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Abstract:
Research on human microbiota points to a previously overlooked disaster: many of the microbes with which our bodies had symbiotic relationships have disappeared or are in the process of disappearing. This account of disappearing microbiota invokes biomedical reasons and major socio-ecological transformations. It is the basis for two global collection and conservation initiatives: the Global Microbiome Conservancy and the Microbiota Vault. This article shows that this narrative, "the theory of the disappearing microbiota", confers a discursive base and a historical imaginary to colonial logics that infuses strands of research on microbiota. This essay characterizes the long duration of colonial patterns that unfold, as well as some of their consequences for understanding the diversity of human communities, their histories, and the historical mechanisms of the alteration of gut microbiota. This article concludes with a series of proposals aimed at determining the conditions necessary for the elaboration of other, less dangerous narratives that would lead scientists to pursue different, anti-colonial practices.

Keywords: Microbiota — Coloniality — Extinction — Narrative — Collection

"I am less interested in history books than in what might happen next."
Martin Blaser

"My main reason for postponing the end of the world is so we've always got time for one more story. If we can make time for that, then we'll be forever putting off the world's demise."
Ailton Krenak

Introduction

In the field of research on microbiota in human health, a narrative has come to prevail, emphasizing the decline of microbial diversity and the disappearance of ancestral gut micro-organisms among the populations of industrialized societies.[1] Sweeping consequences on health have been attributed to this trend, which has been linked to an "epidemic" of chronic diseases.[2] This narrative, which is referred to as "the theory of the disappearing microbiota," is used to explain the dominant chronic and degenerative features in the epidemiology of these populations.

The first explicit formulation of this theory dates back to 2008 in an article written by physician and microbiologist Martin Blaser.[3] This first occurrence drew on his research that established the disappearance of *Helicobacter Pylori* from the guts of Westerners and discussed its likely

[1] No single way of naming human communities is entirely satisfactory, especially when these categories do not reflect the expression of the communities under consideration. As Khan T, Abimbola S, Kyobutungi C, et al. have stressed: "The practice and vocabulary of global health and global development today have their origins in racism and colonialism, which has created a false hierarchy among nations, ascribed a higher value to some lives, and allowed some groups to extract, exploit and subjugate others" Khan et al., "How We Classify Countries and People—and Why It Matters.". Having said this, for readability purposes, I have decided to only occasionally use quotation marks for certain phrases as a reminder of their problematic character.

[2] Blaser, "The Theory of Disappearing Microbiota and the Epidemics of Chronic Diseases."

[3] Blaser, "Disappearing Microbiota."

impacts on health. Since then, multiple studies on the gut microbiota of a variety of rural or "hunter-gatherer" populations in the Global South have strengthened this hypothesis, demonstrating that their gut microbiota may be characterized by greater diversity and the presence of species not found in Western guts.[4] The supposedly imminent disappearance of these populations' lifestyles is thought to herald the irremediable extinction of these microbiota, which should therefore be saved before they disappear altogether.[5]

This narrative on the disappearance of gut microbial diversity has become one of the leading motifs in research on gut microbiota, gaining popularity through books[6], newspaper articles[7] and documentaries[8] geared toward audiences beyond the confines of academia. This narrative has given the impetus for two global collection and conservation initiatives: the Global Microbiome Conservancy (GMbC) and more recently the Microbiota Vault.[9] Their objectives include the collection and preservation of endangered microbiota for the future development of knowledge and the advancement of public health.

Microbiota collections and research practices have raised multiple questions within the community of the biologists and physicians involved, concerning the ethics of research and collection, who owns the collected biological samples and what happens to them, questions surrounding the inclusion and representativeness of varied human populations, whether it is pertinent to consider restoration practices on the basis of allegedly ancestral microbiota, as well as the use and availability of the knowledge and techniques that would come out of this.[10] Recently, anthropologists and historians have questioned the more or less explicit use of racial categories in the microbiota sciences.[11] Others have singled out the discursive and techno-scientific colonial logics underpinning them.[12] These critiques have paved the way for a broader understanding of the ways in which these sciences reenact, extend and transform rationales, assumptions, ways of saying and doing things that involve hierarchies, relations of power and domination between humans. They contribute to characterizing various aspects of the coloniality of the microbiota sciences: "a purportedly natural subordination of non-Western places, humans, forms of knowledge and subjectivities" inherited from previous

[4] Yatsunenko et al., "Human Gut Microbiome Viewed across Age and Geography"; Rampelli et al., "Metagenome Sequencing of the Hadza Hunter-Gatherer Gut Microbiota."

[5] Bello et al., "Preserving Microbial Diversity."

[6] Velasquez-Manoff, *An Epidemic of Absence*; Blaser, *Missing Microbes*; Sonnenburg and Sonnenburg, *The Good Gut*; Yong, *I Contain Multitudes*.

[7] Schenck, "Save the Germs"; Sample, "Build 'Noah's Ark' for Beneficial Gut Microbes, Scientists Say"; Kolata, "You're Missing Microbes. But Is 'Rewilding' the Way to Get Them Back?"

[8] "Microbiote, Les Fabuleux Pouvoirs Du Ventre"; *The Invisible Extinction. The Race to Save Our Vanishing Microbes*.

[9] The Global Microbiome Conservancy (GMbC) was founded in 2016 at the Massachusetts Institute of Technology. More than thirty human communities, including over 1300 participants, have already been included in the collection. See: https://microbiomeconservancy.org. Founded in 2019, The Microbiota Vault is in its "launch phase". It is supported by non-profit institutions and universities active in the field of the human gut microbiome. See: https://www.microbiotavault.org.

