Introduction

Recent decades have seen unprecedented increases in life expectancy for people in all countries, with the average global citizen now expected to live more than 72 years, compared to only 45 years in 1950 (Roser, Ortiz-Ospina and Ritchie, 2013). Just a few generations ago, infectious diseases and a lack of effective medical treatments killed most people at a very young age. Gastrointestinal infections, tuberculosis, influenza, and pneumonia were common causes of death. However, several medical and technological advances that emerged in the 20th century made it possible to control many of the diseases and health hazards that plagued humanity for millennia. Vaccines, antibiotics, and access to sanitation, clean water, and healthcare were among them.

The resulting growth in the human population, along with urbanisation, higher incomes, new technologies, and globalisation were also the catalysts for a massive transformation in the food system and the nature of human–animal interactions in ways completely different than those seen in the past. Industrial processes replaced traditional husbandry practices in the production of animals. The volume and pace of expansion of the population of animals under human custody has been unprecedented, with over 70 billion land animals (FAO, 2018), and an estimated 1–3 trillion fish (Mood and Brooke, 2014), now slaughtered every year. At the same time, the rapid spread of infectious diseases from wild habitats to every corner of the world became possible with the massive movement of animals and people across the globe.

As we discuss in this chapter, these transformations created novel routes for the transmission of pathogens that gained, or re-gained, access to human populations, along with the conditions that are, paradoxically, eroding many of the health advances achieved so far. Livestock health is now considered the weakest link in the global health chain (FAO, 2013), with disease drivers in livestock and wildlife responsible for an increasing share of infectious disease burden (Figure 24.1); human diseases of animal origin (zoonoses) still cause about a billion cases of illness and millions of deaths every year (Karesh et al., 2012). Understanding these drivers, and the inherent link between animals’ health, welfare, and human health, is a necessary step to control disease emergence and other global health threats effectively.

In recognising that human and animal health are interdependent and bound to the health of the ecosystems where they exist, the “One Health” approach was created to address these challenges.
Animal welfare and human health (Karesh and Cook, 2009), which are explored in this chapter. We first describe how the impoverishment of animal health and welfare in modern animal production systems has become a major driver for the emergence of communicable diseases at a global level, and then focus on the direct effects of these systems on environmental pollution, the health of workers and of local communities. We also examine the impacts and biosecurity threats associated with wildlife hunting, farming, trafficking, and trade in a globally connected world. The chapter closes with a section on overconsumption of animal-sourced food as a major risk factor for non-communicable diseases.

**Intensive animal farming and infectious disease emergence and spread**

The emergence of new, or reappearing, infectious diseases is widely recognised as one of the major challenges for global health and socioeconomic development. Despite substantial progress in the reduction of poverty, access to healthcare and sanitation, recent decades have witnessed an increase in the frequency of emerging and re-emerging infectious diseases at a global scale (Jones et al., 2008, 2013). On average, one new infectious disease is recognised every four months, three-quarters of which are zoonotic, originating either through direct contact with wild animal species or with livestock (UNEP, 2020).
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Many are the reasons for the acceleration in the emergence of new zoonotic pathogens. Livestock species now constitute more biomass than all wild mammals combined, harbouring a much larger number of zoonotic viruses than their wild relatives (Johnson et al., 2020) – most of which are capable of infecting multiple hosts, including humans (Rohr et al., 2019).

In addition to representing a massive zoonotic reservoir from which newly emerging pathogens can arise and spill over to the human population, or act as a conduit for pathogens from wild animals (Jones et al., 2013), propitious conditions for the emergence and transmission of zoonotic diseases are found in modern animal agriculture. Gains in productivity have stemmed mostly from the selection of fast-growing and highly productive breeds, helped by the development of diets, drugs, and additives designed to maximise the conversion of animal feed into meat, milk, and eggs. Additionally, housing systems involving the confinement of large groups of animals were adopted widely.

