

The microbiomisation of social categories of difference:

**An interdisciplinary critical science study of the human
microbiome as the re-enactment of the immune self**

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Declaration of Authorship

I, Andrea Núñez Casal, hereby declare that this thesis and the work presented in it is entirely my own. Where I have consulted the work of others, this is always clearly stated.

Signed: _  _____ Date: 25/03/2019

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When I was a child, my mum and my dad often brought me to their workplace with them. They encouraged me to go around and play with other kids in the nearby streets and playgrounds while they had meetings and assemblies with members of the community. I used to love those afternoons. The kids I played with were mostly daughters and sons of people struggling with drug addiction and HIV/AIDS. I have never reflected on the implications of the ‘background’ of the children I used to play with, or on this childhood memory, until I became a mother two-and-a-half years ago. I was then shocked to look back and realise that the attitude of my parents is, today, ‘unconventional’.

Spending time with my son in London's playgrounds, attending baby and toddler activities in the city, I have learnt that social stratification and health disparities start 'in utero' and, inadvertently as it were, they 'gestate' and root in everyday public life, including playgrounds. These early life experiences of immunity and inequalities are the 'seeds' of this thesis. I wish that the 'exceptionality' of my parents will have become a 'normality' when my son reflects on his own childhood. This thesis is dedicated to Hsuan and his generation, in the hope they find novel and pluralistic ways through which to fight for health justice.

Hsuan's birth in September 2016, in the midst of my PhD, transformed my whole world, as the cliché goes, including the prism through which to look at the empirical materials I gathered in the years preceding his birth. He has enriched my empirical and analytical lens in unimaginable and fascinating ways. Despite being a privileged, white Spanish woman, able to spend most of my adult life in higher education, motherhood confronted me with a deep sense of frustration and anger at the huge inequalities we, women, we, mothers, face. If I feel the intensive labour involved in caring in all its racialised, gendered, classed disparities so strongly in my skin, how might unprivileged women feel then? Such negativity and anger brought me closer to feminism, an aspect feminist theorist Elizabeth O. Wilson cogently examines in *Gut Feminism* (2015). Channelling these gut feelings through feminism is something, I hope, this thesis reflects.

ABSTRACT

The human microbiome—trillions of symbiotic microbial cells harboured in the human body—challenges the tenet of a fixed and self-contained human nature by recognising the role of microbes, along with environmental and lifestyle factors, in the shaping of the immune function. Does this mean that the material-semiotic paradigm of the immune self, or immunity-as-defence (Cohen, 2009), is obsolete? Through the development of what I call ‘feminist para-ethnographies’—an intersectional method that entangles embodied experiences and ethnography with ‘fugitive’ qualitative data in technoscientific claims and quantitative research—and through using analytical frameworks from body studies, science and technology studies, and anthropology of science, this thesis asks in what ways and to what extent human microbiome research is shaping and reconfiguring biomedical practice and experimentation and older scientific and popular ideas associated with the immune self.

Drawing on my research findings, I argue that human microbiome science is displacing older ideas of immunity as a guarantor of biological identity and individuality, rendering notions of the self as bounded, universal, and autonomous increasingly difficult to maintain. Yet, I hold that, simultaneously, it instantiates new forms of difference, particularly ‘immunitary privileges’ based on a higher microbial diversity, and reproduces old ones in terms of neo-colonial practices of bioprospecting biodiversity. The central argument I make in this thesis is that human microbiome science takes social groups as pre-existing, ‘natural’ phenomena, and biologises them by attributing microbes and microbial profiles to them. By correlating certain microbial species and diversity with hunter-gatherers (race), women (gender), or high-income families (class), social categories of difference become ‘microbiomised’.

Importantly, this thesis also sheds light on how to (co-)produce scientific knowledge that becomes more sensitive and responsive to its social implications (Stengers, 2018) through another dimension of ‘feminist para-ethnographies’: as a material-semiotic device of registration, documentation, and analysis of embodied experiences of human–microbe relations.

