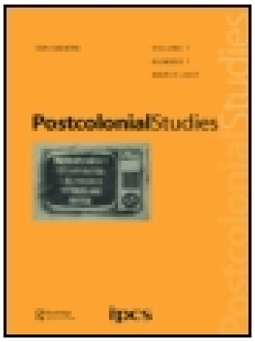

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Antibiotic resistance, planetary health and the mimetic trap: a historical account of present-day sanitary, environmental and social crises

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ABSTRACT
The industrialization of food production over the past century has triggered a series of sanitary crises related to antibiotic resistance. In this article, I contend that to understand the radical transformation of animal farming and its effects on public health, we need to inquire into the historical development of the knowledge on microbes, especially with regard to the agricultural industry's mobilization and repression of microbial metabolism to scale up food production. Moreover, I conceive of the so-called Great Acceleration of the Anthropocene as a postcolonial mimetic trap through which actors who didn't play an active role in the contemporary ecological collapse are subsumed into an indistinct 'we'. To disentangle this alleged collective subject created from accounts of planetary health, I focus on the scientific, social, and institutional histories of antibiotic production and antibiotic use that materialized in the epidemiological issue of antibiotic resistance. Furthermore, I highlight how the history of antibiotic use and resistance is intertwined with the ecological, social, and geopolitical dynamics created by intense industrial production and international rivalries during the Cold War. This article calls for the re-evaluation and creation of counter-narratives of the planetary impact of industry on microbes, local communities, patients, medical personnel, and the global poor.

KEYWORDS
Antibiotic resistance; environmental health; planetary health; World Health Organization; health diplomacy

1. Introduction: The Great Acceleration as a mimetic trap

In recent years, scholars of the Rockefeller Foundation-Lancet Commission on Planetary Health have embraced the Anthropocene framework to dissect the impact of industrialization on human health and the climate. In their arguments, the so-called Great Acceleration of the last seventy years is seen as a process that has both worsened and ameliorated the conditions of 'our civilisation'.[1] On the one hand, they contend, industrial activities and their products have enriched the lives of humans with electricity, oil-fuelled engines to transport customs, citizens, customers, and migrants, drugs to

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cure illnesses, and extended lifespans. On the other hand, they note, the extraction and burning of fossil fuels and related industrial activities have caused 'delayed' air pollution, pollution of aquifers and other primary resources, climate change, and most alarmingly, the worsening of people's health. The Planetary Health report's narratives say that *our* overconsumption is unsustainable and that, if the trend does not change soon, *our* civilization will collapse.[2] The Lancet Rockefeller report on Planetary Health has the merit of recognizing the paradoxical, schismatic pathways that 'our civilisation' has generated – i.e. technologically improved life conditions for some, realized through the exploitation and degradation of natural resources and environmental equilibria that underpin good health conditions for the majority. And yet, while providing a variety of data on environmental health and climate change, the report overlooks the historical and political conditions under which the trajectories of industrial, technological, and scientific progress that led to the planetary collapse have taken place.[3]

What kind of collective subject does the Lancet Rockefeller report imply, and what are the human and non-human subjects excluded from the presupposed 'we'? In addressing the question about the subjects excluded from the 'we', I will cast light on the scientific knowledge developed around the deep time of microbes, and their role in mechanized food production. My approach consists therefore in looking at the multiscalar biological bodies of late industrialism so as to illuminate the social and geopolitical history of the last century, as sedimented through biological and sociotechnical metabolic dynamics.[4]

To break down the false unity of an alleged unitary and ahistorical 'human civilisation' represented by economically rising societies, as put forward in the Planetary Health and other Anthropocene-framed proposals, I use the lenses of the history of science to deconstruct the collective, indistinct apocalyptic agency attributed to all humans. As Priya Kumar and Amit R. Baishya write in the introduction of this special issue, the postwar Great Acceleration coincided with the period of decolonization and the subsequent modernization of former colonies. The industrialization processes and economic growth at the core of the Great Acceleration were, and still are, showcased by rich countries as the main destination of the global poor's journey. Kumar and Baishya refer to Sylvia Wynter's 'mimetic trap', a postcolonial political device employed by the richest countries to portray *homo oeconomicus* as the only genre of the human, a device of wealthy societies that activates a mimetic desire conflating many classes and countries into an alleged collective subject.

Through the 'mimetic trap', undefined actors from the richer countries promise poorer communities a better future and by so doing blur the roles that different subjects play in the supposed road to supposed wealth for all. The 'mimetic trap' also foreshadows a common path of economic growth and development that leads to planetary ecological cataclysm. While within the Anthropocene's main narrative, financial markets and neoliberal economic doctrines are recognized in general as major drivers of geological and environmental processes associated with ecological degradation, because these economic factors do not leave direct stratigraphic traces in rock strata, they are not considered as factors to be mitigated.[5]

In this article I therefore develop a narrative of the history of industrialized food production that attributes agency in ecological collapse to the uses of national forces of production, the related exploitation of natural resources, and the scientific and technological advancements as well as logics of economic growth underpinning them. The historical analysis here proposed specifically focuses on the production and use of antibiotics for agriculture – for mechanized, biologically ‘assisted’ food production – which have led to the allegedly ‘delayed’ degradation of the very natural resources that support human health, here in the form of antibiotic resistance.[6] In analysing the use of antibiotics in agriculture and the consequent crisis of antibiotic resistance, I inquire historically into the knowledge and practices surrounding the metabolism of bacteria, fungi, and moulds and their connection to social and geopolitical events of the last century. In unravelling the histories of food and drug production on an industrial scale, I highlight the scholarship of scientists who have studied microbes as the most necessary and basic elements that support the living conditions of all animal and plants. As I show below, microbes have been the allies of food production for centuries, yet during the last seventy years, in the context of industrial production, they have been perceived according to the Malthusian logic to which Sylvia Wynter refers, that is, microbes have been thought of and used as a function of macroeconomics and its consideration of populations in aggregate terms. In the following portrayal of modernity, woven through stories of science, politics, and activism, I emphasize scientific accounts of microbes that recognize them as the most sublime biogeological force on planet Earth.[7] Although microbes have been mostly associated with their noxious effect – i.e. bacteria and viruses can obliterate millions of humans, animals, or plants in a few days – I contend that the hallmark of life on Earth is the symbiosis of microbes and members of distinct species, their intimate sharing of everything from foods to physical bodies and even metabolic pathways.[8]

