

# FOOD & PANDEMICS REPORT

## PART 1: MAKING THE CONNECTION

Animal-based food systems and pandemics



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Part I: Making the connection –  
Animal-based food systems and pandemics

Part II: Preventing pandemics –  
Food-systems change as a multiproblem solution

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## IMPRINT

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## PROVEG INTERNATIONAL

ProVeg is an international food awareness organisation working to transform the global food system by replacing conventional animal-based products with plant-based and cultured alternatives.

ProVeg works with international decision-making bodies, governments, food producers, investors, the media, and the general public to help the world transition to a society and economy that are less dependent on animal agriculture and more sustainable for humans, animals, and the planet.

ProVeg has permanent-observer status with the UNFCCC, is accredited for UNEA, and has received the United Nations' Momentum for Change Award.

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The ProVeg *Food & Pandemics Report* clearly demonstrates the connection between industrial animal production and the increased risk of pandemics. Never before have so many opportunities existed for pathogens to jump from wild and domestic animals to people.”

### DR MUSONDA MUMBA

*Chief of the Terrestrial Ecosystems Unit of the United Nations Environmental Programme (UNEP)*



Sadly, as explained in stark terms in the ProVeg *Food & Pandemics Report*, this is unlikely to be the last pandemic this generation has to face. Right now, the perfect conditions exist for another virus to spill over from animals to humans in multiple places all over the world. These conditions are created by our animal-based food system.

A future pandemic could be even worse as it may be more infectious, or more deadly. We must do everything possible to prevent this happening. And we can act. We have the power to drastically reduce the chance of future pandemics, and at the same time reduce illness in our population, reduce air pollution and solve world hunger.”

### DR LAURA JANE SMITH

*Respiratory and Internal Medicine Consultant at King's College Hospital*



Factory-farm practices necessitate the overuse of antibiotics, which is contributing to the rise of antibiotic-resistant infections in humans. If allowed to continue, we risk entering a post-antibiotic era, an outcome too terrible to contemplate.

The new *Food & Pandemics Report* by ProVeg highlights the intrinsic links between large-scale animal agriculture and pandemics. We can and must make radical changes to our food system while we still have the chance. A shift towards more plant-based diets will not only reduce the risk of future pandemics, but will radically transform human health.”

### PROFESSOR SHIREEN KASSAM

*Consultant Haematologist and Honorary Senior Lecturer at King's College Hospital*

## FOREWORD



I was 24 years old, a graduate student at Oxford University, when I first heard of factory farming. In 1970, few people were talking about **what was happening to farmed animals**. I read Ruth Harrison’s trailblazing book, *Animal Machines*. That shattered my fond illusion that the animals I was eating could at least enjoy their lives out in the fields. Instead, I learned, they were crowded into sheds, with barely enough room to move. Harrison showed that in modern industrial agriculture, “cruelty is acknowledged only when profitability ceases” – and profitability is compatible with very severe cruelty. I couldn’t support treating animals in this way when I didn’t need to eat them, so I became a vegetarian.

In the 1980s, I learned that there is another powerful reason for not eating meat. **Meat is a major contributor to global warming**. If the world doesn’t start consuming less meat and dairy soon, then, even if we stop burning coal and reduce our use of oil and gas, we will be unable to avoid warming the planet to an extent that has potentially catastrophic consequences for billions of people.

In the early 2000s, when we discovered that people working with chickens were spreading a lethal strain of avian influenza, it became clear that **there is a third urgent reason for eliminating meat from our diet: our own health and perhaps the survival of our species**. That reason was given added weight by the 2009 swine flu pandemic, in which somewhere between 150,000 and 575,000 people died. The pandemic appears to have been caused by a new and more deadly strain of the virus that was first identified in a factory farm for pigs in North Carolina. Still, because most of those who died were not living in affluent countries, the rich world did not take much notice of the virus or its origins.

COVID-19 has dramatically changed that. Now we all know that dangerous viruses and antibiotic-resistant bacteria come to us from the animals we eat. So far we have been lucky – yes, even with more than 10 million cases and close to half a million deaths (at the time of writing) from the coronavirus that causes COVID-19, we are lucky because most of the people it infects survive. There can be **no guarantee that the next virus, bred on a factory farm or unleashed from the wild through human interference, will not be just as infectious, but far more deadly**.

Eating animals from factory farms has always been unethical, because of what it does to the animals. Since we learned about climate change, it has been doubly unethical, because of what it is doing to our planet as well as what it does to the animals. Now we know that it is triply unethical, because it also poses a serious risk to our survival.

But don’t take it from me. Read the report.

### PETER SINGER

*Philosopher, Professor of Bioethics at the University Center for Human Values, Princeton*  
June 2020



# EXECUTIVE SUMMARY

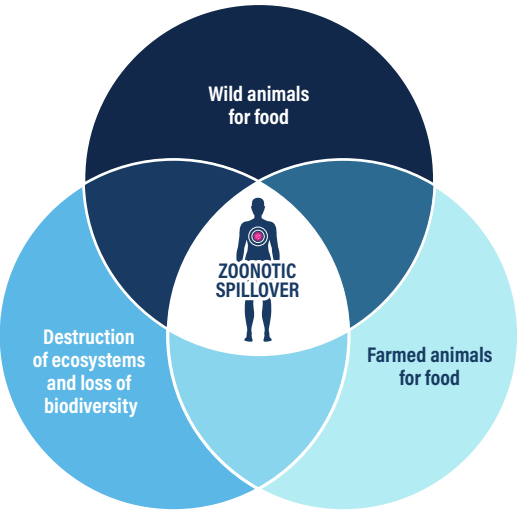
## INTRODUCTION: FOOD AND PANDEMICS – MAKING THE CONNECTION

COVID-19 is a zoonotic disease, transmitted from animals to humans, that has turned into a global pandemic. It was first recognised in December 2019 and has since led to a large-scale shutdown of all aspects of life around the world. Its impacts are unparalleled in modern times, including a death toll in the hundreds of thousands as well as serious long-term socio-economic effects. It is unclear how long it will take for societies and economies to recover – or how it will change the world in the long run.

While most of the current focus is on the crucial aspects of emergency response and containment of the COVID-19 crisis, the *ProVeg Food & Pandemics Report* explores **risk mitigation and the prevention of future outbreaks by addressing the root causes of zoonotic emergence and spread.**

Part I of this report looks at the **crucial connection between the current COVID-19 crisis and our global animal-based food system.** It highlights how our food choices help to create a recipe for zoonotic pandemics that consists of three mutually reinforcing ingredients:

- (1) The destruction of ecosystems and loss of bio-diversity (driven largely by animal agriculture)
- (2) The use of wild animals for food
- (3) The use of farmed animals for food (in intensified animal agriculture)



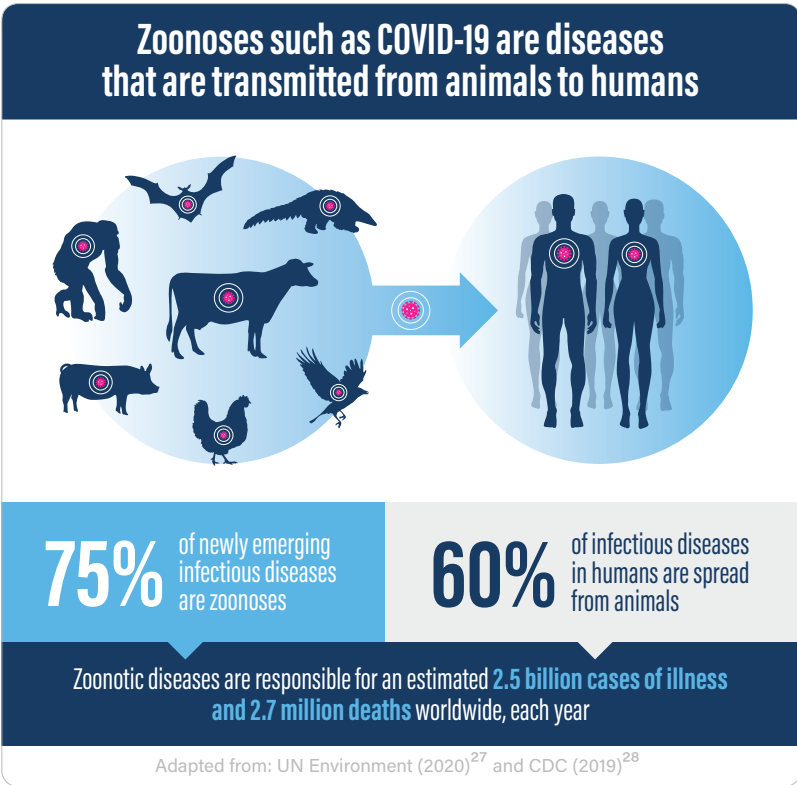
Crucially, Part I demonstrates how **the risk of future zoonotic outbreaks and the severity of their impacts increase with a surge in demand for animal-based products** in today's globalised world. The report strongly urges transformation of the global food system in order to prevent future pandemics.

## 1. ZOO NOTIC PANDEMICS: VIRUSES, ANIMALS, AND HUMANS IN A GLOBALISED WORLD

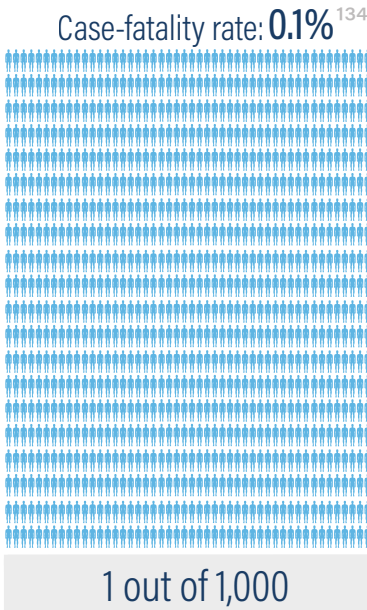
Zoonoses are diseases of animal origin that have spread to humans. Mounting evidence suggests that the increase in zoonotic events is directly linked to humans' increasing interactions with animals, particularly in terms of food sourcing. Our appetite for meat, eggs, and dairy has brought us into **ever-closer contact with both domesticated and wild animals by keeping ever more of them in increasingly confined spaces and invading ever more of their habitats.** Together with the human modification of the environment, this increases the likelihood of viruses jumping the species barriers, resulting in new zoonotic diseases.

About 75% of all emerging infectious diseases in humans are zoonoses. Some of the most well-known zoonotic diseases include SARS, MERS, Ebola, rabies, and certain forms of influenza. Whether originating in wild animals, as is assumed with COVID-19, or in farmed animals, as is the case with avian and swine flu, they all pose serious threats to individual and global health – and already **cause more fatalities than diabetes and traffic accidents combined.**

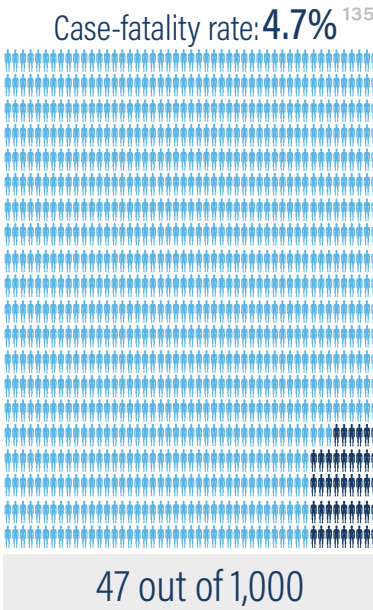
COVID-19's fatality rate of 4.7% makes it about 47 times more deadly than regular flu – which is pushing healthcare systems worldwide to the limit. However, it is nowhere near as deadly as some other zoonotic diseases – such as the H5N1 avian flu, with a fatality rate of up to 60%. Not only might future outbreaks be **more dangerous**, experts agree that they are also expected to be **more frequent**. The causes behind this alarming forecast are human-made – and the most central ones are all linked to our global food system.



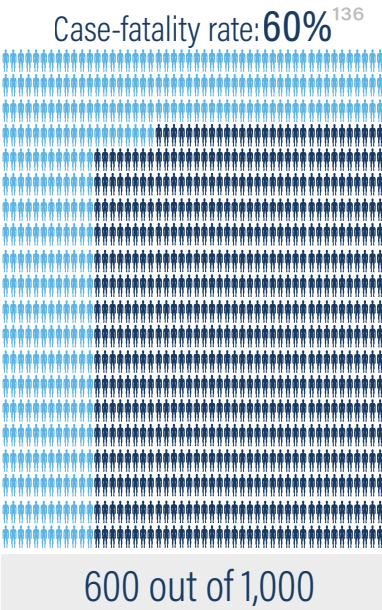
### SEASONAL INFLUENZA



### COVID-19



### H5N1





## 2. THREE FOOD-RELATED ACTIVITIES THAT INCREASE THE RISK OF ZONOTIC PANDEMICS

There are three human activities related to the eating and farming of animals that strongly increase both the risk of pandemics and the severity of their impacts. **Intensified animal agriculture plays a key role**, since it functions as a large-scale zoonotic incubator, as well as a contributor to environmental degradation, loss of biodiversity, and climate change, and is the main driver of antimicrobial resistance.

### Destruction of ecosystems and loss of biodiversity

We are living in the midst of the sixth mass extinction and are facing a rapid global loss of biodiversity. Our actions have heavily impacted more than 75% of the Earth's land surface, significantly altering the prevalence and composition of its flora and fauna.

**Animal agriculture is one of the key drivers of land-use change worldwide**, as forests are cleared to provide space for feed crops and pastures in order to satisfy the increasing demand for meat. This leads to massive encroachments into natural habitats and biodiversity loss.

Additionally, climate change also contributes to the increased transmission of pathogens from animals to humans. **One of the main drivers of climate change is animal agriculture**, accounting for about 16% of global greenhouse gas emissions, while also being a major contributor to environmental degradation.

**Fuelled by our food choices, our environmentally destructive activities are bringing us closer to wild animals and their often unknown pathogens.** This creates favourable conditions for viruses to spread, and ultimately enables the development of global zoonotic pandemics.

### Wild animals as food



Picture by Jiri Prochazka, Shutterstock

Every year, millions of wild animals are taken from their natural habitats – often illegally. In addition, various wild animal species are bred in unnatural, intensive farm settings.

The processing of wild animals provides a gateway for novel pathogens. When handling, slaughtering, or eating wild animals, viruses present in the animals can jump the species barrier. Pathogens that have been **transmitted to humans via using wild animals as food** include the Ebola and Marburg viruses, HIV,

the West Nile virus, and the coronaviruses which caused the global pandemics of SARS and MERS, as well as various strains of influenza. **COVID-19 is the most recent result of zoonotic transmission from wild animals**, probably involving bats and pangolins.



### Farmed animals as food

Many pathogens of concern to human health are **transferred to humans from domesticated animals farmed for human consumption**. Diseases such as diphtheria, measles, mumps, the rotavirus, smallpox, and influenza A all have their origin in domesticated animals.

The intensification of animal agriculture and aquaculture plays a key role and dramatically escalates the risk of zoonotic pandemics. Cramming large numbers of genetically similar individuals into unsanitary, high-density settings that induce poor health and high stress levels strongly increases the chances of pathogenic

spillovers between wild animals and farmed animals – and, ultimately, humans. **Industrial animal agriculture is much like a large-scale petri dish**, providing the perfect conditions for viruses to emerge, spread, and cross species barriers. Each new factory farm increases the risk of the next virus spillover – along with the next zoonotic pandemic.

Owing to increases in population growth and prosperity levels, the global production of meat, eggs, dairy, and seafood from intensive-production facilities is forecast to **increase by 15% by 2028**.

While COVID-19 did not originate in factory farms or slaughterhouses, it has nonetheless found its way into them. With its multiple impacts, the current pandemic has demonstrated **the profound vulnerability and fragility of the animal-agriculture industry**, as well as a host of serious ethical and economic implications for humans, animals, and the food system.



Picture by Sergey Bogdanov, Shutterstock



### 3. FOOD-RELATED DISEASES AND OTHER FACTORS INCREASING THE IMPACT OF PANDEMICS

In addition to the risks of newly emerging pathogens, there are other factors that can further exacerbate the overall impact of zoonotic pandemics, as they all pose additional risks for individual health and healthcare systems. Again, they are all related to the eating and farming of animals.

#### Antimicrobial resistance (AMR)

Globally, antimicrobial-resistant infections currently claim at least 700,000 lives each year. The United Nations has declared antimicrobial resistance (AMR) a global health risk, stressing that this number could reach an annual toll of 10 million by 2050.

**It is animal agriculture which is mainly responsible for the development of AMR.** Globally, more than 70% of antibiotics (including those of last resort) are used on animals in intensive farming – in order to prevent losses owing to problematic breeding and husbandry conditions, and to accelerate growth and profits, rather than for the treatment of humans.

With multi-resistant strains of bacteria emerging at alarming rates, the world is on the cusp of a post-antibiotic era. Without effective treatment for secondary bacterial infections, **future pandemics are poised to get worse**, leaving health professionals helpless against a threat that we thought we had overcome.

#### Other communicable food-borne diseases

As well as their involvement in the spread of viruses and the development of AMR, animal-based products also pose other direct health risks that can **worsen the impact of a zoonotic pandemic**. There is a host of communicable diseases that are associated with the production and consumption of animal-based products, such as *Campylobacter*, *Salmonella*, and *E. coli* – with many of them having already developed strains that are resistant to antibiotics.

#### Non-communicable diet-related diseases

While all eyes are currently on communicable diseases, it is important to note that, in many countries, the major burden on the healthcare sector and people's quality of life usually lies elsewhere. In high-income countries, nine out of the 10 leading causes of death are non-communicable diseases. Statistically, chronic diseases constitute by far the greatest pandemic. And neither social distancing nor the recommended hygiene procedures can protect us from them.

There is mounting evidence that the development of diet-related chronic diseases such as obesity, type-2 diabetes, and cardiovascular diseases, as well as some forms of cancer, is made more likely by the **excessive consumption of animal-based products**. All of these conditions constitute serious threats to individual and public health. Additionally, they put people in a **high-risk group during a pandemic such as COVID-19**, putting further strain on individual health and healthcare systems.

## CONCLUSION



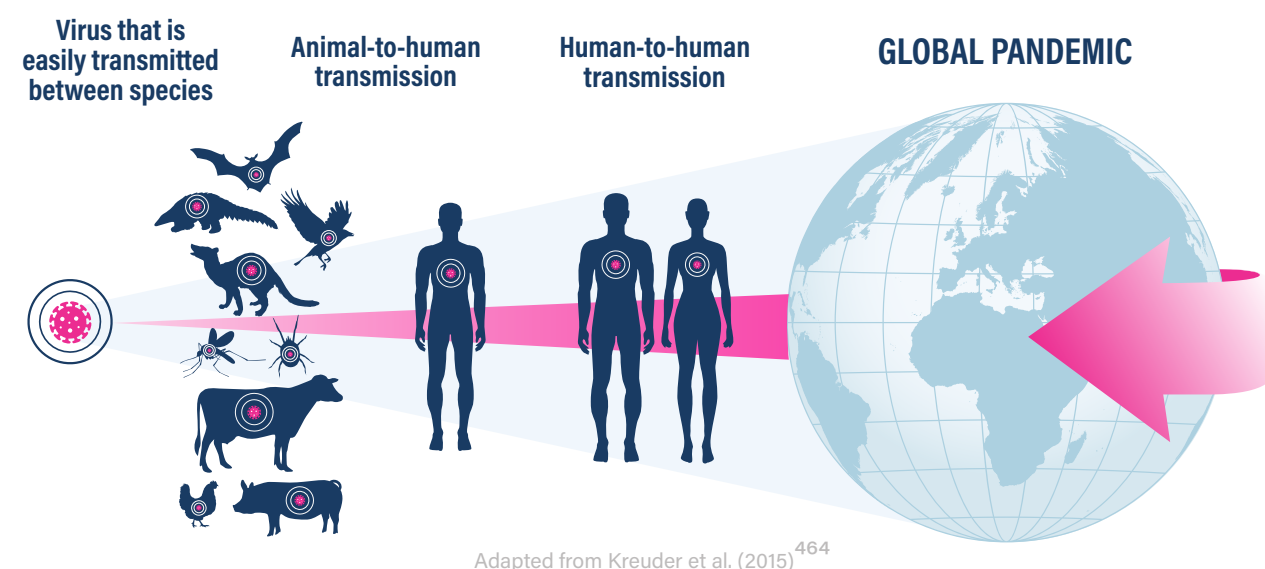
Picture by vodograj, Shutterstock

The recipe for disaster is surprisingly simple: one animal, one mutation, one human, and one point of contact is all that it takes for a global pandemic to become a reality and bring the world to a standstill.

This makes using animals as food – and intensified animal agriculture in particular – the most risky human behaviour in relation to pandemics, and **one of the most risky behaviours in relation to the long-term survival of human society**.