[10] Dominguez-Bello et al., "Ethics of Exploring the Microbiome of Native Peoples"; Mangola et al., "Ethical Microbiome Research with Indigenous Communities"; Hawkins and O'Doherty, ""Who Owns Your Poop?"; Pérez Ortega, "Studies of Human Microbiome Have Ignored the Developing World, Potentially Compromising Treatments"; Carmody, Sarkar, and Reese, "Gut Microbiota through an Evolutionary Lens."

[11] Benezra, "Race in the Microbiome"; Nieves Delgado and Baedke, "Does the Human Microbiome Tell Us Something about Race?"; Wolfe et al., "Chasing Ghosts."

[12] Maroney, "Reviving Colonial Science in Ancestral Microbiome Research"; Hobart and Maroney, "On Racial Constitutions and Digestive Therapeutics"; Raffaetà, *Metagenomic Futures*.

forms of colonial domination.[13] Building on these critiques and drawing on tools developed in science studies, subaltern historical studies and in the history and anthropology of colonialism, this paper seeks to evidence how the disappearing microbiota narrative feeds into this coloniality, acting as its discursive foundation of sorts and as its historical imagination.

As feminist cultural studies of science have taught us, scientific practices of knowledge production are embedded in narratives and these narratives are in no way neutral as they bring into play broader socio-political motives and imaginaries that precede them.[14] These narratives and the imaginaries they convey affect the work of researchers, the ways in which knowledge is produced, circulated and transformed; they inform the framework of practices, participate in the description of the situations, the definition of the problems and delimit the range of possible answers to them—in the case at hand, the collection and conservation of microbiota from supposedly preserved human communities in response to the observed alteration of gut biodiversity. In doing so, as we will see, the narrative of the disappearing gut microbiota impacts both human communities and the microbes enlisted in this research, thus raising a tangle of political, ethical *and* biological questions with which the scientists pursuing this research must learn to situate themselves if they want to appreciate them. That is, learning to consider the position they occupy, its blind spots and implications, and to make it an object of critical inquiry in its own right. It also means learning to respond to them, without presupposing that the so-called universality or neutrality of science gives them a free pass or that they should only speak up on the scientific aspects, even though these very scientific aspects are actually also biological, political and moral (or ethical) ones.[15] "Situating" oneself does not mean denouncing this or that situation, or openly taking sides against, for example, the governments of countries that oppress certain populations that are the subjects of collection. This can be done, but first and foremost what is meant by this is the work of understanding the contradictions, injustices and forms of violence involved in all forms of knowledge production practices, and more generally, their consequences and impact on researchers' positions.

Importantly, this need to learn to situate oneself is just as valid for the researcher that I am. As I engage in this research, I cannot be satisfied with a *distanced* moral and political critique or condemnation of the disappearance narrative. The diagnosis of the scientists, the materiality of the worldly and ecological devastation that they indicate, matters to me. This is why I also make a deliberate effort to take it seriously, to describe it accurately and to do it justice, to pave the way for other narratives. In other words, while my critique tends to point to some of the colonial dimensions of this narrative and of its associated practices, I cannot simply argue: "This is a bad, dangerous narrative." I must also consider the way in which it can be received by the biologists who work on these subjects and allow for the elaboration of other, less dangerous (and I believe more relevant) ways of narrating the joint transformations of human microbiota and societies. The point here is accordingly not to dispute the diagnosis of a historical alteration of gut microbial ecologies, but on the contrary to offer a critique of the historicist, Western-centric narrative that accounts for it to broaden the historical and political horizon of its understanding, and in doing so, help bringing about the possibility of

[13] Escobar and Restrepo, "Anthropologies hégémoniques et colonialité," 86.

[14] Haraway, *Primate Visions*; Martin, "The Egg and the Sperm: How Science Has Constructed a Romance Based on Stereotypical Male- Female Roles"; Keller, *Making Sense of Life*; Wald, "Blood and Stories."

[15] Harding, *The Science Question in Feminism*; Haraway, "Situated Knowledges"; O'Brien, "Being a Scientist Means Taking Sides."

scientific narratives and practices that strive to depart from colonial rationales.[16] In a way, I am trying to reverse Martin Blaser's opening proposition: this is an invitation to look at history and the way it is embedded in our statements, practices, habits and the evidence that structures them, in order to make us better able to appreciate what is coming next and to make us consider new or neglected possibilities.

In fact, this article is also a proposal for a critical analysis forged within a dialogue initiated almost four years ago with GMbC co-founders and scientific directors Mathilde Poyet and Mathieu Groussin, concerned with the unintended consequences of their practices.[17] This learning about the socio-historical implications and power relations inevitably involved in scientific research requires, I believe, this kind of critical, frank, and long-term dialogue. This text and the always generous exchanges to which its elaboration has given rise leave me believing in the ever-open possibility of a dialogue and a common learning of other ways of doing science. The continuation of this research will reflect the extent of this.

This article is based on a series of interviews, some regular and long-term, with biologists involved in this field, and more specifically with stakeholders of the two collection initiatives mentioned. They were conducted during research visits to their laboratories, at conferences or by videoconference, as part of a longer-term dialogue with them on these issues. These interviews enabled me to circumscribe and assess the scientific literature (in biology and biomedicine) in which this narrative on the disappearance of gut microbiota has been elaborated and discussed, and more generally on the literature that attempts to understand and to pinpoint the consequences of the lifestyles and histories of human communities on microbiota. But these interviews also allowed me to put my critique to the test, as many elements of its construction—right up to the final reading of this article—were the subject of discussion. So, drawing on critical, anthropological, historical and anti-colonial approaches, I characterize the colonial motifs exhibited in this narrative over the long term, as well as some of their consequences on the understanding of the diversity of human communities, of their histories and of the historical mechanisms involved in the alteration of gut microbiota. I will then show how this account tends to reduce the understanding of the situation it describes to biomedical knowledge alone, to implicitly disqualify other forms of knowledge and to perpetuate the idea that the world is naturally available to scientific research. I will subsequently confront the promise of the techno-scientific resolution of this disappearance carried by this narrative with the fundamentally local and situated microbiota biologies, to account for its limitations.[18] I will conclude with a set of proposals aimed at creating the conditions for scientists to hear the voices and the knowledge that are tuned out by this hegemonic narrative and to take them seriously, in order to develop other, denser and, I believe, less dangerous accounts, guiding scientists towards anticolonial practices.