To briefly summarize the arguments of this article, in the next section I identify the main narratives that have guided microbiologist Lynn Margulis in telling the deep history of the biogeological activities of bacteria, which posit microbes as central and necessary biological actors that sustain all living beings. In this section, I hold that symbiosis is the central recurring pattern of all biological processes and that microbes have been deceptively invoked by industrial strategies such as the Gaia hypothesis to circumvent the problems posed by their polluting emissions. In section three, I sketch a short history of the alliances between microbes and industrialists, starting with the production of beer and wine, for it was the by-products of fermentation, and the scientific understanding of these by-products, that came to underpin productive activities such as the farming of animals at industrial scales. The most dramatic scientific event that allowed the scaling up of meat production was the suppression of microbial life, also known as chemotherapy, which eventually gave way to the ideation, production, and use of antibiotics as growth promoters and as drugs to prevent the recurrent infections of crowded industrial farms. In section four, I broaden the analysis on antibiotics, relocating them at the centre of Cold War political struggles, especially within the World Health Organization (WHO), through which the rich countries owning the technologies and patents needed to produce antibiotics hindered political rivals and poor countries from producing proprietary drugs or buying them at fair prices. The section also introduces the issue of antibiotic resistance from a historical point of view, from its first appearance as a laboratory problem in 1908 to its later appearance as an epidemiological problem for the US military in 1943, when antibiotics had come into extensive use. The scaling up of antibiotic resistance increased over the years, as did the public and scientific awareness of the issue, especially when sanitary emergencies were traced to their zoonotic, industrial origin. Following the social protests of the 1960s concerning UK citizens and scientists, microbes and antibiotics became the legitimate subjects of political action and regulations. In the last section, I reflect on the rising production and use of antibiotics as well as on the increasing awareness of antibiotic resistance, pointing at ways to integrate scientific activism and environmental conflicts to eventually spot the immaterial logics underpinning the practices of antibiotic overuse that have led to antibiotic resistance. Moreover, I reflect on antibiotic resistance as a trait of globalism – a phenomenon of the last fifty years, specifically derived from the scattered global dislocation of financial capital and industrial plants – and as an invisible phenomenon whose scattered geographical and temporal dimensions hinder effective public and scientific action.

2. The biogeological and atmospheric agency of microbes

> From an enlarged and less human-centred perspective, bacteria really are the dominant form of life on Earth – and always have been and probably always will be. They are more abundant, more indestructible, more diverse in biochemistry […], and inhabit a greater range of environments than all the other four kingdoms combined.[9]

Stephen Jay Gould wrote these words to describe the majestic work of microbiologist Lynn Margulis and Karlene V. Schwartz, who authored *Five Kingdoms: An Illustrated Guide to the Phyla of Life on Earth*. Margulis and Schwartz tell us that bacteria, the only forms of life to inhabit our planet for the first two billion years, have been responsible for major atmospheric and geological changes on Earth. The work of Margulis followed the inquiries conducted by scientists such as Joseph Priestley, Justus Liebig, and Otto Warburg, who in the eighteenth, nineteenth, and twentieth centuries focused on the role of plants in exchanging gases.[10] Some of the scientific hypotheses proposed by Margulis, largely accepted by today's scientific communities worldwide, point to evidence of microbial presence in rocks retrieved from Australia and South Africa dated older than 3 billion years.[11] This geological, stratigraphical evidence shows that microbes thrived in oxygen-less pasts.[12] During the first billion years of Earth, oxygen was present not in its gaseous form, as it is nowadays, but as a compound of water, water vapour, and carbon dioxide, all elements of the hellish gases flowing in the first phases of Earth's atmosphere, suggesting that it was part of a nebula. In their 1988 *Garden of Microbial Delights*, Lynn Margulis and Dorion Sagan illustrate how one of the most transformative steps for life on Earth and its geological depths was enacted by a specific class of photosynthetic bacteria known as cyanobacteria, microbes that use sunlight, carbon dioxide from the air, and hydrogen from water to make their own food. By using these three elements to thrive, cyanobacteria emit oxygen as by-product. Over 500 million years, they transformed Earth's atmosphere into an oxygen-rich environment, and fixed carbon dioxide underground and underwater, a setting that would eventually allow for the genesis of animal life. Later, cyanobacteria established a symbiotic relationship with a bigger host, which eventually became the foundational cell of today's plants, known as chloroplast. As a biological agent embedded in all cells' plants, the chloroplast, which is understood to be a descendant of cyanobacteria, performs photosynthesis. As soon as Earth's atmosphere became rich in oxygen, other microbes, known as alpha-protobacteria, developed the ability to thrive without oxygen and without sunlight. Once this alpha-bacteria established a symbiotic relationship with a larger bacterium, it becomes a mitochondrion, an organelle embedded in all animals' cells which regulates their and our cellular life cycle.

The most fundamental functions of all animals and plants therefore depend on embedded bacteria that have established endosymbiotic relationships with bigger bacterial hosts. Microbiology, developmental biology, and epigenetics have shown that the developmental processes of all animals and plants, their functions, and the coordinating genes are often regulated by the coupling of environmental factors inside and outside the organism with bacteria.[13] Endosymbiotic relationships of microbes form animals' and plants' bodies, and contribute in fundamental geological processes such as fixing elements like carbon dioxide into the soil and water, eventually creating black coal, oil, limestone, and shale rock. Matts of cyanobacteria give shape to fossils called 'stromatolites', and the metabolism of some bacteria contribute to forming ore deposits of copper, zinc, lead, iron, silver, manganese, and sulphur.[14] This knowledge has been produced by inquiries into the deep time of bacteria, showing that they have managed the elemental components of Earth for billions of years. The ability of bacteria to develop 'resistance' to elements threatening their lives precedes the appearance of humans as well as the appearance of the industry. In other terms, antibiotic resistance pertains to a deep time of bacteria, an ancient phenomenon that over the last seventy years has reached a critical acme for its impact on health care systems,[15] and has acquired a central role in international relations and health diplomacy.

Despite the outstanding abilities of microbes, first attributed to them following the invention of the microscope, their autonomous agency and symbiotic relationships with other living beings can neither fix nor disguise the impact that industrial activities have on human health. The alleged teleological, cybernetic-like, self-repairing abilities of our planet postulated by Margulis's colleague James Lovelock and named the 'Gaia hypothesis' was the outcome of Lovelock's collaboration with Royal Dutch Shell and Dupont, two industrial manufacturers that were subject to regulatory governmental actions for their polluting activities.[16] The Gaia hypothesis was used by Lovelock to point to the alleged abilities of microbes to produce the same polluting sulphides emitted by fossil fuel combustion, and to fix the effects of chlorofluorocarbons (CFC) on the ozone layer. As shown by Leah Aronowsky, even if Lovelock's research opened the way for the discovery of ozone holes, his Gaia hypothesis, which he began to develop as a working hypothesis back in 1972, was used shortly thereafter by Dupont in 1974–1975 as a PR strategy to counter the US ban of CFC use in aerosol spray, which would have come into force in 1977. Meanwhile, concealed by such propaganda, the material mobilization of microbial metabolism undertaken during the postwar period by nascent industries, which thrived upon the knowledge and practices of microbiology and biotechnology, especially fermentation, had a political and environmental impact on an international scale. An analysis of the industrial mobilization of microbial metabolism is therefore particularly relevant to understanding the industrial interventions of the 1960s and 1970s to address Malthusian concerns around the 'population explosion' and its corollary, 'mass starvation'.[17]

3. The industrial mobilization of microbial metabolism and Malthusian logic

Although the use of microbial fermentation to produce foods and beverages has been known to humanity for millennia, during the second half of the twentieth century, scientific and technological breakthroughs in this context were at the centre of production upheavals, especially with regard to agriculture. Already in the nineteenth century, fermentation was the focus of scientific knowledge, especially as it related to the production of beverages such as beer and wine.[18] Zymotechnics (from the ancient Greek *zúmē*, 'leaven') – as named by Prussian physician Georg Ernst Stahl (1659–1734) to refer to the study of practical fermentation, the basis of the art of brewing – was an attempt to exploit the scientific understanding of fermentation to improve the commerce and, as highlighted by Robert Bud, the first original work in biotechnology.[19] In the nineteenth century, the industrial knowledge of zymotechnics acted as a 'tent' for disciplines such as chemistry, microbiology, bacteriology, mycology, and botany. It was also a knowledge to counter the French take on the microbial world developed by Louis Pasteur, who greatly contributed to the understanding of microbial life. By the late twentieth century, zymotechnics transcended a mere applied science, as it integrated chemistry, microbiology, and engineering; it also allowed conventional market boundaries to be crossed, and was implemented in European countries and the United States. Its application ranged from the manufacture of sugar, starch, vinegar, pickles, soap, and glue to tanning, the preservation of eggs, and the valuation of milk products. Between 1884 and 1909, collections of bacteria (yeasts) and fungi were established in Prague and Berlin. After World War I, microbes were introduced in sewage plants as biological degrading agents, and most importantly, they started playing a central role for the large-scale farming of animals.