**Making the connection between our outdated global food system and the current and potential future pandemic crises** is a crucial first step towards acknowledging the root cause of pandemics and identifying solutions to prevent future outbreaks. **Transforming the global food system by replacing animal-based products with plant-based and cultured alternatives provides a multiproblem solution** – preventing not only future pandemics but also helping to mitigate major parallel crises such as climate change, world hunger, and antibiotics resistance.

**Part II of the Food and Pandemics Report**, which will be published in the third quarter of 2020, will detail the solution landscape, showcasing the encouraging developments that are already taking place, as well as emerging opportunities and concrete calls-to-action – in order to inspire much-needed action among decision makers in the field of food-systems change.



Adapted from Kreuder et al. (2015)<sup>464</sup>

## INTRODUCTION

**At the time of writing this report, the world as we know it has come to a standstill** due to a virus that has been transmitted to humans through animals. SARS-CoV-2, widely known as the coronavirus, which causes COVID-19 (the coronavirus disease), was first recognised in Wuhan, China, in December 2019. The global impacts are severe and pervasive: a still-increasing death toll in the hundreds of thousands, with large numbers of hospitalised patients pushing national healthcare systems to the limit; an immediate and large-scale shutdown of public life, services, production, trade, and travel; and serious long-term socio-economic effects, including massive job losses, store closures, and widespread recessions. All of this will have profound impacts for many years to come.



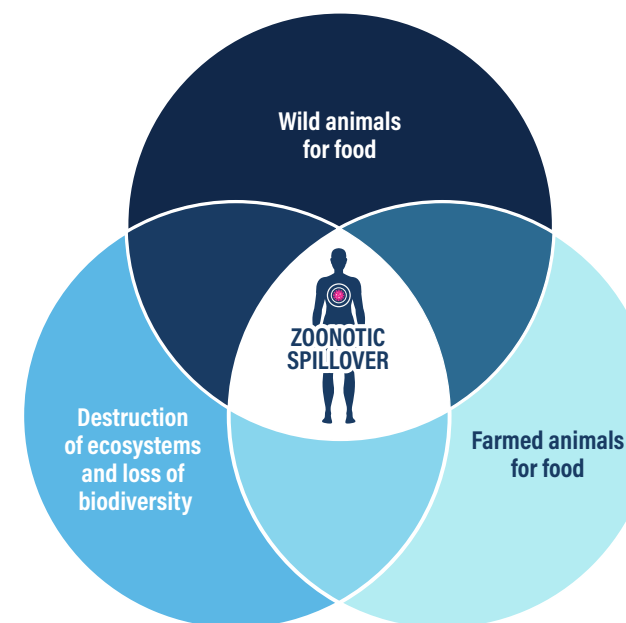
Picture by Gengwit Wattakawigran, Shutterstock

National lockdowns, social distancing, wearing facemasks, and travel restrictions have become the new normal, constituting profound interference with individual freedoms, social stability, and economic safety. **The impact of the COVID-19 pandemic is unparalleled in modern times** – constituting the biggest global disruption since World War II – with the economic damage very likely to surpass the recession of 2008.<sup>1</sup> There is currently no reliable prediction as to how long it will take to contain the pandemic or how long it will take for societies and economies to recover from its impacts. There is little doubt that it will change the world as we know it.

### Food and pandemics – making the connection

Most of the current focus on COVID-19 explores the vital aspects of emergency response and containment. This *Food & Pandemics Report* now also directs attention towards **risk mitigation and the prevention of future outbreaks by addressing the root causes of zoonotic emergence and spread.**

Part I of this report makes the crucial connection between the current COVID-19 crisis and the global animal-based food system. It highlights how our food choices help to create **a recipe for zoonotic pandemics – consisting of three mutually reinforcing ingredients:**



**(1) The destruction of ecosystems and the loss of biodiversity** (driven largely by animal agriculture) – resulting in increased contact and virus spillover to humans and farmed animals.

**(2) The use of wild animals for food** – resulting in increased contact and virus spillover to humans and farmed animals.

**(3) The use of farmed animals for food in high-density, intensified animal agriculture** – resulting in ideal conditions for viral mutation, spread, and spillover to humans and wild animals.

The trajectory of this interplay is alarming, given the world's **fast-growing appetite for animal protein.**<sup>2</sup> With meat and milk production expected to increase by approximately 15% by 2028<sup>3</sup> due to growing global human population and prosperity levels, the risk of future pandemics becoming more intense and frequent is also expected to further increase – as are the additional food-related risks exacerbating their impacts. This report demonstrates how **we are literally eating our way to the next pandemic** – and how food-systems change provides a high-potential risk-mitigation strategy.

**'Part I: Making the connection – animal-based food systems and pandemics'** introduces the basic biological and epidemiological concepts around zoonoses and pandemics, details the contribution of three food-related human behaviours that increase pandemic risks, and describes a host of food-system and consumption-related diseases that increase the negative impacts of pandemics. In doing so, the report reveals the **key role of animal agriculture** within this complex interplay, along with its numerous destructive aspects: from providing ideal breeding grounds for the emergence and spread of viruses, to driving antimicrobial resistance loss of biodiversity, and climate change. The report also reveals the **profound vulnerability and fragility of the animal industry** as it experiences disruptive shocks as a result of COVID-19.



## Scientific facts and evidence

In light of the current crisis, public trust in science is on the rise. In Germany, for instance, 90% of the population believe that the expertise of researchers is crucial to slowing down the pandemic, while 81% of people want **political decisions to be based on scientific facts and findings**.<sup>4</sup> The authors of this report unreservedly share the view that the facts and findings of science and research should inform the analysis of the current crisis, as well as the exploration of the solution landscape. To this end, scientific insights need to be made accessible and intelligible to decision makers, thought leaders, and the general public – which is why we have made sure that this report is informed by good science based on strong data points, and is, at the same time, accessible and easy to understand.

At the time of writing, some details about the virus are still unclear and are being critically scrutinised and debated – such as the exact animal species involved in the animal-to-human transmission, the virus's precise case-fatality rate, and its various health impacts, as well as the most effective emergency responses and containment strategies. However, at this stage, there are **three things that are clearly evident**:

- (1) There is a fundamental connection between pandemics and our animal-based food system.
- (2) The health, social, and economic consequences of a pandemic can be extensive, comprehensive, and long-term.
- (3) Action is now required to minimise the alarming increase in the risk of future occurrences – with food-systems change presenting a high-potential risk-mitigation strategy.

## Preventing pandemics – food-system transformation as a multiproblem solution

Focusing on solutions is all-important in times of crisis. **Part II of the *Food and Pandemics Report***, which will be published in the third quarter of 2020, will explore the solution landscape by addressing the root cause of the problem. **Replacing animal-based products with plant-based and cultured alternatives can help to transform our global food system into a multiproblem solution.** It provides not only a risk-mitigation strategy for the sharply increasing risk of future pandemics, but also a partial solution for some of the challenges that have been with us for far longer: climate change, environmental destruction, world hunger, lifestyle diseases, antimicrobial resistance, and animal suffering.

Part II will showcase the inspiring and **encouraging developments** that are already taking place across all sectors of society, prompting a paradigm shift in consumers' eating habits and thus in market demand and supply. In order to accelerate this shift, the report will also highlight **emerging opportunities** and spell out **specific calls-to-action** across all relevant sectors.

## Make the connection – take action, prevent pandemics

What is needed now is to make the connection – and take action. The current pandemic has clearly shown that taking fast and decisive action in the face of a global crisis is indeed possible. Now is the time to shift towards a better food system that will help **prevent future pandemics and make the world a more resilient and sustainable place.**

## PART 1: MAKING THE CONNECTION – ANIMAL-BASED FOOD SYSTEMS AND PANDEMICS



### 1. ZOO NOTIC PANDEMICS – VIRUSES, ANIMALS, AND HUMANS IN A GLOBALISED WORLD

What are zoonoses? And how do they lead to global pandemics? This section provides a brief backstory of zoonotic diseases, introduces the biological and epidemiological basics, and sketches the escalating history of viruses jumping species barriers and causing havoc on human health and life – culminating in the COVID-19 pandemic of 2020.

#### 1.1 EATING OUR WAY TO ZOO NOSES – A SHORT BACKSTORY

Zoonoses are diseases of animal origin that have spread to humans. There is mounting evidence which suggests that the increase of zoonotic events is directly linked to humans' increasing interactions with animals, many of which are related to our food sourcing.

#### The Neolithic Revolution – domestication and zoonoses

The Neolithic Revolution and the dawn of agriculture, which began roughly 10,000 years ago, marked an important step in the development of modern humans and laid the foundations for our societies as they are today. With all its benefits, there is also evidence that in pre-agricultural societies, humans didn't get the flu, measles, or smallpox. **Something changed – and that something was almost certainly the domestication of animals for farming.** Previously, there had only been occasional contacts with animals, for example during hunting. Then, we brought them close to our homes – along with the diseases they carry. This spurred an increasing exchange of pathogens between animals and humans.<sup>5</sup> While now endemic to humans, some of the most common infectious diseases, including diphtheria, measles, mumps, the rotavirus,

smallpox, and influenza A, are believed to have their origin in or were transmitted by domestic animals.<sup>6 7</sup> In shifting towards the domestication of animals for food, humans created the perfect hotbed for the development and transmission of zoonotic diseases.

Today, it is perfectly normal for us to get vaccinations against these diseases – early on in our childhood and sometimes repeatedly throughout our lives. We simply accept that those diseases exist. **When we cough or sneeze, we readily blame viruses and bacteria – but we seldom think about their origins.** Yet, it is a fact that humans share the highest number of viruses with domesticated animals (such as livestock) rather than with any other animals.<sup>8</sup> This is not a coincidence, but a result of the ongoing intensification of animal agriculture.

### Post-World War II – intensification and escalation of mass production

After World War II, **rapid population growth and rising income levels led to a growing appetite for meat and other animal-based products**, which, in turn, required food systems to become more productive. New scientific advancements such as genetic breeding programmes, veterinary medicine, and chemical fertilisers enabled the intensification of both crops and livestock farming. Dairy cattle moved from pasture-based to confinement feeding systems, and antibiotics found their way into veterinary practices – initially to control disease, and later for their growth-enhancing properties.<sup>9 10</sup> The starvation and deprivation of wartime, along with accelerating population growth and rising prosperity, led to a growing demand for meat – and a substantial intensification and expansion of animal agriculture that has been heavily incentivised and subsidised.



Picture by Gengwit Wattakawitgran, Shutterstock

### Eating our way to zoonoses

Today, livestock accounts for 60% of all mammal biomass on the planet (with wild mammals accounting for only 4% and most of the rest attributed to humans), while poultry accounts for 70% of bird biomass,<sup>11</sup> marking a major human-made transformation in the species-composition of our planet. Our appetite for meat has brought us in ever-closer contact with both domesticated and wild animals – **by keeping ever more of them in ever more confined spaces, and invading ever more of their habitats.** Together with the anthropogenic modification of the environment, this has helped the number of emerging zoonotic diseases to increase.<sup>12 13 14</sup> Or, to put it differently, many of today's contagious diseases are a problem of our own making. We have literally eaten our way to zoonoses.

## 1.2 ZOONOSSES – EMERGENCE AND PREVALENCE

Bacteria and viruses are microorganisms that have been around on this planet far longer than human beings. While most of them pose no threat, and some are even beneficial to us, others are mildly parasitic. Some, however, are extremely harmful, causing serious infectious diseases that spread among individuals and can ultimately lead to pandemics – with all their consequences. Microorganisms that cause diseases are called pathogens.

### Zoonotic virus evolution – accidentally jumping the species barrier

It is not uncommon for viruses to spread from animals to humans, as it is in their nature to find new hosts. Once a virus infects an animal's cells, it reprogrammes those cells in order to produce copies of the virus. These copies then leave the reprogrammed cell and infect other cells. As a result, the animal becomes a host to the virus, and can infect other animals. Animal species can become reservoir hosts for pathogens, maintaining them permanently, without the host necessarily showing symptoms but still able to spread it to other individuals, populations, or species that then might show symptoms. Other pathogens are actively spread via vectors such as ticks or mosquitos which bite their hosts, thus spreading vector-borne diseases such as malaria.

Viruses carry structures on their surface which function in a similar way to keys. Only viruses with a matching 'key' can enter a host cell. This usually rules out transmission to other species, since the 'key' does not fit. However, during the copying process, mistakes can occur. These mutations cause changes in the genetic material of the virus, resulting in different 'keys' being created, some of which may also happen to fit the cells of other species. Infectious diseases that usually only affect certain non-human animals can thus be transferred to humans and vice versa. **When this happens, and a virus jumps the species barrier from animals to humans, the resulting disease is called a zoonosis,**<sup>17</sup> while the transmission from humans to animals is referred to as reverse zoonosis. The process of a pathogen jumping the species barrier is called zoonotic spillover. Zoonoses can be caused by a multitude of infectious agents, including viruses, bacteria, prions, and parasites.

### VIRUSES

Viruses are tiny infectious agents and the most abundant entities on earth, populating all habitats and organisms.<sup>15 16</sup> Lacking cells and their own metabolism, they are not living organisms in the classic sense but consist simply of a protein shell with genetic information (in the case of naked viruses) that is sometimes coated with a lipid membrane (in the case of enveloped viruses). They can only reproduce in living hosts such as humans, animals, plants, and microorganisms. Their genes enable them to mutate and evolve – often rapidly – into new forms, with hosts having little protection against them. Because the influenza virus, for instance, mutates a great deal, new vaccines are needed every year. **Some mutations can result in viruses jumping the species barrier, causing zoonoses and – in the worst case – pandemics.**



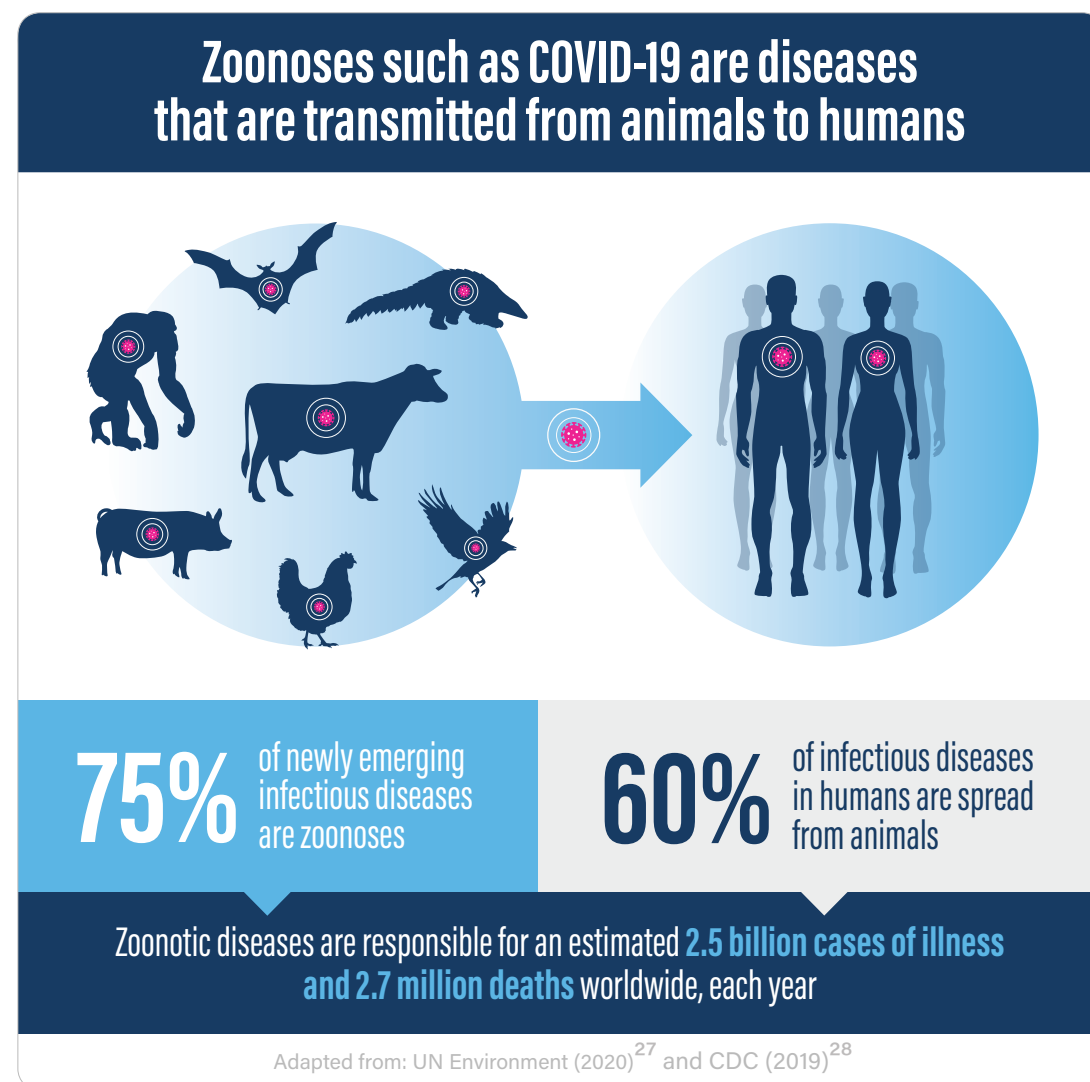


## Three out of four infectious diseases in humans are of animal origin

Despite the ubiquity of viruses on the planet, zoonotic spillovers seem to be quite rare. It is thought that there are between 260,000 and more than 1.5 million viruses that have their origin in mammals and birds.<sup>18 19</sup> Of these, only 219 viruses have thus far been shown to infect humans.<sup>20</sup>

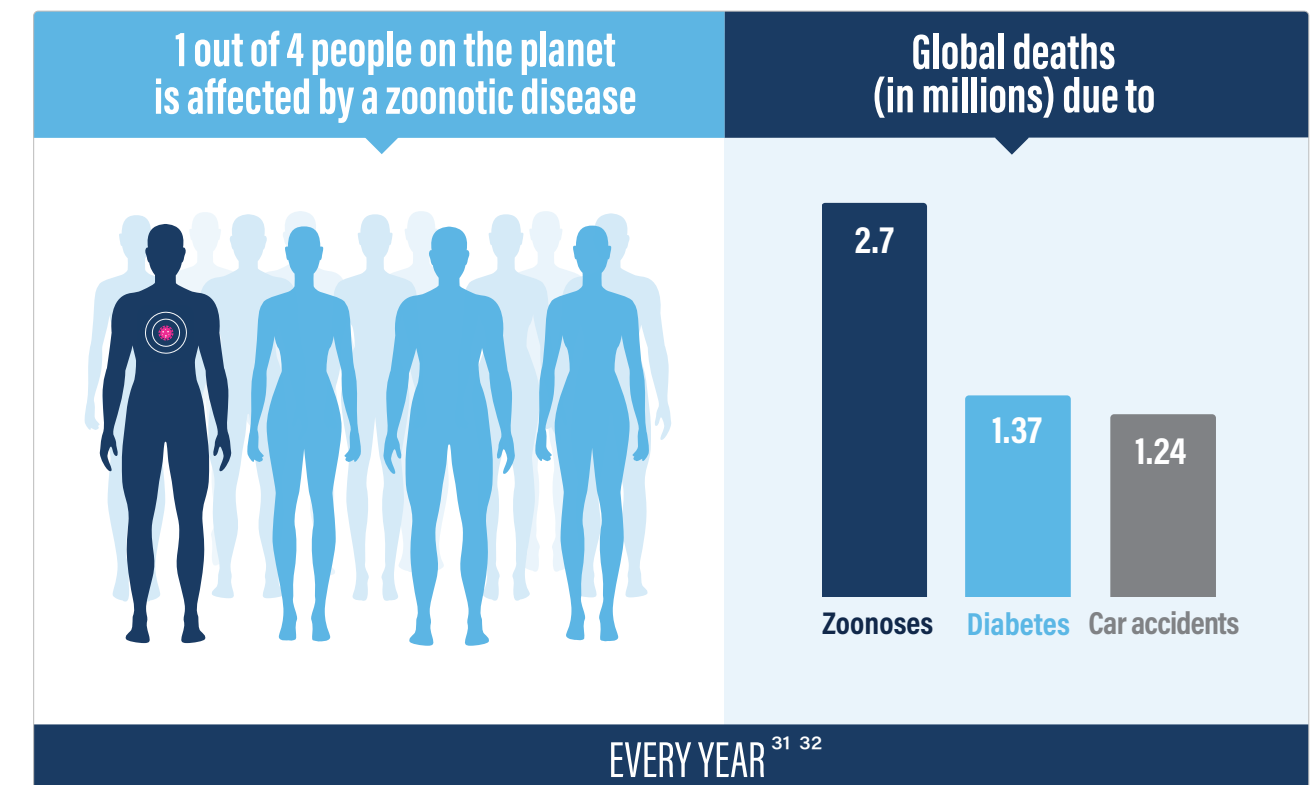
Nonetheless, **about 75% of all emerging infectious diseases that affect humans are zoonoses**. In other words, when we are confronted with new communicable diseases, three out of four times they originated in, and have been transmitted to us by, wild or farmed animals<sup>21 22 23 24 25 26</sup> – with potentially serious consequences, as past outbreaks have demonstrated.

