Zoonoses diversity

1. Some emblematic examples

1.1. The flu

Figure 1. A building on a laying hen farm in Thailand, with few biosecurity measures. (Photograph by the authors)

Influenza is above all a disease of the animal world. The influenza viruses, responsible for influenza, affect many animal species (birds, pigs, horses, marine mammals, canids, felids, small carnivores, etc.). The emergence of an influenza virus from the animal world that would adapt to humans remains a major danger of epidemics and pandemics, and it is enough to go back a few years to find examples: in 2010 a new H1N1 type virus (Human lethality rate = 52%) [1] appeared in the human population after a stint in pigs, raising fears of a severe pandemic; in 2003, the appearance of an H5N1 avian virus infected a few humans with a lethality of more than 50%, fortunately without direct human-to-human transmission, but this possibility remains formidable. The history of influenza is full of many devastating pandemics. The most emblematic is the 1918-1919 pandemic, known as the Spanish flu (between 40 and 80 million deaths), but we can also remember the Asian flu pandemic (1957, at least one million deaths) or the Hong Kong flu pandemic (1968, 4 million deaths).

The danger of a possible transgression of the species barrier comes from the high level of mutations to which influenza viruses are subjected during viral replication, and the segmented nature of their genomes. All the dangers are considerably increased in industrial farms, which number in the thousands (or even tens or even hundreds of thousands in some poultry farms), inducing considerable viral replication when contagion is spread on the farm, and therefore a high probability of the appearance of dangerous variants that are potentially transmissible to humans (Figure 1).

Since the 1980s, we have benefited from major assets in the prevention of influenza pandemics: mass vaccination, the development of rapid diagnostic methods, the development of effective antivirals, and the establishment of surveillance networks at the global level. The danger of a new influenza pandemic of animal origin is still very present.

1.2. Rabies

Rabies is a viral disease that mainly affects mammals, including humans. The virus can infect a wide range of animals, including bats, raccoons, skunks, foxes, and dogs. Bats are natural reservoirs of the virus. Generally, transmission to humans occurs through the bite or scratch of an infected animal. Human-to-human transmission is exceptional.

Rabies remains a serious public health problem in many parts of the world, especially in areas where vaccination programmed for domestic animals are not finalized and early treatment after bites is limited. Rabies is responsible for nearly 59,000 annual deaths worldwide, mainly in Asia and Africa, despite highly effective vaccines in preventing the disease in animals and humans.

1.3. The Plague

The plague is thought to have originated in Central Asia in wild rodent populations, which are considered natural reservoirs of *Yersinia pestis*, the bacterium responsible for the disease. The natural cycle of the bacterium includes several key elements: reservoir hosts (rodents, squirrels, prairie dogs) and vectors (the rat flea that infects or is infected by biting). Periodically, there may be plague outbreaks among reservoir hosts, with high mortality. Infected humans (through the bite of an infected flea or direct contact with the reservoir) can develop various forms of the disease. During epidemics, transmission can also be human-to-human, mainly through respiratory droplets or direct contact with infected bodily fluids.

The plague has been the cause of devastating historical epidemics. In the fourteenth century, the Black Death pandemic killed some 25 million people, about a third of the European population at the time. Plague still exists today in some parts of the world, but modern medical knowledge and public health measures have made it possible to control its spread and mitigate its impact.

1.4. SARS, MERS, COVID-19

Coronaviruses mainly affect the animal world (bats, birds, pigs, rodents, dogs, cats, horses, dolphins, etc.) and cause respiratory infections in animals. As such, China occupies a central place for the spread of coronaviruses. Indeed, it is a vast country whose varied climates lead to a great diversity of bats and viruses (See Bats and viruses or how to live together in harmony). In addition, bats are in close proximity to a large human population, which potentially promotes the transmission of viruses to humans and farm animals (See Focus Bats and the emergence of coronaviruses).

Some viruses concern humans, in whom it generally causes a simple flu-like illness. Nevertheless, in 2003, a new virus emerged in China (**Severe Acute Respiratory Syndrome with Coronavirus,** SARS-CoV) which caused a severe respiratory infection in humans. Human-to-human transmission is direct, and the virus is spreading rapidly around the world. More than 8000 people will be infected, mainly in China, with nearly 800 deaths. Thanks to strong international mobilization and coordination, the epidemic was quickly controlled and then stopped. In 2012, a new human coronavirus, named MERS-CoV, was identified in the Middle East. Although it causes a high lethality rate (about 35%), it is not easily transmitted and remains confined to its emerging region. At the end of 2019, a new human coronavirus emerged, again in China (SARS-CoV-2). This virus, like the SARS-CoV of 2003, causes a potentially severe respiratory disease (COVID-19), is easily transmitted between humans, and the epidemic quickly turns into a pandemic without it being possible to contain it despite numerous containment measures and restrictions on contacts.