The first European attempt to run an agricultural enterprise on an industrial scale goes back to 1914, when the Hungarian engineer Karl Ereky planned and realized, in Hungary, a pig farm that was able to raise and slaughter 100,000 heads a year. Ereky, who took inspiration from the Danish cooperatives of brewers, based the Hungarian agribusiness model on the economic capitalist doctrine of American industrialists. The industrial expansion of agricultural production helped to satisfy national needs during World War I – i.e. to solve the problem of famine and the manufacture of common goods such as textiles, fuel, and weapon components. Given the advancements of zymotechnics, microbial metabolism was mobilized to scale up agricultural production. Yeasts commonly used by brewers were added to yeasts grown on molasses (enriched with synthetically produced ammonia), and the combination was used in Germany during World War I, and later in other countries, as feed for livestock.[20]

One of the most dramatic breakthroughs for the scaling up of agricultural production regarded the control and suppression of microbial metabolism, named 'chemotherapy', which opened the way to the development and use of antibiotics. Initiated by Paul Ehrlich in 1906, chemotherapy is a mode of selective toxicity operated through man-made molecules, which are produced by tinkering with organic compounds.[21] The chemical affinity and selective toxicity studied by Ehrlich regarded the capacity of synthetic molecules such as synthetic aniline dyes and arsenic to selectively bind themselves to bacteria. His initial intention was to make them visible under the light microscope, but he later discovered, by coincidence, that such a biochemical affinity would destroy them.[22] Already in 1908, Ehrlich observed a case of antibiotic resistance, namely strains of *Trypanosomiasis gambiense*, a microorganism responsible for the sleeping sickness disease, which developed resistance to atoxyl, a synthetic arsenic-based molecule used to cure the disease.[23] Theories and practices of induced toxicity experimentally developed around the chemical structure–activity of molecules led to the practice of antisepsis and the related use of phenols in surgery,[24] one of the most important medical innovations of the nineteenth century. Disinfectants for antisepsis, and other phenol-based drugs, are developed from the refinement of coal-tar, a by-product made through pyrolysis, the thermal destruction of coal. Phenols, which are among the many chemical compounds present in coal-tar, have been used since the 1870s. Like phenols, sulphonamides are also derived from coal-tar and today associated with the petrochemical industry. They were developed in Germany by I.G. Farben and first used as far back as 1935. They represented a revolution for their outstanding therapeutic impact in terms of reducing mortality from bacterial infections, for instance, maternal mortality from childbirth, pneumonia, and meningococcal meningitis.

During the late 1930s, a group of researchers based in Oxford studied the fermentation of penicillium mould, already described in 1928 by Alexander Fleming, whose derivative molecule was able to cure fatal infectious diseases. By 1942, the British discovery of penicillin made its way to American facilities, which attempted to scale up production, and the circa 4 billion units produced in 1943 expanded to 42 billion units in 1947.[25] The massive therapeutic and nontherapeutic use of antibiotics proved central in food production, both to prevent and cure infections and to increase animal growth, laying the basis for far more efficient farming methods.[26] Indeed in 1949, a study pointed to the antibiotic growth effect, namely that the feeding of antibiotics at low levels to agricultural animals resulted in enhanced growth,[27] ultimately creating ‘more food for all’.[28] Claas Kirchhelle has clearly shown how after World War II the agricultural use of antibiotics as growth promoters on farms in the United Kingdom and the United States allowed farmers to raise more heads of bigger chicken and pork in less time and less space. The deep agricultural transformation that followed the use of antibiotics in farms was also connected to Malthusian concerns motivated by Cold War rivalries.[29] Indeed, food security was considered as particularly relevant for international political competition, key to sustaining a well-fed and larger population ready for economic and military confrontation with communist and socialist rivals.[30] Antibiotics were constantly added in small doses as prophylactics to prevent epidemics on farms and as growth promoters to breed larger animals. Milking machines were washed with sulphonamides and quaternary ammonium compounds, as were other machines used in food production and dairy cans and tanks used for transport.[31] The postwar agricultural uses of antibiotics allowed for the manyfold increase of food production so as to breach the very limits illustrated by Robert Malthus – i.e. limits of resources that would have caused famine and therefore hindered population growth, or increased the possibility for the advent of communism.[32]

Since World War II, an influential group of social scientists and policymakers, with the support of scientific research and technological innovation, have considered population growth and the scarcity of resources as economic problems to be solved by different means, among them the industrialization of agriculture, now a primary tool in the 'structural adjustment of economies'.[33] As shown by Michelle Murphy, scientists such as biologist Raymond Pearl, demographers Frank Notestein and Ansley J. Coale, and economist Edgar M. Hoover have helped tie together population growth and economic growth within a social planning scheme that projects the past of European countries onto the future of former colonies such as Bangladesh and India, a postcolonial translation underpinned by the so-called demographic transition. The processes of postcolonial modernization and economic growth underpinned by the demographic transition of wealthy countries and former colonies and put in action by institutions such as the United States Agency for International Development and the United Nations Populations Division 'allowed a differential valuation of human life to be explicitly monetized' through an intensive actuarial abstraction – an abstraction unconcerned with the effects on individuals, their communities, and their natural environments and intended to serve the consolidation of a specific global order.[34]

This history of continuous prophylaxis regarding humans, livestock, and crops that contributed to strengthen a particular global order brings us to the current crisis of antibiotic resistance. This crisis is founded in the massive production and use of antibiotics and the related disruption of ecological conditions, which elicit bacterial mutations through selective pressures and thus cause the proliferation of multi-resistant bacteria. However, in order to consolidate a specific global order some of the most influential countries hindered their geopolitical rivals from producing and using antibiotics.