Some of the most well-known zoonotic diseases include SARS, MERS, Ebola, rabies, and certain forms of influenza. Whether originating in wild animals, as is assumed with COVID-19, or in farmed animals, as is the case with avian and swine flu, they all pose serious threats to individual and global health – with some of them being potentially far more severe and deadly than COVID-19. **Increasing incidents of human-animal interaction and contact points (such as humans expanding into natural areas or high-density farming) increase the risk of zoonotic events.**



## Zoonoses – more fatalities than traffic accidents and diabetes combined

Not every zoonotic disease necessarily develops into a pandemic of COVID-19-like proportions. And they don't need to in order to pose a serious threat to humans. But, even without turning into acute pandemics, zoonoses are still responsible for **about 2.5 billion cases of illness and 2.7 million human deaths worldwide**, every single year.<sup>29</sup> To put these figures into perspective: traffic accidents caused 1.24 million deaths and diabetes caused 1.37 million deaths globally in 2017.<sup>30</sup> So, regular, non-pandemic zoonoses cause **far more harm than all traffic and diabetes fatalities around the world, combined**. Even non-fatal zoonoses cause massive damage to human health, societies, and economies, given that one out of four people on this planet is affected by a zoonotic disease – annually.



## CASE-FATALITY RATE<sup>33</sup>

Regarding the number of people who die from a disease, a key concept is the case-fatality rate (also known as the lethality rate). It is defined as the percentage of deaths in relation to the number of diagnosed cases of the disease. This is the rate that is widely used in the media (and often confused with the infection-fatality rate, which is the percentage of deaths in confirmed and unconfirmed cases). However, this figure can be very unreliable and can vary greatly between regions due to lack of testing or improper testing. To put things into perspective: **for the seasonal flu, the case-fatality rate is about 0.1% – killing 1 out of 1,000 patients.**<sup>34</sup>

## 1.3 AN OVERVIEW OF ZOO NOTIC DISEASES – FROM AIDS TO ZIKA

There are various types of pathogens that can be transferred from animals to humans. And, while they occasionally make the headlines when they first emerge or when there are larger outbreaks, it's easy to forget about zoonotic diseases in our everyday life. But just because they are off the media radar, it does not mean that they have disappeared. Many of them **continue to circulate in populations, putting significant strain on global healthcare and other resources.**

**Avian influenza** is probably the most common form of influenza. The main reservoir (or source animal) for the influenza A virus (IAV) is wild birds, who frequently spread it to domesticated and farmed birds. The primary risk factor for humans is exposure to infected live or dead poultry, contaminated environments such as live-bird markets, and intermediate hosts such as domesticated pigs. Recent cases include H5N1, which was first detected in 1997, causing a major outbreak in 2004, and H7N9, which was first detected in 2013.<sup>35</sup> Both originated in wild birds and were transmitted to humans via poultry. **The case-fatality rate for humans is up to 60% for H5N1 and about 40% for H7N9.**<sup>36 37</sup>



**Swine flu** is common in pigs and easily transmitted between them, especially when in close contact with each other (as in factory-farm settings), but can also be transmitted to humans.<sup>38</sup> Swine flu has various subtypes, including H1N1, H1N2, and H3N2. Having originated from birds and pigs, who may have functioned as intermediate hosts,<sup>39 40</sup> H1N1 is assumed to have caused the so-called **Spanish flu of 1918**. The latest H1N1 pandemic occurred in 2009 and was first identified in Mexico,<sup>41</sup> with an estimated 11-21% of the global human population contracting the illness.<sup>42</sup> It is assumed that **between 151,700 and 575,400 people died, worldwide**, during the first year of the 2009 H1N1 pandemic.<sup>43</sup>

**Bovine spongiform encephalopathy (BSE)**, commonly known as mad cow disease, is a progressive neurological disorder in cattle caused by a prion (an abnormal version of a protein). The probable source of BSE was cattle feed prepared from bovine tissue (brain, spinal cord, etc.).<sup>44 45</sup> In 1996, a human version of BSE called **variant Creutzfeldt-Jakob disease (vCJD)** was identified in the UK.<sup>46</sup> vCJD is caused by eating products from cattle infected with BSE. Since 1996, more than 170 people have died from vCJD<sup>47</sup> and over 4.4 million cows have been killed in the attempts to contain BSE.<sup>48</sup> In the wake of the mad-cow-disease epidemic, the European Commission placed a ban on the export of beef from the UK in 1996,<sup>49</sup> effective for 10 years,<sup>50</sup> while Japan did not open its market to British beef until 2019.<sup>51</sup>



**Coronaviruses** are a large group of viruses that cause diseases in birds and mammals.<sup>52</sup> Human coronaviruses were first identified in the mid-1960s.<sup>53</sup> Some coronaviruses (such as 229E, OC43, NL63, and HKU1) only cause mild to moderate disease in humans,<sup>54</sup> including acute upper respiratory tract infections. They are responsible for 15-30% of cases of the common cold.<sup>55 56</sup> However, there are more deadly coronavirus strains, including Middle East respiratory syndrome (MERS) and severe acute respiratory syndrome (SARS), which had its first outbreak in 2003 and was first identified in Guangdong, China. **SARS-CoV** (the virus that causes SARS) affected more than 8,000 people in 26 countries on five continents, with an 11% case-fatality rate.<sup>57 58</sup>



Middle East respiratory syndrome (MERS) is caused by a coronavirus named **MERS-CoV**, which was first identified in Saudi Arabia in 2012 and spread to 25 countries – with a **case-fatality rate of 30-40%**.<sup>59</sup> Some studies suggest that both SARS and MERS (as well as other coronaviruses) might have originated in bats, as the virus has been identified in bats, worldwide.<sup>60 61 62 63</sup>

**The Nipah Virus (NiV)** disease first appeared in Malaysia in 1998. The virus's natural reservoir is fruit bats.<sup>64</sup> However, most human infections have resulted from direct contact with pigs,<sup>65 66</sup> and it is assumed that the virus can infect a wide variety of animals. NiV can cause encephalitis but can also be present in the body without any symptoms. **The case-fatality rate for humans ranges from 40% to 75%.**<sup>67</sup>

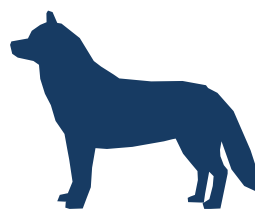
**Ebola** was first discovered in Central Africa in 1976, near the Ebola river. It is assumed that its emergence in humans is linked to human encroachment into forested areas due to population growth, resulting in increased direct interaction with wildlife. African fruit bats are likely involved in the spread of the Ebola virus and may even be the reservoir host.<sup>68 69</sup> **The case-fatality rate is around 50% but has varied greatly during past outbreaks, from 25% to 90%.**<sup>70</sup>

The earliest known case of the **Human Immunodeficiency Virus (HIV)** was probably identified in the Democratic Republic of Congo (then the Belgian Congo) in 1959.<sup>71</sup> HIV spreads through certain bodily fluids, attacks the immune system and, if untreated, can lead to acquired immunodeficiency syndrome (AIDS),<sup>72</sup> which was first identified in 1981.<sup>73</sup> HIV is assumed to have been transmitted via apes to humans, when humans consumed them for food and came into contact with their infected blood.<sup>74 75</sup> Today, there is no region in the world that is unaffected by this pandemic.<sup>76 77</sup> Since 1981, **an estimated 74.9 million people have become infected with HIV, and 32 million people have died of AIDS-related illnesses.**<sup>78</sup>





**The rabies virus (RABV)** is one of the oldest virus species, belonging to the ever-expanding genus of **lyssaviruses**. RABV and other lyssaviruses have been detected in bats.<sup>79</sup> However, unlike other lyssaviruses, RABV can be found in multiple reservoir hosts, for example, domestic dogs, red foxes, and raccoons.<sup>80</sup> Canine-associated rabies kills more than 55,000 people each year in developing countries due to limited vaccination regimes.<sup>81 82</sup>

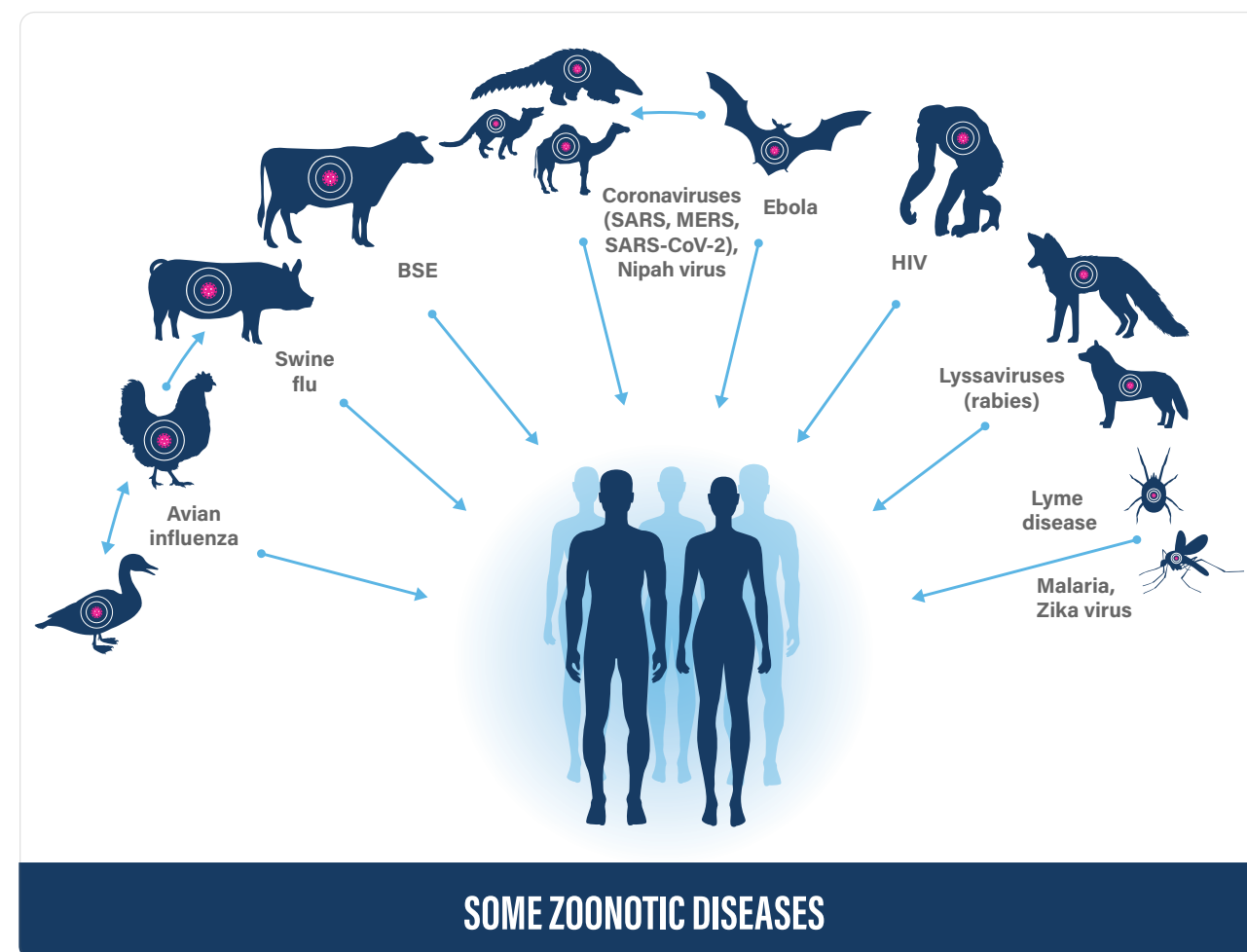


**Malaria** is an ancient disease caused by parasites of the genus *Plasmodium*, which are transmitted through the bite of the *Anopheles* mosquito. More than 95% of malaria cases evolved from *Plasmodium* parasites infecting wild African apes.<sup>83</sup> In 2018, there were **228 million known cases of infection and 405,000 malaria deaths around the world**.<sup>84</sup> Africa carries the highest share of the global malaria burden, with 93% of malaria cases and 94% of malaria deaths.<sup>85</sup>

**Lyme disease** is the most prevalent vector-borne infection in North America and Europe.<sup>86</sup> It is caused by the bacterium *Borrelia burgdorferi*, which is transmitted to humans via the bites of infected ticks. The main natural reservoirs for *B. burgdorferi* are birds, chipmunks, mice, and other small mammals.<sup>87</sup> It is estimated that approximately 300,000 people contract Lyme disease each year just in the US,<sup>88</sup> and between 650,000 and 850,000 people in Europe.<sup>89</sup> Research shows that mosquito- and tick-borne diseases are **increasing as a consequence of climate change**.<sup>90 91 92</sup>



**The Zika virus (ZIKV)** disease was first identified in Uganda in 1947.<sup>93</sup> ZIKV is transmitted to humans primarily through infected *Aedes* mosquitoes, which are also responsible for spreading dengue fever (DENV) and chikungunya (CHIKV).<sup>94</sup> ZIKV has been linked to spikes in the birth defect microcephaly.<sup>95</sup> In 2016, the World Health Organization (WHO) declared a Public Health Emergency of International Concern due to the ZIKV epidemic in South America, and especially in Brazil.<sup>96</sup> The case-fatality rate in Brazil is 8.3% in cases of microcephaly and other serious conditions which arise as a result of ZIKV infection.<sup>97 98</sup>



## Inter-human transmission and permanent establishment

Not all zoonotic diseases allow transmission from human to human. However, some pathogens, such as SARS-CoV-2 and certain forms of influenza, can be easily transmitted between humans, with the potential to cause serious pandemics that can take some time to decline in human populations. Some zoonotic diseases can establish themselves permanently in the human population through mutation and adaptation, with humans becoming a primary reservoir host and no animals needed to spread the infections.<sup>99</sup> In order for this to happen and for an animal virus to transform into a virus affecting humans, **it takes just a few spillover events**.

## 1.4 ESCALATING ZONOTIC DISEASES – EPIDEMICS AND PANDEMICS

When a disease spreads substantially, it is called an epidemic. Normally, it is spatially restricted to a specific area or region, but an outbreak can also extend further and eventually cover a larger area. A pandemic has a national or international scale and occurs when an epidemic spreads beyond the initial area of contagion into other regions, countries, and even continents. **A global pandemic is the highest level of a global health emergency**.<sup>100</sup> When this happens with zoonotic diseases, it is called a zoonotic epidemic or pandemic.



Throughout history, some zoonotic diseases have indeed escalated. These include:

### The plague – ‘the black death’

The plague, or ‘the black death’, is among the most infamous epidemics and pandemics in human history, with one of the biggest outbreaks taking place in the 14th century and regular fatal recurrences occurring up to the 17th century. Considered to be the most fatal pandemic on record, the plague probably **killed up to 60% of the European population,<sup>101</sup> reducing the global population from about 450 million to about 350 million people.<sup>102</sup>** The plague is caused by a bacterium called *Yersinia pestis* that is transmitted to humans via the bites of fleas. Rodents, such as rats, are considered intermediate hosts, after having been infected by fleas themselves. The plague is still around in the 21st century. According to WHO, between 2010 and 2015, there were more than 3,200 cases reported worldwide, including nearly 600 deaths.<sup>103</sup>

### The Spanish flu – ‘the mother of all pandemics’

In the wake of World War I, the so-called ‘Spanish flu’ of 1918, often referred to as the ‘mother of all pandemics’, had an unusually high death toll. It is estimated that **about a third of the world's population were infected, resulting in up to 50 million deaths.<sup>104</sup>** Although there is little doubt that the Spanish flu is of zoonotic origin, the question of the animal involved is still under debate, with the avian H1N1 virus being the most likely explanation.<sup>105</sup> **H1N1 has recurred repeatedly since then, with the largest recent outbreak taking place in 2009, and leading to the deaths of between 150,000 and 575,000 people worldwide.<sup>106</sup>** The 2009 H1N1 virus was a combination of different swine, avian, and human influenza A viruses, involving strains from North America and Eurasia.<sup>107</sup>

### Then and now – increasing risks and impacts of pandemics

Zoonotic pandemics have always had serious impacts on humans – although some factors have changed. In the past, less advanced hygienic and medical knowledge and equipment caused spreads of devastating proportions. This is sadly still true for some regions of the world with limited means and infrastructure, where it may not be possible to follow hygiene protocols correctly, and which is also often the case in developed countries.<sup>108 109 110</sup> In today’s globalised world, however, international travel and trade have become an hitherto unparalleled accelerator for spreading pandemic diseases around the globe within a matter of days.

There is substantial evidence that outbreaks of animal-borne and other infectious diseases are on the rise.<sup>111</sup> The World Health Organization (WHO) tracked about 1,500 epidemic events in 172 countries during the period between 2011 and 2018,<sup>112</sup> and it is highly likely that **the current coronavirus crisis is only a forewarning of what is yet to come. Epidemiologists are waiting for the ‘big one’ – not if but when.** Many experts had in fact warned about the risk of a new coronavirus causing a pandemic<sup>113 114 115</sup> – which is exactly what happened.

## 1.5 THE COVID-19 PANDEMIC – (ONE STEP CLOSER TO) THE BIG ONE?

According to a report by the Global Preparedness Monitoring Board, co-convened by WHO and the World Bank, and published in September 2019, **“the world is at acute risk for devastating regional or global disease epidemics or pandemics that not only cause loss of life but upend economies and create social chaos.”<sup>116</sup>** Just a few months later, the world witnessed this prediction materialise. Whether the current COVID-19 pandemic is in fact ‘the big one’ is yet to be seen. However, it is already quite clear that the world has never before experienced a pandemic that has spread so rapidly, affecting virtually every human on the planet, and representing an unprecedented crisis. Those who are not infected with the virus itself are impacted by governmental regulations aimed at limiting its spread, and by the resulting social and economic hardship.

### Late 2019 – the unfolding of a pandemic crisis

The virus SARS-CoV-2 (widely known as the coronavirus) which causes COVID-19 (the coronavirus disease) was first officially identified in Wuhan, China, in December 2019 – with the first cases probably dating back earlier.<sup>117</sup> The virus quickly spread through the surrounding province of Hubei, and, by March 2020, the number of confirmed corona infections exceeded 80,000 cases for the whole country.<sup>118</sup> Since then, **the virus has spread around the globe, resulting in millions of cases and hundreds of thousands of deaths.<sup>119</sup>** Governments around the world have since taken drastic measures to contain the spread of the virus, including nationwide lockdowns, strict social distancing, and international travel bans – affecting all aspects of social, political, and economic life and daily routine.