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LIST OF ABBREVIATIONS

AGP	American Gut Project
AMI	American Microbiome Institute
AMIS	antimicrobials in society (network)
AMR	antimicrobial resistance
ANT	actor-network theory
AR	antibiotic resistance genes
ART	antiretroviral therapy
BG	British Gut
BMI	Body Mass Index
BRIC	Brazil, Russia, India, China
CAICET	Amazonic Centre for Research and Control of Tropical Diseases
CB	cord blood
CNS	central nervous system
DOHD	Developmental Origins of Health and Disease
DVI	Dengue Vaccine Initiative
EC	European Commission
ELSI	Ethical, Legal and Social Implications
EMP	Earth Microbiome Project
GBS	Group B Streptococcus
hCG	human chorionic gonadotropin
HEP	Human Epigenome Project
HFP	Human Food Project
HGDP	Human Genome Diversity Project
HGP	Human Genome Project
HMOs	human milk oligosaccharides
HMP	Human Microbiome Project
HPV	human papillomavirus
HTS	high-throughput sequencing
IBS	irritable bowel syndrome
IVIC	Instituto Venezolano de Investigaciones Científicas (Venezuelan Institute of Scientific Research)
KCL	King's College London
LGT	lateral gene transfer
LMICs	low- and middle-income countries
LSHTM	London School of Hygiene and Tropical Medicine

MHC	Microbiomes of Homes across Cultures
MINT	Mexico, Indonesia, Nigeria, Turkey
MMG	Map My Gut
MOOC	massive open online course
MRSA	methicillin-resistant <i>Staphylococcus aureus</i>
NB	A new biology for the 21 st century
NBB	National bioeconomy blueprint
NCD	non-communicable diseases
NCT	National Childbirth Trust
NGHRI	National Human Genome Research Institute
NGS	next-generation sequencing
NHS	National Health Service
NIH	National Institutes of Health
NRC	National Research Council
NSC UK	National Screening Committee UK
NTD	neglected tropical diseases
NYU	New York University
OUT	operational taxonomic units
OWOH	One World, One Health
PAR	participatory action research
PCR	polymerase chain reaction
PHE	Public Health England
R&D	research and development
SSK	sociology of scientific knowledge
STDs	sexually transmitted diseases
STEM	science, technology, engineering, and mathematics
STS	science and technology studies
UCL	University College London
UCLH	University College London Hospital
UFAM	Federal University of Amazonas
UN	United Nations
UPR	University of Puerto Rico
UPR-RP	University of Puerto Rico, Río Piedras Campus
USDA	United States Department of Agriculture
WHO	World Health Organisation

INTRODUCTION

Background

The immune system

For more than a decade, I have been aware of colonies of Escherichia coli populating my urinary tract, a bacterium found in mammals and birds, plants, and soil. My bladder and kidneys were in a constant circuit of pain–remission for several weeks for years.

Countless prescriptions of nitrofurantoin, trimethoprim, norfloxacin, ciprofloxacin (i.e. antibiotics), paracetamol, naproxen, ibuprofen (UK), buscapina (Spain), Uro-vaxon (found and bought in Brasil), Uronid (Spain). Ferrol, Spain: three days in the hospital. London, UK: scan done, three cystoscopies cancelled. Doctors told me that my recurrent UTI (urinary tract infection) was probably a consequence of a weakened immune system.

