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 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 [1]. 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 animals (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

Emerging zoonosis / pathogen	Reservoir / intermediate host	Virus (Family)	Geographic origin
hMPV respiratory syndrome	Bird	Human metapneumovirus (hMPV) (*Paramyxoviridae*)	2001, Netherlands
Severe acute respiratory syndrome SARS	Bat / civet	SARS-CoV-1 (*Coronavidae*)	2002, South China
Influenza-like illness, encephalitis, hydrops fetalis PARV4	Porcine or bovine	Parvovirus 4 (PARV4) (*Parvoviridae*)	2005, Ghana
MELV respiratory disease	Bat	Melaka virus, MELV (*Reoviridae*)	2006, Malaysia
Hemorrhagic fever	Bat	Bundibugyo ebolavirus (*Filoviridae*)	2007, Uganda
Hemorrhagic fever	Rodent	Lujo (*Arenaviridae*)	2008, South Africa
Influenza-like illness (avian influenza)	Birds	Avian Influenza H7N1 (AIV H7N1) (*Orthomyxoviridae*)	2008, United Kingdom
Hemorrhagic fever	Small rodent	Chapare virus (*Arenaviridae*)	2009, Bolivia
Influenza-like illness (swine flu)	Pig	Influenza A virus H1N1 (IAV H1N1) (Orthomyxoviridae)	2009, Mexico
Influenza-like illness	Birds and pigs	IAV H3N2; Canine-avian reassortant (*Orthomyxoviridae*)	2009, North China
Severe fever and thrombocytopenia syndrome	Rodent / Tick	Dabie bandavirus (*Phenuiviridae*)	2009, South China
Influenza-like illness	Chickens	IAV H10N8 (*Orthomyxoviridae*)	2012, China
Middle East respiratory syndrome (MERS) MERS	Bat	coronavirus (MERS-CoV) (*Coronaviridae*)	2012, Saudi Arabia
Poxvirus	Small rodent	Akhmeta (Poxviridae)	2013, Georgia
Febrile syndrome	/ Tick *Ixodes persulcatus*	Alongshan (*Flaviviridae*)	2019, NE China
Painful fever	/ Tick	Bourbon (*Orthomyxoviridae*)	2014, USA, KS
Painful fever	/ Tick *Amblyomma americanum*	Heartland virus (*Phenuiviridae*)	2019, USA, MO
Coronavirus Disease-2019 (COVID-19)	Chiropteran	SARS-Cov-2 (*Coronaviridae*)	2019, China, W

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

Re- emerging zoonosis	Reservoir / Vector	Virus	Geographic Expansion in the 21st Century
Acute painful fever from Chikungunya	Monkeys, *Culicidae* (mosquitoes)	Chikungunya (*Togaviridae*)	Africa, Indian Ocean ➡ Asia ➡ Caribbean ➡ South America ➡ Eastern Mediterranean ➡ Southeast Asia ➡ Pacific
Hemorrhagic fever	Tick, cattle, sheep	Congo-Crimea (Bunyaviridae)	Africa-Crimea ➡ Asia
Acute fever, hemorrhagic fever	Mosquito, monkeys	Dengue (*Flaviviridae*)	Asia ➡ South America ➡ Africa
Flaccid myelitis	Primates	Enterovirus D68 (*Picornaviridae*)	California ➡ Northern Hemisphere
Hemorrhagic fever	Bats	Ebola virus (*Filoviridae*)	Central Africa ➡West Africa
Hemorrhagic fever, renal failure	Rodents	Hantavirus (*Hantaviridae*)	Asia ➡Global
Encephalitis	Bats	Hendra (*Paramyxoviridae*)	Queensland Australia ➡ North➡West➡South Wales
Hemorrhagic fever	Bats	Marburg virus (*Filoviridae*)	Germany - South Africa ➡ Equatorial Guinea ➡ DRC➡ Angola➡ Uganda➡ Ghana ➡Tanzania
Monkeypox	Micromammal*	Monkeypox (*Poxviridae*)	Africa ➡Europe➡ Americas
Encephalitis	Bats	Nipah virus (*Paramyxoviridae*)	Malaisia ➡Bengladesh ➡India (Kerala)
Fever, enteritic & neurological signs	Ticks	Powassan virus (*Flaviviridae*)	Ontario, Canada ➡ Russian Far East ➡ Mid-Atlantic, northeastern, & midwestern U.S.
Hemorrhagic fever	Ticks	Rift Valley Fever (*Phenuiviridae*)	Kenya ➡ Central Africa ➡ West Africa ➡ SouthAfrica ➡ Saudi Arabia
Flu-like syndrome & neurological signs	Mosquito, primates	Zika (*Flaviviridae*)	Uganda- Southeast Asia ➡West & East Africa ➡ Asia ➡Micronesia ➡ Caribbean ➡ Americas ➡ Europe
Fever	Mosquito, birds	West Nile	Uganda➡ Africa➡ Europe➡ Middle East ➡ North America ➡ Europe ➡ West Asia
Acute fever, hemorrhagic fever	Moustique, Primates	Dengue	Southeast Asia ➡ West Africa ➡ South Asia ➡ South América ➡ Central América➡ Caribbean ➡ Africa ➡ India➡ Pacific

● **Table 3.** Historic pandemic zoonoses

Year	Pandemic (Animal Origin)	Mortality
1346-53	Black Death (rat)	~ 200 x 10^6 (1/3 population)
1665-66	Great Plague of London (rat)	75,000 (20 % of London's population)
1855	The Third Plague (rat)	15 million
1918	Spanish Flu, H1N1	40-80 million
1957	Asian Flu (Avian species)	1.1 x 10^6 (116,000 in the USA)
1968	Hong Kong Flu (Avian species)	4 million
1981	HIV/AIDS (Non-human primate)	35 million
2003	SARS-COV-1 (Chiroptera)	774
2009	Swine Flu H1N1 (Swine)	12,469 deaths in the US
2019	COVID-19 SARS-COV-2	7 million (over a billion cases)

● **Table 4.** Zoonoses with H-H Transmission (Vector or Not?) and Proven Pandemic Potential

Zoonosis	Natural Host	Criteria for H-H Transmission
Plague	Rats & fleas	Human mobility, direct contact, cosmopolitan vectors
Influenza H1N1, H5N1, H7N9, H5N8	Birds, Swine	Highly infectious respiratory transmission
COVID-19	Bats	Respiratory Transmission
Ebolavirus Disease	Bats	Transmission through close contact
MERS	Bats	Respiratory Transmission
SIDA	Primates	Transmission intimate contact
SRAS 1	Bats	Respiratory transmission & contact with infected surfaces
Nipah Virus Encephalitis	Bats	Transmission through direct and indirect contact

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.