this concept to strictly animal diseases should be examined, as greater attention on the part of donors, decision-makers and researchers would enable better investments in animal health in cold spots (Perry *et al.*, 2013), meaning areas where the most vulnerable populations live.

Opposition between the vision of donors and politicians and the interests of livestock farmers may limit the effectiveness of surveillance and control. For example, foot-and-mouth disease, an animal disease that is highly contagious but causes little mortality, hampers regional and international trade. The management of this disease may be imposed although livestock farmers in countries where the disease is enzootic (sub-Saharan Africa, South-east Asia) do not consider the disease important, even though it has indirect economic consequences (production losses) (Bellet *et al.*, 2012). In addition to incorporating participatory approaches that can help improve surveillance and control systems in certain contexts, when possible these systems should, rather than focusing on a single disease, be able to monitor diverse health conditions and be capable of detecting unexpected events. More broadly, and this was emphasized for the ongoing Ebola epidemic in West Africa, surveillance mechanisms should be better integrated into overall health systems (Dhillon and Yates, 2015) and not be dependent on funding obtained through time-limited projects. Surveillance requires permanent mobilization.

For a surveillance system to operate smoothly, it must be based on a network of stakeholders: patients, livestock farmers, health professionals, etc. Under this framework, the One Health concept adopted by international regulatory agencies (OIE and UN agencies) and supported by major donors can be applied to surveillance, particularly to zoonoses and health conditions linked to the environment. One Health surveillance would have the advantage of being able to pool strengths and resources. In Cambodia, the fact that avian influenza was detected first in people before the infected farms which caused the human cases is indicative of important weaknesses in the field of veterinary surveillance.

Are we moving towards a new end of infectious diseases, like that announced in 1967 by the United States Secretary of Health, or are epidemiologic transitions continuing with the gradual replacement of infectious diseases by chronic diseases as countries develop? Or are we on the verge of an epidemiological rupture with the emergence of new pathogens hitherto 'buried' in certain ecosystems and animal reservoirs, including intensive livestock farms and, in parallel, the efficacy of antimicrobials reaching its limits?

We do not understand all of the parameters of diseases and we can only partially, or on a very short term basis, predict the occurrence of new diseases. Appropriate surveillance systems can help us understand and analyse ecological changes and epidemiological trends while improving the control of emerging and endemic diseases. Such systems must be efficient, specific and non-specific, syndromic and etiological, operating on diverse geographic scales, but also firmly rooted in the field in the most vulnerable regions, collecting health information as well as environmental, climatic, and behavioural metadata.

"Why does health, regularly described as a global public good [or global common good, see Chapter 4]–remain an area where international inequalities are so profound?" (Gadreau, 2014). South-South and North-South cooperation in the fields of public health and animal health must be strengthened through joint research platforms, health networks, and integrated surveillance systems. The joint action of international agencies is crucial. Avian influenza, for example, enabled a "return to an integrated human and animal health approach" (Vagneron, 2015) between WHO, OIE and FAO and to set down the concrete foundations of One Health in action.

Four of the Millennium Development Goals (MDG), launched in 2000 for a 15-year period, refer explicitly to health. Despite significant progress, the burden of infectious diseases, in general endemic and for some neglected, remains heavy, particularly in the least developed countries. For the period after 2015, when the MDGs will be replaced by a new set of poverty reduction and sustainable development goals (Sustainable Development Goals, SDG, 2015–2030), the Director-General of WHO (Dye, 2014) is focusing on five aspects of the fight against infectious diseases:

– study of the biological links between infectious and non-infectious diseases;
– control of infections in urban areas;
– improvement of the response to international health threats;
– expansion of vaccination programmes for children to prevent acute and chronic diseases in adults;
– development of universal health coverage.

However, the post-2015 health era must not neglect the improvement of animal health which, combined with strengthening the productivity of livestock farming, is a major lever for poverty reduction (Pradère, 2014), and must broaden its vision of health by integrating sectors and disciplines outside the strictly medical field.

Even though some risks are known – antimicrobial resistance, unceasing evolution of influenza viruses – it is difficult to see what the future holds. Major rupture based on increasingly frequent emergences? Transition and end of infectious diseases? Either way we must have warning systems and be able to respond in real time.

A multi- and interdisciplinary approach to health, combining biological, human, social and mathematical sciences, is essential, whether to address the interdependence of animal, human and environmental health (One Health) (Lapinski *et al.*, 2015) or to be able to transfer research outputs to decision-makers, particularly in the field of health management.