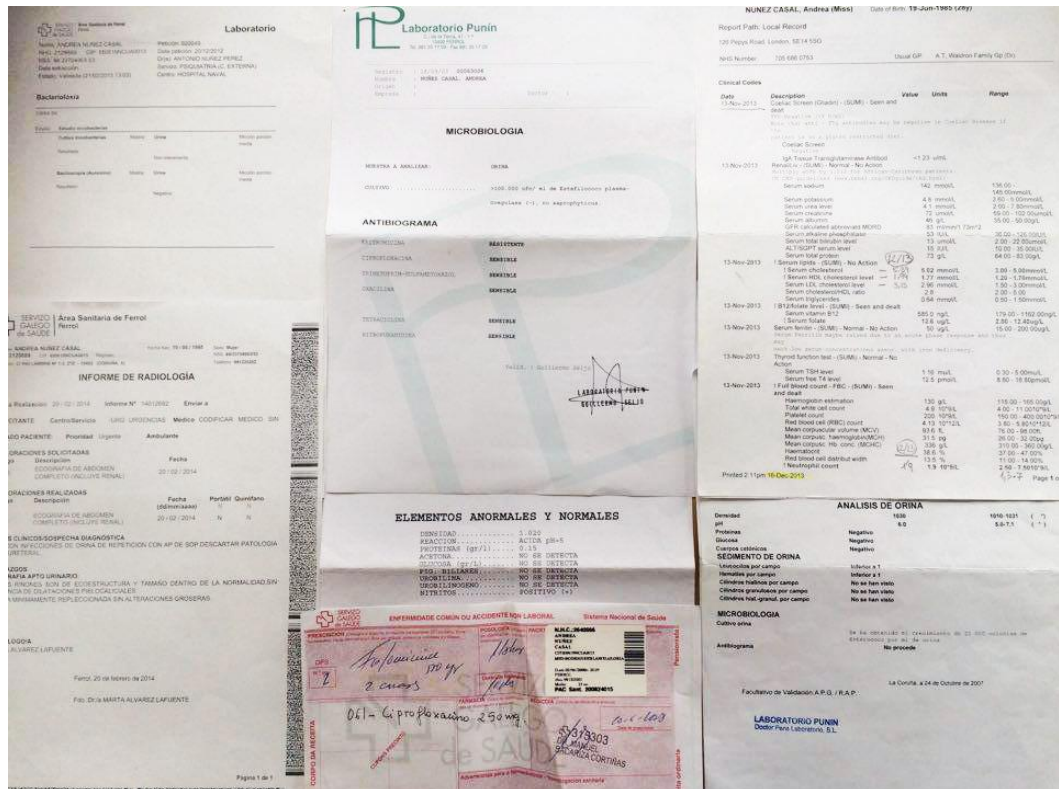


Figure 1. Urine cultures' tests results. Photo by the author.

The immune system is commonly conceived of as a series of molecular mechanisms that protect the body from infections. It is like a microguardian that assures the healthy functioning of our organism. It largely reaches the social realm accompanied by militaristic, self-defensive rhetoric, a conception which originally came from an immunological theory called 'the self and non-self discrimination model', postulated in the 1950s by Frank Burnet. Put simply, Burnet's model describes the immune function as a chain of molecular and biochemical processes that can distinguish between self and

non-self, proper and foreign. As such, the immune system neutralises whatever it recognises as ‘other’, such as viruses or bacteria. Within this framework of warfare between the human body and microbes, cultural theorist Ed Cohen proposes the notion of ‘immunity-as-defence’. Immunity-as-defence ‘refigures medicine as a powerful weapon in the body’s necessary struggle to defend itself *from* its life-threatening context’ (2009, p. 6):

It imagines the individual organism as the space within which a cellular struggle for survival (a.k.a. disease) takes place, and conversely defines a specific microbial agent as the hostile cause against which the organism must wage its relentless war with death (p. 6).

Despite its widespread influence, the paradigm of immunity-as-defence has been contested by immunologists (Coutinho, 1989; Jerne, 1974; Matzinger, 1994) as well as critical theorists and philosophers of science with various orientations. These critiques predominantly come from feminist post-structuralism and science and technology studies (STS) (Cohen, 2009; Esposito, 2008, 2011; Haraway, 1991; Hird, 2009; Howes, 2008; Lock, 2002; Martin, 1994; Martin, 2010; Moulin, 2001; Shildrick, 2010; Tauber, 1994, 2001, 2008; Weasel, 2001) (Chapter 1).