This intensification process took a heavy toll on the health of animals and their ability to withstand pathological challenges. Productivity gains that have enabled greater production efficiency have stretched the animals’ physiology beyond natural limits, increasing the incidence of metabolic, bone and joint disorders (Grandin, 2014). For example, among chickens raised for their meat (broilers), growth rates have increased by over 400% in less than four decades. Because these birds gain weight so rapidly, the growth of bones and internal organs cannot keep pace with it; musculoskeletal, cardiovascular, and respiratory diseases are highly prevalent (Hartcher and Lum, 2020).

Importantly, when genetic selection is narrowly focused on growth and productivity, critical organ systems and biological functions can be compromised. Crucially, immune function is among them, as energy that would otherwise be used for defence is diverted to growth and reproduction (van der Most et al., 2011). For example, modern broiler breeds have been shown to exhibit damaging over-inflammatory responses to certain disease challenges and insufficient responses to clear other pathogenic challenges (Aylward, 2020). Likewise, strains highly selected for productive traits have shown a decline in humoral immune capacity (Bridle et al., 2006).

The genetic diversity of the immune system is also a determinant of resistance to infectious disease: without genetic variation, the likelihood that some individuals in a population will be resistant to a newly emerging pathogen is greatly diminished. Indeed, epidemiological modelling shows that lower genetic heterogeneity is associated with an increased probability of major (catastrophic) epidemics (Springbett et al., 2003). Yet, modern breeds of animals are extremely homogeneous. For example, poultry breeds have shown diminished polymorphism at loci of the major histocompatibility complex (a group of genes that code for proteins essential for the immune system) associated with pathogen-specific disease resistance (Kaufman et al., 1999; Bridle et al., 2006).

The confinement of large populations of susceptible animals at high densities further increases the likelihood of infectious disease emergence and spread through other mechanisms (Jones et al., 2013). For example, high levels of aerial pollutants such as ammonia and faecal dust, which naturally result from the high volume of animal waste, are found in modern animal operations. Exposure to these pollutants compromises respiratory function, damaging the first barriers of defence against infection by respiratory pathogens (Greger, 2007). Accordingly, in pigs raised intensively, post-mortem findings of lesions in the respiratory tract as a result of pneumonia, pleuropneumonia, pleurisy, and other diseases are pervasive.

It is also well documented that chronic exposure to stress (physical and emotional) has a suppressive effect on the immune system, activating the release of corticotropin–releasing hormone (CRH) by the hypothalamus, a brain region that links the nervous and endocrine systems. Through a cascade of effects, CRH promotes the release of cortisol, a stress hormone
known particularly for its anti-inflammatory and immunosuppressive action. Higher levels of cortisol are associated with a lower number of lymphocytes (white blood cells important in the immune response) in blood, also affecting the production of cytokines (signalling molecules of the immune system) and antibodies (Martínez-Miró et al., 2016). Animals exposed to social stressors have also shown alterations in natural killer cell cytotoxicity (cells that kill aberrant cells, such as virally infected cells) and response to vaccination (Proudfoot and Habing, 2015).

Accordingly, there is ample evidence that, as with humans, chronic stress in animals increases disease incidence, the secondary complications of viral infections, and prolongs healing times (Glaser and Kiecolt-Glaser, 2005). For example, physical restraint in mice dramatically enhanced morbidity and mortality following infection with the influenza (H1N1) virus (Luo et al., 2020). In pigs, psychosocial stress is associated with dysregulation of inflammatory processes, neuroendocrine alterations, impaired immune function, and increased susceptibility to disease (Gimsa, Tuchscherer, and Kanitz, 2018). In chickens, chronic exposure to corticosterone downregulates proinflammatory responses and immune function (Kaiser et al., 2009) and in minks (farmed for their fur), lack of housing enrichment induces endocrine and organ changes associated with impaired immunity (Díez-León et al., 2016). Stress-mediated impairment of immunity and increased disease susceptibility is also widely described in fish (Yada and Tort, 2016). Environmental and psychosocial stressors in farmed animals include their stocking at high densities, the deprivation of highly motivated behaviours, limited opportunities for movement, social isolation, maternal deprivation, short sleep periods, limited access to natural light, as well as fear and pain induced by widely employed management practices (e.g. mutilation of body parts, feed restriction, transport between facilities).