### The origin question – where and who?

At the time of writing, the question of the exact point of origin of SARS-CoV-2 is still being debated. The initial assumption was that the outbreak started at a wet market in Wuhan in December 2019.<sup>120</sup> Now, there is also evidence of unrelated earlier cases, which suggests that the Wuhan market was the first super-spreader location rather than the actual point of origin.<sup>121</sup> While determining the exact location may prove impossible, the more relevant question is about the species involved. It is generally assumed that viruses such as SARS-CoV and MERS-CoV originate in bats, are then transmitted to other animals as intermediate hosts, and finally spread to humans.<sup>122 123 124 125</sup> Bats are also believed to have been the hosts for the SARS-CoV-2 predecessor, and other wild animals (possibly pangolins) may have served as intermediate hosts, before transferring the virus to humans.<sup>126 127</sup>

An alternative theory suggests that a possible predecessor of SARS-CoV-2 jumped to humans from an unknown intermediate host much earlier and acquired its specific traits in humans (rather than in the intermediate host), while staying undetected and allowing human-to-human transmissions.<sup>128</sup> **Regardless of these alternative emergence theories, COVID-19’s zoonotic origin remains unquestioned.**







## THE LABORATORY THEORY

At the time of writing, an alternative origin theory has emerged, claiming that the virus outbreak started from a maximum-security biosafety facility in Wuhan, rather than from one of the city's animal markets. But even if the virus actually spread from a laboratory, the relevant question is a different one: was it artificially designed in a laboratory? Or was it the product of natural selection, resulting from interactions between animals and humans, which happened to end up in a laboratory? While it is currently impossible to completely disprove alternative-origin theories, scientific analysis of the virus's structure suggests that it is not a purposefully manipulated virus, making a laboratory-origin scenario implausible.<sup>129</sup> **If the virus is a zoonotic product of natural selection, as its structure suggests, it makes no difference to the argument at hand whether its actual spread started in a wet market or via a laboratory. The origination process remains the same – as does the risk of future outbreaks.**

## Putting COVID-19's case-fatality rate into context

When it comes to assessing the hazard posed by a virus, the most widely used measure is the case-fatality rate. While the impact of COVID-19 is unparalleled in modern times, it is not nearly as deadly as some other zoonotic diseases. Although the actual case-fatality rate is still under debate, the case-fatality rate varies greatly according to region, with a current average of 4.7% (as of 5 July 2020).<sup>130</sup> **This makes COVID-19 substantially more dangerous than regular flu,** which has a case-fatality rate of less than 0.1%.<sup>131</sup>

Its case-fatality rate, however, is dwarfed dramatically by that of, say, avian flu and its variants, with rates of up to 60% (H5N1)<sup>132</sup> or, potentially, up to 90% in the case of Ebola<sup>133</sup> – making them 600 or 900 times more deadly than the seasonal flu. If one of these zoonoses turns into a pandemic, the consequences on health, healthcare systems, societies, and economies are difficult to imagine, and most aspects of human social organisation are likely to collapse. Even with COVID-19's relatively low case-fatality rate, healthcare systems are already experiencing serious strain – despite the massive political and social containment measures that have been put

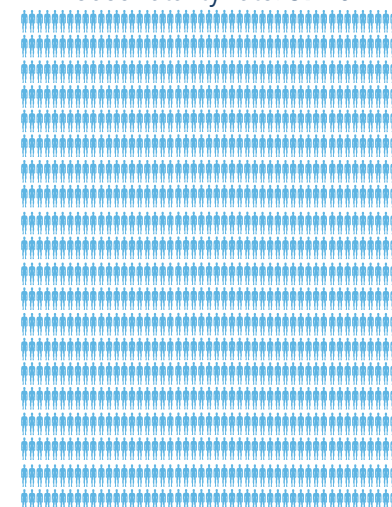


Picture by sondem, Shutterstock

in place. **If the case-fatality rate of a future global zoonotic outbreak is similar to those of Ebola, H5N1, or the 1918 flu pandemic, its effects will certainly overwhelm virtually all existing infrastructure.** It will no longer be a question of enough ventilators and intensive-care capacities – but of enough doctors and nurses still able to do their jobs.

### SEASONAL INFLUENZA

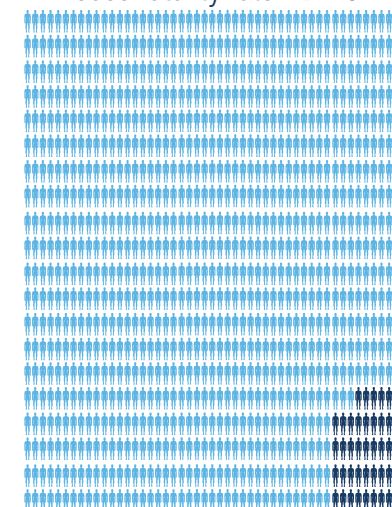
Case-fatality rate: **0.1%**<sup>134</sup>



1 out of 1,000

### COVID-19

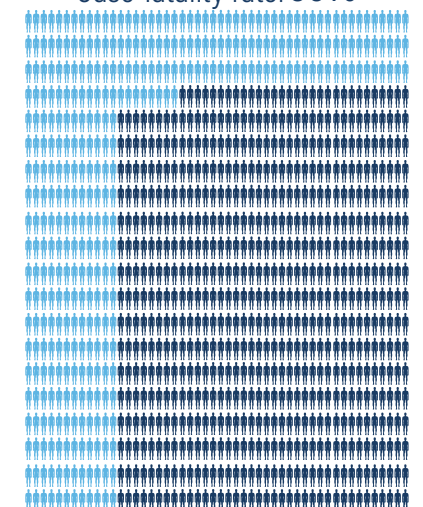
Case-fatality rate: **4.7%**<sup>135</sup>



47 out of 1,000

### H5N1

Case-fatality rate: **60%**<sup>136</sup>



600 out of 1,000

**Not only might future outbreaks be more dangerous, experts agree that they are also expected to be more frequent.**<sup>137 138</sup> The potential causes behind this alarming forecast are human-made – and the most central human activities in this context are all related to our global food system.



## POVERTY AND PANDEMICS

Low-income and marginalised communities, as well as those living in developing countries, carry a disproportionately high share of the burden of zoonotic infections.<sup>139</sup> The reasons for this include the fact that these communities are more susceptible to disease because they often lack access to clean water and sanitation, adequate nutrition, safe working conditions, access to medical care, training, education, and information.<sup>140</sup> Additionally, they often do not report symptoms or seek immediate medical attention because of the high cost implications.<sup>141 142</sup> **In a globalised world, these factors also contribute to an overall higher risk of pandemics – for everyone.**



## 2. THREE FOOD-RELATED HUMAN ACTIVITIES THAT INCREASE THE RISK OF ZOO NOTIC PANDEMIC S

The emergence of a novel zoonotic disease is a highly complex process, involving many factors. Yet, there is compelling evidence that certain human activities strongly increase the likelihood of such developments. This chapter highlights three aspects of human behaviour which are particularly devastating – all of which have to do with human-animal interactions in the context of food, and which increase both the risk of pandemic occurrence and the severity of its impacts. These three factors are:

- (1) **The destruction of ecosystems and the loss of biodiversity** (driven largely by animal agriculture) – resulting in increased contact and virus spillover to humans and farmed animals.
- (2) **The use of wild animals for food** – resulting in increased contact and virus spillover to humans and farmed animals.
- (3) **The use of farmed animals for food in high-density, intensified animal agriculture** – resulting in ideal conditions for viral mutation, spread, and spillover to humans and wild animals.

The trajectory of this interplay is alarming, given the world's fast-growing appetite for animal protein, and **intensified animal agriculture's key role** in satisfying it. With meat and milk production expected to grow by approximately 15% by 2028<sup>143</sup> due to rising global human population and prosperity levels, **future pandemic risk is also expected to further increase.**

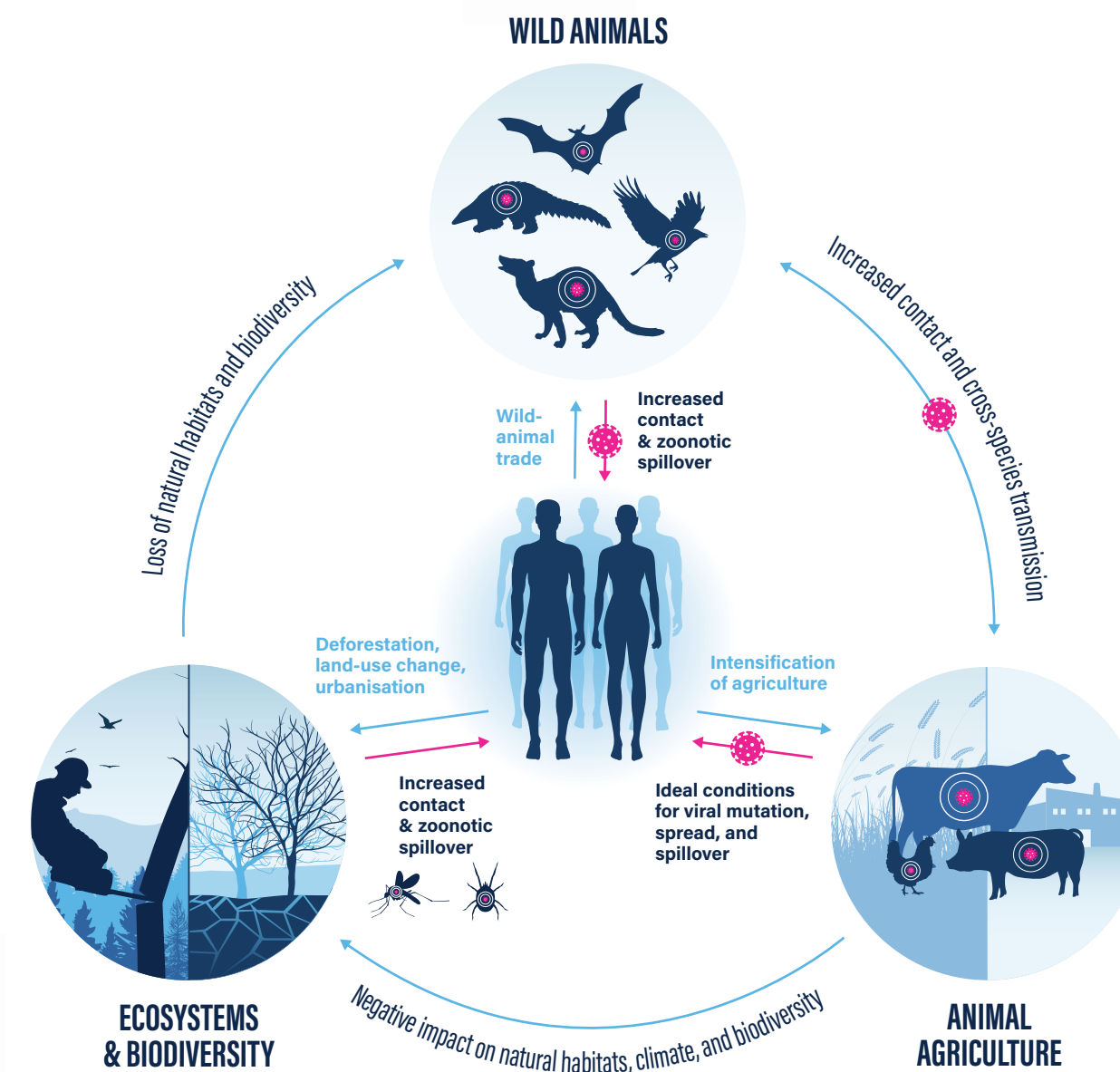
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*Rampant deforestation, uncontrolled expansion of agriculture, intensive farming, [...] as well as the exploitation of wild species, have created a 'perfect storm' for the spillover of diseases from wildlife to people.*

Settele et al. (2020), IPBES guest article<sup>144</sup>



Picture by Rich Carey, Shutterstock



### 2.1 THE DESTRUCTION OF ECOSYSTEMS AND LOSS OF BIODIVERSITY

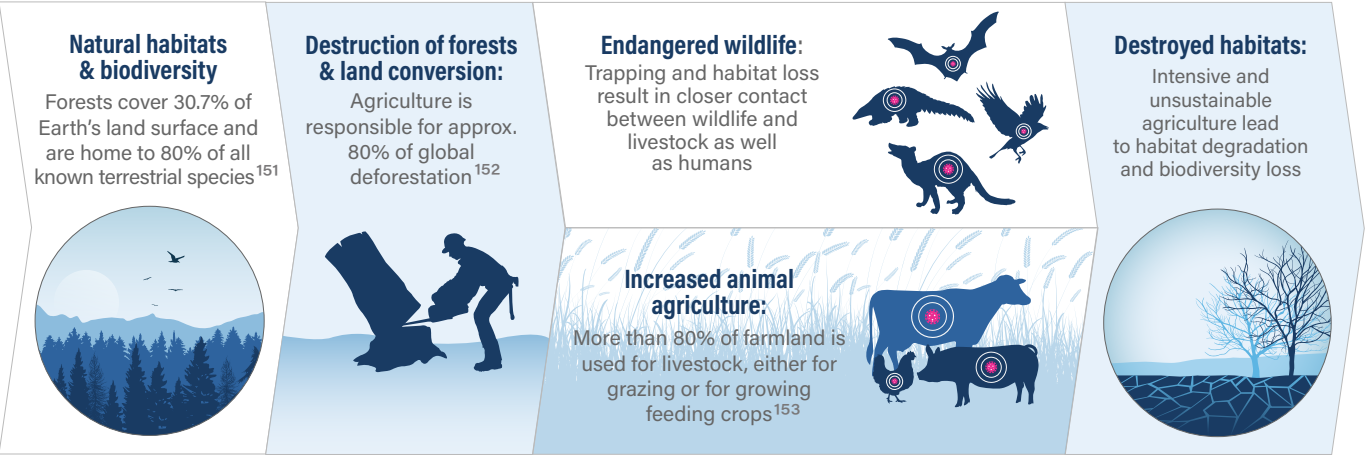
The health of humans is directly linked to the health of the planet and all its inhabitants. While most research is clear about the importance of intact ecosystems, human activities don't seem to reflect this insight. Instead, there is an ever-increasing exploitation and disruption of ecosystems, causing species diversity and animals' natural habitats to continuously decline.

#### The sixth mass extinction – human-made biodiversity loss

We are living in the midst of the sixth mass extinction on the planet and are facing a rapid global loss of biodiversity. For the first time in the history of the planet, such an event is human-made.<sup>145</sup> Our actions have heavily impacted more than 75% of the Earth's land surface,<sup>146</sup> significantly altering the prevalence and composition of its flora and fauna. Expanding urbanisation, as well as increasing commercial and infrastructural activities, driven by growing populations and



prosperity levels, are significant contributors to these developments<sup>147</sup> – with animal agriculture playing a central role. Tropical regions with high biodiversity are particularly vulnerable to, and affected by, all of these developments. The consequences are dramatic: more encroachment into, and destruction of, natural ecosystems **means greater exposure to hitherto unknown viruses – and an increased risk of zoonotic spillover.**<sup>148 149 150</sup>



“

*We have created densely packed populations where alongside us are bats and rodents and birds, pets and other living things. That creates intense interaction and opportunities for things to move from species to species.”*

**Eric Fevre**

Epidemiologist at the University of Liverpool's Institute of Infection and Global Health,  
The Guardian<sup>154</sup>

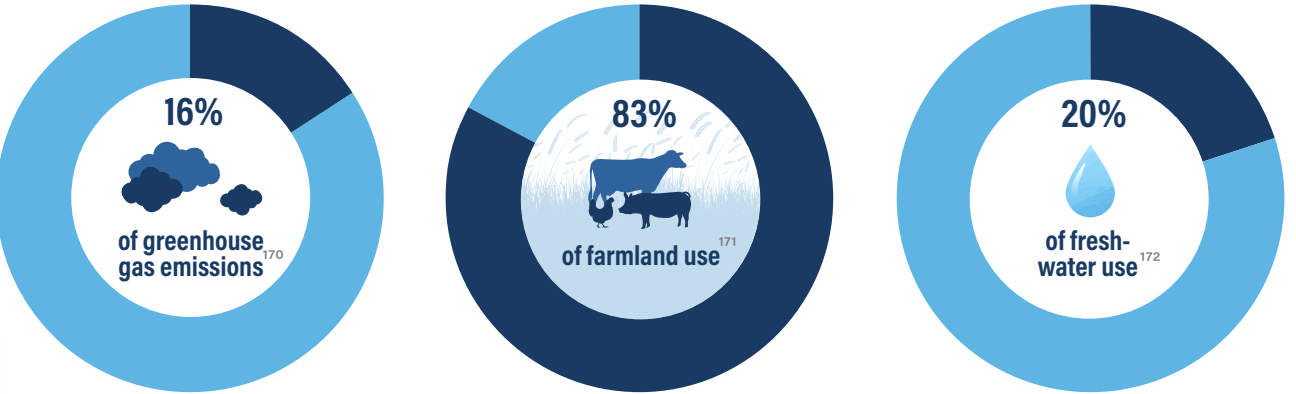
### Animal agriculture – a key driver of the destruction of ecosystems

Animal agriculture is one of the key drivers of land-use change worldwide, as forests are cleared to provide space for feed crops and pastures in order to supply the increasing demand for meat.<sup>155 156 157 158 159 160</sup> Currently, 70% of fresh water and 50% of habitable land is used for crops and livestock production,<sup>161 162</sup> while more than 80% of the world's farmland is used for the production of meat, eggs, and dairy. However, animal-based products provide a mere 18% of global calories.<sup>163</sup>

Compared to other forms of agriculture, livestock farming is particularly inefficient owing to its **poor protein-efficiency ratio** (that is, the quantity of plant protein required to produce one kilogramme of edible animal protein). Farmed animals need to consume between 6 and 12.5 kg of plant protein in order to produce a single kilogram of animal protein.<sup>164 165 166</sup> The consumption of animal-based products leads to **massive encroachments into natural habitats – with very low yields.**<sup>167 168</sup>



### Globally, animal agriculture is responsible for:



### Decreased biodiversity and increased zoonotic emergence

There is now substantial evidence that shows a clear correlation between human intrusion into ecosystems and the resultant habitat destruction, and an increased risk of pathogenic spillover. Ecosystems consist of communities of plants, animals, and microorganisms, as well as all the physical and chemical components of a specific environment or habitat. The interactions between all the components of an ecosystem are highly complex. As are the effects of biodiversity loss on pathogens, since their biological life cycles, as well as climate and host requirements, may vary greatly.<sup>173</sup> While some pathogens might be very specialised in relation to a specific host, there are others that have a larger host range and might be able to cross species barriers more easily.

Undisturbed habitats allow for a natural composition and balanced spatial distribution of species, which can result in a high diversity of both animals and pathogens.<sup>174</sup> While a high diversity of pathogens sounds like a problem, this seems not to be the case: the dilution-effect hypothesis proposes that undisturbed habitats with high biodiversity make it much more difficult for pathogens such as viruses to spread and find suitable hosts.<sup>175 176 177 178 179</sup>

“

*Mounting evidence indicates that biodiversity loss frequently increases disease transmission [...] current evidence indicates that preserving intact ecosystems and their endemic biodiversity should generally reduce the prevalence of infectious diseases.”*

Keesing et al. (2010)<sup>180</sup>

### The dilution effect – nature’s version of social distancing

One of the reasons for this is that the more diverse a biological community, the higher the probability is that there are species and individuals that are immune to a virus or unsuitable as a host. In habitats with high biodiversity, the number of individuals of the same species within a population may be lower (owing to natural regulating mechanisms such as predation or competition between species). As a consequence, viruses spread more slowly or are stopped by natural barriers. In other words, the risk of pathogens spreading is ‘diluted’ – a little like nature’s version of social distancing. However, if a habitat contains only a few animal species that are potential hosts for viruses and those animal species are genetically very similar (for example as a consequence of human environmental interference), then **the virus can spread easily**. And it might become so abundant that there is an increased risk that it will evolve the ability to jump the species barrier and infect other species – including humans.<sup>181 182</sup>

### Loss of diversity + increase in numbers = higher spillover risk

This is supported by evidence that mammal species (such as rodents, bats, primates, and domesticated animals) that have increased in population size due to human environmental interference share more viruses with humans than less abundant species. Human interference with the composition and numbers of wild animals thus increases the chances of interaction between wild animal species – and the viruses they carry – who would never meet under natural conditions in intact ecosystems. Adding domesticated animals such as farmed animals to this equation further increases the risk of pathogen transmission – **making a zoonotic spillover event to humans significantly more likely**.<sup>183</sup>

“

*Never before have so many opportunities existed for pathogens to pass from wild and domestic animals to people [...] Our continued erosion of wild spaces has brought us uncomfortably close to animals and plants that harbour diseases that can jump to humans. Our long-term response must tackle habitat and biodiversity loss.”*

Inger Andersen

Executive Director of the UN Environment Programme, The Guardian<sup>184</sup>

### Climate change – a risk multiplier

Along with human population growth and the anthropogenic destruction of ecosystems, climate change also contributes to the increased transmission of pathogens from host animals to humans.<sup>185</sup> Changing climatic conditions such as higher average temperatures can shift the habitats of both animals and pathogens.<sup>186 187 188</sup> This further spurs imbalances in ecosystems and loss of biodiversity, resulting in higher risks of new infectious diseases emerging.<sup>189 190</sup> In addition, changes to the climate may also favour the spread of vector-borne diseases (diseases that are transmitted by carriers such as ticks and fleas). Alarming examples include malaria or dengue fever, which are now expanding to new geographical areas, since the mosquitoes which transmit them are finding favourable conditions in these areas.<sup>191 192 193 194</sup> There is no doubt that climate change is the result of human activities. **One of the main drivers of climate change is animal agriculture**, accounting for about 16% of global greenhouse gas emissions,<sup>195</sup> while also being a major contributor to environmental degradation.

“

*Studies have found that long-term climate-warming tends to favor the geographic expansion of several infectious diseases, and that extreme weather events may help create the opportunities for more clustered disease outbreaks or outbreaks at non traditional places and time.”*

Wu et al. (2016)<sup>196</sup>

### A destructive interplay – fuelled by our food choices

Our environmentally destructive activities bring us closer to wild animals and their often unknown pathogens. This creates favourable conditions for viruses to spread, and ultimately enables the development of dangerous zoonoses that have the potential to become global pandemics. Add increasing temperatures and changing climate conditions to the equation, and the threat multiplies substantially.