1. The Disappearance Narrative

The reasons cited for the presumed disappearance of microbiota are manifold. Much of the literature emphasizes iatrogenic and biomedical reasons such as the "overuse" of antibiotics,

[16] For a consideration of these logics within scientific practices and a proposal for a consistent method for anti-colonial sciences, see Liboiron, *Pollution Is Colonialism*., and more broadly all the work done by the members of the CLEAR laboratory: https://civiclaboratory.nl.

[17] For example, the GMbC founders published a text that criticized the "practice of 'dropping in' on another country to take whatever is needed to further research" in the newsletter of their research center. "Leave 'Parachute Science' Behind When Jumping into Global Microbiome Research | MIT Center for Microbiome Informatics & Therapeutics (CMIT)."

[18] Niewöhner and Lock, "Situating Local Biologies."

particularly during the first three years of life, and a purportedly excessive recourse to caesarian sections. Childbirth and early childhood are indeed considered as "critical windows" for the formation of microbiota (which is why infant formula is also often named as a culprit). Some authors explicitly reference the "hygiene hypothesis" developed in the late 1980s by British epidemiologist David Strachan, to point to the nefarious role played by the expansion of hygiene rules and practices over more than a century.[19] According to the proponents of that theory, the lack of exposure of children to infectious agents in infancy accounts for the insufficient maturing of the immune system and an associated surge in allergic dispositions. The more recent "old friends" hypothesis reformulates and complements this theory to account for the decrease in microbiota diversity and the significant increase in inflammatory diseases.[20]

More largely, a wide variety of lifestyle changes in Northern countries that have led to multiple transformations affecting our relationships to microbes are listed in the literature: the transformation and urbanization of housing; the supply and chlorination of drinking water; the industrialization of food production and the rise of ultra-processed foods; the considerable changes in the relationships between humans and animals, altering microbial exchanges, etc. The words "industrialization," "urbanization," "Westernization" or "modernization" have been used somewhat indistinctly by biologists as generic labels to refer to the broader processes encompassing these joint transformations of lifestyles and guts. An explicit connection has been made with climate change, the sixth mass extinction and the Anthropocene.[21] This narrative conveys a sense that the defining environmental crises of our time, the consequences of Western lifestyles on water, soil, air, fauna and flora are replicated and extended into the guts of many human populations' bodies. The transformations of microbiota ecologies are considered as the means through which these long-term historical processes inform bodies and are inscribed in bodies by altering their health and biology, a signature among others of a "biology of history", a way in which "human historical events and processes have materialized as biological events and processes and ecologies".[22]

Yet, this narrative and these causes, whose chronology spans over 200 years, are embedded in an even longer-term standard narrative: the anthropological narrative of humanity's evolution. The life-threatening gradual drop in the diversity of gut microbiota and the concurrent development of modern diseases is thought to go hand in hand with the succession of "stages of development," "economies," "subsistence regimes" and of the "revolutions"—Neolithic and industrial—they have witnessed—the shift from hunting-gathering to farming, followed by the gradual, continuous extension of urban lifestyles (fig. 1).

Figure 1. Declining human intestinal microbial diversity with industrialization. Bello, Maria G. Dominguez, Rob Knight, Jack A. Gilbert, and Martin J. Blaser. "Preserving Microbial Diversity". *Science* 362, nº 6410 (5 October 2018), 34.

This narrative and this image, among others, describe a gradual loss of "ancestral microbiota", microbiota that were purportedly adjusted to their host's biology.[23] In the same way as

[19] Strachan, "Hay Fever, Hygiene, and Household Size."
[20] Rook, Lowry, and Raison, "Microbial 'Old Friends', Immunoregulation and Stress Resilience."
[21] Gillings and Paulsen, "Microbiology of the Anthropocene"; Bello et al., "Preserving Microbial Diversity."
[22] Landecker, "Antibiotic Resistance and the Biology of History," 21.
[23] Gomez et al., "Gut Microbiome of Coexisting BaAka Pygmies and Bantu Reflects Gradients of Traditional Subsistence Patterns"; Brewster et al., "Surveying Gut Microbiome Research in Africans"; McCall et al., "Home

technical objects or certain inventions or discoveries have served as markers in cultural anthropology, the degradation of gut microbiota communities is presented as a biological marker of stages of development or civilization of the societies of those who carry them. The urban lifestyle, which is the most advanced in this line of human history eras, is equated with a decline in the diversity of gut microbes. This paradoxically heralds the achievement of the modern agenda of the emancipation of human societies from natural elements. For indeed, this narrative is also the universal history of a literally *antibiotic* humanity: viscerally opposed to life, or at least to the lives of its microbial companions.