4. Institutions, politicians, and the public amidst the scarcity of antibiotics and antibiotic resistance

The development undertaken by technologically advanced countries of technological products such as antibiotics for medical uses to temporarily ameliorate the human condition, and the withholding of such technological products to being used in poor countries is an example of the *mimetic trap* to which Sylvia Wynter refers. Events of induced scarcity of antibiotics were motivated by geopolitical, economic and postcolonial reasons. While the use of antibiotics in the agricultural setting was and still is the main driver of the inception of multi-resistant bacteria, the use of antibiotics for human health has posed the issue, for poor countries and former colonies, of limited access. This issue has been addressed internationally in so-called *list of essential medicines*, under which many antibiotics were also listed. The political debate on access to essential medicine was articulated within the WHO, and it mainly took the form of two opposing fronts: countries in need of antibiotics *versus* countries owning the patents and technologies to produce such drugs.[35] The first definition of essential medicines was formulated in a 1977 technical document of the WHO. Since then, international struggles between countries with different political regimes or belonging to opposite fronts have taken place within the WHO on the topics of access, cost, and quality of essential medicines. At the 1982 World Health Assembly, for instance, a group of countries composed by the Netherlands, Chile, Cuba, Romania, Sudan, and Ghana, and united under the Health Action International, an organization that supported critical studies of the pharma industry, tried to establish an agenda for stronger standards on the international marketing of pharmaceuticals so as to prevent the practice of drug-dumping, in which Northern countries' industries sold low-quality drugs at high prices to poor countries and former colonies.[36] The 1982 proposal for a well-defined standard on the international marketing of pharmaceuticals was nevertheless defeated within the World Health Assembly by a front of countries composed by the United States, Britain, France, and Germany. The struggles over the suspension of patents on essential medicines for poor countries culminated in the suspension of US contributions to the WHO for two years, in 1986 and 1987 – at that time, the United States owned several patents on essential medicines.[37] In 1988, WHO Director General Halfdan Theodor Mahler, who initiated the campaign for essential medicines in 1975, was replaced by Hiroshi Nakajima, who scaled back the campaign. Before the WHO campaign to promote a list of essential medicines, and just after the inception of the WHO in 1946, antibiotics were at the centre of an even more radically polarizing debate along political lines. In 1949, the US delegate to the WHO and his allies explicitly blocked Czechoslovakia from developing penicillin production plants for having turned to 'Socialism'.[38] In 1948, about two years after the inception of the WHO, Albania, Bulgaria, Romania, Hungary, Czechoslovakia, and Poland each left the international agency because the United States and its allies withheld medical resources – i.e. the knowledge and the technical apparatuses to produce antibiotics – from Eastern Europe.[39]

The commercial, Cold War-driven limitation of the use of antibiotics as drugs for civilians after World War II, on the one hand, and the military and agricultural overuse of antibiotics, on the other, are two sides of the same coin.[40] Indeed, national institutions of both socialist and capitalist regimes have often considered production, stockpiling, and use of antibiotics as a factor of national security and as a geopolitical advantage.[41] Antibiotic resistance, which makes it impossible for doctors and medical institutions to rely upon antibiotics and other medicaments to cure their patients,[42] was first tackled as an epidemiologic problem by the American military during World War II. In 1943, it had to respond to the medical emergency of sulphonamide-resistant gonorrhea, for which it was necessary to administer penicillin and other combined medications.[43] Indeed, following World War II, the converging development and use of antibiotics and disinfectants enabled them to address the striking rise of streptococcal infections associated with the sudden formation of military cities.

To tackle the rising issue of epidemics caused by bacteria resistant to antibiotics, between 1962 and 1975 the Expert Committee on Antibiotics of the WHO developed a so-called antimicrobial sensitivity test, formed by a series of technologies for the effective clinical diagnosis of infections caused by antibiotic-resistant bacteria.[44] In the United States and United Kingdom, institutions have managed the introduction of antibiotics and monitored the emergence of antibiotic resistance since the 1960s in reaction to concerns among citizens and physicians.[45] The first casualties produced by antibiotic resistance in the United Kingdom were registered as early as 1956, when a *Staphylococcus aureus* strain resistant to penicillin and other antibiotics circulated in hospitals. In 1960, the Bristol-based Beecham company solved the problem of penicillin-resistant bacteria through the production of methicillin, or semisynthetic penicillin, an antibiotic able to effectively act on the resistant strain of *Staphylococcus aureus*. Nevertheless, a methicillin-resistant *Staphylococcus aureus*, today known as MRSA, emerged almost immediately.[46]

The public reaction to antibiotic resistance reached a critical mass when the environmental degradation caused by industrialization was denounced by authors such as Rachel

Carson, with her 1962 *Silent Spring*, and Ruth Harrison, whose 1964 *Animal Machine* underlined the health risks caused by industrial farming and antibiotic resistance.[47] In 1965, after several outbreaks caused by bacteria resistant to antibiotics – in many cases afflicting the British population – bacteriologist Ephraim Saul Anderson and geneticist Naomi Datta published an article in the Lancet in which they hypothesized the transfer of penicillin-resistant *Salmonella thyphimurium* bacteria from pigs to humans.[48] What was new in their research consisted in noting that resistance selection and transfer also arose in nonhuman circumstances and could cross over to bacteria in human populations, a process called zoonosis.[49] Namely, Anderson and Datta raised awareness of the human threat posed by the casual use of antibiotics in animals. In 1966, after the occurrence of outbreaks caused by resistant bacteria, the critique of Ruth Harrison, and the study of Anderson and Datta on the zoonotic origin of antibiotic resistance, the UK Ministry of Agriculture established the Brambell Committee and went on to enforce a new law on Farm Animal Welfare in 1967. From that moment on, writes Robert Bud, 'microbes and antibiotics [became] the legitimate subjects of political action', and the focus on antibiotic resistance passed from the use of antibiotics in the hospital to the use of antibiotics in food production.[50] Importantly, the 1969 British Swann report 'recommended that key antibiotics important to humans including penicillin and tetracycline should not administered to animals solely to promote growth'.[51]

In the United States, in contrast to the concerns of UK institutions over antibiotic resistance, antibiotics were extended to food preservation, crops, and even whaling, and their use constituted a central element of the infrastructure with which farmers were brought to reform their facilities – i.e. more heads of cattle in less space, with a resulting increase of infections. The Food and Drug Administration adopted a wait-and-see attitude, and at the 1967 US National Academy of Sciences symposium, 'most conference attendees remained convinced that global malnutrition posed a far graver threat than nonhuman AMR [antimicrobial] selection'.[52] In the same year, the Food and Drug Administration, without directly tackling the rising problem of antibiotic resistance, adopted a new national surveillance programme for antibiotic residues in meat. The tradition of US molecular biology that had developed since the early twentieth century gave America a lead in the development of techniques to analyse and measure antibiotic resistance till the discovery of so-called horizontal or lateral gene transfer.[53] Molecular tests such as CHARM II used by officials of the Food and Drug Administration at the end of the 1980s to detect resistant bacteria in milk products were sensitive enough to detect bacteria resistant to sulfamethazine illegally administered to cows in more than half of the supermarket samples analysed.[54]

The contribution that such scientists and their emancipatory use of detection technologies bring to the study of antibiotic resistance lies in illuminating how several historical dynamics – i.e. industrialism, the Cold War, and related anthropogenic activities – have shaped the biology of bacteria and therefore the biology of humans, and subsequently the activities of national and international health institutions. As Hannah Landecker clearly highlights, antibiotic resistance regards 'the biology of history'. In other words, history regards not only human societies but also bacteria, individual living beings that are collectively coordinated and that change in time and space at a rate much quicker than that of humans and other bigger organisms. The historical dimension of bacteria is synchronous with the historical dimension of industrial development. Bacterial metabolism syncs up with the decisions made by politicians and experts who regulate technology-backed industrial progress and its uses within the international rivalries underpinning the endless growth of synthetic products such as antibiotics. In other words, all these complicated processes converged in the industrialized production of food underpinned by antibiotics, a form of 'pyrrhic progress' that has provided more food for all and simultaneously worsened people's health via the spillover of antibiotic-resistant zoonotic bacteria, eventually causing infections and epidemics. Therefore, antibiotics, whose agricultural use is linked to contagious disease in humans, are also offered as the cure for contagious disease caused largely, if indirectly, by the use of antibiotics in agriculture. By this logic, the cause of the problem is offered as the cure. This logic has led to the trouble of antibiotic resistance, which has classified as a 'global epidemic' since 2016.[55]