### Profound impacts – and little awareness

Although there is widespread agreement about the destructive effects of this interplay, there is alarmingly little awareness of the fact that animal agriculture is one of its key drivers. While stressing the need to preserve ecosystems, natural habitats, and biodiversity, **even experts often fail to make the connection**. This is particularly unfortunate in light of the fact that animal agriculture contributes substantially to both environmental destruction and climate change. Globally, we raise and kill more than 75 billion land animals every year,<sup>197</sup> with that number continually increasing. Breeding, feeding, processing, and shipping these staggering numbers of animals takes up vast resources, including land and water, and consequently leads to massive impacts on global ecosystems.



“

*The message we are getting is if we don't take care of nature, it will take care of us [...]*

**Elizabeth Maruma Mrema**

Executive Secretary of the UN Convention on Biological Diversity, The Guardian<sup>198</sup>

In order to address the occurrence and transmission of pathogens and the emergence of future zoonotic pandemics, **we need to address our preference for animal-based foods – including both the products of animal agriculture and using wild animals as food.**

## 2.2 WILD ANIMALS AS FOOD

One form of human intrusion into ecosystems and animals' natural habitats is the use of wild animals as food in the context of hunting, wet markets, and bushmeat. Historically, the consumption of wild animals has been a component of the diets of many hunter-gatherer and forager cultures. Today, wild animals remain part of the diets of many communities around the world.<sup>199</sup> At the same time, illegal wildlife trafficking has also become a big business that is worth up to US\$ 23 billion.<sup>200</sup> **Every year, millions of wild animals are taken from their natural habitats – often illegally.** In addition, various wild animal species are bred in unnatural, intensive farm settings.

“

*We invade tropical forests and other wild landscapes, which harbour so many species of animals and plants – and within those creatures, so many unknown viruses [...]. We cut the trees; we kill the animals or cage them and send them to markets. We disrupt ecosystems, and we shake viruses loose from their natural hosts. When that happens, they need a new host. Often, we are it.*

**David Quammen**

Author of *Spillover: Animal Infections and the Next Pandemic*, New York Times<sup>201</sup>

### Wild-animal exploitation – endangering biodiversity and driving zoonoses

The pangolin – probably involved in the emergence and spread of COVID-19<sup>202</sup> – is one example of an animal that is consumed as both meat and as medicine. Two out of the four Asian species are classified as 'critically endangered' and the other two as 'endangered'.<sup>203</sup> Pangolins are believed to be the world's most trafficked mammal, accounting for a large part of all illegal wildlife trade and imported illegally into various countries on a massive scale.<sup>204</sup> About a million pangolins are assumed to have been killed over the course of the last decade. However, the actual amount might be much higher as only a small portion of illegal trade is intercepted.<sup>205 206 207</sup> There are estimates that close to 2.7 million pangolins are poached every year, in central Africa alone.<sup>208</sup> Beyond pangolins, there is a wide range



Picture by Jiri Prochazka, Shutterstock

of wild animals and products from wild animals that are illegally traded – from bats to tigers to elephants. This makes the human exploitation of wild animals an additional risk factor for endangering biodiversity and already highly vulnerable species. Crucially, it also **drives the emergence of zoonoses** – through both aggravating the general environmental conditions (see 2.1) and creating direct gateways.

### Wild-animal processing – a gateway for novel pathogens

When handling, slaughtering, or eating wild animals, viruses present in the animals can jump the species barrier. If humans are exposed to the virus, it can be transferred via compromised skin tissue or the mucosal membranes of the mouth, nose, or eyes, potentially allowing for the emergence of novel zoonotic infections.

### Beyond Wuhan, pangolins and COVID-19

Regardless of whether the spillover of SARS-CoV-2 to humans actually occurred at the wet market in Wuhan, and irrespective of the exact animal species involved (see 1.5), the wild animal trade nevertheless poses a major risk for the emergence of zoonotic pathogens. It enables the supply of wild meat to urban consumers, leading to an increased movement of species and thus increasing the likelihood of zoonotic pathogen spread and exposure. This presents a major health risk to human populations worldwide.<sup>209</sup> Wildlife has been identified as a source of high-impact, recently emerging zoonoses. Such pathogens include the

## WET MARKETS



Wet markets are found in many places throughout the world, including Africa, South East Asia, and China. The term 'wet market' comes from the fact that the floors of these markets are often wet because products are washed with water or kept on ice. Many people rely on wet markets for food as well as for economic reasons. They are common market-places for fresh products such as vegetables, fruits, fish, and meat, usually from domesticated animals (dead or alive), and are similar to farmer's markets in the Western world. However, there are also wet markets that sell wild animals. Crammed into tight spaces and butchered on request under poor sanitary conditions, multiple animal species are kept in close proximity, unsanitary conditions, and under high risk of mixing bodily fluids. In an environment of acute stress for the animals, which weakens their immune systems, **this mixing of pathogens from multiple host species creates the perfect conditions for the emergence of novel pathogens – which are then just a meal away from jumping to humans.** It is specifically these markets that pose a high risk of close contact between different animal species as well as humans, allowing pathogens to cross species barriers more easily.



Ebola and Marburg viruses, HIV, Nipah, Hendra, the Menangle virus, the West Nile virus, and others such as the coronaviruses which caused the global pandemics of SARS and MERS and, of course, various strains of influenza A.<sup>210</sup> Theoretically, **just one human being handling just one animal carrying a virus might suffice for animal-human transmission to occur** – and to set in motion a disastrous process such as the one the world is currently experiencing.

“

*The underlying causes of zoonotic spillover from bats or from other wild species have almost always been shown to be human behavior, [...] When a bat is stressed – by being hunted, or having its habitat damaged by deforestation – its immune system is challenged and finds it harder to cope with pathogens it otherwise took in its stride. [...] You can think of it like if people are stressed and have the cold-sore virus, they will get a cold. [...] This can happen in bats too."*

**Andrew Cunningham**

Professor of Wildlife Epidemiology at the Zoological Society of London, CNN 2020<sup>211</sup>

## The emergence of HIV – another food-related disaster

An example of how using wild animals for food can lead to the global spread of a dangerous pathogen is the emergence of the human immunodeficiency virus (HIV), which leads to acquired immunodeficiency syndrome (AIDS) in humans. **While the virus and the disease are well known to the general public, its food-related origin is not.**

To date, HIV has infected about 75 million people, claimed more than 32 million lives, and continues to newly infect about 1.7 million people each year, despite extensive awareness campaigns.<sup>212</sup> AIDS is a disease for which, almost 40 years after its first clinical report, there still is neither a cure nor a vaccine, but only lifelong treatment measures to keep it at bay. The multi-staged emergence of HIV-1 and HIV-2, the two subtypes, is highly complex. However, it is now widely accepted that both types of HIV are the result of multiple cross-species transmissions of simian immunodeficiency viruses (SIVs), a virus that naturally occurs in African primates.<sup>213</sup>

## Bushmeat and AIDS

The emergence of HIV can be traced back to Kinshasa in 1959, a time when urban populations in central Africa were expanding and logging operations had started to advance deep into the rainforest.<sup>214</sup> Because roads provided access to remote forests, they enabled a growing bushmeat trade between hunters and urban centres. The hunting and butchering of nonhuman primates, an integral element of traditional livelihoods for many people in the region, has been identified as a high-risk behaviour. It is viewed as a likely source for the repeated transmission of SIVs to humans, which eventually led to the virus's ability to spread from human to human.<sup>215</sup> This is not a problem of the past. With expanding human populations in many economically

deprived regions, the **bushmeat trade has continued to expand and has been increasingly commercialised.** It is now estimated to total as much as 3.4 million tons of wild meat per year, in Africa alone.<sup>216</sup> The Food and Agriculture Organization of the United Nations (FAO) has named unsustainable bushmeat consumption in West and Central Africa as one of the region's most important biodiversity and conservation challenges.<sup>217 218</sup>

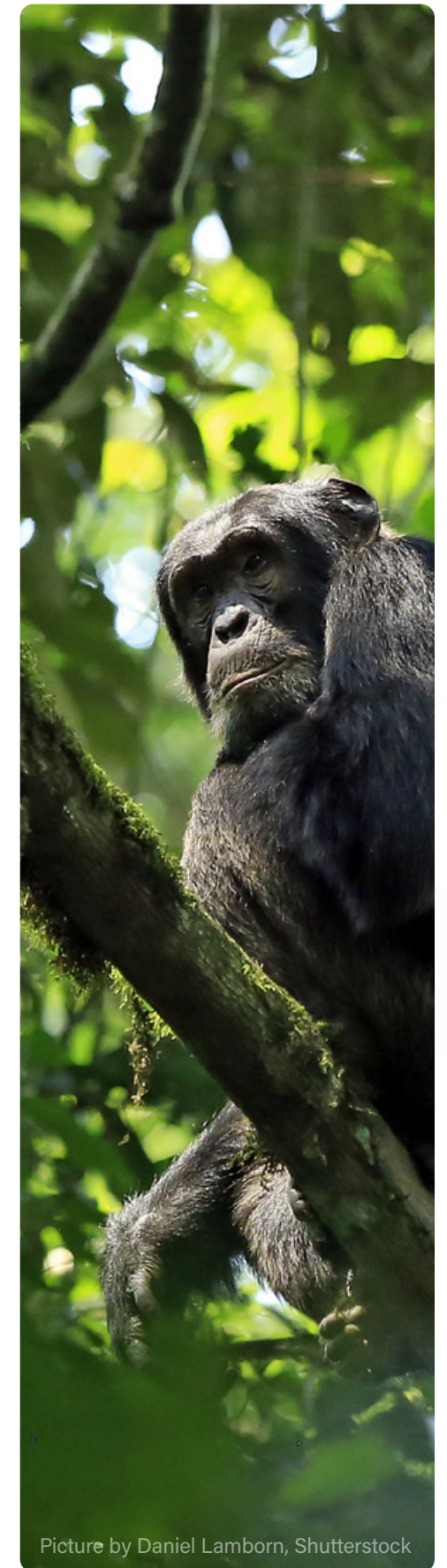
## Humans as threat multipliers

The overall outlook is highly alarming for two reasons: first, wild animals carry a great diversity of as yet unknown viruses; second, humans are increasingly interfering with wild animals' natural habitats and using them for commercial purposes such as food, medicine, and fashion. Of course, **the solution to reducing the risk of zoonoses is not the eradication of wild animals as carriers of viruses, but the preservation of their natural habitats and ending their use as food items.** The single most culpable species for the emergence of pandemics is us: *Homo sapiens* has become a super vector – a threat multiplier – for zoonotic pandemics.<sup>219</sup>

Increasing conservation efforts and empowering local communities to find alternative sources of food and income is crucial to preventing new pathogens emerging from the depths of complex ecosystems. Given the potential global risks, this is **a task not only for local governments but – crucially – also for the global community.**

## Banning wildlife markets – and the elephant in the room

In the wake of the coronavirus pandemic, the UN has urged for a ban on the trade of live wild animals at wet markets as a preventive measure for future pandemics.<sup>220</sup> While banning the trade of wild animals – not only for food but also for other uses such as fur and medicine<sup>221</sup> – may be a reasonable step, the risk of emerging viral diseases largely remains. This is due to the fact that many pathogens of recent concern to human health originate in, or are transferred to humans from, domesticated animals farmed for human consumption.<sup>222</sup>



Picture by Daniel Lamborn, Shutterstock



## 2.3 FARMED ANIMALS AS FOOD

Outbreaks of animal-borne infectious diseases such as Ebola, SARS, avian flu, and now COVID-19, caused by a novel coronavirus, are on the rise.<sup>223 224</sup> With COVID-19 most likely having emerged from bats and other wild animals, many people associate zoonotic diseases with exotic wild animals. However, spillover events do not occur only between wild animals and humans. The intensification of animal agriculture and aquaculture plays a key role and further escalates the risk of zoonotic pandemics. **Cramming large numbers of genetically similar individuals into unsanitary, high-density settings that induce poor health and high stress levels strongly increases the chances of pathogenic spillovers between wild animals and farmed animals, and ultimately humans.**

“

*A high density of livestock is a challenge, because if a pathogen does jump from the forest into those livestock, it can spread very readily. Pathogens spread much better when their hosts are at high density. That's what COVID is doing right now.*

**Felicia Keesing**

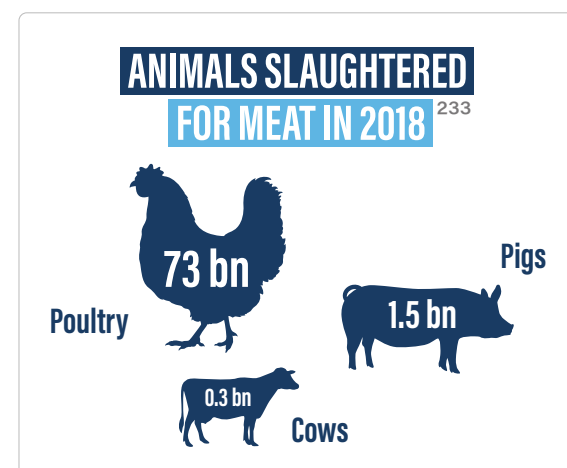
Ecologist and educator, Bard College, New York, CBC<sup>225</sup>

### Sharing viruses – farmed animals as an interface for spillovers

There is mounting evidence that human activities facilitating contact between different animal species have likely accelerated the selection of viruses that are shared by a variety of animal hosts.<sup>226</sup> Farmed animals frequently function as an interface which encourages virus spillover to, and subsequent spread among, humans.<sup>227</sup> The key role of this transmission pathway is illustrated by the fact that it is domesticated animals such as livestock who share the highest number of viruses with humans.<sup>228 229</sup> **Diseases such as diphtheria, measles, mumps, the rotavirus, smallpox, and influenza A all have their origin in domesticated animals.**<sup>230</sup>

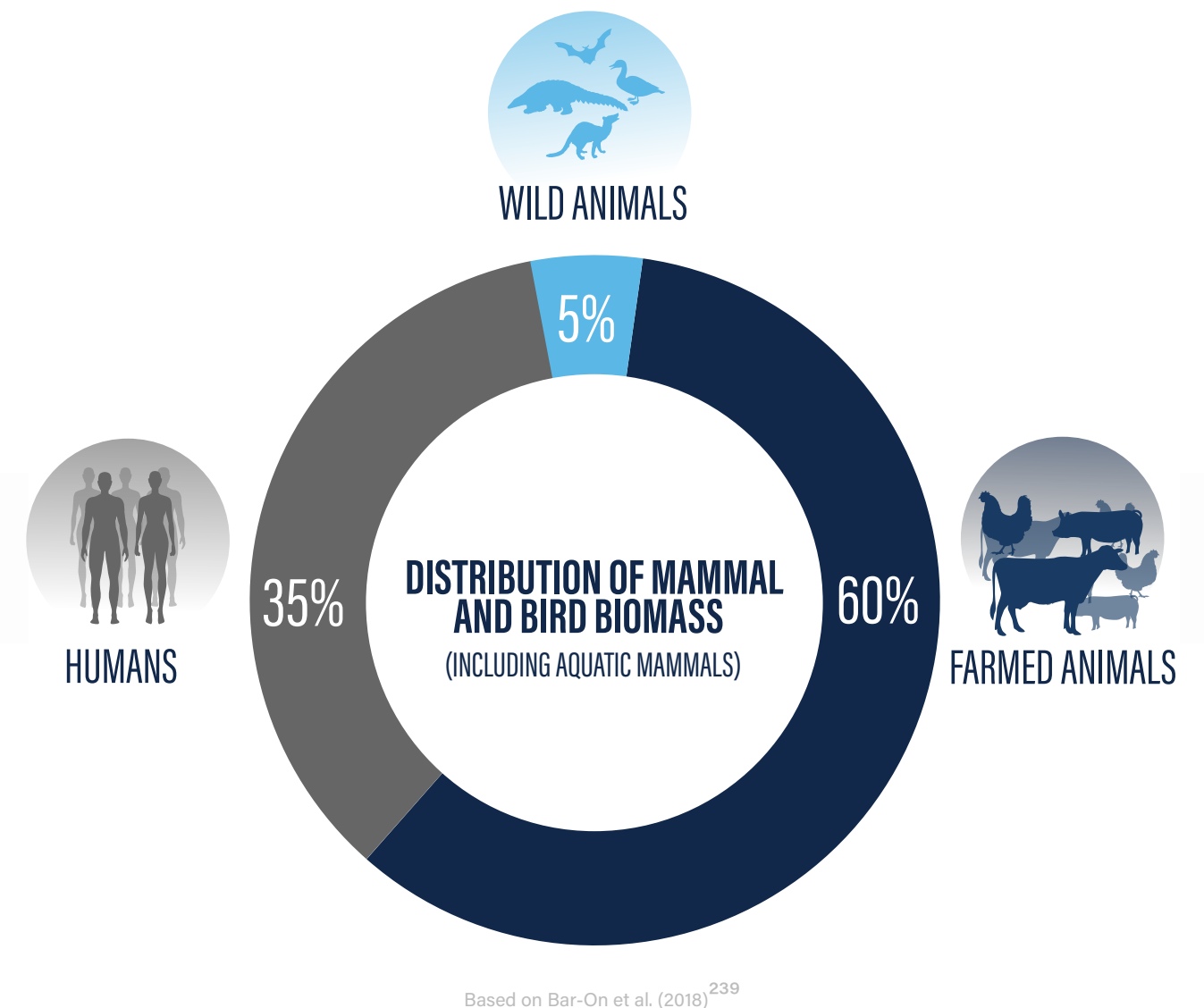
### Growing demand for animal protein is driving the intensification of animal agriculture

Today, the world is seeing a rapid growth and massive intensification of animal agriculture, fuelled by a rising global demand for meat, eggs, dairy, and seafood. **Accelerated population growth and increased prosperity levels have led to a growing appetite for animal-based products** – with chicken and pigs at the very centre of this development.<sup>231 232</sup>



### Our hunger for animal products – staggering numbers, trending upwards

Globally, more than 75 billion land animals are slaughtered for food, every single year.<sup>234</sup> This is about 10 times the number of humans living on this planet. At any point in time, there are more than 30 billion farmed animals on earth, the vast majority (82%) of them poultry such as chickens, ducks, and turkeys.<sup>235</sup> Today, livestock accounts for 60% of all mammal biomass, and poultry for 70% of bird biomass,<sup>236</sup> with these figures continuing to grow. While these numbers are already staggeringly high, they leave fish out of the equation – with aquaculture estimated to account for up to 167 billion individual fish slaughtered each year.<sup>237</sup> **The global production of meat, eggs, dairy, and seafood from intensive-production facilities is forecast to increase by 15% by 2028.**<sup>238</sup>



## Maximising productivity and pathogenic risks – breeding our way to zoonoses

Alongside strongly intensified husbandry conditions, the creation of new and more ‘productive’ breeds of cows, pigs, chickens, and fish have made these high livestock numbers possible. And they have helped to maximise the yield of meat, eggs, and milk per animal. Maximising productivity has put the world’s livestock species and their genetic diversity at risk, making them less resilient to environmental changes and pathogens.<sup>240</sup> This approach has also radically increased the number of individuals confined in high-density settings. The unnatural and unhygienic conditions of large-scale animal agriculture leads to poor health and high stress levels in individual animals.<sup>241</sup> The sum of these developments makes farmed animals more susceptible to infections,<sup>242 243</sup> and has thus created the **perfect conditions for the emergence and spread of zoonotic diseases**.



Picture by Sergey Bogdanov, Shutterstock

### High density and high virulence – the opposite of social distancing

Moreover, the close and unsanitary proximity of individuals in intensive, high-density facilities can favour the development of high virulence – that is, the increased ability of a pathogen to infect and harm a host.<sup>244 245</sup> A well-studied example of the complex connection between virulence and transmission<sup>246</sup> is the salmon louse and its host. Lice originating from farmed salmon are more harmful, i.e. they have a higher virulence (greater damage to skin tissues as a measure of virulence), than lice from wild-caught salmon.<sup>247</sup> The reasons for this are various – including high host density and limited genetic diversity, as well as reduced lifespans of the fish due to scheduled slaughtering, which may cause parasites to adapt to shorter life cycles.<sup>248</sup>

Under natural outdoor conditions, high virulence is costly to the virus, since killing its host too fast stops it from spreading if there is no new host nearby. This naturally limiting mechanism is bypassed, however, under the cramped and unhygienic conditions of factory farms and

aquaculture. There, **virus transmission, even from severely sick or dead animals to live animals, is easily possible**. Literally constituting the opposite of social distancing, this makes industrialised animal agriculture a hotbed for the evolution of pathogens with a greater virulence than is naturally possible. And it strongly encourages their eventual spread.