These new human coronaviruses all come from the animal world. Like influenza viruses, coronaviruses are subject to many mutations during viral replication, which makes them particularly susceptible to the phenomena of transgression of the species barrier and adaptation to a new host. Since its emergence, SARS-CoV-2 has become endemic in the human population.

2. The main zoonotic diseases

There are now more than 150 zoonotic diseases in the world, a dozen of which alone are responsible for 2.2 million deaths per year. While there are more than 5000 viruses identified (while more than 320,000 are expected by research), only a little more than 200 species of viruses have been recognized and identified as capable of infecting humans. Of these viruses, 62% are of animal origin, and most are derived from wildlife (Tables 1 and 2).

Zoonotic pandemics highlight the interconnection between humans, animals and the environment. Factors such as increasing human encroachment on wildlife habitats, changes in land use, and the mobility of people and products can facilitate the spread of pathogens from animals to humans. Detecting and responding to pathogens with zoonotic potential is essential to prevent the pandemic from escalating (e.g., border control) (Tables 3 and 4).

- **Table 1.** Viral zoonoses that have emerged in the 21st century

Zoonose émergente / agent pathogène	Réservoir/hôte intermédiaire	Virus (Famille)	Origine géograp
Syndrome respiratoire à hMPV	Oiseau	Human metapneumovirus (hMPV)	2001, P
Syndrome respiratoire aigu sévère SRAS	Chiroptère /civette	SRAS-COV-1 (*Coronavidae*)	2002, C
Syndrome pseudo-grippal, encéphalite, anasarque fœtale à PARV4	Porcin ou bovin	Parvovirus 4 (PARV4) (*Parvoviridae*)	2005, G
Maladie respiratoire à MELV	Chiroptère	Melaka virus, MELV (*Reoviridae*)	2006, M
Fièvre hémorragique	Chiroptère	Bundibugyo ebolavirus (*Filoviridae*)	2007, O
Fièvre hémorragique	Rongeur	Lujo (*Arenaviridae*)	2008, A
Syndrome grippal (grippe aviaire)	Oiseaux	Avian Influenza H7N1 (AIV H7N1) (*Orthomyxoviridae*)	2008, R
Fièvre hémorragique	Petit rongeur	Chapare virus (*Arenaviridae*)	2009, B
Syndrome grippal (grippe porcine)	Porc	Virus Influenza A H1N1 (IAV H1N1) (*Orthomyxoviridae*)	2009, M
Syndrome grippal	Oiseaux et porcs	IAV H3N2 ; Reassortant canin-aviaire (Orthomyxoviridae)	2009, C
Syndrome de Fièvre et thrombocytopénie sévères	Rongeur / Tique	Dabie bandavirus (*Phenuiviridae*)	2009, C
Syndrome grippal	Poulets	IAV H10N8 (*Orthomyxoviridae*)	2012, C
Syndrome respiratoire du Moyen-Orient (MERS)	Chiroptère	Coronavirus du MERS (MERS-CoV) (*Coronavidae*)	2012, A Saoudit
Poxvirose	Petit rongeur	Akhmeta (*Poxviridae*)	2013, G
Syndrome fébrile	/ Tique *Ixodes persulcatus*	Alongshan (*Flaviviridae*)	2019, C
Fièvre douloureuse	/ Tique	Bourbon (*Orthomyxoviridae*)	2014, U
Fièvre douloureuse	/ Tique Amblyomma *americanum*	Heartland virus (*Phenuiviridae*)	2019, U
Coronavirus Disease-2019 (COVID-19)	Chiroptère	SRAS-Cov-2 (*Coronavidae*)	2019, C

● **Table 2.** Viral zoonoses that have re-emerged in the 21st century with an unprecedented geographical spread