5. Microbial epistemology meets scientific and environmental activism

Since the early 1980s, concerned natural and social scientists have organized concerted activities to raise awareness of antibiotic resistance. Such scientists have directed the public's attention to antibiotics used in food, agriculture, and pharma industries, and prompted it to critically assess and lower their consumption.[56] In recent decades, the use of antibiotics based on arsenicals in the United States and Europe has decreased due to publicity about the disruptive effects that these substances produce on public health. Nevertheless, global production and consumption of antibiotics, especially for food production, have continued to rise.[57] The intensified international trade of multinational companies, realized by distribution chains that have come into being over the last decades, has coupled with increasing production and consumption of food animals and the rising number of large-scale industrial agricultural facilities. In industrial pig farms, a higher density of farmed animals requires an extended use of antibiotics, a process that has boosted the spread of antibiotic-resistant bacteria on a planetary scale. As shown by a study published in 2015, a strain of *E. coli* resistant to colistin, an antibiotic used as the last resort medicament in Western hospitals, was detected in pigs farmed in China.[58] After a year, the resistance to colistin was detected in bacteria on five continents. In a similar fashion to what happened in former colonies after World War II, where developmental models of economic growth and rising industrialization were extensively applied, the Chinese government has scaled up the industrialization of food production, within a historical trajectory of what Ruth Rogaski has called a 'hypercolony'.[59] The modernization of the Chinese agricultural system, which is a historical process in which foreign political powers such as the United States and the Soviet Union have played direct and indirect roles, is key to understanding the trajectory that has led China to become world champion in the consumption of agricultural antibiotics.[60] Indeed, both the Soviet Union and the United States played central roles in the scientific, technological, and industrial development of twentieth-century China, which has facilitated the opening of new markets and helped to stabilize the world situation.[61]

Lately, international institutions such as the WHO have proposed to enact market incentives to overcome the issue of antibiotic resistance, especially to push the industry towards the invention of new kinds of antibiotics.[62] Such a proposal overlooks the main material cause of the problem, which is the agricultural use of antibiotics, and leaves aside or even reinforces the more general overemphasis on macroeconomic factors and programmes of national security built upon the gigantic antibiotics infrastructure.[63] In valuing economic growth and related variables such as large-scale agricultural facilities, the economic doctrines of the last century have allowed for and justified the detachment between industrial production and its impact on natural resources and the health of local populations.

A solution based on market incentives or on financial offset can hardly solve the issue of antibiotic resistance, as it is a phenomenon that puts economic, social, and natural metabolisms in a highly complex relation of positive feedback loops that hasten environmental and social collapse. Indeed, the economic growth underpinned by Malthusian logic implies an increasing use and presence of antibiotics in an even greater number of even larger livestock, aquacultures, and related runoffs, all processes that produce selective pressures on the microbial world, intensifying genetic mutations of bacteria and therefore raising the incidence of infectious disease caused by resistant bacteria. The invisible multiplication of genetic mutations producing bacterial resistance to antibiotics occurs gradually and out of sight, a process scattered across time and space.[64] Similar to climate change, deforestation, and acidifying oceans, the major challenge of antibiotic resistance resides in its invisibility and its sparse agency. Antibiotic resistance cannot be represented as an event that happens in seconds, minutes, or hours and therefore cannot fit into the sensational, spectacular images of a television broadcast; nor is it immediate in time – even if in ten hours, a small colony of one million bacteria can produce around three hundred genetic mutations. At a different temporal scale, the elicitation of bacterial mutations by massive selective industrial pressures has been taking place for the past hundred years or so.[65] This intertwining of different bacterial and industrial rhythms causes an exponential leap, one in which billions of bacterial mutations foment the planetary emergency of antibiotic resistance, which 'slowly' kills many hundreds of thousands of people every year – without counting those living in the Global South or those on the peripheries, where national and international sanitary epidemiological surveillance systems hardly function.[66] The logic of 'the polluter pays', a legacy of the nineteenth century, has been combined with the imperative of economic profitability and contributed to allocating the most dangerous tasks to the weakest sections of the population, whose illnesses often remain invisible, and to localities in which social and natural resources have been impoverished by aggressive industrial policies.[67]

The spatial dimension of antibiotic resistance follows the scattered geography of globalism – i.e. the international delocalization of industrial plants enabled by the fluidity of financial capitals over the last fifty years.[68] By tracking international industrialization, environmental research has registered bacteria carrying genes resistant to antibiotics in environments as diverse as wild fish, oysters, pigs, and cows all around the globe.[69] Even if the impact of antibiotic resistance on humans is mainly recorded in hospitals and in industrial districts where local communities often engage in environmental conflicts,[70] its roots lie in several locations, some of them thousands of kilometres away from the problem's acme, and within century-old historical trajectories of heavy environmental and human degradation.[71] The communities experiencing on their bodies the injuring effects of the great industrialized acceleration are left out from the collective subject 'we' implied by scientific institutions. Their proposals for ecological recovery and health promotion leaves the *homo oeconomicus* undisturbed, Wynter tells us, and very likely produces devastating effects for the global poor, mainly because of the economically enforced Malthusian logic pervading such proposals.[72] In Wynter's terms, the economic-driven Malthusian logic that primarily considers human populations as numerical aggregates is the *cause* of environmental and social collapse, especially for those who are more exposed to the noxious effects of industrial modernity.

6. Conclusion: towards a historical and political epistemology of planetary health

In this essay I have used the history of science and disease to inquire into the collective subject 'we' invoked by proponents of planetary health and the Anthropocene, intending to show that historical, economic, technological, and geopolitical factors must also play central roles in a comprehensive narrative of the social and ecological collapse of our time. In contrast to the proposals developed by the Rockefeller Lancet Commission on Planetary Health, the analysis here presented is based on a critical evaluation of the Malthusian logic of growth enacted by the *homo oeconomicus*, a logic underpinned by specific economic and industrial models ideated by European countries since World War II in order to overcome the limits to economic growth posed by the finitude of natural resources. Agriculture was therefore seen as one of the economic factors to influence by technological means so as to eventually scale up its throughput. The association of economic and populational growth therefore represented an ideal imaginary to which every former colony has supposedly adhered, a presumed collective pathway in which every single country and community of the planet has walked to eventually arrive at ecological collapse. This supposed collective path, following the suggestion of Sylvia Wynter, is a mimetic trap, a device to attract the policies of former colonies and poor countries to materially implement the models of production of Western countries, whose ruinous ecological and social impact remains concealed.

To weave a more comprehensive narrative, it is necessary to explicitly consider the scientific models and industrial practices of production that have intensified the interaction between human and non-human actors. Following the scientific models of microbiologist Lynn Margulis, I contend that the microbes represent the most sublime planetary force, and that despite having acquired a bad reputation, they are one of the most important natural resources for the flourishing of human cultures. Endeavours as old as fermentation and zymotechnics show the core importance that microbial metabolism has had for both food cultures and industrial production. As I have tried to show, during the Cold War and under the neoliberal economic doctrine, antibiotics assumed geopolitical and diplomatic meanings. The production and use of antibiotics for human health underwent geopolitical and economic controversies, especially within the WHO in its first years of existence. In the late 1940s and throughout the 1980s, some countries of the Western bloc hindered socialist governments, former colonies, and poor countries from deploying this life-saving technology. Furthermore, since the 1950s and 1960s, the intensive agricultural use of antibiotics and the first epidemics caused by bacteria resistant to antibiotics posed serious and extensive concerns among citizens and scientists who organized social protests. Most importantly, in 1965, the zoonotic origin of antibiotic-resistant bacteria resistant was scientifically proven by Ephraim

Saul Anderson and Naomi Datta, a topic that was politically addressed in 1967 through the UK governmental Brambell Committee.