## Factory farm waste – spreading pathogens to the outside world

This alarming situation is further aggravated by the poor management of faeces, waste, and water in intensive-farming facilities, affecting not only the animals in those facilities but also those in close proximity outside. **The sheer magnitude of the outputs of these facilities, including both living and dead animals, excrements, and other bodily fluids, makes it effectively impossible to contain pathogens.** Existing biosecurity protocols can do little to change that (when they are in place at all). With animal agriculture continuing to rapidly expand and intrude into the natural environment, the chances of close contact between other domesticated animals (both inside and outside of farming settings) and wild animal species increase dramatically. As does the risk of zoonotic spillover events between them.<sup>249 250 251 252 253 254</sup>

There are several pathways to zoonotic spillover, including contaminated aerosol particles which can transmit viruses between farm facilities and humans.<sup>255 256</sup> For example, pig farms can be a source of infectious aerosol particles which are transported downwind.<sup>257</sup> Pathogens can also travel together with faeces, dust, debris, water, respiratory fluids, bedding, and hair particles.<sup>258</sup> Smaller particles can remain suspended for long periods, facilitating the infectivity of pathogens.<sup>259</sup>

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*Animals held in confinement produce large amounts of waste, which need to be disposed of. Much of this waste, which may contain large quantities of pathogens, is disposed of on land, posing an infection risk for wild mammals or avians. Poultry house waste is also utilized in aquaculture, a form of food animal production, which results in the creation of artificial wetlands and thereby increases direct opportunities for contact with wild avians.”*

Otte et al. (2007)<sup>260</sup>

### Bigger, faster, tighter – a risky paradigm shift

While all animal agriculture intensifies the emergence and spread of zoonotic diseases, this holds especially true for large-scale, high-density operations. Aiming for ‘optimisation’ in terms of productivity and economic efficiency, small-scale farming with a few animals, kept predominantly outdoors and foraging for food in fields, is increasingly a fading memory of the past.<sup>261</sup> Research demonstrates that significantly higher risks of H5N1 outbreaks were found in large-scale commercial poultry operations, compared to backyard flocks. In Canada, H5N1 spread rapidly, also owing to air exchange between neighbouring poultry barns. The facilities’ industrial-scale ventilation systems generate aerosolised dust which facilitates pathogen transmission. Air samples from one study revealed particle concentrations in factory farms being a million times higher than in semi-rural areas.<sup>262</sup> Given that **factory farms and aquaculture are estimated to account for more than 90% of global meat and fish production,**<sup>263</sup> **the overall trajectory points towards a greater risk of zoonotic outbreaks in the future.**<sup>264 265</sup>



“

Recent outbreaks in Asia have shown that transmission of infectious agents can arise from small farms raising poultry in proximity to domiciles and to other animals. However, because CAFOs [Concentrated animal feeding operation] tend to concentrate large numbers of animals close together, they facilitate rapid transmission and mixing of viruses. There is a concern that increasing the numbers of swine facilities adjacent to avian facilities could further promote the evolution of the next pandemic.”

Gilchrist et al. (2006)<sup>266</sup>

## Factory farming – an industrial-scale zoonoses incubator

Modern-day animal agriculture is much like **a large-scale petri dish, providing perfect conditions for viruses to emerge, spread, and cross species barriers.** The actual spillover can happen when viruses undergo genetic changes, either through antigenic shift (when different strains of a virus recombine – a process potentially accelerated by the close proximity of multiple hosts) or through antigenic drift (when small changes in the genetic information accumulate).<sup>267</sup> Both mechanisms can lead to the emergence of viruses which have the ability to infect humans. An example of an antigenic shift is the 1918 Spanish flu outbreak, which was an avian H1N1 influenza strain that mutated, probably with pigs functioning as a mixing vessel, and subsequently became transmissible between humans.<sup>268 269</sup> An example of antigenic drift is seasonal influenza.<sup>270 271</sup>

## Influenza – the classic among the zoonotic diseases

One of the most well-known examples of a constantly changing and mutating zoonotic disease that is connected to animal farming is the influenza A virus (IAV). While this virus occurs naturally among wild aquatic birds across the globe,<sup>272 273</sup> certain strains of IAV also occur in humans. This implies that the virus jumped the species barrier at some point.<sup>274</sup> **While there is widespread awareness of the threat that IAV poses to human health, little is known by the general public about its animal origins.**

### SEASONAL INFLUENZA

Influenza, commonly known as the flu, is an infectious disease transmitted by a virus. With various symptoms that can range from mild to severe, it is a seasonal disease that quickly mutates. Influenza type A is most relevant for human health and constitutes one of the most worrisome of all known infectious diseases – which is why, each year, healthcare systems brace themselves for the next flu season. **Respiratory deaths due to seasonal influenza are estimated to number between 290,000 and 645,000 globally every year.**<sup>275</sup>

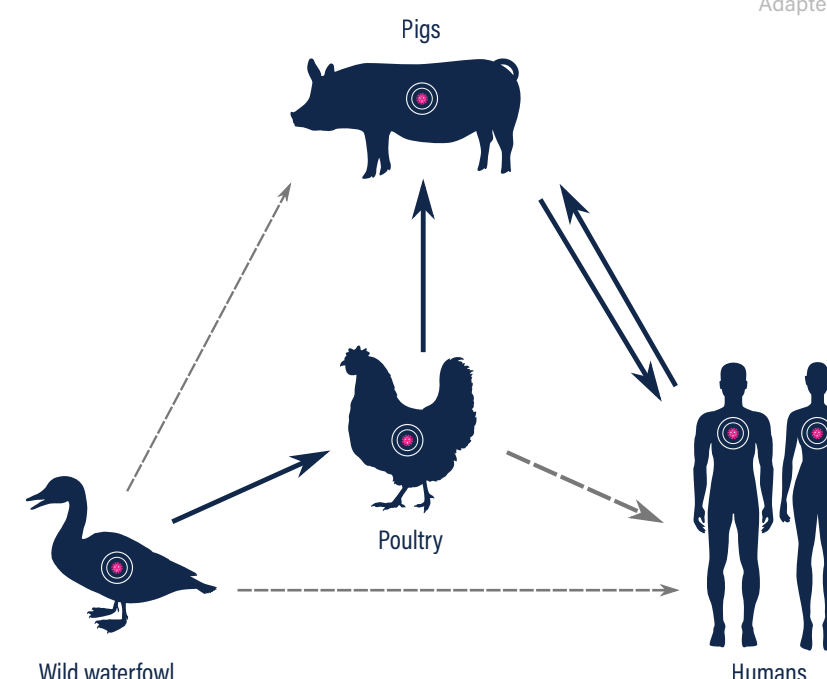


## Birds, pigs, and humans – growing populations and increasing influenza spillover risks

As probable intermediate hosts, pigs are thought to be a particularly good fit to host the processes mentioned above. Since they are susceptible to both avian and mammalian influenza viruses, they are seen as mixing vessels and transmitters for viruses, leading to the creation of new strains of viruses with zoonotic or even pandemic potential.<sup>276 277 278 279</sup> One of the primary risk factors for spillover to humans is **exposure to infected live or dead animals, for example, when raising, slaughtering, processing, or preparing them for consumption.** However, humans also transmit influenza viruses and other pathogens to animals such as pigs (reverse zoonosis), potentially also making humans the catalyst for future pandemics.<sup>280 281</sup> Either way, the ongoing close contact with, and use of, farmed animals by humans increase the future risks of further zoonotic transmission.<sup>282</sup> This holds particularly true for the transmission of influenza viruses, as **the three species involved in their emergence – poultry, pigs, and humans – are all predicted to increase in number.**<sup>283</sup>

## TRANSMISSION PATHWAYS OF INFLUENZA

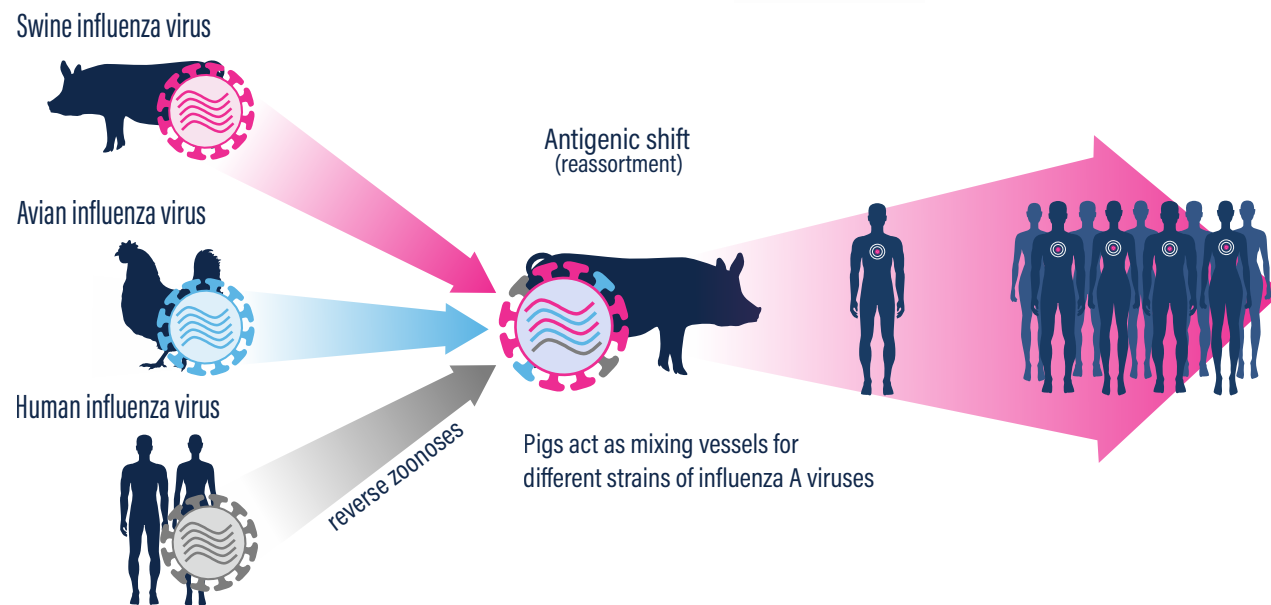
Adapted from: Ma et al. (2008)<sup>284</sup>



**73** billion chicken, ducks, geese, and turkeys slaughtered in 2018

**1.5** billion domestic pigs slaughtered in 2018

At any point in time, there are more than **30 billion** farmed animals on earth, a number that is predicted to continually increase.



### The H5N1 influenza outbreak in 2004 – just short of a global disaster

With H5N1, the world has already witnessed a frightening example of how serious a threat zoonotic spillovers involving factory farming can be. After two relatively mild pandemics in 1957 and 1968, the world teetered on the brink of catastrophe in 2004, when large parts of Asia experienced unprecedented outbreaks of the highly pathogenic avian influenza strain H5N1. There is evidence that H5N1 avian flu may have started to spread when **migratory birds wound up in close proximity to poultry farms** as the intensification of farming practices brought them closer together. The virus evolved, crossing the species barrier and infecting humans – **with a devastating case-fatality rate of up to 60%**, taking its heaviest toll on children and young adults.<sup>285 286</sup> This particular strain of the virus met all necessary prerequisites for a devastating pandemic – with only the lack of efficient human-to-human transmission preventing its extensive spread and a subsequent emergency of unforeseeable magnitude.<sup>287</sup>

### Our growing hunger for poultry – breeding the next influenza pandemic

At the time of writing, the avian influenza strain **H5N8 is causing havoc in Eastern Europe**. Since the end of 2019, there has been an increase in outbreaks of bird flu in poultry farms in Eastern Europe, leading to the killing of millions of birds.<sup>288</sup> Although the likelihood seems low, human infection with H5N8 is indeed a possibility.<sup>289</sup> However, the Asian avian influenza strain **H7N9**, which has been circulating in poultry in China since 2013, is rated by the Centers for Disease Control and Prevention (CDC) as the influenza A strain with the greatest potential to cause a zoonotic pandemic and to severely impact public health if it were to achieve sustained human-to-human transmission.<sup>290</sup> So far, human infections have only occurred sporadically but have killed about 40% of patients, **making it 400 times more dangerous and deadly than normal seasonal influenza**. Thus, our growing hunger for chicken reveals itself to be one of the most critical risk factors in breeding the next influenza pandemic.<sup>291</sup>

### Putting zoonotic risks into perspective – one mutation away from a global disaster

The case-fatality rate of COVID-19, caused by the virus SARS-CoV-2, is currently estimated to be somewhere between 0.1% and 18.9%, with a global average of about 4.7% (as of 5 July 2020).<sup>292 293</sup> The virulence of a virus such as H5N1 or H7N9, paired with the infectivity of SARS-CoV-2, would have catastrophic consequences (see graphic in 1.5). And it would take just one mutation for this to occur. To put things into perspective: **if a pandemic similar to the 1918 Spanish flu occurred today, experts expect 100 to 400 million deaths globally.**<sup>294</sup> The likelihood of this event becoming a reality increases with every single chicken and pig housed for food production – and with every single day this practice is maintained.

“

*Factory farms are the best way to select for the most dangerous pathogens possible.”*

**Rob Wallace**

Evolutionary Biologist at the Agroecology and Rural Economics Research Corps in St Paul, Minnesota, Vox<sup>295</sup>



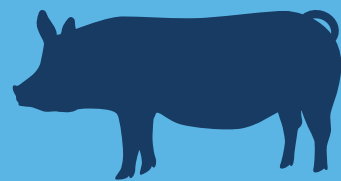
Picture by SOMRERK WITTHAYANANT, Shutterstock



## Infectious disease outbreaks – backfiring on animal agriculture

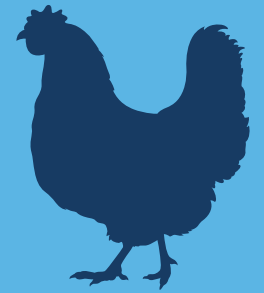
The development of new infectious zoonotic diseases as a result of intensified animal agriculture does not only pose a threat to human health and healthcare systems. It also backfires on the industry itself in various ways – in turn, negatively impacting humans, animals, and the food system. Animal agriculture is affected by a host of endemic and reemerging infectious diseases on an ongoing basis, including African swine fever (ASF), swine flu, and avian flu. Not only do these diseases have **profound ethical implications** – with animals suffering and dying from them, as well as being culled to curb their spread. They also cause **enormous economic damage to meat, dairy, and poultry producers** – from small-scale subsistence agriculture to large-scale commercial farming.

**African swine fever** (ASF) is a highly contagious viral disease found in pigs, for which there is no cure or vaccine, and which has a mortality rate of up to 100%.<sup>296</sup> ASF ranks among the most prevalent diseases affecting the pork industry. In 2019 25% of the global domestic pig population either died from the disease or were culled in order to prevent its spread.<sup>297</sup> Globally, the economic costs of ASF are estimated to amount to several hundreds of billions of dollars. At the time of writing, **the pork industry in Western Europe is on high alert, with an outbreak of ASF on a Polish pig farm close to the German border.**<sup>298</sup>



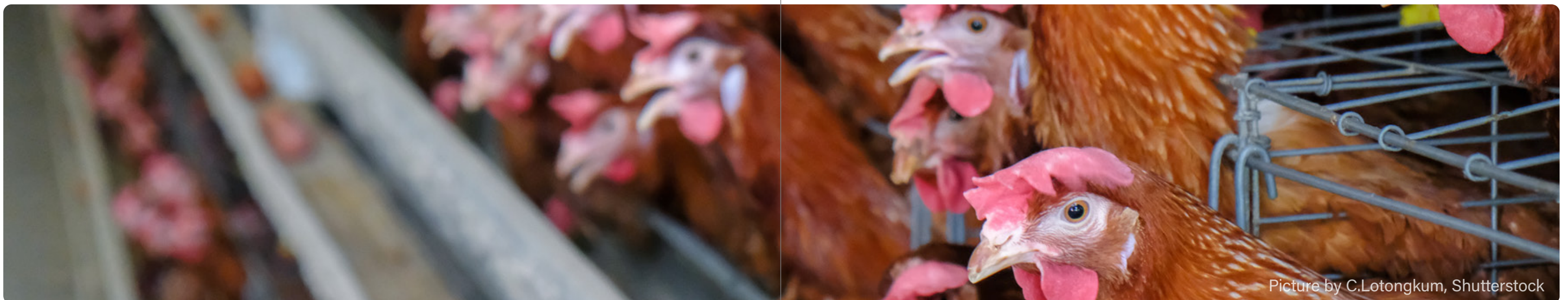
**Swine flu** is a respiratory disease that is **endemic in pig populations around the world, with a morbidity rate of up to 100%.**<sup>299</sup> Due to the constantly evolving nature of the virus and pigs acting as ‘mixing vessels,’ swine flu has transformed from a seasonal disease to a disease that is prevalent all year round. And because of the constant mutation, significant efforts are needed to continuously develop new vaccines.

**Avian flu** is a viral disease that is highly contagious and regularly decimates farmed poultry around the globe. With **repeated spillover events to humans taking place, drastic containment measures have had to be put in place.** In 1997, an outbreak in Hong Kong led to the culling of the entire 1.4-million chicken population – with recurring outbreaks and similar levels of death and culling taking place again in 2001 and 2002. Similarly, the emergence of a highly pathogenic avian flu strain in the Netherlands in 2003 resulted in the death of 23 million chickens.<sup>300</sup> During the H5N1 outbreaks in Asia, up to 140 million birds died or were killed within the space of three months. According to the FAO,<sup>301</sup> it led to **the culling of 400 million domestically farmed birds across the globe**<sup>302</sup> – more than the combined total of all previous large outbreaks of highly pathogenic avian influenza recorded in the previous 40 years.<sup>303</sup>



## Animal industry workers – victims and vectors

Many of the diseases circulating among farmed animals can infect humans, thus becoming zoonotic. Being in constant contact with potentially infected animals exposes those working in the animal industry to greater risk, putting them on the frontline of possible spillover events. There is substantial evidence that farmers, veterinarians, and abattoir workers, particularly, are at an increased risk of contracting zoonotic diseases and play an important role in their spread,<sup>304</sup> with one particular outbreak **putting this group at a 1,500-times higher risk** than the general population (see also 3.1).<sup>305</sup>



Picture by C.Lotongkum, Shutterstock



## COVID-19 impacting the animal industry

**While COVID-19 did not originate in factory farms and slaughterhouses, it has nonetheless found its way into them.** With its multiple impacts, the current pandemic has demonstrated **the profound vulnerability and fragility of the animal industry**, as well as a host of serious ethical and economic implications for humans, animals, and the food system.

### Direct impacts – coronavirus in slaughterhouses, and workforce shortages

Abattoirs around the world have become significant vectors for infection and have faced unprecedented outbreaks of COVID-19, affecting thousands of slaughterhouse workers.<sup>306 307</sup> In the US, more than 20,000 meat packers have fallen ill, reducing the country's total hog-slaughtering capacity by 25%.<sup>308</sup> In Germany too, hundreds of slaughterhouse workers have tested positive for the virus, with the Netherlands, Ireland, France, and the UK reporting similar cases.<sup>309 310</sup> Disruptions and closures of slaughterhouses around the world have shone a light on the poor working and living conditions of their employees. Routinely working through subcontractors for substandard wages, the largely untrained workforce stems from economically deprived backgrounds – and are often from other countries. They have to endure cramped working conditions, mass accommodation and catering, poor sanitation, and a lack of compliance with safety procedures.<sup>311 312 313</sup> The current crisis demonstrates the disproportionate vulnerability of the meat-processing sector to the pandemic – particularly since **its workforce has to endure the same high-density environment as the animals they process.**

### Cullings – killing animals as a systems requirement

As the meat-processing industry faces significant disruptions due to COVID-19, workforce shortages also require the culling of animals that cannot be processed. A single processing facility in the US was recently forced to **kill 2 million chickens**, while another one is expected to **cull 13,000 pigs a day**, with their carcasses ending up in landfills.<sup>314 315</sup> As with all killings of animals, **culling has serious ethical implications.** This holds especially true since the killings, related to a lack of processing capacities, serve no purpose at all but are simply a consequence of the system. Moreover, cullings often involve particularly inhumane practices – such as foam suffocation (pouring large quantities of foam on poultry to make them suffocate), ventilation shutdown (purposefully turning off the barn's ventilation system to let animals die of heat stress and organ failure), or maceration (feeding live birds into high-speed grinders). Such practices may also **incur significant reputational risks for producers.**<sup>316</sup>

## Indirect impacts – reduced consumer demand and wastage

COVID-19 is also dealing an indirect blow to the fragile system of animal agriculture through a decrease in consumer demand. Restaurants, canteens, school cafeterias, and coffeeshops around the world have been forced to close due to lockdown and containment restrictions. This has led to sharp drops in demand, particularly in the food-services industry. As a consequence, **farmers in the UK dump an estimated 1 million litres of milk each day,<sup>317</sup> while in the US it is an estimated 14 million litres every day.<sup>318</sup>** Beyond the dairy industry, other animal-agriculture sectors are also affected. In addition to lockdown-related decreases in demand, there are other factors driving down demand for animal products, including **consumers looking for safer alternatives in the wake of the COVID-19 crisis** (see Part II).