Emergence of highly pathogenic viral strains

For decades, one of the greatest concerns of public health officials everywhere has been the possibility of emergence of a highly pathogenic influenza strain achieving sustained transmission in the human population. Influenza viruses that spilled over from animal reservoirs have been responsible for multiple epidemics and pandemics throughout history, including the 1918 “Spanish flu”, the 1957 “Asian flu”, the 1968 “Hong Kong flu”, and more recently the 2009 H1N1 (“swine flu”) pandemic (Poovorawan et al., 2013). Avian influenza (“bird flu”) is of particular concern, as some subtypes (H5, H7) cause extremely severe illness in humans (Poovorawan et al., 2013). For example, over 700 human infections with H5N1 viruses have been reported so far, and about 60% of the cases have died.

There are many types of influenza viruses circulating in wild animal species, mainly waterbirds. Spillover from these species to humans is not trivial, as many are the adaptations needed for viruses adapted to infect the intestinal tract of aquatic birds, to replicate instead in the respiratory tract of humans. The conditions favouring the selection and spread of these mutations have been achieved in the intermediate hosts between aquatic animals and humans: the pigs and birds we breed for consumption (Poovorawan et al., 2013). Pigs, in particular, having receptors for avian, swine, and human influenza viruses, are regarded as ideal mixing vessels to generate influenza viruses with pandemic potential (Ma et al., 2008). Indeed, the intensification and expansion of pig production at a global level provided multiple opportunities for a strain with mixed genes from avian, human, and swine influenza viruses to become established in this population, leading to the first influenza pandemic of swine origin in 2009 (Trovão and Nelson, 2020).

Similarly, intensive poultry farming has made highly pathogenic avian influenza pervasive. Despite fear that backyard chicken production and other outdoor production systems expose domestic poultry to wild birds (a natural reservoir of influenza viruses), most genetic conver-
ion events from low to highly pathogenic influenza strains were traced back to commercial poultry farms in high-income countries (where intensive poultry farming is ubiquitous) and in countries transitioning to intensive production (Dhingra et al., 2018). Indeed, intensive farming favours the emergence of highly pathogenic strains in multiple ways. To spread in a population, pathogens must multiply within the host, while maintaining the opportunities for transmission by ensuring the host’s survival (i.e. maintaining low virulence). This is particularly the case if a pathogen cannot survive for too long in the environment. In such cases, a high level of virulence (causing more severe disease) is costly to the virus, as it may stop spreading when its host dies and contact with other hosts is interrupted (Greger, 2007). Influenza virus survival periods are much shorter outdoors, as it is rapidly inactivated by sunlight and desiccation, making the evolution of high virulence less likely outdoors (Greger, 2007a). Conversely, the longer viral survival period in confined intensive systems increases the likelihood that a highly virulent strain continues spreading in the population. The much higher number of susceptible hosts and contact rates in intensive systems further promote higher virulence, facilitating the spread of viruses causing severe disease.

Hundreds of avian flu outbreaks, involving millions of birds, were detected in commercial poultry flocks in Europe, Asia, Africa, and the Americas in recent years. In some of these outbreaks, humans were also infected (Shi and Gao, 2021). These many new cases provide numerous opportunities for these viruses to mutate or reassort (mix genetic material) with other strains, and at some point acquire the capability of sustained human transmission.

Biosecurity in animal operations

Although large animal operations often rely on biosecurity protocols to reduce zoonotic disease risk, the sheer scale of the outputs of these systems, the common outsourcing of production stages to a variety of independent producers, the transport of live animals, and the many opportunities for contamination during slaughter and processing, make it unlikely that these measures would be sufficient even if they were strictly implemented.