These "ancestral" microbiota have not yet disappeared entirely, they note. To determine their characteristics, researchers draw both on the analysis of coprolites—fossilized stools—and of feces from great apes. However, the quality of the data that can be gathered from coprolites and the relativity of those from great apes place limitations on the inferences researchers can draw from them. To address this, "another method of inferring features of an ancestral microbiota involves studying samples derived from populations living some type of traditional lifestyle, such as hunter-gatherers or rural, agrarian cultures"[24]. Some so-called "traditional" or "hunting-gathering" populations, believed to have remained more or less on the sidelines of the previously described "modernization" processes, are thus considered to be the living carriers of these microbiota. According to some estimates, however, by 2050, over 2.5 billion people will have left their "traditional" lifestyles behind to adopt "urban" ones.[25] The extension and generalization of this history of a gradual and supposedly unstoppable "Westernization" of lifestyles *and* guts is what preoccupies these scientists. They are all the more concerned as, once it has begun, this alteration of microbiota is thought to be passed on and irreversibly amplified from generation to generation.[26]

Prominent specialists of the biology of human microbiota have issued the following call: "Most urgently, we need to preserve the diversity of ancestral microbes from globally diverse human populations and especially include those who have had the least exposure to urbanization". [27] Indeed, as exemplified by Figure 1, the disappearance narrative also comes with the techno-scientific promise of a possible resolution to this irreversible decline. This involves the elaboration of strategies to restore microbiota diversity relying on "the collection and banking of microbes from minimally disturbed traditional populations".[28] While the natural slant of *this* history of humanity is an *antibiotic* one, sciences and technologies, which are key actors in this history, are paradoxically always seen as means to remedy this inherent defect; scientists play the role of saviors of a biologically decadent, inevitably damaged humanity.

2. The waiting room of history: The coloniality of the disappearance narrative

Beginning in humanity's infancy, the narrative of the disappearing gut microbiota spans over 10,000 years of history of the human species to account for the current state of gut microbiota

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Chemical and Microbial Transitions across Urbanization"; Sonnenburg and Sonnenburg, "The Ancestral and Industrialized Gut Microbiota and Implications for Human Health."

[24] Sonnenburg and Sonnenburg, "The Ancestral and Industrialized Gut Microbiota and Implications for Human Health," 385.

[25] United Nations, Department of Economic and Social Affairs, and Population Division, *World Urbanization Prospects*.

[26] Blaser and Falkow, "What Are the Consequences of the Disappearing Human Microbiota?"; Sonnenburg et al., "Diet-Induced Extinction in the Gut Microbiota Compounds over Generations."

[27] Bello et al., "Preserving Microbial Diversity."

[28] Bello et al.; Sonnenburg and Sonnenburg, "The Ancestral and Industrialized Gut Microbiota and Implications for Human Health."

in the urban populations of Northern countries. In the process, this narrative also reproduces and shares intertwined motives from a number of typical narratives: the paradoxical narrative of a reparation of the damage of progress by its main scientific and technological culprits; the older narrative of the pathologies of progress or of the degeneration of populations in industrial societies; the aforementioned narrative of the universal history of humanity's evolution, or the related narrative of the inevitable disappearance of native or colonized peoples, and those, concomitantly, of their biological specificities.[29] All motivated concomitant quests in biomedical research, from collection practices to the organization of clinical trials, for "virgin" subjects or those supposedly preserved from the consequences of history.[30] Through the unproblematized, and even in some cases naïve reiteration of these narratives or categories of description of historical processes—such as the succession of "stages" of development or the definition of modes of subsistence—the underlying assumptions of the spontaneous historical theory and anthropology that inform this narrative are problematic.

This is first because they tend to *naturalize* this history, to make it the outcome of *a continuous*, *inevitable* unfolding of processes or events fundamentally oriented or governed by a strictly Western *telos* and whose realization determines the biological nature of the organisms that are its vectors. In other words, this narrative traces the outlines of *a* universal history—biological and cultural—of *a* humanity that is working towards its Western actualization, relegating the others, the not-yet Western, "to an imaginary waiting room of history" (which is still full of microbes) and to the (more antiseptic) waiting room of the promised future of biomedicine.[31] There are reasons to cast doubt on the universality and the naturality of this history.[32] This narrative is a provincial one. Historically, it is connected to the Europeans' colonial projects. This "distinctively European way of going back in time and constructing the past (…) was a key instrument of Western colonization".[33] By relegating the other, colonized peoples to the past history of a common humanity, such narratives and their associated historicism have "enabled European domination of the world".[34] Colonization could accordingly be seen as the acceleration of an *already* ongoing history: a forced, anticipated integration of allegedly backward human communities. What disappeared as a result of colonial violence was in the process downplayed or even justified, on the grounds that it was *bound* to disappear anyway at some point. "The belief that savagery was vanishing of its own accord from the world of progress and light mitigated guilt and sometimes excused or even encouraged violence toward those deemed savage".[35] Colonial societies developed an array of practices and types of knowledge—from the first questionnaires at the time of the colonization of the New World to the survey and collection practices of the natural sciences and of anthropology—aimed at documenting and collecting entire swaths of the nature-culture of colonized societies "before they disappear".[36] Museum collections and scholarly

[29] Rosenberg, "Pathologies of Progress"; Kevles, *In the Name of Eugenics*; Brantlinger, *Dark Vanishings*; Radin, *Life on Ice*.

[30] Reardon, *Race to the Finish*; Petryna, *When Experiments Travel: Clinical Trials and the Global Search for Human Subjects*.

[31] Chakrabarty, *Provincializing Europe*, 8.

[32] The criticism of teleological versions of history is considerable, some references, Koselleck, *Futures Past*; Hartog, *Chronos*; Lowy, *Fire Alarm*.

[33] Gruzinski, *La machine à remonter le temps. Quand l'Europe s'est mise à écrire l'histoire du monde*, 14.

[34] Chakrabarty, *Provincializing Europe*, 7.