The metabolism of microbes in an industrial setting specifically, i.e. the production of antibiotics to scale up the production of food animals, has been shown to act at a planetary scale in ways that endanger local communities, ultimately exposing them to antibiotic-resistant bacteria. As one of the core aspects of modernity, industrialism has allowed for the increase of goods of common use such as food animals and, at the same time and place, on the industrial farm, has intensified the mutations of microbes by mobilizing their ancient ability to resist toxic elements, thus creating a public health issue. During the last years, international institutions such as the WHO and the World Trade Organization have conceived of antibiotic resistance as a global epidemic, and have introduced financial and market incentives in response. Nevertheless, technologically and economically driven solutions are very likely prone to reinforce the problem, as the immaterial cause of antibiotic resistance, which resides in economic models of endless growth and international rivalries, remains untouched. Rather, as Nancy Fraser has recently highlighted, safeguarding the planet will require the constitution of a counter-hegemonic perspective envisioned through alliances between local communities and engaged scholars.[73] The historical and political inquiry I have attempted is meant to serve this end.

Notes

1. Sarah Whitmee et al., 'Safeguarding Human Health in the Anthropocene Epoch: Report of the Rockefeller Foundation-Lancet Commission on Planetary Health', *Lancet*, 386(10007), 2015, pp 1973–2028.
2. Richard Horton et al., 'From Public to Planetary Health: A Manifesto', *The Lancet*, 383 (9920), 2014, p 847.
3. For a historical illustration of the Anthropocene, see Jürgen Renn, *The Evolution of Knowledge: Rethinking Science for the Anthropocene*, Princeton, NJ: Princeton University Press, 2020, chapters 14–17.
4. Flavio D'Abramo and Hannah Landecker, 'Anthropocene in the Cell', *Technosphere Magazine*, 20 March 2019, accessed 31 March 2020. Available at: https://technosphere-magazine.hkw.de/p/Anthropocene-in-the-Cell-fQjoLLgrE7jbXzLYr1TLNn.
5. 'Money is clearly a hugely significant driver, amplifier and modulator of geological process today […] But its activity – particularly now that much finance is 'virtual' and created and transferred electronically – will not leave direct stratal traces.' Jan Zalasiewicz et al., 'Petrifying Earth Process: The Stratigraphic Imprint of Key Earth System Parameters in the Anthropocene', *Theory, Culture & Society*, 34(2–3), 2017, pp 83–104, pp 94–95.
6. Whitmee et al., 'Safeguarding Human Health in the Anthropocene Epoch'.
7. I consider the sublime character of microbes in Kantian terms, namely as entities that at the same time attract and repulse humans. Immanuel Kant, *Critique of Pure Reason*, M Muller – M Weigelt (trans), New York: Penguin, 2007; Flavio D'Abramo and Sybille Neumeyer 2020, 'A Historical and political Epistemology of Microbes', *Centaurus*, 62(2), 2020, pp 321–330.
8. Dorion Sagan and Lynn Margulis, *Garden of Microbial Delights: A Practical Guide to the Subvisible World*, Orlando: Harcourt Brace Jovanovich Publishers, 1988.
9. Stephen J Gould in Lynn Margulis and Karlene V Schwartz, *Five Kingdoms. An Illustrated Guide to the Phyla of Life on Earth*, New York: W. H. Freeman and Company, 1998, p xiii.
10. For an extensive, in-depth historical analysis on photosynthesis, see Kärin Nickelsen, *Explaining Photosynthesis. Models of Biochemical Mechanisms, 1840–1960*, Heidelberg: Springer Dordrecht, 2015.

11. Margulis's proposal, largely accepted by scientific communities worldwide, is known as 'endosymbiotic theory' and holds that microbes are agents of innovative evolutionary changes of life on earth (see below).
12. Sagan and Margulis, 'Garden of Microbial Delights'.
13. Gilbert, Bosch and Ledon-Rettig, 'Eco-Evo-Devo: Developmental Symbiosis and Developmental Plasticity as Evolutionary Agents'; Eva Jablonka, Marion J Lamb, and Anna Zeligowski, *Evolution in Four Dimensions, Revised Edition: Genetic, Epigenetic, Behavioral, and Symbolic Variation in the History of Life*, Cambridge, MA: MIT Press, 2014.
14. Lynn Margulis and Michael J Chapman, *Kingdoms and Domains. An Illustrated Guide to the Phyla of Life on Earth,* 4th edition, New York: W. H. Freeman and Company, 2009, pp 88, 40.
15. Vanessa M D'Costa, Christine E King, et al. 'Antibiotic Resistance is Ancient', *Nature* 477, 2011, pp 457–461; Miriam Barlow and Barry G Hall, 'Phylogenetic Analysis Shows That the OXA b-Lactamase Genes Have Been on Plasmids for Millions of Years', *Journal of Molecular Evolution*, 55, 2002, pp 314–321.
16. Leah Aronowsky, 'Gas Guzzling Gaia, or: A Prehistory of Climate Change Denialism', *Critical Inquiry*, 47, 2021, pp 306–327.
17. Robert Bud, *The Uses of Life*, Cambridge: Cambridge University Press, 1993, p 124.
18. A course on fermentation chemistry was offered in Prague in 1818 at the Ständische Ingenieurschule, where Bohemian brewers trained experts for their industry, cfr. Bud, 'The Uses of Life', p 18.
19. Bud, 'The Uses of Life', p 9.
20. Max Delbrück, 'Hefe ein Edelpilz', *Wochenschrift für Brauerei*, 27(31), 1910, p 375; R Braude, 'Dried Yeast as Fodder for Livestock', *Journal of the Institute of Brewing*, 48(5), 1942, pp 206–212.
21. Alexander von Schwerin, et al., *Biologics: A History of Agents Made from Living Organisms in the Twentieth Century*, London: Pickering & Chatto, 2013.
22. Hannah Landecker, 'Antimicrobials before Antibiotics: War, Peace, and Disinfectants', *Palgrave Communications*, 5(1), 2019, article number: 45.
23. Christoph Gradmann, *Laboratory Disease: Robert Koch's Medical Bacteriology*, Baltimore, MD: Johns Hopkins University Press, 2009.
24. John K Crellin, 'Internal Antisepsis or the Dawn of Chemotherapy?', *Journal of the History of Medicine and Allied Sciences*, 36(1), 1981, pp 9–18.
25. Bud, 'The Uses of Life' p 104.
26. Hannah Landecker, 'A Metabolic History of Manufacturing Waste: Food Commodities and their Outsides', *Food, Culture & Society*, 22(5), 2019, pp 530–547.
27. E L R Stokstad, T H Jukes, J Pierce, et al., 'The Multiple Nature of the Animal Protein Factor', *Journal of Biological Chemistry*, 180(2), 1949, pp 647–654.
28. Maxwell Reid Grant, 'Engineering Better Meat', *Popular Mechanics*, 91, 1949, pp 174–177, 246, 252.
29. On the scientific developments underpinning Cold War rivalries, Naomi Oreskes and John Krige, *Science and Technology in the Global Cold War*, Cambridge: MIT Press, 2014.
30. Biochemist Harry J Prebluda, who worked with the state-owned US National Chemicals Company, highlighted in a 1953 speech given at the National Farm Chemurgic Council, a few months before the end of the Korean War (1950–1953), that the use of antibiotics to make healthy and faster-growing crops and livestock 'may solve most of the world's hunger problems, thus eliminating one of the causes of unrest upon which communism has tried to capitalize', JP, 'Scientist predicts antibiotic farms', *Daily Illini*, 11 March 1953.
31. Landecker, 'Antimicrobials before Antibiotics'.
32. Bud, 'The Uses of Life', chapter 6; Claas Kirchhelle, *Pyrrhic Progress: The History of Antibiotics in Anglo-American Food Production*, New Brunswick: Rutgers University Press, 2020, chapter 2.
33. Michelle Murphy, *The Economization of Life*, Durham: Duke University Press, 2017, p 29.