Zoonose ré-émergente	Réservoir/vecteur	Virus	Expansion Géographique au 21e si
Fièvre aigue douloureuse à Chikungunya	Singes, Culicidés	Chikungunya (*Togaviridae*)	Afrique Océan Indien ➡Asie ➡Cara ➡Amérique du Sud ➡Méditerranée Asie du Sud-Est ➡ Pacifique.
Fièvre hémorragique	Tique, Bovins, Ovins	Congo-Crimée (*Bunyaviridae*)	Afrique-Crimée ➡Asie
Fièvre aigue, Fièvre hémorragique	Moustique, Singes	Dengue (*Flaviviridae*)	Asie ➡Amérique du Sud ➡Afrique
Myélite flaccide	Primates	Enterovirus D68 (*Picornaviridae*)	Californie ➡Hémisphère Nord
Fièvre hémorragique	Chiroptères	Ebola virus (*Filoviridae*)	Afrique centrale ➡Afrique de l'Oue
Fièvre hémorragique, insuffisance rénale	Rongeurs	Hantavirus (*Hantaviridae*)	Asie ➡Mondial
Encéphalite	Chiroptères	Hendra (*Paramyxoviridae*)	Australie Queensland ➡ North➡W Wales
Fièvre hémorragique	Chiroptères	Marburg virus (*Filoviridae*)	Allemagne - Afrique du Sud ➡Gui Équatoriale ➡ RDC➡ Angola➡ Oug Ghana ➡Tanzanie
Variole du Singe ou Monkeypox	Micromammifères*	Monkeypox (*Poxviridae*)	Afrique ➡Europe➡ Amériques
Encéphalite	Chiroptères	Nipah virus (*Paramyxoviridae*)	Malaisie ➡Bengladesh ➡Inde (Ker
Fièvre, signes gastrique et neurologiques	Tiques	Powassan virus (*Flaviviridae*)	Canada (Ontario) ➡ Extrême-Orien ➡centre Atlantique, nord-est et cen des États-Unis
Fièvre hémorragique	Tiques	Rift Valley Fever (*Phenuiviridae*)	Kenya ➡ Afrique centrale ➡ Afriqu ➡ Afrique du Sud ➡ Arabie saoudit
Syndrome grippal et signes neurologiques	Moustique, Primates	Zika (*Flaviviridae*)	Uganda- Southeast Asia ➡Africa d de l'Est➡ Asie ➡Micronésie ➡ Car Amériques ➡ Europe
Fièvre	Moustique, Oiseaux	West Nile (Nile de l'Ouest)	Uganda➡ Africa➡ Europe➡ Moyer Amérique du Nord ➡ Europe ➡ Asi
Fièvre aigue, Fièvre hémorragique	Moustique, Primates	Dengue	Asie du Sud-est➡ West Africa ➡ A Amérique du Sud ➡ Amérique Cent Caraïbes➡ Afrique ➡ Inde➡ Pacifi

● **Table 3.** Historic pandemic zoonoses

Année	Pandémie (Origine animale)	Mortalité
1346-53	Peste noire (rat)	~ 200 x 10^6 (1/3 population)
1665-66	Grande Peste de Londres (rat)	75,000 (20 % pop. Londres)
1855	La troisième peste (rat)	15 millions
1918	Grippe espagnole, H1N1	40-80 millions
1957	Grippe Asiatique (Avifaune)	1.1 x 10^6 (116,000 aux USA)
1968	Grippe de Hong Kong (Avifaune)	4 millions
1981	HIV/AIDS (Primate non humain)	35 millions
2003	SARS-COV-1 (Chiroptère)	774
2009	Grippe porcine H1N1 (suidés)	12,469 décès in the US.
2019	COVID19 - SARS-COV-2	7 millions (plus d'un milliard de cas)

● **Table 4.** Zoonotic diseases that have acquired H-H transmission (vector or not?) with proven pandemic potential

Zoonose	Hôte naturel	Critères de Transmission H-H
Peste	Rats et puces	Mobilité des humains, contact direct, vecteurs cosmopolites
Grippes H1N1, H5N1, H7N9, H5N8	Oiseaux, porcins	Transmission respiratoire hautement infectieuse
COVID-19	Chiroptères	Transmission respiratoire
Maladie à Ebolavirus	Chiroptères	Transmission par contact rapproché
MERS	Chiroptères	Transmission par voie respiratoire
SIDA	Primates	Transmission par contact intime
SRAS 1	Chiroptères	Transmission par voie respiratoire et contact de surfaces infectées
Encéphalite à virus Nipah	Chiroptères	Transmission par contact direct et indirect

Notes & References

[1] A study published on May 3, 2024 in the *New England Journal of Medicine* (Uyeki, T. M. et al. *N. Engl. J. Med*. (2024)) confirmed that a dairy worker in Texas had been infected with influenza A H5N1 virus. However, U.S. authorities have not reported a large number of deaths or severe cases in humans, which suggests that the virus has not yet become highly transmissible or deadly, according to Michael Worobey, an evolutionary biologist in Tucson (Arizona, USA). However, Gregory Gray (Epidemiologist in Galveston, Texas, USA) says there are anecdotal reports of many other cases in humans. Jessica Leibler (Environmental Health, Boston, USA) suspects that the exposure of agricultural workers may already be very high. It's not a virus that's going to disappear in any way. Especially since in the last two years, the list of animals that have died [from avian influenza] has become impressive (polar bears, penguins, in particular). It is no longer a disease that only affects poultry and birds in general.