[35] Brantlinger, *Dark Vanishings*, 3.

[36] Boumediene, *La colonisation du savoir*; Clifford, *The Predicament of Culture*.

accounts constitute, among others, devices for the conservation of what colonial societies have been able and have seen fit to collect, irrespective of broader worlds and ways of knowing and living that could continue to disappear.

By situating the societies to which scientists belong at the end of a universal history, at the closest point to its achievement, the disappearing gut microbiota narrative unthinkingly reproduces the colonial assumptions of a history polarized by its Western accomplishment. The human communities concerned by these collections are many, including the Northern Cheyenne, the Inuit in Canada, the Sami in Finland, the BaAka in Cameroon and the Hadza in Tanzania. The very ways in which they are characterized and named owe much to colonial history.[37] What jeopardizes the plurality of these communities' current lifestyles is not so much the outcome of a natural, inevitable historical process as the continuation and updating of various forms of stigmatization, marginalization and oppression caused by the appropriation and exploitation of their lands and means of subsistence. In some cases, these forms of oppression are typical of the capitalist frontiers; in others, of fauna and flora conservation policies that exclude human communities; in every instance, they reflect the perpetuation of rationales of appropriation and exploitation of territories that disregard the distinct lifestyles of the communities concerned.[38] It is quite difficult to comprehend these contemporary situations without considering the *longue durée* of past colonial oppression, which continues to shape them today. By naturalizing these histories, the disappearing microbiota narrative prevents us from grasping the multiple—political, economic *and* colonial—reasons underpinning simultaneously the alteration of microbial ecologies and the repeated, long-term attempts to weaken or destroy human communities. By silencing and negating this past and current violence, this narrative redoubles it.[39]

The coloniality of the disappearance narrative involves the negation of histories of "non-Western places, humans, forms of knowledge and subjectivities" and of the colonial violence that characterizes them.[40] This narrative reproduces a narrow version of the diversity of the pasts and presents of human communities. In the process, it hinders or preempts present and future ways out of the situation it describes, confining them to a technoscientific solution.

3. Disappearing Worlds, Available Worlds and Technoscientific Promises

As Maria Dominguez Bello clearly states in *The Invisible Extinction. The Race to Save our Vanishing Microbes*, a documentary dedicated to her and Martin Blaser's work: "We see answers in places where the problem hasn't yet begun." The capacity for anticipation claimed by these researchers is a characteristic feature of biomedical technoscience.[41] Based on the assumption of the inevitability of a universal history and of the urgency to act that follows, it tends to point to the techno-scientific response of collection and conservation of gut

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[37] Khan et al., "How We Classify Countries and People—and Why It Matters"; Stoler, *Carnal Knowledge and Imperial Power*.

[38] Tsing, "Natural Resources and Capitalist Frontiers"; Spence, *Dispossessing the Wilderness*; Blanc, *The Invention of Green Colonialism*; Liberty, *Cheyenne Memories*; Labba, Roué, and Sule, *Vies de Samis - Les déplacements forcés des éleveurs de rennes*; Coulthard, *Red Skin, White Masks*. Thus, to say, as is sometimes the case, that microbiota research is considered one of the new frontiers of biomedicine is far more than a simple metaphor.

[39] "I'm particularly concerned with doubled violence. The doubling I refer to is a continuing act of wounding that not only kills parts of a living system but actually disables or kills the capacity of a living system to repair itself. (…) In more personal contexts, doubling up refers to the amplification of pain through repetition and denial." Rose, *Reports From a Wild Country*, 7.

[40] Escobar and Restrepo, "Anthropologies hégémoniques et colonialité," 86.

[41] Adams, Murphy, and Clarke, "Anticipation."

microbiota as evident and as one of the few if not the only credible alternative to disappearance. For this response to appear self-evident or desirable, a prerequisite is denying the value of the knowledge and practices of Indigenous communities, which are never mentioned in scholarly publications.[42] As these human communities are positioned at a less advanced stage of the civilization process, their knowledge and their practices are negated, considered as worth less those of scientists from the former metropolises. To be more specific, as Jenny Reardon and Kim TallBear have shown us, one may argue that this knowledge and these practices are implicitly disqualified and depreciated in that they are considered incapable of transforming a so-called natural resource into goods with a higher value for humanity in general.[43] This is a staple of colonial appropriation: it is justified in the name of the purported inability of Indigenous communities to transform their territories and give them value through work.[44] Then, as scientific practices and knowledge are positioned at the end of that inevitable history, scientists appear to be the best suited to save what they consider relevant in what is otherwise disappearing. The integration of these diverse human and microbial communities as representatives of a previous period of this universal history of a common humanity, constitutes their microbiota as part of a shared heritage, necessarily available to scientific research.[45] All this allows to make evident and necessary the collection and conservation by scientists "for the long-term health of humanity" of microbiota samples, and the production in their name, of data, knowledge and practices deriving from it.[46]

The scarcity of a "disappearing" resource and the perspective of new forms of knowledge and therapeutic innovation, give the collected samples a biological and scientific value, constituting them as new biological and scientific capital.[47] This narrative thus also places the biology of microbiota within an economy of techno-scientific promise.[48] This promise further legitimates the scientific actors who have defined the problem (as well as its expected solutions) and contributes to bolstering the epistemic foundations of its treatment. Additionally, in an economy of knowledge that requires ever more capital, it also attracts new actors to join the effort and fund this research.[49] In doing so, it outlines the temporal horizon of the resolution of the problem they set out to address. It defines hypothetical futures that the certain progress of biomedical knowledge and practice will bring about. The disappearing microbiota narrative is thus imbued with a paradoxical temporality which combines a linear temporality of progress, full of technological promise and optimism, and the temporality of an inevitable ongoing disaster. Yet this temporality might not be as paradoxical as it seems. It probably characterizes what is meant by progress in that worldview, namely the unfolding of a linear, promise-filled time that justifies or at least downplays the destruction-filled present. This promise would, however, be meaningless without a material basis, which is provided by collection and low-temperature conservation techniques. The latter involve another form of