Many are the pathways through which pathogens can spill over from farm animal hosts to the human population. Transmission risk is highest for humans in contact with animals, but under the right conditions pathogens are also capable of surviving for weeks, or months, without a host. During this time they may travel outside farmhouses together with animal waste, water, clothing, equipment, garbage, trucks, bedding, animal vectors (e.g. insects, ticks, rodents), or even through the air, in contaminated aerosol particles expelled by the wind or by ventilation systems.

Besides the inherently challenging nature of mitigating biosecurity risks, failures of compliance with even basic standards of biosecurity are endemic in the industry. Whenever surveyed, biosecurity flaws were found to be widespread, even in developed nations (Racicot et al., 2011). The situation is worse in resource-limited settings: not only is biosecurity expensive, it also requires a clear understanding of strict technical guidelines and behavioural protocols. Seriously risky practices, such as the unsafe disposal of carcasses of dead and sick animals, are common in many places (Negro-Calduch et al., 2013).

Live animal transportation as an epidemic risk

Live animal transportation represents a major epidemic risk. Every year, over two billion animals are loaded onto ships and trucks and sent on national and international journeys lasting from hours to weeks (Levitt, 2020). Among the many welfare challenges to which animals are exposed in these journeys are dehydration, exhaustion, thermal stress, injuries, fear, and even death.
The crowding of animals from multiple origins into poorly ventilated, small, and stressful conditions promotes infectious disease transmission in multiple ways, as well as the opportunity for the mixing of genetically diverse pathogens. In addition to the high contact rate among animals, high pathogen loads are promoted by the immunosuppressive effects of stress, as discussed earlier. Long-distance transport has been also shown to increase the “faecal shedding” of pathogens (their release into the stool). In general, the more pronounced the stress, the higher the levels of pathogens released (Rostagno, 2009).

Predictably, animal trade has long been an effective way of spreading zoonotic diseases. Bovine spongiform encephalopathy (“mad-cow disease”) (Hardstaff, Häslér, and Rushton, 2015) and foot-and-mouth disease (Di Nardo, Knowles, and Paton, 2011) are two well-known examples of diseases in which transportation was a primary driver of their spread across borders. Bovine respiratory syncytial virus, infectious bovine rhinotracheitis virus, herpesviruses, bovine parainfluenza, and multiple pathogens associated with gastrointestinal diseases are also known to have their incidences increased during transport (Broom, 2014). Importantly, the rapid expansion in the diversity of influenza A viruses in pigs is attributed to the long-distance live swine trade (Trovão and Nelson, 2020). Naturally, the same risks are present in the trade of wild animal species, as discussed later in this chapter.

Industrial animal farming and antimicrobial resistance

The power of antibiotics to fight infections is rapidly eroding. The emergence of antimicrobial-resistant bacteria is currently one of the biggest threats to global health (Osterholm and Olshaker, 2017). Pathogens associated with serious medical problems, such as tuberculosis, pneumonia, sexually transmitted diseases, urinary tract infections and hospital infections, have now become resistant to several antibiotics. About 700,000 deaths per year already occur due to antibiotic-resistant infections, with an estimated 10 million deaths per year due in 2050 if trends continue unchanged (O’Neill, 2016).

Because bacteria can rapidly adapt, antimicrobial resistance is expected to emerge naturally when bacteria are exposed to antibiotics. Although the misuse and overuse of antibiotics in human medicine accelerated this process, about 70% of the antibiotics sold in the world are not used in humans, but in animals raised in intensive farming systems (Van Boeckel et al., 2019). In these systems, the primary use of these drugs is not the treatment of sick animals, but instead the promotion of growth and/or prevention of infections, to ensure that animals can survive until the slaughter age under the conditions typical of intensive systems (McKenna, 2017). As discussed, intensive farming favours infectious disease emergence and spread. Additionally, animals raised indoors, without contact with the soil, have been shown to lack health promoting gut bacteria that can help maintain mucosal immune homeostasis and limit pathogen colonisation (Mulder et al., 2009). These conditions have created an inherent need for disease prevention – for which antibiotics have been a cheap solution.