The reason that the immune system is attractive as an object of critical enquiry for the humanities is twofold: first, the self/non-self model raises metaphysical questions about the nature of the self, such as how to define the self and its boundaries (Howes, 2008, p. 272). Second, this established understanding of the basic principles of immunology belongs to a tradition in Western thought rooted in onto-epistemological individualism, which has its antecedent in the Cartesian self/other, mind/body, nature/culture divisions. Hence, humanities scholars engaging with immunology have tried to deconstruct the vision of an immunological self by proposing alternative understandings of the immune function, by which the latter, instead of providing self-defence against the ‘foreign’, is grounded in coexistence and communal capabilities (Cohen, 2009; Esposito, 2008, 2011; Haraway, 1991; Hird, 2009; Napier, 2003; Pradeu, 2012; Tauber, 1994). Furthermore, the work of several feminist critical theorists deals with the immunological rhetoric by attending to the materiality of scientific practice and experimentation (Lock, 2002; Martin, 2010; Moulin, 2001; Shildrick, 2010).

My embodied experiences of UTI and my training in biology—an aspect that I will highlight later in the introduction—marked my academic interest in the immune system, laying the foundations of this thesis. Since the immune system became a scientific concept in the 1960s (Moulin, 1989), its main role, according to immunology, consisted

of two elements: self-preservation (of the human body) and self-defence (against microbes) (Chapter 1). As I experienced during my bachelor's degree in Biology, this idea was unquestionable in scientific training as well as teaching. The repeated 'fact' that 'ten out of one cells' in the human body are microbial rather than human (Knight, 2014) made me wonder what happens, then, to human immune systems. How then is immunity (re)conceptualised, (re)mobilised, in the light of the human microbiome? I wondered. I then transformed this 'fugitive', speculative thought into the main research questions I address in this thesis: How is human microbiome science shaping and reconfiguring biomedical practice and experimentation and older scientific and popular ideas associated with the immune self? Is microbiome science informing alternative modes of scientific knowledge production that include more-than-humans (microbes, in particular)? Are there vestiges of the immunological past (i.e. biological essentialism, liberal subject) percolating the epistemic, ontological, and empirical values of microbiome research?

As I will argue in Chapter 1, the principal limitation of cultural studies of immunity has to do with its (almost exclusive) focus on biopolitical and metaphorical perspectives on the topic, excluding thereby a vast body of (predominantly feminist) literature engaged with experimental immunology. Responding to this gap in the existing literature, this thesis updates cultural studies of immunity by providing a critical science studies account of the human microbiome.

The human microbiome

Months before I embarked on my PhD programme, I noticed a bodily pattern: A few days before suffering a UTI, a herpes simplex virus (HSV-1), physically manifested as a cold sore on either my upper or lower lip. I interpreted this biological occurrence not as an isolated fact without relation to other body parts (i.e. bladder, kidneys) but as a 'message' or 'sign' delivered by the virus. I wondered: was there a relation between these two microbial communities (i.e. E. coli and herpes simplex) harboured within my body?

Herpes simplex virus is a life-long infection. Its persistent form is in a latent state in the neural ganglia, a group of nerve-cells bodies of the nervous system. Periods of reactivation or viral replication are characterised by periodic recurrence or outbreaks, which produce cold sores. I believed that the herpes virus in its activated form through the appearance of a cold sore had a meaning: the beginning of a UTI. I was also certain that both infections were closely related to my impaired immunity in periods of either emotional and/or physical stress. This speculative rumination on my embodied experience of disease came at a time when I did not know the meteoric emergence of a new scientific area of biomedical research yet: the human microbiome.

Back in the late 1960s, microbiologist Lynn Margulis proposed a symbiotic vision of life with her endosymbiotic theory of evolution, also known as symbiogenesis. According to Margulis, prokaryotic cells (such as bacteria) led to eukaryotic cells (such as human cells). Symbiogenesis, as Margulis proposed, ‘is a theory of coming together, of merging cells of different histories and abilities’ (1999, p. 40). As she recalls in her book *The symbiotic planet* (1999), symbiogenesis started attracting scientific attention during the 1970s and 1980s, when studies in genetics and molecular biology confirmed that ‘the once-radical nineteenth-century idea that the cells of plants and of our animal bodies (as well as those of fungi and all other organisms composed of cells with nuclei) originated through a specific sequence of mergers of different types of bacteria’ (p. 40).