### Factory farms – the perfect accelerators for pathogen emergence

The current COVID-19 pandemic did not originate in factory farms but most likely came from using wild animals as food, probably involving bats and pangolins. Yet, simply looking at wildlife markets in specific geographical regions while ignoring the broader picture of the use of animals for food overlooks the elephant in the room. Factory farming – everywhere in the world – represents the perfect accelerator for the emergence and transmission of pathogens between farmed animals, wild animals, and humans. **Each new factory farm increases the risk of the next virus spillover – as well as the next zoonotic pandemic.**

“

*If you actually want to create global pandemics, then build factory farms.”*

**Dr Michael Greger**

Physician and founder of NutritionFacts.org, Vox<sup>319</sup>



### 3. FOOD-RELATED DISEASES AND OTHER FACTORS INCREASING THE IMPACT OF PANDEMICS

In addition to the risks of newly emerging pathogens, there are other factors that can further exacerbate the overall impact of zoonotic pandemics. Antimicrobial resistance and the resulting superbugs, other communicable food-borne diseases, and non-communicable diet-related diseases all pose additional risks for individual health and present massive strains on healthcare systems, particularly in the context of a pandemic. Again, they are all factors that are **related to our animal-based food system**.

#### 3.1 ANTIMICROBIAL RESISTANCE (AMR)

The discovery of antibiotics was one of the key medical achievements of the 20th century. Yet, less than 100 years after Alexander Fleming first discovered penicillin, the world is on the cusp of a post-antibiotic era, with multi-resistant strains of bacteria emerging at alarming rates all around the world. **The United Nations has declared antimicrobial resistance (AMR) a global health risk**, stressing that deaths due to AMR could soon surpass annual cancer fatalities.<sup>320</sup> Globally, antimicrobial-resistant infections currently claim at least 700,000 lives each year. This number could reach an **annual toll of 10 million by 2050**.<sup>321 322</sup> Common bacterial infections that used to be easily treatable with the aid of antibiotics can now be fatal – again! This is not only a problem for individual and public health in and of itself, with AMR having become one of hospitals' biggest challenges.<sup>323</sup> It also renders affected individuals even **more vulnerable to novel pathogens and adds to the massive strain on healthcare systems during a pandemic**.

#### Animal agriculture – the unrecognised driver of AMR

While there is growing awareness of the challenge of AMR, little is known about the driving force behind it. Animal agriculture is chiefly responsible for the development of AMR. **Globally, more than 70% of antibiotics are used on animals in intensive farming – to prevent losses owing to the problematic breeding and husbandry conditions, and to accelerate growth and profits – rather than for the treatment of humans**.<sup>324</sup> Yet, the main focus when tackling antimicrobial resistance is usually on the importance of doctors prescribing antibiotics appropriately, rather than on their large-scale misuse in animal agriculture.

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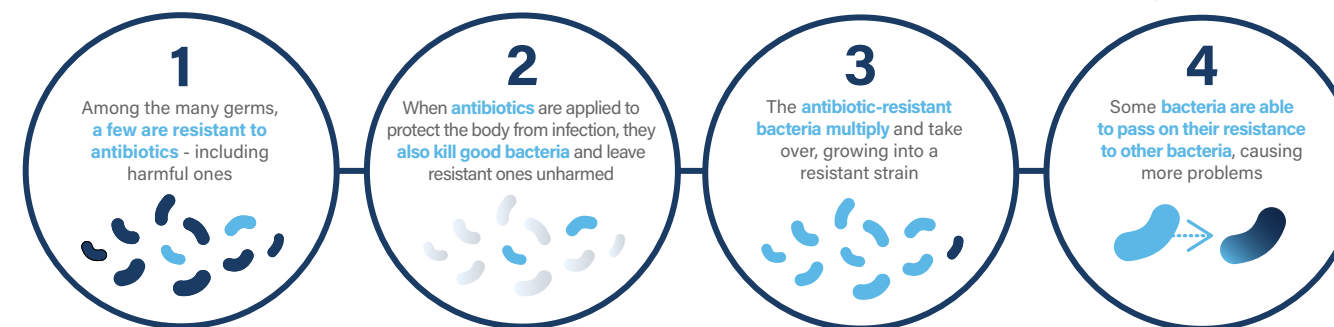
*We use tremendous quantities of antibiotics on animals that are not ill. It's not a therapeutic use; it's prophylactic, and it increases yield, so it's economically viable because antibiotics are cheap. To be honest, antibiotic resistant bacteria are globally perhaps the most important source of disease emergence.”*

**Dr. Richard Ostfeld**

Disease Ecologist at the Cary Institute of Ecosystem Studies in Millbrook, New York, The Counter<sup>325</sup>

### ANTIBIOTIC ABUSE - CREATING ANTIMICROBIAL RESISTANCE

adapted from: CDC<sup>326</sup>



#### AMR in pandemics – a profound risk multiplier

Although antibiotics are not able to kill or inhibit viruses, their declining efficacy in treating bacterial pathogens aggravates the overall health risk for humans and increases the burden on healthcare systems.<sup>327</sup> They are essential in fighting bacterial infections which may accompany a primary viral infection. Lower and upper respiratory infections are the fourth-highest cause of global mortality and are usually caused by a virus.<sup>328</sup> However, additional secondary bacterial infections are common complications, increasing the severity of a viral infection and further raising the morbidity and mortality rates of viral diseases.<sup>329</sup> When antibiotics are effective and readily available, this risk decreases. However, with more and more strains of antimicrobial-resistant bacteria emerging, AMR can further escalate an epidemic or a pandemic. In the case of influenza, for instance, bacterial infections are assumed to contribute to up to 50% of total deaths.<sup>330 331 332</sup> During the 2009 swine influenza pandemic, cases of secondary bacterial infections increased, causing up to 55% of total deaths.<sup>333</sup> This makes AMR **a massive risk in and of itself – as well as a profound risk multiplier in the context of a zoonotic pandemic**.

“

*If [influenza] condemns, the secondary infections execute.”*

**Louis Cruveilhier (1919)<sup>334</sup>**

#### ANTIMICROBIAL RESISTANCE (AMR)

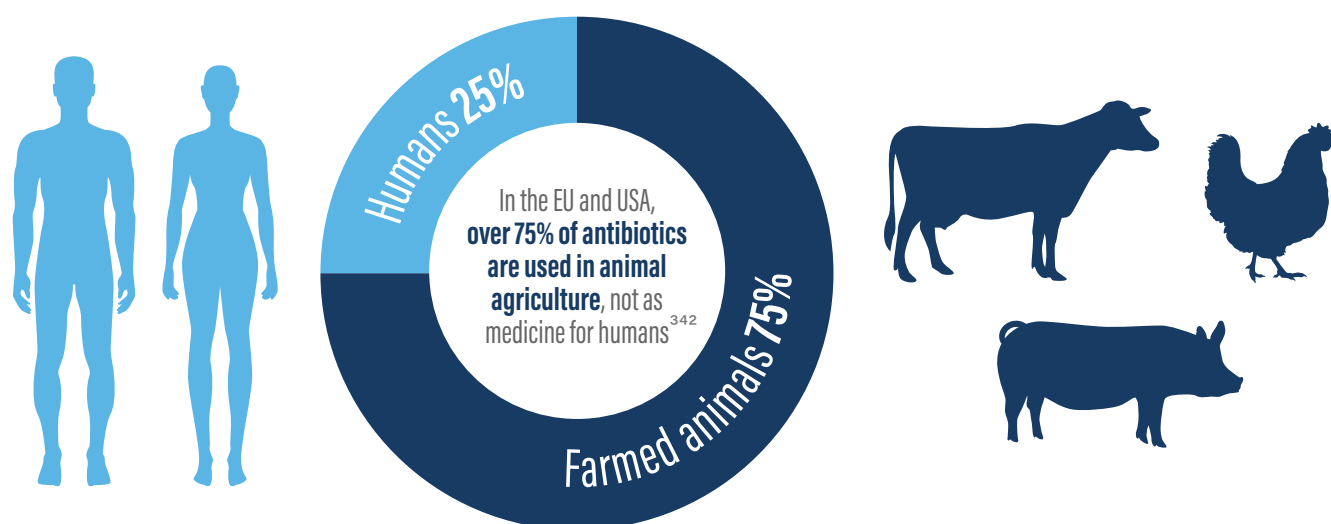
Antimicrobials (including antibiotics, antiviral, and antifungal medicines, as well as disinfectants and sanitisers) are compounds that kill or inhibit the growth of harmful microorganisms such as bacteria, fungi, and viruses. However, microorganisms may acquire resistance to specific antimicrobials (such as medical antibiotics or disinfectants). **The overuse of antimicrobials encourages the development of antimicrobial resistance (AMR). If bacteria acquire resistance against multiple antibiotics, they are called multiresistant or 'superbugs'.** As a result, antimicrobials such as antibiotics become ineffective, and it becomes harder to treat infections, leading to prolonged illness, higher medical costs, and increased mortality. The more antibiotics are used, the less they are effective. **Indiscriminate use in animal agriculture is the main driver of the escalating AMR emergency.**

## Towards a post-antibiotic era

Research on the 1918 influenza pandemic revealed that secondary bacterial infections might have been the main cause of death, probably responsible for up to 90% of fatalities.<sup>335</sup> This happened in the pre-antibiotic era, when the treatment of bacterial infections was still a challenge. With more and more antibiotic-resistant bacteria, and AMR increasingly posing a global health risk again, we are now headed for a post-antibiotic era. **Without effective treatment for secondary bacterial infections, future pandemics are poised to get worse,** leaving health professionals helpless against a threat we thought we had overcome.

## Animals, humans, and AMR

While physicians and patients are supposed to follow strict antibiotic prescription guidelines in order to prevent AMR, that advice again misses the elephant in the room: globally, more than 70% of antibiotics are not used for the treatment of humans but for animals in intensive farming setups.<sup>340</sup> The key problem here is the overlap: 76% of the antibiotics commonly used in agriculture and aquaculture are also important in human medicine<sup>341</sup> – with the animal-usage dramatically decreasing the efficacy of antibiotics intended for humans.



## COVID-19 DRIVING THE AMR CRISIS

**Paradoxically, the virus-caused Covid-19 pandemic itself has the potential to escalate the global AMR situation even further.** Although ineffective on viruses, antibiotics are being administered to COVID-19 patients to prevent superinfections – that is secondary bacterial infections that could exacerbate the primary viral infection. This approach is routinely applied as a precautionary measure and is often unwarranted, strongly increasing the risk of AMR development.<sup>336 337 338</sup> Moreover, the significantly increased use of disinfectants and sanitisers during the COVID-19 pandemic may further drive AMR. Bacteria can acquire resistance to the very products designed to kill them, increasing the number of strains of antimicrobial-resistant bacteria. Not only does this put further strain on health-care systems, causing more deaths, it could also **remain a problem long after the current COVID-19 pandemic has abated.**<sup>339</sup>

## Preventing losses and accelerating growth in factory farms – a recipe for AMR emergence

Animal farming is the main consumer of antimicrobial medicines due to its problematic breeding and husbandry conditions. Farmed animals suffer physically from impaired immune systems, weaker bones or cardiovascular systems, and bodily mutilations, as well as from genetic predisposition to various injuries and diseases.<sup>343</sup> They also experience mental suffering due to a range of causes, including stress, the inability to display normal behaviour, and severely restricted movements due to overcrowding or otherwise unsuitable husbandry,<sup>344</sup> as well as from unhygienic conditions.<sup>345 346</sup> This makes the animals more vulnerable to infectious diseases. **In intensive-farming facilities, outbreaks are more common and harder to control when they occur.**<sup>347 348</sup>

In order to prevent excessive losses of animals – and thus profit – a seemingly ‘easy’ solution is the extensive use of antibiotics. This is why antibiotics are routinely given, for example, to sows who are kept continuously impregnated, except for a few weeks after giving birth, or to young pigs in order to reduce disease symptoms caused by stressful early weaning.<sup>349</sup> Antibiotics are also administered to poultry to combat heat stress, overcrowding, and other substandard living conditions.<sup>350</sup>

The majority of animals are treated with antimicrobial medicine as a preventive measure. However, antibiotics are not administered to animals only for disease control. Some of these drugs also **induce growth and weight increase in animals** – a welcome side-effect for the animal-farming industry, as it reduces the timespan needed for animals to reach their slaughter weight or increase it. Unsurprisingly, this has led to very generous use of these drugs.<sup>351 352</sup> And, while regulatory efforts have attempted to curb such misuse of vital antibiotics, in reality, they have mostly failed.<sup>353</sup>

“

*In the future, we should fully expect our maltreatment of animals to wreak havoc on our own species. In addition to future pandemics, we face the very real risk of breeding antibiotic resistance. The major contributor to this is the use of antibiotics in the animal-agriculture industry, as a growth promoter (to bring animals to slaughter weight as quickly as possible) and to curb the spread of infections among animals reared in cruel intensive ‘factory farmed’ conditions”.*

David Benatar

Professor of Philosophy and Director of the Bioethics Centre at the University of Cape Town, NY Times<sup>354</sup>

## Wasting powerful drugs on animal agriculture – including antibiotics of ‘last resort’

Two of the most commonly used antibiotics in animal agriculture are tetracyclines and fluoroquinolones, both of which are also used to treat various severe illnesses in humans, **including cholera and malaria.**<sup>355 356</sup> Resistance to tetracyclines has already been detected in industrial poultry farming.<sup>357 358</sup> And the use of fluoroquinolones also poses a public-health concern as they are suspected of encouraging **bacterial resistance, which can be transmitted into the food chain.**<sup>359</sup> The misuse of antibiotics in animal agriculture also



extends to drugs of 'last resort' – that is, antibiotics which are used as a last line of defence for humans whose infections are failing to respond to standard drugs. Life-saving medicines for humans, such as colistin, are wasted, mostly on healthy animals in order to boost their growth and weight, or to prevent them from contracting infectious diseases resulting from inadequate husbandry conditions.<sup>360 361</sup> Colistin is used in the treatment of *E. coli* infections (see 3.2) but also to treat pneumonia. Resistance to colistin has been detected around the world<sup>362</sup> with **nearly 100% of farmed animals in some regions – as well as a rising number of people – carrying the resistant gene.**<sup>363</sup> Since colistin is a valuable drug that is used to treat multi-resistant bacteria, this development poses a serious and growing global threat.<sup>364</sup>

### Factory farms and aquaculture – breeding grounds for dangerous superbugs

There is a strong link between the intensive use of antibiotics in animal farming and the rapid emergence of new resistant bacteria, leading to a record level of superbugs in various domesticated animal species.<sup>365 366 367 368</sup> (Superbugs are microorganisms that have developed multi-drug resistance.) This holds particularly true for the clear increase in resistant bacterial strains occurring in chickens and pigs.<sup>369 370 371</sup> Globally, the production of animal-based products is estimated to increase by 15% by 2028.<sup>372</sup> This increase in meat, milk, and egg production also implies a rise in antibiotics use in animal farming, which is projected to rise by 67% by 2030<sup>373</sup> – with some countries expected to see an up-to-80% increase.<sup>374</sup> Global AMR maps (available at [resistancebank.org](https://resistancebank.org) and [ourworldindata.org](https://ourworldindata.org))<sup>375 376</sup> show that **the countries with the highest resistance rates are also the countries that have the highest use of antimicrobials commonly used by humans also used in animal farming.**<sup>377 378</sup>



Picture by neenawat khenyothaa Shutterstock

The indiscriminate use of antibiotics makes **the aquaculture sector another hazardous breeding ground for AMR**<sup>379</sup> – and one that deserves special attention, since aquaculture is one of the fastest-growing food-production sectors worldwide.<sup>380</sup> Global fish production rose to about 171 million tons in 2016, with aquaculture constituting 47% of the total.<sup>381</sup> As aquaculture intensifies in order to meet global demand, so too do the diseases and pathogens affecting aquatic animals.<sup>382 383</sup> The intensification of aquaculture enables an ideal setting for rapid changes in pathogen populations, genetic exchange, and recombination to take place. All of these factors have long-lasting evolutionary effects on pathogen virulence and outbreaks.<sup>384 385</sup> Furthermore, many countries practice an integrated agriculture-aquaculture farming system in which aquaculture is sustained via livestock and human waste, maximising the exposure of animals, humans, and the environment to AMR.<sup>386 387</sup>

### Animal-agricultural waste and the spread of AMR

Factory farms produce large quantities of waste, which, in most cases, is disposed of in nearby areas.<sup>388</sup> This increases the risk of the transfer of AMR genes to farmed animals, humans, wildlife, and watersheds.<sup>389 390</sup> Antibiotics not only pose a direct threat to overall human health but also have an impact on the environment. Most of the antibiotics are excreted and disseminated into the environment via run-off water or manure used as fertiliser, after which they get into rivers, lakes, and groundwater used for human consumption, as well as into our soils. In this way, they potentially **alter the microbial community and cause the emergence of new resistant strains.**<sup>391 392</sup>

“

*Pathogens cross borders with impunity, not only on meat but through the environment and in the bodies of people who have already acquired them.”*

**Maryn McKenna**

Author of *Plucked*, *The Independant*<sup>393</sup>

### Animal-agriculture workers and the spread of AMR

Factory farms enable frequent and close contact between animals and people who work on or live close to the farms. Methicillin-resistant *Staphylococcus aureus* (MRSA) is a clinically significant superbug that causes infections of the respiratory system worldwide. In Germany alone, there are about 132,000 cases of MRSA each year. MRSA is widespread in various different species of farmed animals and is easily transmitted to humans who are in direct contact with them.<sup>394</sup> In German regions with high numbers of farmed animals, **86% of hospital-admitted MRSA cases are farmers, and more than 4% are farmers' relatives.**<sup>395</sup>



## AMR AND POVERTY - A VICIOUS CIRCLE



Drug-resistant infections have become harder to treat globally, but the burden of bacterial infections is higher in low-income countries and vulnerable communities.<sup>396 397</sup> In low-income countries, many people lack access to basic and affordable healthcare facilities and often attempt to self-medicate.<sup>398</sup> In combination with poor infection control, a lack of education, and inadequate sanitary conditions, this encourages the spread of AMR.<sup>399 400 401</sup> Poverty-related infectious diseases such as tuberculosis (TB)<sup>402 403</sup> are at the centre of the AMR challenge. TB kills 1.5 million people every year (more than any other infectious disease) – 214,000 of which die from multi-drug-resistant TB.<sup>404 405</sup> In addition to its disastrous health impacts, AMR also has profound secondary consequences – such as exacerbating global poverty and inequality. Illness always tends to have a disproportionate financial impact on the poor and disadvantaged. AMR poses a huge challenge for the economies of low-income countries because it renders the treatment of diseases harder and more expensive.<sup>406</sup> This makes it a fundamental developmental problem. The World Bank estimates that, **by 2050, 28 million people might face extreme poverty every year due to AMR**, of whom the majority (26.2 million) would be in low-income countries, resulting in global economic costs of US\$1 trillion per year.<sup>407</sup> **Poverty and AMR form a vicious circle, with AMR exacerbating poverty, and poverty facilitating the spread and development of AMR.**<sup>408 409</sup>

## AMR – the superbugs we grow in our farms

Instead of using antibiotics to keep humans healthy, our current food system wastes these valuable drugs in order to maintain the lives of animals who would otherwise not be viable under the circumstances they are kept in – all in order to produce large amounts of cheap animal-based products. As a consequence of the ever-increasing global demand for animal-based products, the unabated growth of antimicrobial resistance is particularly alarming, since the massive misuse of antimicrobial drugs increases the risk of the impacts of pandemics becoming even more severe.

“

*Misuse and overuse of existing antimicrobials in humans, animals and plants are accelerating the development and spread of antimicrobial resistance. Antimicrobial resistance poses a formidable challenge to achieving Universal Health Coverage and threatens progress against many of the Sustainable Development Goals, including in health, food security, clean water and sanitation, responsible consumption and production, and poverty and inequality.”*

**IACG (2019)** IACG (2019): No time to wait: Securing the future from Drug-Resistant Infections<sup>410</sup>

The current model of animal agriculture **not only enables and encourages viral evolution and transmission, but also increases antimicrobial resistance**. This alarming combination poses a threat to human health everywhere, regardless of whether people eat the animals raised under those conditions or not.

In terms of the increase in antibiotic resistance, there is a further connection with our animal-based food system and what we eat: **many microorganisms that have developed antimicrobial resistance are also involved in food-borne diseases**. These include *Salmonella*, *Clostridium*, *Campylobacter*, *Staphylococcus*, *Escherichia coli* (*E. coli*), and *Listeria*. Crucially, they all have meat or dairy as their main sources.<sup>411 412</sup>

## 3.2 OTHER COMMUNICABLE FOOD-BORNE DISEASES

As well as their involvement in the spread of viruses and the development of AMR, **animal-based products also pose other direct health risks that can worsen the impact of a zoonotic pandemic**. There is a host of communicable diseases that are associated with the consumption of animal-based products, creating additional risks for individual health and putting additional strain on healthcare systems. WHO estimates that, **in 2010, unsafe food caused 600 million cases of food-borne diseases and more than 400,000 deaths**.<sup>413</sup> While virtually every food contains toxins or pathogens when spoiled, when it comes to food-borne infections of humans, animal-based products deserve special attention. Not only do they harbour some particularly harmful microorganisms, but the sourcing of animal-based products also increases the antimicrobial resistance of these pathogens (see 3.1), rendering them even more dangerous.