As developing nations increasingly intensify animal-food production, antimicrobial resistance is rising rapidly too. Countries such as China, India, Brazil, and Kenya, where meat production increased dramatically, are now hotspots of antimicrobial resistance in animals (Van Boeckel et al., 2019). Antibiotics critical for human medicine are also widely used in intensive fish farming, one of the fastest growing food industries on the planet and now a hotspot for bacterial resistance (Watts et al., 2017). In these farms, infectious diseases are fought by adding large amounts of antibiotics to the water, most of which are also important in human medicine (Done, Venkatesan, and Halden, 2015).
There is ample evidence for a direct causal link between antibiotic consumption in animals and resistance in humans (O’Neill, 2015). The presence of antibiotic-resistant strains of bacteria in animal-sourced foods sold in supermarkets and grocery stores has been reported in nearly every published study that investigated it. For example, in the United States, 75% of the bacteria the Food and Drug Administration found on grocery store meat was antibiotic-resistant (Undurraga, 2018). Often, the same genetic strains present in animal-food samples are those isolated in hospital patients (Wang et al., 2017).

Environmental contamination is another route of infection: bacteria are excreted in the urine and stool of animals still in their active form, making their way to water bodies and the soil, and contaminating other agricultural produce through the use of manure as fertiliser (Founou, Founou, and Essack, 2016). Veterinarians, farmers, slaughterhouse workers, and food handlers can also be contaminated by direct contact with food animals and their products, acting as bridges to spread the resistance in the human population.

In recent years, many countries have regulated the use of antibiotics in livestock, gradually banning their use as growth promoters (McKenna, 2017). However, the line between the use of antibiotics for growth promotion and disease prevention is a blurred one. Additionally, the industry has increased the use of ionophore antibiotics that are not currently categorised as medically important, but have the potential to become effective treatments for serious human infections (ASOA, 2019).

It is important to note, however, that animals raised under typical intensive conditions may see both their health and welfare impoverished in the absence of antibiotics. For example, data on broilers raised in conventional operations, but never given antibiotics, showed a higher prevalence and severity of eye lesions, footpad dermatitis, and airsacculitis (inflammation of the air sacs caused by bacteria) (Karavolias et al., 2018). Therefore, bans on the prophylactic use of antibiotics must be accompanied by simultaneous interventions that ensure both the genetics and living conditions conducive to good health and welfare.

**Foodborne infections of animal origin**

The impact of foodborne illnesses on global health is far from negligible. Food contamination episodes cause over 600 million cases of illness every year, resulting in 420,000 deaths worldwide (Devleesschauwer et al., 2018). Animal-sourced products are responsible for the greatest share of these cases (Karesh et al., 2012).

For example, chickens are a natural host for Campylobacter species, the most common bacterial cause of human gastroenteritis in the world (WHO, 2018). Salmonella is also responsible for over 50,000 deaths every year (GBD, 2019) following the consumption of contaminated chicken, eggs, and pork. Other important foodborne pathogens coming from animal reservoirs include toxin-producing strains of *Escherichia coli* and *Listeria monocytogenes*.

Nowadays, a major source of contamination of meat is the process of evisceration at the slaughter plants, through which internal organs, especially those in the abdominal cavity, are removed. Needless to say, meat comes from animals who once had a gut, and it is not easy to ensure that faecal matter does not contaminate the animal carcass. Likewise, the use of manure as fertiliser, the contamination of water bodies with animal waste or contact (direct or indirect) with animal products, may also contaminate other products, such as fruits or vegetables.

Poorer animal welfare further increases food safety risks. Stressed animals tend to release more pathogens, such as *E. coli*, Salmonella, or Campylobacter, in their faeces. In pigs, increased feed withdrawal times were associated with increased Enterobacteriaceae and Salmonella in faeces. Likewise, higher stocking densities and stress-inducing conditions (e.g. forced moulting)
have been shown to result in increased occurrence, persistence, and spread of Salmonella in poultry (EFSA, 2019).