Symbiogenesis has recently gained unprecedented recognition and wide acceptance from the life sciences. In a visionary statement, Margulis explained symbiogenesis, alluding to the microbe–human entanglement: ‘we are walking communities’, she explained, ‘ten percent or more of our body weight is bacterial [in its evolutionary origins, ANC], and it is just foolish to ignore that’ (Mann, 1991, p. 378). Now, more than two decades later, these very same words are commonplace in the scientific and popular science literature, especially in relation to the human microbiome, ‘the collective genome of the 10–100 trillion symbiotic microbial cells harboured by each person, primarily bacteria in the gut’ (Ursell et al., 2012, p. 538). Co-evolution and symbiosis seem to have replaced the neo-Darwinian dogma of ruthless interspecies competition: the ‘survival of the fittest’.

Microbes are no longer biomedically conceived as causative agents of disease. Scientific research on the collective genome of microorganisms that live in and on the human body, that is, the human microbiome, is transforming, together with epigenetics and synthetic biology, or contemporary biomedicine. Since the National Institutes of Health (NIH) launched the initiative Human Microbiome Project (HMP) 2007, the biomedical understanding of microbes in human health and disease has shifted abruptly. Pathogenic microbes are the exception. Most microbes inhabiting the interior, surfaces, and orifices of the human body are symbiotic and commensal organisms, essential for metabolic, immunological, and even behavioural functions (Blaser, 2006). Likewise, human microbiome science emphasises co-evolution and symbiosis between microbes and humans. This disproves and contests the dominant antimicrobial culture—in the form of hygiene and sanitation techniques (see Latour, 1988) and the wide implementation of vaccination since the nineteenth century—which, along with antibiotic consumption

since the mid-twentieth century, was a ubiquitous biopolitical tool in the control and domestication of microbes.

Since September 2012, when I commenced my doctoral studies, scientific research on the human microbiome has dramatically surged. Today, scientific articles and media news on the microbiome are being published daily.¹ It has been both challenging and exhausting to remain updated on all the information, advances, and controversies in such a fast-moving field. Consequently, social sciences and humanities scholars' interest in this new biomedical phenomenon has followed the rise of microbiome science. For example, while between 2013 and 2014, the conference papers I presented at several international meetings such as the Society for the Social Studies of Science (4S) or the British Society for the Philosophy of Science were the only ones on the topic, the 2016 4S/EASST meeting in Barcelona dedicated two panels to the topic. Back in 2013, my audience was clueless about the microbiome. Today, its popularity has traversed the life sciences, reaching the social sciences and humanities as well, particularly those academic fields concerned with social and cultural aspects of postgenomics such as science studies, body studies, anthropology of science, and sociology of medicine.

Multispecies

Over the past decade, multispecies sensitivities have become a very prolific theme of social and anthropological research. An 'anthropology of microbes' has been proposed as a transdisciplinary field of research to 'reevaluate the way we view our human biological and cultural diversity' as well as to investigate how our "indigenous" microbial populations (microbiota) are shaping human health and how they could impact clinical practice' (Benezra, DeStefano, & Gordon, 2012, p. 6378). In the article 'The emergence of multispecies ethnography' (2010), anthropologists Eben Kirksey and Stefan Helmreich define multispecies ethnography as a method which 'centers on how a multitude of organisms' livelihoods shape and are shaped by political, economic, and cultural forces' (p. 545). Influenced by Eduardo Kohn's 'anthropology of life', that is, an anthropology 'concerned with the effects of our entanglements with other kinds of living selves' (2007, p. 4, as cited in Kirksey & Helmreich, 2010, p. 545), the authors delineate multispecies as interdisciplinary studies coming from animal and environmental studies

¹ According to ScienceDirect, a website that provides access to a large database of scientific and medical research, there were 680 articles mentioning the keyword 'microbiome' in 2012, while there were 4,312 articles in 2017. By February 2018, there were 1,551 articles published on the topic already, indicating that microbiome science is a biomedical area undergoing exponential expansion.

and STS (p. 566). ‘Multispecies ethnographers’, they write, ‘are studying contact zones where lines separating nature from culture have broken down, where encounters between *Homo sapiens* and other beings generate mutual ecologies and coproduced niches’ (p. 546).