34. Murphy, *The Economization of Life*, p 42. Murphy shows that Raymond Pearl further developed Malthusian logic by considering the natural resources limiting population growth as adjustable variables depending on levels of civilization – i.e. levels of technology and state policy. Pearl's hypothesis relied on data from the postcolonial modernization of Algeria, where the 'civilizing' action of the French boosted population growth. Murphy argues that 'the economization of life was generated at this encounter [among the hegemony of the US politics, former colonies such as Bangladesh and socialist rivals] between Cold War and postcolonial social science, at the crux between imperialism and decolonization', p 9.
35. Jeremy A Greene, 'Making Medicines Essential: The Emergent Centrality of Pharmaceuticals in Global Health', *Biosocieties*, 6(1), 2011, pp 10–33.
36. As explained by Jeremy A Greene,

    > By 1976, Thailand spent 30.4 per cent of public health budget on drugs, whereas Bangladesh spent 63.7 per cent of its budget on prescription medicines. The private sector market in pharmaceuticals, meanwhile, contained a staggering number of brand names: by the early 1970s, Brazil and Argentina had 24 000 and 17 000 brand name drugs on the market, whereas Egypt had over 50 000 brands. Norway, by contrast – which had enacted the earliest national drug safety legislation – allowed a market of only 1000 drug brands. (Jeremy A Greene, 'Making Medicines essential', pp 16–17)

37. Christoph Gradmann and Jean-Paul Gaudillière, 'Inadequate, yet Indispensable: The WHO and the History of Global Health', *Geschichte der Gegenwart*, 27 May 2020. Available at: https://geschichtedergegenwart.ch/inadequate-yet-indispensable-the-who-and-the-history-of-global-health/ (accessed 31 May 2021); Greene, 'Making Medicines Essential'.
38. Dora Vargha, 'Technical Assistance and Socialist International Health: Hungary, the WHO and the Korean War', *History and Technology*, 36(3–4), 2020, pp 400–417.
39. Marcos Cueto, Theodore M Brown, and Elizabeth Fee, *The World Health Organization. A History*, Cambridge: Cambridge University Press, 2019.
40. Hannah Landecker, 'Antibiotic Resistance and the Biology of History', *Body & Society*, 22 (4), 2016, pp 19–52.
41. Antibiotics are sensitive elements of national security, for instance as considered within the discipline that has studied so-called emerging diseases since the 1970s, cfr. Nicholas B King 'The Scale Politics of Emerging Diseases', *OSIRIS*, 19, 2004, pp 72–66.
42. Landecker, 'Antimicrobials before Antibiotics'.
43. By 1943 sulphonamides were no longer effective for gonococcus, the biological agent responsible for gonorrhea. Nonetheless, by the late 1960s, doctors prescribed sulphonamides at a rate of 15–20 million a year in the United States alone. Cfr. Landecker, 'Antimicrobials before Antibiotics'; John E Lesch, *The First Miracle Drugs. How the Sulfa Drugs Transformed Medicine*, Oxford: Oxford University Press, 2007.
44. Christoph Gradmann, 'Sensitive Matters: The World Health Organisation and Antibiotic Resistance Testing 1945–1975', *Social History of Medicine*, 26(3), 2013, pp 555–574.
45. Kirchhelle, 'Pyrrhic Progress'.
46. Robert Bud, 'From Epidemic to Scandal: The Politicization of Antibiotic Resistance, 1957–1969', in Carsten Timmermann and Julie Anderson (eds), *Devices and Designs. Medical Technologies in Historical Perspective*, New York: Palgrave, 2006, pp 195–211.
47. Ruth Harrison pointed to the danger of zoonosis caused by the veterinary use of drugs: 'surely and gradually the poultry bugs are becoming conditioned to the drugs and disaster cannot be so very far off'. Ruth Harrison, *Animal Machines*, Oxford: CABI, 2013, p 154.
48. Ephraim Saul Anderson and Naomi Datta, 'Resistance to Penicillins and its Transfer in Enterobacteria', *Lancet*, 1(7382), 1965, pp 407–409.
49. Kirchhelle, 'Pyrrhic Progress'.
50. Bud, 'From Epidemic to Scandal', p 203.
51. Bud, 'From Epidemic to Scandal'.

52. Kirchhelle, 'Pyrrhic Progress', p 72.
53. Cfr. Joshua Lederberg and Edward L Tatum, 'Gene Recombination in Escherichia Coli', *Nature*, 158(4016), 1946, p 558. Tsutomu Watanabe showed that several plasmids encoding for resistance to man-made antibiotics can contribute to the formation of single strain of bacteria resistant to multiple antibiotics. Tsutomu Watanabe, 'Infective Heredity of Multiple Drug Resistance in Bacteria', *Bacteriological Reviews*, 27(1), 1963, pp 87–115; Tsutomu Watanabe and Toshio Fukasawa, 'Episome-mediated Transfer of Drug Resistance in Enterobacteriaceae', *Journal of Bacteriology*, 81(5), 1961, pp 669–678.
54. Kirchhelle, 'Pyrrhic Progress', p 156.
55. Cfr. Secretariats of WHO WIPO and WTO, 'Antimicrobial resistance – A global epidemic', *WHO News*, 2016, retrieved from https://www.who.int/phi/news/Trilateral_AMR_background_finalpdf.pdf?ua=1
56. I here refer to the activities of scholars such as Stuart Levy, Christoph Gradmann, Hannah Landecker, Mindy Schneider, and Claas Kirchhelle.
57. On the rise of global production and consumption of meat and antibiotics, cfr. Bill Winders and Elizabeth Ransom (Eds), *Global Meat: Social and Environmental Consequences of the Expanding Meat Industry*, Cambridge: The MIT Press, 2019. On broader analyses on the rising use of antibiotics in agriculture, see Thomas P Van Boeckel, Charles Brower et al., 'Global Tends in Antimicrobial Use in Food Animals', *Proceedings of the National Academy of Sciences of the United States of America*, 112(18), 2015, pp 5649–5654; Katie Tiseo, Laura Huber, Marius Gilbert et al., 'Global Trends in Antimicrobial Use in Food Animals from 2017 to 2030', *Antibiotics (Basel)*, 9(12), 2020, p 918.
58. Kirchhelle, 'Pyrric Progress'; Yi-Yun Liu et al., 'Emergence of Plasmid-Mediated Colistin Resistance Mechanism MRC-1 in Animals and Human Beings in China: A Microbiological and Molecular Biological Study', *Lancet Infectious Diseases*, 16(2), 2016, pp 161–68.
59. As late as 1862, seven European powers had obtained economic and political concessions in the treaty-port city of Tianjin in order to take advantage of the burgeoning Chinese markets of salt, textiles, and grain. Ruth Rogaski, *Hygienic Modernity. Meanings of health and disease in treaty-port China*, Berkeley: University of California Press, 2004.
60. Before and during Maoist China, pigs were primarily valorized as 'small scale, organic fertilizer factories' producing manure for agricultural use, cfr. Sigrid Schmalzer, *Red Revolution, Green Revolution: Scientific Farming in Socialist China*, Chicago: University of Chicago Press, 2016, p 12. When the first large ammonia factories were built during the mid-1970s with the help of the multinational food manufacturing company Kellogg's, the dependence on hogs to produce manure loosened, and pork farming was increasingly allocated to food production. Cfr, Van Boeckel et al 'Global Tends in Antimicrobial Use in Food Animals'; Mindi Schneider, 'China's Global Meat Industry', in Winders and Ransom, *Global Meat*, pp 79–100.
61. During the second half of the last century, the US backed up the technological innovation of China in the hope that a modernized China would help in the balance against the Soviet Union, especially against its expansionist foreign policy. Zuoyue Wang, 'U.S.-China Scientific Exchange: A Case Study of State-Sponsored Scientific Internationalism during the Cold War and Beyond', *Historical Studies in the Physical and Biological Sciences*, 30(1), 1999, pp 249–277.
62. Interagency Coordination Group on Antimicrobial Resistance, 'No Time to Wait: Securing the Future from Drug-Resistant Infections', *Report to the Secretary-General of The United Nations*, April 2019. Available at: https://www.who.int/docs/default-source/documents/no-time-to-wait-securing-the-future-from-drug-resistant-infections-en.pdf?sfvrsn=5b424d7_6; Interagency Coordination Group on Antimicrobial Resistance, 'Antimicrobial Resistance: Invest in Innovation and Research, and Boost R&D and Access', IACG discussion paper, June 2018. Available at: https://www.who.int/antimicrobial-resistance/interagency-coordination-group/IACG_AMR_Invest_innovation_research_boost_RD_and_access_110618.pdf.