**Water and air pollution**

The contamination of water with livestock waste is nowadays a major public health risk. The farming of land animals alone is now among the leading causes of water pollution globally (FAO, 2017).

In addition to leakage from manure lagoons that are poorly constructed or that overflow during precipitation events, the widespread application of animal waste to agricultural crops is another major route of contamination. Livestock excreta contain high quantities of nutrients (e.g. nitrate and phosphorus) that can impact aquatic and marine ecosystems as well as drinking water supplies. Waste from intensive farming systems also carries heavy metals (e.g. zinc, copper, cadmium, lead, mercury), veterinary pharmaceuticals, hormones, and antibiotics (which can promote increased antimicrobial resistance in naturally occurring pathogens in surrounding ecosystems). The rapid expansion of intensive fish farming further adds to the problem, with fish excreta, feed, veterinary drugs (antibiotics, fungicides), and anti-fouling agents similarly polluting downstream ecosystems.

Importantly, animal waste also carries high concentrations of microorganisms harmful to human health, including pathogens such as Campylobacter, Escherichia coli, Salmonella, Clostridium, and parasitic protozoa. Swine waste, for instance, has been found to carry over 100 pathogens associated with human illness (Burkholder et al., 1997).

As a result of activities such as storing and spreading of manure, as well as the fertilisation of crops destined as animal feed (e.g. corn, soybeans), animal-food production is also a major emitter of fine particulate matter in the air, an important risk factor for heart disease, cancer, and stroke (Domingo and Balasubramanian, 2021). High levels of ammonia – an irritant gas emitted from animal waste that reacts with other gases and forms fine dust particles – are particularly conducive to lung function decline and the impairment of the respiratory health of human populations living near intensive animal operations (Borlée et al., 2017). Airborne transmission of zoonotic pathogens that are carried through the air from farms, manure lagoons, and spray fields, is also a concern. For example, antibiotic-resistant bacteria from livestock waste can be dispersed by the wind (McEachran et al., 2015). Respiratory viruses can also travel long distances through the air.

**Worker health**

The health effects of exposure to animal farming settings are potentiated in farm workers and include a myriad of conditions, such as respiratory disorders, occupational injuries, mental health disorders, and zoonotic infections.

A high prevalence of respiratory disease among farm workers naturally results from the high levels of ammonia, inhalable dust, and endotoxins (an inflammatory substance present in the cell membrane of bacteria) within animal facilities (Dignard and Leibler, 2019). Health effects include impairment of lung function, chronic bronchitis, asthma–like syndrome, among other types of chronic and intermittent respiratory disorders (Von Essen and Auvermann, 2005).

These occupational hazards are also present among slaughterhouse workers. A high level of exposure to bioaerosols, released in the slaughter process, has been associated with a significantly higher incidence of airway disorders in this population (Kasaeinasab et al., 2017). Additionally, an increased prevalence of mental health disorders, such as depression and anxiety, has been identi-
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Faced given the traumatic nature of the work (Slade and Alleyne, 2021). Importantly, exposure to farm animals at any stage of the production chain also translates into a substantially higher risk of infection by zoonotic pathogens. Several studies have reported higher sero-prevalence of pandemic H1N1 influenza, hepatitis E, and highly pathogenic avian influenza H5 and H7 in farm workers (Jones et al., 2013).

Occupational hazards at meat processing plants have also been widely documented, including musculoskeletal disorders and long-term injuries due to the physically intensive and repetitive nature of the work. Processing plants have been also shown to be hotspots of infectious disease transmission, favoured by the low temperatures (to reduce the risk of meat spoilage), high levels of humidity, and high concentration of employees in a closed environment.