In multispecies ethnographies, I claim, the richness of the ethnographic detail leaves little or no room for more analytic and less descriptive views. My main criticism of multispecies ethnographies is that it is a very human area of scholarship, theorised and practised by humans. This limitation is rarely discussed among multispecies scholarship. As I will further develop in Chapter 2, microbial accounts in theory and practice are still written by humans, made by their instruments and methodologies.

Against depoliticised and romantic multispecies narratives, I will demonstrate how the work of several authors brings biome depletion and multispecies ecologies together with capitalist political economy (Haraway, 2016; Tsing, 2015) and examines socio-economic relations in the ‘making’ of interspecies health (Hinchliffe, 2015). These perspectives are more attuned to the approach of the thesis, as developed in Chapters 1 and 2. Beyond the multispecies ethnography/studies framework, the critical social study of the human microbiome also falls within a biosocial framework of postgenomics, as I will explain in the next section.

Postgenomics: A new biosocial paradigm?

The term postgenomics, a notion that I will often be using throughout the thesis, refers to ‘all those areas of the biological and medical sciences that now use genomic information or approaches as a foundational or standard element of their research practices’ (Richardson & Stevens, 2015, p. 3). Postgenomics comprise

the study of interacting systems such as proteomics, studies of gene-environment interactions, and increasingly complex models of biological pathways and requir[e] powerful and sophisticated informatics and computational skills, as well as expanded and speedier sequencing genomes (p. 232).

Postgenomics marks a new epoch in biomedicine after the completion of the Human Genome Project (HGP) (1990–2003). It shifts its scope from reductionism and determinism to a holistic, complex, and integrative perspective on genes, genomes, and genetics. But genes, and therefore genomes, do not say much in and of themselves (see Keller, as cited in Richardson & Stevens, 2015). Only when genetic sequences are put together with non-genetic factors, such as lifestyle habits or environmental exposures, can genetic information be meaningful. Likewise, postgenomics does not imply a break

with genomics (Richardson & Stevens, 2015) (Chapter 3). Rather, it figures and refigures the latter as embodied in the wider milieu of the organism.

Postgenomics recognises the importance of being-with-the-world (Barad, 2007), of being shaped by environments, relations, and cultures rather than being-in-statics as immutable organisms shaped by destiny, by the capricious nature of ‘genes’. For historian of science Evelyn Fox-Keller, ‘human beings are reactive systems on every level at which they are capable of interacting: cultural, interpersonal, cellular, and even genetic’ (Fox-Keller, as cited in Richardson & Stevens, 2015, p. 28). The ‘postgenomic genome’, Fox-Keller argues, is ‘primarily a mechanism for responding to our environments’ (p. 28). This new postgenomic framework ‘([with its shift] from agentic to reactive) allows us—indeed obliges us—to abandon dichotomies between genetics and environment, and between nature and culture that have driven so many fruitless debates, for so many decades’ (pp. 28, 29).

Echoing feminist technoscientist Donna Haraway’s ‘naturecultures’² and anthropologist of science Paul Rabinow’s ‘biosocialities’,³ the nature-culture or social-biological interplay that inhabits postgenomics has sometimes been framed with the adjective ‘biosocial’ in recent sociological and anthropological literature (Ingold & Palsson, 2013; Meloni, 2014a, 2014b, 2014c) (Chapter 3). Sociologist Maurizio Meloni (2014a) claims that ‘a “social turn” in the life-sciences is taking shape’, a ‘new social biology’ (pp. 594–595, 603). Meloni, along with other contemporary commentators (Dupré, 2012; Fox-Keller, 2010; Ingold & Palsson, 2013) has recently argued that ‘biology has become porous to social and even cultural signals to an unprecedented extent’ (Meloni, 2014a, p. 594). However, I argue that the problem with this claim and, more broadly, with the biosocial literature, is that it (tacitly) assumes that the biosocial is a novel conceptual development in both the life sciences and the social sciences and humanities. Is the biosocial literature adopting the concept of ‘biosocial’ from life science research? Is it a social sciences and humanities heuristic device? Or is it both? Against this lack of specificity and detail in the biosocial literature, my view is that biology has

² Donna Haraway’s term ‘naturecultures’ (2003) refers to the ‘constitutive relationship’ between nature and culture, in which ‘none of the partners pre-exist the relating, and the relating is never done once and for all’ (p. 12).