[42] Seth, "Colonial History and Postcolonial Science Studies."
[43] Reardon and TallBear, "'Your DNA Is Our History.'"
[44] Bishop, "Locke's Theory of Original Appropriation and the Right of Settlement in Iroquois Territory."
[45] This point more generally sheds light on one of the fundamental features of scientific practice and of the scientific ethos: the rarely questioned presupposition that all things in the world are always already available to scientific research and ready to be transformed into scientific knowledge. This is why some scientists are so puzzled when certain human communities refuse to pass on biological samples or ask to have previously collected ones returned, Reardon and TallBear, "'Your DNA Is Our History.'"
[46] As indicated on the home page of the Microbiota Vault website.
[47] Rajan, *Biocapital*; Helmreich, "Species of Biocapital."
[48] Audetat et al., *Sciences et technologies émergentes*.
[49] Jasanoff, *States of Knowledge*.

unprecedented temporality: the suspension of disaster.[50] This suspension, which is materialized by the cryopreservation of stool samples, could however (paradoxically?) lead us to downplay the seriousness of the ongoing disappearance.

Indeed, these technologies remain extremely incomplete: they can be used only to preserve some of the gut microbiota: (i) those found in feces and which are only fragments of all the microbiota located in the intestinal tracts; (ii) those that cryopreservation and culturing technologies are able to preserve and resuscitate; it bears reminding the variety and multiplicity of the organisms that make up microbiota—bacteria, viruses, archaea, protists—whose conservation and culture cannot for the most part under the current practices be guaranteed; (iii) lastly, those that were collected at a specific moment, as microbiota are subject to temporal (daily, seasonal, etc.) variations.[51] These biologists admit that this response is largely lacking, especially considering that microbiota are not so much considered as the sum of the multitude of microbial entities that compose them, but rather as dynamic ecologies, sets of situated relationships that condition what microbes are and do. The biology of microbiota indeed tends to affirm the primacy of relationships over their terms, or, as the biochemist and philosopher of science W. Ford Doolittle and Austin Booth have put it: "It's the song, not the singer"—the song comes before the singer, or rather, the song makes the singer.[52]

The narrative of the disappearance of gut microbiota is therefore paradoxical. As it allows us to grasp the inextricable intertwining of human and microbial histories, it downplays its importance by situating it within a purportedly inevitable universal history and proposing a strictly techno-scientific response. Yet, this narrative tells us something important that adds to the above and deserves emphasis: the disappearance that comes with the alteration of ecologies and the loss of some gut microbial strains is not so much about isolated microbial species, about empty spaces in their classification, but about the collapse of distinctive worlds and ways of life.[53] This narrative suggests that these worlds are full of interspecific relationships, that produce ways of feeding oneself and caring for oneself and others, birthing and growing, ways of inhabiting territories and maintaining relationships with multiple creatures that populate and shape them: different ways to live and die in worlds that are far broader than just those of humans, *a fortiori* of Western ones, and different ways to weave and tell stories.[54] Borrowing the terms used by W. Ford Doolittle and Austin Booth, one might say that these worlds upon which microbiota depend are multispecific ecologies, songs that demand, call for, replay and enable other songs and that make a home for the microbiota. The unraveling of these worlds and of their constitutive relationships makes it difficult for the companionship of some microbes with some humans to endure. As these relationships are mutually constitutive, the consequence of their severance is that the biologies of humans and microbes are transformed and embarked on singular evolutive trajectories whose impacts are difficult to assess. To extend the metaphor, we might ask: what happens to the singers once they are deprived of their songs? This is certainly an enigma, but what is also certain by now is that to explore that enigma, the disappearing microbiota narrative is not useful.

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[50] Radin and Kowal, *Cryopolitics*.

[51] Chung et al., "Fecal Microbiome Does Not Represent Whole Gut Microbiome"; Biclot et al., "Effect of Cryopreservation Medium Conditions on Growth and Isolation of Gut Anaerobes from Human Faecal Samples"; Vandeputte et al., "Temporal Variability in Quantitative Human Gut Microbiome Profiles and Implications for Clinical Research."

[52] Ford Doolittle and Booth, "It's the Song, Not the Singer: An Exploration of Holobiosis and Evolutionary Theory."

[53] Chrulew, Rose, and Dooren, *Extinction Studies*.

[54] Brives, "Pluribiosis and the Never-Ending Microgeohistories."

Conclusion: Coming up with different narratives on what is disappearing and what causes disappearance

The disappearing microbiota narrative brings together the typical motifs of colonization-related disappearance narrative. As a result, it makes it quite difficult, other than by pinpointing "resources" considered worthwhile, to take seriously the forms of knowledge, practices, lifestyles and worlds of those who are purportedly disappearing. In doing so, the narrative reinforces the necessity of *a* world as it is. A world that is characteristic of "Northern" countries and of their modernity, with its scientists, its knowledge and technology infrastructure, its conceptions of ownership, its hierarchies for practices and knowledge and its ways of telling disappearance stories.[55] This is, according to this narrative, the very same "Western" world that appears to be contributing to the disappearance of microbiota. The very utterance of this narrative supposes this world and its extension. This is colonialism by other means.