“

*With the increase in animal factories, we are opening the door to antibiotic resistant diseases like salmonella, E.coli, campylobacter and the pig strain of MRSA that spread from the workers and neighbours, through the air and contaminated water.”*

**Tracy Worcester**

Farms not Factories, The Independent<sup>414</sup>

## Campylobacteriosis – chickens as a reservoir of bacteria

Infection with *Campylobacter* is one of the most prevalent food-borne diseases, responsible for one out of four cases of diarrhoeal diseases, as well as being the most common cause of human gastroenteritis, globally.<sup>415</sup> Chickens are a natural reservoir for *Campylobacter*. Infected birds carry a very high load of the bacteria in their gastrointestinal tract, which results in contaminated muscles, blood, and bones in the slaughtering and processing stages, which can then lead to the transmission of the pathogens to humans.<sup>416</sup> In many parts of the world, *Campylobacter* shows high levels of resistance to antibiotics such as tetracyclines and fluoroquinolones. The **resistance to fluoroquinolones seems to be associated with their use in poultry farming**. The campylobacteriosis case-fatality rate fluctuates between <0.01 % and 8.8%.<sup>417</sup>



Infections with *Campylobacter* can result in serious long-term impacts on individual health. Among them are Guillain-Barré syndrome (GBS), reactive arthritis, and irritable bowel syndrome. GBS is an autoimmune response that can lead to the deterioration of the nervous system, and is quite severe, with 20% of cases requiring intensive care, and a case-fatality rate of between 3% and 10% in high-income countries.<sup>418</sup> Globally, one in three GBS cases is triggered by *Campylobacter*.

### Salmonellosis – eggs and excretion

A pathogen that is more familiar to the general public is *Salmonella*, which causes salmonellosis. **Salmonellosis occurs after consumption of food or water that has been contaminated by the fecal or urinary excretions of animals** that are reservoirs of *Salmonella*.<sup>419 420</sup> *Salmonella* lives naturally in the intestines of many different animals, including rodents, poultry, pigs, and dogs.<sup>421</sup> **A recent study links the emergence of human-adapted *Salmonella* to the introduction and intensification of animal farming.**<sup>422</sup> *Salmonella* causes typhoid fever (Typhoidal *Salmonella*) as well as gut distress (non-typhoidal *Salmonella*).<sup>423</sup>



Typhoidal *Salmonella* is responsible for typhoid fever, which constitutes an ongoing burden on developing countries. Between 11 and 21 million people contract typhoid fever annually, and up to 161,000 people die from it.<sup>424</sup> Its overall case-fatality rate ranges between 2.5% and 4.5%.<sup>425</sup> Non-typhoidal *Salmonella* (NTS) is one of the main causes of bacterial diarrhoea worldwide and causes around 153 million cases of gastroenteritis globally annually.<sup>426</sup> NTS is responsible for the death of more than 50,000 people each year, particularly the very young and the elderly. In 2017, the case-fatality rate for NTS was 14.5% for all ages.<sup>427</sup>

The emergence of highly virulent and antibiotic-resistant *Salmonella* has led to greater morbidity and mortality in humans, particularly in the last few decades. A considerable number of **multiresistant strains that have emerged in animal farming show resistance to a wide variety of antibiotics, constituting a significant food-safety hazard.**<sup>428 429</sup>

### *E. coli* – friend and foe

The bacteria *Escherichia coli* (*E. coli*) normally live in the intestines of humans and other animals. While many strains are harmless and part of a healthy gut microbiome, some can produce toxins that lead to severe diseases.<sup>430 431</sup> ***E. coli* human infections occur when consuming food or water contaminated with faeces**, with the consequences varying from mild to severe diarrhoea for most of those infected. However, in a tiny percentage of cases, infants may develop haemolytic uraemic syndrome (HUS), a life-threatening disease that causes kidney failure and the destruction of red blood cells.<sup>432 433</sup>

There are different groups of pathogenic *E. coli*. One of the best known groups, Shiga toxin-producing *E. coli* (STEC), causes abdominal cramps and diarrhoea and is primarily **transmitted through the consumption of raw or undercooked animal-based products such as meat and milk**. Ruminants, mainly cattle, are recognised as its primary natural reservoir.<sup>434</sup> Some outbreaks are associated with the consumption of fruit and vegetables such as lettuce, sprouts, and spinach which have been **cross-contaminated through the use of manure as fertiliser or via contaminated water.**<sup>435</sup> STEC is responsible for 90% of HUS cases in infants<sup>436</sup> and causes about 2.8 million cases of acute illnesses, annually.<sup>437</sup> Although STEC case-fatality ratios are low, its economic impacts are far more severe.<sup>438</sup> As with other food-borne diseases, **antibiotic resistance in *E. Coli* is on the rise, with animal farming at the forefront of producing antibiotic-resistant strains.**<sup>439 440</sup>

### Food-borne diseases – the risk of eating what is close to us

Looking closely, it is not surprising that many food-borne pathogens are derived from animal-based products. For one thing, **humans are evolutionarily much closer to other animals than to plants or fungi**. A virus that has adapted to infect a pig's lung cell requires much less of a shift in its genetic material in order to be able to infect a human lung cell than would a virus originally adapted to infect a plant cell.

Additionally, **the processing of animals poses a contamination risk that is difficult to control**. Evisceration processes at slaughterhouses can easily lead to the cross-contamination of meat by fecal matter, which may spill when the organs are being removed, resulting in infections of a wide range of organs in humans consuming the contaminated meat. Finally, there is **the risk of handling and preparing raw animal-based products at home**. Even if the chicken is properly cooked, the tomatoes on the same chopping board might not be.

With every single meal containing animal-based products, the risk of contracting food-borne diseases increases. Although these food-borne diseases do not cause pandemics, **they come at a considerable cost to individual health and healthcare systems – and consequently have the potential to worsen the impact of pandemics.**



### 3.3 NON-COMMUNICABLE DIET-RELATED DISEASES

While all eyes are currently on communicable diseases, it is important to note that, in many countries, the major burden on the healthcare sector and people's quality of life usually lies elsewhere. Ischaemic heart disease and strokes are the world's biggest killers – in high-income countries, nine out of the 10 leading causes of death are non-communicable diseases.<sup>441</sup> Statistically, **chronic diseases constitute by far the greatest pandemic**. And neither social distancing nor recommended hygiene procedures can protect us from them.

#### Animal-based products – a double-risk diet

There is mounting evidence that the development of diet-related chronic diseases such as obesity, type-2 diabetes, and cardiovascular diseases, as well as some forms of cancer, is made **more likely by the excessive consumption of animal-based products**. All of these conditions constitute, in and of themselves, serious threats to individual and public health. Additionally, they put people in a **high-risk group during a pandemic such as COVID-19, putting further strain on individual health and healthcare systems**.

#### Lifestyle diseases – tipping the scale for COVID-19 patients

Early studies from China show that the risk of a severe case of COVID-19 is significantly increased in people with diet-related diseases. Data from 1,590 laboratory-confirmed hospitalised COVID-19 patients shows that people with hypertension and cancer had particularly severe cases, defined as being admitted to an intensive care unit, requiring invasive ventilation, or death.<sup>442</sup> A second analysis of a total of 72,314 patient records shows that people over the age of 80 had the highest case-fatality rate of all age groups, at 14.8%, followed by patients with cardiovascular disease (10.5%), diabetes (7.3%), chronic respiratory disease (6.3%), hypertension (6.0%), and cancer (5.6%) – most of which are so-called lifestyle diseases that are closely linked to the ways we eat and live.<sup>443</sup>



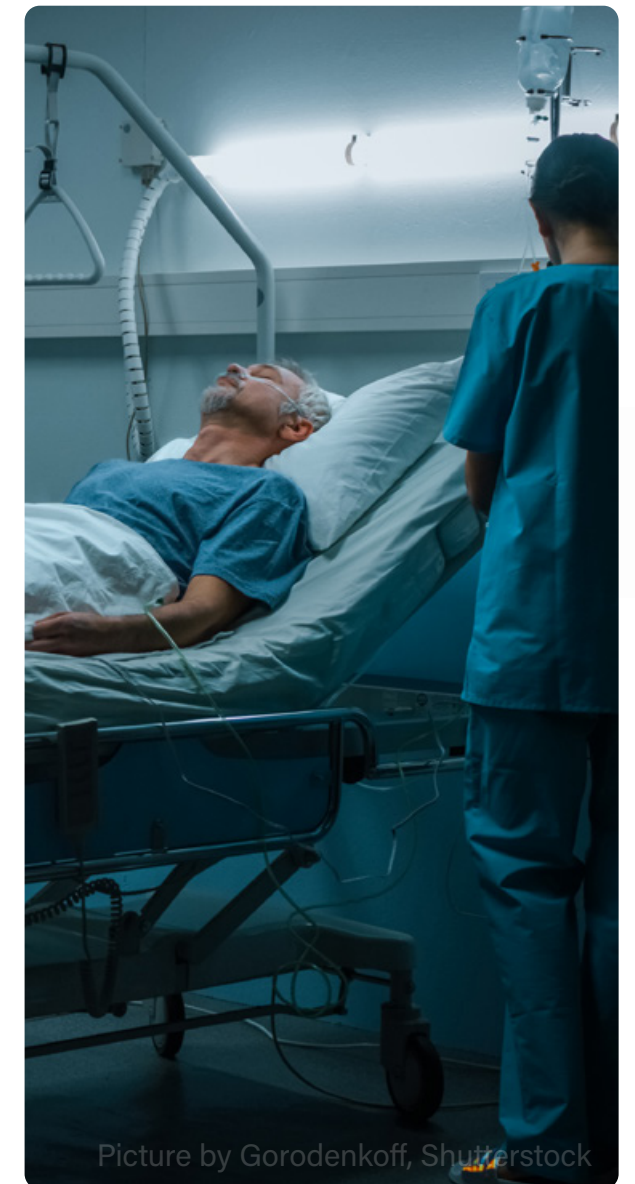
#### Obesity

Obesity has been coined a global epidemic by WHO and referred to as **“one of today's most blatantly visible – yet most neglected – public health problems”**.<sup>444</sup> And, like other diseases that put a strain on the body, it is positively correlated with the impact of infections. Data from 274 US counties showed that communities with a greater prevalence of obesity were more likely to have high influenza-related hospitalisation rates. Similarly, people with **lower fruit-and-vegetable consumption tended to have higher influenza-related hospitalisation rates, even after accounting for obesity**.<sup>445</sup> In addition, during the 2009 influenza A (H1N1) pandemic, obesity was a risk factor for hospitalisation and death.<sup>446</sup> Long-term studies of the links between lifestyle, diet, and disease found that the more kinds of animal-based foods in participants' diets, the higher their BMI (body mass index) scores.<sup>447 448</sup>

#### Cardiovascular diseases

**Cardiovascular diseases are the number one cause of death, globally.** They include diseases of the heart and blood vessels such as coronary heart disease, cerebrovascular diseases, and rheumatic heart disease.<sup>449</sup> Diet and lifestyle have a major influence on the development of cardiovascular diseases. An unhealthy diet, low in fruits and vegetables and rich in saturated fatty acids, along with physical inactivity, tobacco use, and harmful use of alcohol, are the most important risk factors. However, **a high level of meat consumption is considered an independent risk factor in the development of cardiovascular diseases**. A 2009 study in the US, which included an impressive 500,000-plus participants, showed an increased risk for cardiovascular disease in the participants who consumed the most meat, compared with those participants with the lowest meat intake.<sup>450</sup> WHO points out that “most cardiovascular diseases can be prevented by addressing behavioural risk factors”.<sup>451</sup>

Previous evaluations of patients with COVID-19 show that **cardiovascular disease increases the incidence and severity of infection**. In addition, coronavirus infection can cause damage to the heart muscle, which can be another major factor for a negative prognosis.<sup>452</sup> For example, in an analysis





of 187 patients from Wuhan who were hospitalised with COVID-19, 35% had underlying cardiovascular disease and 28% had indications of acute myocardial injury.<sup>453</sup> Another small study of 150 patients with laboratory-confirmed COVID-19 indicated that cardiovascular disease was more common in patients who died (13 out of 68) than in patients who survived (1 out of 82).<sup>454</sup> Similarly, the largest analysis to date of COVID-19 cases in mainland China shows that the case-fatality rate was 2.3% (1,023 deaths out of 44,672 confirmed cases), but reached 10.5% in patients with underlying cardiovascular disease.<sup>455</sup>

## Cancer

**High consumption of red meat is also associated with numerous cancers.** In 2015, WHO classified processed meat as a Group 1 carcinogen. This classification means that there is sufficient evidence from epidemiological studies that foods such as bacon, sausages, and ham can cause cancer. In addition, red meat has been classified as a Group 2A carcinogen, which means that foods such as beef, veal, and pork are likely to cause some types of cancer.<sup>456</sup>

During a pandemic, patients with cancer face all the same risks as the rest of the population. In addition, patients with some forms of cancer or who are at specific stages of their disease or treatment are also **particularly susceptible to bacterial infections due to weakened immune systems.**<sup>457 458</sup> While there is not yet much information about the effects of COVID-19 on cancer patients, early data from China has shown that 39–54% of patients with cancer were reported to have a severe event when infected with COVID-19.<sup>459</sup>

## Eating our way to hospital

**The current animal-focused food system is driving an antibiotics apocalypse, while also increasing the occurrence of communicable and non-communicable food-related diseases and escalating the risk of future zoonotic pandemics.** The consumption of animal-based products thus intensifies the overall burden on the healthcare system, monopolising emergency capacities. It can also contribute to an individual's chances of ending up in a high-risk category when contracting an infectious disease such as COVID-19.

## PANDEMICS AND CANCER

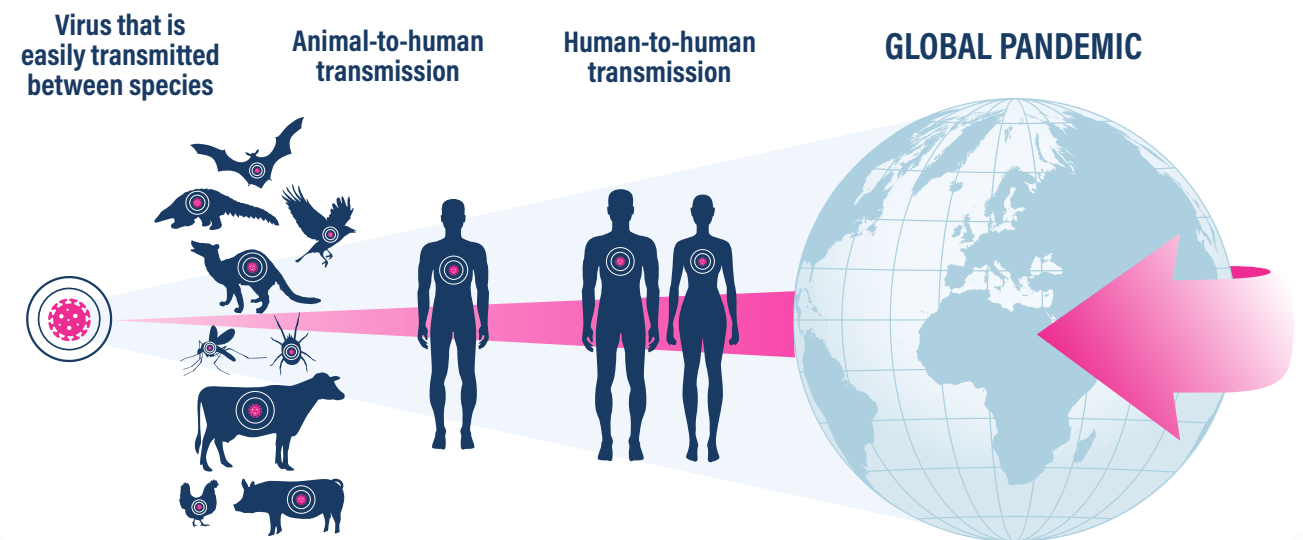
A zoonotic pandemic can also have other severe consequences on cancer care. Hospitals around the world have postponed important surgeries – including cancer surgeries – in order to free up emergency capacities for COVID-19 patients. With tumour-removal surgeries being postponed for six months, a UK study concluded that **for every 10 COVID-19 patients saved through hospital treatments, four cancer patients might die due to a lack of treatment.**<sup>460</sup> There is also evidence that there have been fewer diagnosed cases of cancer, probably due to the fact that potential patients are anxious about becoming infected with COVID-19 in a healthcare setting, or have general assumptions about insufficient capacities for non-COVID-19-related illnesses during the pandemic.<sup>461</sup> Of course, this is true for many other diseases as well.



## CONCLUSION

### The recipe for disaster – 1 animal + 1 mutation + 1 human + 1 contact

The recipe for disaster is surprisingly simple. A single mutation of a virus in a wild or farmed-animal species is sufficient to enable it to jump the species barrier and spread to humans. A single human interacting with a single animal who carries this mutated virus provides sufficient conditions for transmission to take place. Now, add a globalised world with international trade and travel in which a person can travel around the globe in 24 hours, making countless contacts with other people – and **a global pandemic, with all its devastating effects, can become a reality.**



Adapted from Kreuder et al. (2015)<sup>462</sup>

This is precisely how a virus that used to circulate among bats or pangolins in East Asia, without causing major harm, has now evolved to infect millions of people around the globe – causing **extensive human suffering, along with social and economic disruption of immeasurable proportions.** This development has been driven by what scientists have called “the human hand of pandemic emergence”. Neither the original virus nor its natural hosts are to blame for this – rather **it is the impact of human interference on them and their environment.**<sup>463</sup> And it can happen again – at any time.

“

*Because of human and livestock population growth, changes in livestock production, the emergence of worldwide agro-food networks, and significant changes in personal mobility, human populations increasingly share a global commons of disease risk, among themselves and with domestic and wild animal species.”*

FAO 2007<sup>464</sup>





## Three food-related human activities

There are three human activities – all related to our use of animals as food – that strongly encourage the emergence of zoonotic pandemics. Among them, **intensified animal agriculture plays a key role** since it functions as a large-scale zoonotic incubator, as well as a contributor to environmental degradation, loss of biodiversity, and climate change, and is the main driver of antimicrobial resistance. In addition, our animal-based food systems foster a host of food- and diet-related diseases that constitute not only a health problem in and of themselves, but also exacerbate the severity of pandemic impacts on individual and public health.

**This makes using animals as food – and intensified animal agriculture in particular – the most risky human behaviour in relation to pandemics – and one of the most risky behaviours in relation to the long-term survival of human society.**



## Escalating risks and impacts

And the risks keep increasing. **Not only are there far more lethal diseases than COVID-19** that can become zoonotic and infect humans, suggesting the disastrous potential of future outbreaks, **zoonotic pandemics are also predicted to become more frequent in the future** due to the increasing production and consumption of animal-based foods. The world's growing appetite for meat, eggs, dairy, and fish further escalates this development every single day – by further intrusions into ecosystems and natural habitats, by using ever more wild animals for food, and by cramming ever more farmed animals into large-scale production facilities. **We are literally eating our way to the next pandemic.**

## Making the connection

Thus far, little attention has been paid to the link between our outdated global food systems and the current and potential future pandemic crises. However, making this connection now is a crucial first step towards acknowledging the root cause of pandemics, as well as identifying solutions to reduce the risk of future outbreaks.

## Food systems change – a multiproblem solution on our plates

Moving away from animal agriculture and animal-based products can help preserve ecosystems and biodiversity, reduce interference with wild animal species, and remove the need for factory farms that provide hotbeds for zoonotic pandemic emergence and spread.

**Shifting to a better, more resilient, and sustainable global food system that replaces animal products with plant-based and cultured alternatives ranks among the best options.** It provides a multiproblem solution that not only mitigates future pandemic risks, but also helps to minimise major parallel crises such as climate change, world hunger, and antibiotic resistance.



## Part II

By making the connection between food and pandemics, Part I of this report also makes a strong case for immediate and decisive action. Part II will explore the food-related solution landscape that was already developing before the current crisis – and has been further accelerated by it. Looking at all relevant social sectors, the report will detail **encouraging developments, emerging opportunities, and concrete calls-to-action** in order to take this development to the next level. It aims to inspire much-needed **action among decision makers in the high-potential field of food-systems change.**

“

*Along with human culpability, though, comes hope: If changes in human activity can cause new diseases, then changes in human activity may prevent them in the future.”*

**Dr Michael Greger (2007)**<sup>465</sup>



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