Despite the multiple health and safety hazards, reporting of these issues in the animal production chain is rarer than in other work settings – in many countries, workers are migrants, do not speak the local language, or are not legally authorised to work, so fear of reporting system failures is widespread. Poor qualifications and working conditions are also inherently associated with poor stockmanship, which substantially increases the risk of poor animal health and welfare.

Biosecurity threats from wildlife hunting, trafficking, and trade

Extensive capture of wild animals for human use (mainly as a food source) is practised in all countries, for instance in the form of fishing. Although aquatic animals can be reservoirs of pathogens that can infect humans, here we concentrate on those practices that involve species that are evolutionarily closer to us, hence from which pathogen spillover to humans is more likely (Wolfe, Dunavan and Diamond, 2007; Morse et al., 2012).

Bushmeat hunting and consumption

Bushmeat hunting and consumption is sometimes perceived as an extinguishing practice in the fringes of modern civilisation, hence with little significance for global health. This impression is incorrect for two reasons: its actual magnitude, and the exceptionally high biosecurity threat inherent to this activity.

Consider, for example, that in the Congo Basin alone, an estimated 4.9 million tonnes of wild mammals are hunted annually for consumption (Fa, Peres, and Meeuwig, 2002). Hunting is very important for some local populations: cases of childhood anaemia among poor children in Madagascar could triple if bushmeat consumption were eliminated (Kurpiers et al., 2015). Paradoxically, economic development does not necessarily lead to the extinction of this practice, as bushmeat is increasingly consumed as a “gourmet” delicacy by urban populations (Kurpiers et al., 2015).

The disproportionate biosecurity threat posed by bushmeat stems from the privileged pathway that it creates between zoonotic pathogens from wildlife (mainly from ecosystems where pathogen diversity is high (Jones et al., 2008)) and the human population. The risk does not emerge so much from the consumption of the meat (since it is generally cooked), but from the process of hunting, cleaning, and preparing it. During these procedures, the chances of contamination by the body fluids and tissues of the infected animal through small wounds or mucous membranes (e.g. eyes, nose) are not negligible (Kurpiers et al., 2015; Greatorex et al., 2016). In fact, interviewing bushmeat hunters and traders in Sierra Leone, a study found that 38% are cut during prey processing (Subramanian, 2012).

In a globalised world, an infection by a novel pathogen may not be contained to a village in the middle of the jungle. HIV, which most likely emerged as a result of hunting and field-
implications of SARS transmission from bat to human in Yunnan province, China. The emergence of SARS-CoV-2 at the time of writing has coalesced around two hypotheses: a laboratory escape or a zoonotic emergence. In the latter case, as with SARS, a live animal market is believed to be the birthplace of the pandemic (Holmes et al., 2021).

Expansion of livestock production near wildlife habitats

Alternated patches of preserved areas and land used for different purposes (including pastures) are a component of many traditional landscapes, increasing biological diversity and socioecological resilience. Nevertheless, they also increase the risk of pathogen spillover directly to humans or intermediated by livestock (Jones et al., 2013). This has been the case, for example, of pig
farms in Malaysia, which acted as an intermediate step for the transmission of the Nipah virus from bats to humans. Once pigs are infected, they can transmit the virus to other pigs (particularly in places with a high density of pig farms) and to humans, like any respiratory disease. Nipah killed about 40% of the people who got infected. When livestock is introduced in wild habitats, a “bridge” between wildlife and humans is made (Jones et al., 2013).

**Diseases of overconsumption**

Besides the global health risks of animal-food production discussed previously, evidence is robust that overconsumption of animal-sourced products is associated with multiple adverse health outcomes, being also a major risk factor for non-communicable diseases.

Meat consumption has increased dramatically over the last five decades, from a global average supply of 26 kg per person in 1960 to over 42 kg (or 63 kg when fish is included) in 2018. In many high- and middle-income countries, the average citizen is now supplied with over 100 kg of animal-sourced products every year. While the intake of meats, eggs, and milk is often much higher than recommended levels, the intake of fruits, vegetables, whole grains, and legumes is much lower (Afshin et al., 2019; Rust et al., 2020), being among the main risk factors for mortality attributable to diet at a global level (Afshin et al., 2019).