³ Drawing on the Human Genome Project (HGP) (see also Chapter 3), Paul Rabinow refers to ‘biosocialities’ (1996b) as the processes through and around which ‘nature will be modeled on culture understood as practice. Nature will be known and remade through technique and will finally become artificial, just as culture will become natural’ (p. 99).

always been porous to the social, and vice versa. The novelty lies not so much in ‘biology’ itself as in its discourse and empirical settings, particularly in the areas of epigenetics and microbiome science.

Furthermore, while the divisions between the social and biological, nature and nurture, and so forth have been a recurrent concern for scholarship in the social sciences and humanities as well as for this thesis, I contend that the existing body of literature on the biosocial ignores a vital and elucidatory precursor of the concept of the biosocial: feminist writer and poet Denise Riley’s notion of ‘socialised biology’ (1983), which refers to how biology is ‘lived within particular lives’ (p. 40). Riley’s notion provides a situated account of embodied biological experience in everyday life. In this thesis, ‘socialised biology’ not only serves as a heuristic device to complement the ‘biosocial’ literature (Chapter 1); I also incorporate ‘socialised biology’ into my methodological core, into what I call ‘feminist para-ethnographies’ (Chapter 2 and Chapter 5). As I will develop later in the introduction, I refer to ‘feminist para-ethnographies’ as an intersectional method that entangles embodied experiences with ‘fugitive’ qualitative data in technoscientific claims and quantitative research.

Postgenomics, therefore, entails continuities and discontinuities of genomics (Richardson & Stevens, 2015). In this thesis, I argue that twentieth-century genomics and, by extension, molecular biology subfields such as immunology are not replaced by a biosocial postgenomic approach. Both approaches intersect and overlap. I will show how and to what extent medicalisation, optimisation, and inequalities inhabit newer genomic articulations of difference, such as microbiome science.

Despite the growing bodies of literature on multispecies studies/ethnography and biosocial postgenomics, there is a lack of social and cultural studies of the human microbiome that examine its effects and consequences in relation to the immune system. Put differently: What happens to the paradigm of immunity (self versus other) in the light of the human microbiome and its newly emerging significance across the sciences and humanities?

In what follows, I provide a background to the scientific links between the human microbiome and immunity. I then outline the scope of the thesis and the research questions.

Entangling the human microbiome and the immune system

It was close to Christmas, 2012. After several visits to A&E departments at several different hospitals in London, I booked an appointment to see a specialist on recurrent UTIs. Professor Shamim Khan, consultant urologist at Guy's and St Thomas' Hospital, defined my condition as a problem of 'dysbiosis'. He suggested a treatment based on low-dose, long-term antibiotics (a year) 'topped up' by 'lots of yogurt'. Having read microbiome studies for over the past two months, it seemed counterintuitive to me to approach a problem of 'dysbiosis' (i.e. lack of 'harmony' between human immune cells and microbial cells) by contributing to it through antibiotics use (which eliminates microbial cells). I took Khan's advice on yogurt and, instead, I experimented with several alternative and homeopathic treatments via word-of-mouth recommendation: cranberry concentrates and pills, probiotics, cantharis, staphysagria, sepia (UK), Oscillocoquinum (France), ba zheng za wan (Taiwan), orthophison, gayuba, brezo, olive leaf, nettle, and nettle tea (UK), D-mannose (US).