The consequences of this narrative are therefore not only discursive. It affects human and microbial communities both: human communities become objects of collection around which scientific communities are built and consolidated, while microbial communities become lab samples and cultures that serve as new resources for research. Research programs are developed and funded, academic papers are written, knowledge is produced, and all of these practices outline a response to a global sanitary and ecological crisis. While these are only emerging practices, by using this narrative as a backbone, they deprive themselves from more specific understandings of the underlying mechanisms of the crisis, ignoring the violence faced by some human and microbial communities. This narrative continues to prevent scientists from taking stock of the specific forms of knowledge, health and care practices cultivated by the variety of these human communities which are henceforth condemned, as are their distinct ecologies, to an allegedly inevitable disappearance. But what is presented as inevitability is actually not a foregone conclusion: it depends on choices, policies and historical logics that are contingent and as such liable to be altered, and that our narratives can destabilize or at least not reproduce. Overall, while the disappearance narrative poorly accounts for what disappears and what makes it disappear, it also does a bad job of describing the scientific practices and technologies it requires, minimizing the relative scope of their promises and of the technical means of their implementation.

With these narratives, "who or what are we encouraging and facilitating to live and who or what, as a consequence, are we leaving to die"? [56] Given their material consequences and their implications on practices and forms of knowledge intended to account for the biological impacts of human histories, it is important to learn to describe and more precisely narrate these processes and the practices and forms of knowledge that are applied to them. It is time to reformulate the call issued by gut microbiota scholars: "we must urgently learn to produce another narrative on the devastation of microbial gut communities and the purported imminent disappearance of human communities that have kept their diversity alive. We must urgently learn from its lessons in our practice and to question its legacies and consequences." To do this, we need to radically challenge the idea that the disappearance narrative is inevitable and that dominant Western knowledge and conceptions are self-evidently superior.

[55] Mitchell and Chaudhury, "Worlding beyond 'the' 'End' of 'the World.'"

[56] Raffaetà, *Metagenomic Futures*.

We[57] need to be able to hear and seriously consider other voices, other forms of knowledge, other conceptions of health cultivated by the diversity of human communities throughout their history. For while this narrative has been part of their silencing, many communities have maintained and cultivated specific, non-hegemonic forms of practice and knowledge. On the one hand, the work of scholars in *subaltern, anticolonial* and *indigenous studies* has helped to make other voices, other knowledge and other practices audible, documenting their persistence and transformations in the face of colonization and providing the means to overturn these imperial visions of knowledge and health.[58] On the other hand, the voices of these communities have succeeded in proposing and implementing other ways of doing science, trying to combine their knowledge with the dominant knowledge, and maintaining a form of sovereignty over the knowledge produced by the members of their community.[59]
On this new basis and to support the biologists concerned by these questions, here are a few propositions that can be explored to start coming up with another narrative and exploring its consequences for their practice:

- We should no longer consider the variety of human communities as representatives of a common past, but as our contemporaries, and recognize their deliberate choice not to partake in a Western history that has had devastating environmental and ecological consequences.[60] These communities can be seen as historical proposals to exit this supposedly universal and inevitable history, rather than as "resources" enabling us to temporarily delay some adverse consequences. As the indigenous scholars Kim Tallbear argues, the world "needs to learn to see indigenous peoples in our full vitality, not as the de-animated vanished or less evolved. Seeing us as fully alive is key to seeing the aliveness of the decimated lands, waters, and the other non-human communities"; or, as phrased differently by Glen Sean Coulthard addressing the white colonial nation of Canada, "I believe your nation might wish to see us, not as a relic from the past, but as a way of life, a system of values by which you may survive in the future. This we are willing to share".[61]
- We should no longer consider history in the making as an inevitable process, but as the outcome of decisions and processes in which societies and the scientists who live and work within these societies have their share of responsibility. We should no longer naturalize or negate what makes human and microbial communities disappear, but learn to describe the processes, decisions and practices that contribute to these joint disappearances. In other words, we should no longer discuss the disappearance of microbiota without describing the worlds, the ways of life and the human and non-

[57] The "we" and "our" that follow concern those who occupy a position in the production of scientific knowledge about the microbiota of non-European communities (and all those who tend to relegate them to a waiting room of history); it is not a universal, inclusive "we".
[58] For an example of provincialization of chemistry, bacteriology and health, see Mukharji, "Parachemistries"; Chakrabarti, *Bacteriology in British India*; Alter, "Heaps of Health, Metaphysical Fitness."
[59] For example, on genetics, see Tsosie et al., "Indigenous Data Sovereignties and Data Sharing in Biological Anthropology." For another in pollution science see Liboiron, *Pollution Is Colonialism*. For a more general statement from a north American and Potawatomi perspective see Kimmerer, *Braiding Sweetgrass*.
[60] Dupuy, "Des esclaves marrons aux Bushinenge"; Scott, *The Art of Not Being Governed*; Clifford, *Returns – Becoming Indigenous in the Twenty–First Century*; Martin, *À l'est des rêves. Réponses Even aux crises systémiques*.
[61] TallBear, "Beyond the Life/Not-Life Binary: A Feminist-Indigenous Reading of Cryopreservation, Interspecies Thinking, and the New Materialisms," 198; Coulthard, *Red Skin, White Masks*, 63.

human communities affected by it. Such a conception of history can teach us to become accountable, attentive to the consequences of our practices.