Accordingly, higher levels of consumption of meat and dairy products have been associated with a higher incidence of multiple negative health outcomes (Oussalah et al., 2020). For example, well-planned diets with restriction of animal products have been shown to be more effective in the metabolic control of diabetic individuals than well-planned diets containing meat and dairy (Kahleova et al., 2011; Kim, Keogh, and Clifton, 2015). Excluding meat, eggs, and dairy from the diet has been also shown to reduce LDL cholesterol levels by over 35% (Ferdowsian and Barnard, 2009) (equivalent to the effect of using statins in therapeutic doses), as well as reduce the diameter of established coronary stenosis (Ornish et al., 1998) – the plaque buildup in the wall of the arteries that supply blood to the heart and can lead to heart attack or stroke.

Overconsumption of meat and dairy has been also strongly linked with the incidence of cancer. For example, a major umbrella review from 2021 (Huang et al., 2021) on the effect of red meat consumption against cancer outcomes showed an increased risk of overall cancer mortality, non-Hodgkin’s lymphoma, bladder, breast, colorectal, endometrial, oesophageal, gastric, lung, and nasopharyngeal cancer. Overall, each 100 g increment in red meat consumption per day was associated with an 11%–51% increased risk of cancer. Consumption of processed meats (those subjected to salting, curing, fermentation, smoking, and other processes to enhance flavour or improve preparation) was also associated with an increased risk of overall mortality, non-Hodgkin’s lymphoma, bladder, breast, colorectal, esophageal, gastric, nasopharyngeal, oral cavity, oropharyngeal, and prostate cancer. Specifically, for each increase of 50 g of processed meat per day there was an 8%–72% increase in risk. Indeed, in 2015 the International Agency for Research on Cancer (World Health Organization) had already classified processed meats as having sufficient evidence of carcinogenicity in humans and unprocessed red meat as probably carcinogenic to humans (IARC, 2015). Dairy consumption has also been associated with an increased risk of prostate cancer, with a 9% increased risk for every 50 g of cheese consumed per day and a 3% increase for every 200 g of milk (Aune et al., 2015).

Overconsumption of red meat, eggs, and dairy products has also been shown to increase substantially the intake of carnitine, phosphatidylcholine, and choline, which are ultimately converted into trimethylamine N-oxide (TMAO), a compound associated with an increased risk of virtually all non-communicable chronic diseases, including neurological disorders, intestinal
inflammation, chronic kidney disease, Alzheimer’s disease, type 2 diabetes, heart failure, stroke, and all-cause mortality (Qi et al., 2018).

The adverse health outcomes associated with the overconsumption of animal foods has also been shown to be a risk factor for communicable diseases. A large study involving healthcare workers from six countries is illustrative, showing that those following dietary patterns low in animal products had significantly lower odds of moderate-to-severe COVID-19-like illness (Kim et al., 2021).

Conclusions and recommendations

We tend to approach each public health problem independently, rather than recognising their common drivers. Animals have served humanity for millennia, but it is necessary to recognise that the way animals are raised and traded nowadays represents a major threat to human health and well-being.

As discussed in this chapter, many of the conditions that translate into poor animal health and welfare are also a threat to public health. Moreover, the extensive human and financial losses associated with infectious disease outbreaks, drug resistance, foodborne illnesses, and the diseases emerging from overconsumption of animal products, make this an enormous economic and social problem too. Enforcing higher animal welfare standards in industry practices, genetic selection, and stockmanship, as well as transparency and independent auditing, will be critical to reduce the risks of emergence and spread of new pathogens, including those with pandemic potential.

Consumption of animal-sourced products is still expected to rise in the next coming decades, further increasing these health risks and their associated costs. While large investments are poured into disease treatment, preparedness efforts, and drug development, we must have this same sense of urgency to accelerate the development of modern methods of food production that can mitigate these risks, and make society more resilient.

References


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