63. Sociologist Clare Chandler has proposed a Foucauldian taxonomy of antibiotic resistance in which the issues are framed not only within the liberal themes of surveillance and the individualized ecological-backed One Health approach, but also in terms of antibiotics as infrastructure, which allows shorter sick leaves and more crowded places where people can easier meet and where microbes breed, travel, and mutate quicker. Chandler points to antibiotics as one of the very cores of modernity and at antibiotic resistance as an invitation to imagine an era of medicine beyond that defined by modernity. Cfr. Clare Chandler, 'Current Accounts of Antimicrobial Resistance', *Palgrave Communication*, 5(53), 2019.
64. Joan Martínez-Alier, *The Environmentalism of the Poor: A Study of Ecological Conflicts and Valuation*, Cheltenham, UK: Edward Elgar Publishing, 2003; Robert Nixon, *Slow Violence and the Environmentalism of the Poor*, Cambridge, MA: Harvard University Press, 2011.
65. In her fieldwork undertaken with Alps' cheese makers Roberta Raffaetà points out to so-called 'microbial antagonism' which 'counteracts pathogens not by directly blocking them but, rather, by transforming the entire system from a field of struggle into one of healthy cohabitation', Roberta Raffaetà, 'Microbial Antagonism in the Trentino Alps. Negotiating Spacetimes and Ownership through the Production of Raw Milk Cheese in Alpine High Mountain Summer Pastures', *Current Anthropology*, 62(24), ahead of print article.
66. Today, the scientific debate around antibiotic resistance represents a highly complex and often controversial arena of voices from diverse communities of experts seeking to prevent an increase in the 700,000 deaths attributed to it each year, cfr. Interagency Coordination Group on Antimicrobial Resistance, 'No time to wait: Securing the future from drug-resistant infections', *Report to the secretary-general of the United Nations*, Geneve, 2019. Available at: https://www.who.int/antimicrobial-resistance/interagency-coordination-group/final-report/en/ (accessed 31 May 2021).
67. Bonneuil and Fressoz, *The Shock of the Anthropocene*; Martínez-Alier, *The Environmentalism of the Poor: A Study of Ecological Conflicts and Valuation*; Michael Common and Sigrid Stagl, *Ecological Economics: An Introduction*, Cambridge: Cambridge University Press, 2005.
68. I date the inception of globalization to the 1970s, when the mobility of financial markets underpinned by quick telematic infrastructure for exchanging communications and data allowed for the relocation of industries of the Global North across the whole globe, cfr. Mark Harrison, 'A Global Perspective: Reframing the History of Health, Medicine, and Disease', *Bulletin of the History of Medicine*, 89(4), 2015, pp 639–689.
69. Flavio D'Abramo, 'Oysters, Selective Pressures, and Antibiotic Resistance in the Mississippi River Delta', *Anthropocene Curriculum*, Berlin: Haus der Kulturen der Welt, March 23, 2020, accessed 31 March 2020. Available at: https://www.anthropocene-curriculum.org/contribution/oysters-selective-pressures-and-antibiotic-resistance-in-the-mississippi-delta.
70. For a compelling reference example on how to develop community driven participatory research to address environmental health issues caused by the food industry, see Sarah Rhodes, KD Brown, Larry Cooper, Naeema Muhammad, and Devon Hall, 'Environmental injustice in North Carolina's hog industry', pp 99–116, in Thom Davies and Alice Mah (eds), *Toxic Truths: Environmental Justice and Citizen Science in a Post-truth Age*, Manchester: Manchester University Press, 2020. Available at: https://www.manchesteropenhive.com/view/9781526137005/9781526137005.00014.xml; On environmental conflicts in Terra dei Fuochi in Southern Italy, see Giacomo D'Alisa, David Burgalassi, Hali Healy and Marina Walter, 'Conflict in Campania: Waste Emergency or Crisis of Democracy', *Ecological Economies*, 70(2), 2010, pp 239–249; Marco Armiero, *Wastocene*, Cambridge: Cambridge University Press, 2021. On the Louisiana Cancer Alley and other environmental conflicts of the New Orleans area cfr. Sharon Lerner, 'A Tale of Two Toxic Cities. The Epa's Bungled Response to an Air Pollution Crisis Exposes a Toxic Racial Divide', *The Intercept*, 24 February 2019. Available at: https://theintercept.com/2019/02/24/epa-response-air-pollution-crisis-toxic-racial-divide/ (accessed 31 March 2020).
71. The history of antibiotic resistance, which is the history of environmental degradation caused by industrial activities, intersects, not by chance, with the history of social oppression, which in Louisiana is the history of slavery. After 1865, when the US Congress

outlawed slavery, the lands of southeast Louisiana formerly belonging to slavers were then sold to oil and chemical industries, which tested their by-products by spraying, from aircraft, chemical agents to protect the crops from pests. In their alleged freedom, former slaves still working on plantations were caught by the toxicity caused by pesticides. Roger Ashley and Yvonne Holden, 'Whitney Plantation Museum Tour', in Whitney Plantation Museum, New Orleans, September 2, 2019.

72. Sylvia Wynter and Katherine McKittrick, *On being Human as Praxis*, Durham: Duke University Press, 2015.
73. Nancy Fraser, 'Climates of Capital. For a Trans-Environmental Eco-Socialism', *New Left Review*, 127, January-February 2021, pp 94–127; Nancy Fraser, 'Incinerating Nature. Why Global Warming is Backed into Capitalist Society', Inauguration of the Vienna Karl Polanyi Visiting Professorship, 2021, Online Public Lecture. Available at: https://www.youtube.com/watch?v=iZQmGb9P3JA&t=0s.

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