- As previously stated, we cannot go on looking at the care and healthcare practices and knowledges of Indigenous communities as secondary and negligible, whether implicitly or not. Many of these communities are bearers of knowledge and practices that do not dissociate the body and health from the broader milieus and histories, including colonial ones, that have shaped them.[62] What may seem new in many areas of contemporary biology, particularly in microbiota science, forms the basis of the understanding of health for these communities. Rather than seeing the dominant sources of scientific knowledge as the only possible ways of understanding and devising propositions, we must put ourselves in the position of learning from these long-disqualified sources, work towards granting them their full cope, instead of merely seeking to gather from them what could be "useful" to "us".[63] Indeed, as the botanist Robin Wall Kimmerer reminds us "It is crucial that new enthusiasm [on indigenous knowledge] not take the form of 'knowledge mining'. […] Attempts of outside actors to 'incorporate' Indigenous knowledge into their own work without the full consent of Indigenous communities is highly extractive and undermines the sovereignty of these communities over their own knowledge."[64]
- We should no longer promise techno-scientific solutions to situations whose implications extend far beyond this realm. This proposal would likely result in questioning certain rationales of research funding and bringing attention to the fact that reliance on these solutions requires believing in a chimera, "trust us and everything will work out" or in a less presumptuous version, "trust us, it's the best thing to do." Yet, this would also require specifying what we could learn from these collections that wouldn't be based on this chimera and partake in a rationale of accumulation of things that one day might come in handy. [65]

These proposals are only initial; because, in addition to being partial, they will only make sense if they come with transformations of the ways in which biology is practiced and knowledge is produced. For unless we want to keep perpetuating chimeras, changing our narratives inevitably means changing our practices.[66] Certainly, this effort requires new types of alliances between scholars in biology and in the human and social sciences.[67] This alone, however, will not suffice. In order to stop "stealing" histories, narratives cannot be written and new ways of doing science cannot be invented without the agreement and participation of the human communities to which they pertain and without scientists genuinely committed to learning anti-colonial scientific practices.[68] We have a lot of work on our plates, and we need to start or continue doing this right now.

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[62] Marya and Patel, *Inflamed*.
[63] On the dangers and the perpetuation of extractivist practices applied to Indigenous knowledge, see McGregor, "Traditional Ecological Knowledge"; Liboiron, *Pollution Is Colonialism*.
[64] Kimmerer and Artelle, "Time to Support Indigenous Science."
[65] Stengers, *Another Science Is Possible*.
[66] On the infrastructure of practices and knowledge of which microbes are part, see Brives, *Face à l'antibiorésistance*.
[67] Benezra, "Race in the Microbiome."
[68] Liboiron, *Pollution Is Colonialism*.

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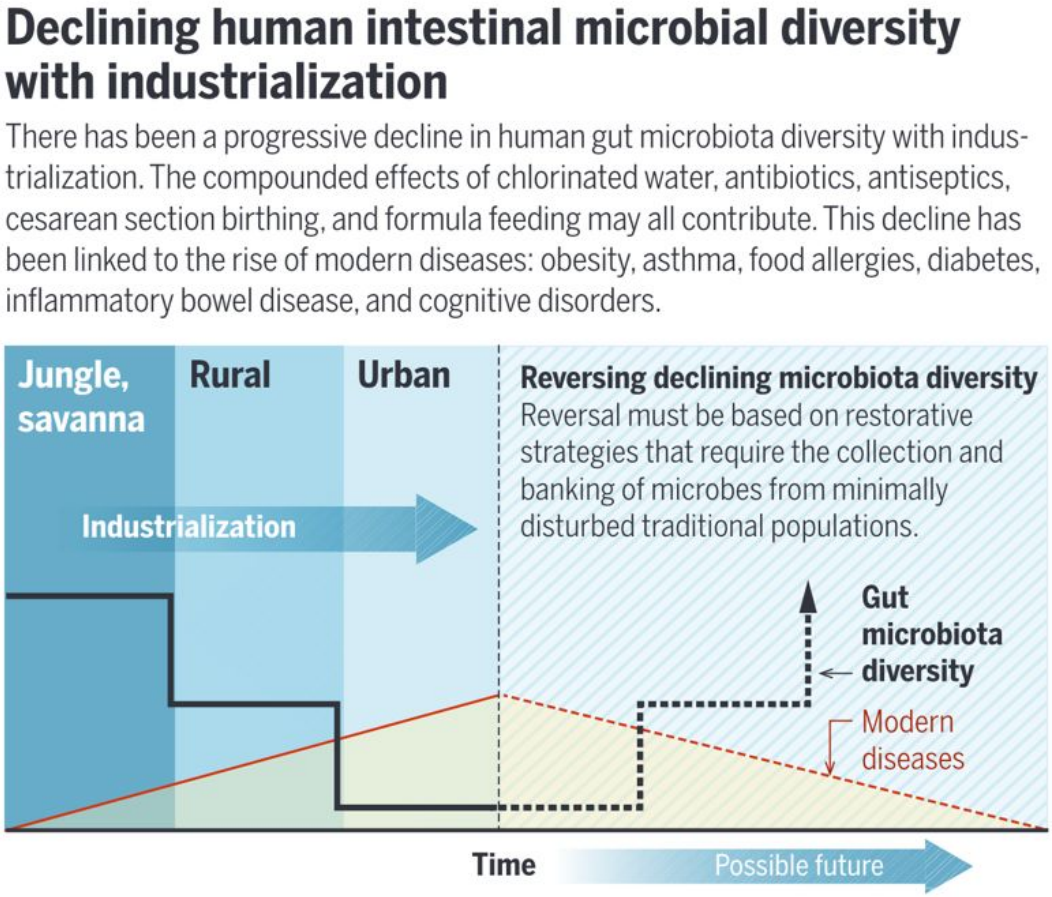

Figure 1. Bello, Maria G. Dominguez, Rob Knight, Jack A. Gilbert, and Martin J. Blaser. « Preserving Microbial Diversity ». *Science* 362, nº 6410 (5 October 2018), 34.