The immune system, microbiome scientists suggest, has evolved to maintain complex relations with microbial organisms. Commensal microorganisms living in and on the human body, on the other hand, have also adapted to the functioning of the immune system. In other words, microbes and the human immune system have been through a process of co-evolution. In a review on the microbiome and its role in the immune system, the authors write:

The highest number of immune cells in the body are resident at sites colonised by commensals such as the skin or the GI tract. In turn, to protect their ecological niche, a dominant action of the healthy microbiota on the immune system is aimed at reinforcing barrier immunity and therefore their own containment (Belkaid & Hand, 2014, p. 123).

The human gut (or gastrointestinal tract) is an interesting body part for fathoming the *intra-action*⁴ between the immune system and the human microbiome. The gut is simultaneously a prominent part of the immune system and a bacterial ecosystem that harbours more than one hundred trillion bacterial species, a fact that makes the gut one of the most diverse body sites (Shreiner, Kao, & Young, 2015). The prominence of the gut in today's biomedicine is far-reaching. It goes beyond gut immunity and microbial ecology to also include behaviour. The so-called 'gut-brain' axis or 'microbiota-gut-brain' axis refers to 'multiple direct and indirect pathways [that] maintain intensive and extensive bidirectional interactions between the gut microbiota and the CNS [central

⁴ The term 'intra-action' is a neologism introduced by feminist physicist and philosopher Karen Barad (2007). Intra-action, Barad writes, '*signifies the mutual constitution of entangled agencies ... [Intra-action] recognizes that distinct agencies do not precede, but rather emerge through, their intra-action*' (p. 33, my emphasis). Barad conceives intra-action as a term opposed to 'interaction', which entails the contact or relationship between two pre-existing bodies. Intra-action, therefore, is a reinterpretation of Haraway's naturecultures (see note 3).

nervous system]; involving endocrine, immune and neural pathways' (Grenham et al., 2011, as cited in Montiel-Castro, Gonzalez-Cervantes, Bravo-Ruiseco, & Pacheco-Lopez, 2013, p. 2).

If under the paradigm of immunity-as-defence ideas of health were established based on genetic kinship and thus the elimination of difference (i.e. identical DNA of human somatic cells against microbial DNA), the human microbiome brings about an alternative onto-epistemic envisioning by which co-evolution, cooperation, microbial diversity, and therefore difference (i.e. human–microbe entanglements) are key features in the understanding of health and the human body in the twenty-first century.

The clinical practice of immunity has also been affected by this change in paradigm. Vaccination, since the end of the eighteenth century, and antibiotics, since the 1950s, are the principal anti-microbial biotechnologies used worldwide in a standardised way: they are mass-produced and applied through the same processes to all human bodies' immune systems in order to cease the spread of pathogenic microbes (antibiotics) or to confer immunity against them (vaccines). From a Foucauldian perspective,⁵ these are biopolitical tools meant for the control of populations through anti-microbial practices.

However, the mutable bodies of microorganisms have increasingly become matters of concern for scientists, health practitioners, and governments alike. In 2012, Margaret Chan, the current Director General of the World Health Organisation (WHO), went so far as to worry that antibiotic resistance could bring about 'the end of modern medicine as we know it' (2012). Antibiotics have modified human–microbe entanglements globally at an unprecedented rate (WHO, 2014). Broad-spectrum antibiotics, the most prescribed type of antibiotics, decimate human microbial communities. The recovery is never complete, altering the microbial composition. In some cases, such as people in early life (Bokulich et al., 2016) or with a weakened immune system, the consequences are far-reaching, even life-threatening (Blaser, 2014a, pp. 16–17). Because of antibiotic overuse for the last sixty years, alongside the dry

⁵ Foucault's writings on biopolitics and biopower premise that control and management of life is the target of governance. Foucault's theory of biopolitics has been widely applied in relation to contemporary biomedicine, in which bodies 'are the locus of contemporary political formations on regimes of biopower and biopolitics (Rabinow & Rose, 2006), they are the target and *raison d'être* of new technologies in genomics, neuroscience and medicine, the object of governance and policy with respect to health (smoking, obesity, healthcare rationing, self-monitoring), reproduction (access to fertility treatment, the resurgent debate on abortion), age, mortality and longevity' (Blackman, Cromby, Hook, Papadopoulos, & Walkerdine 2008, p. 17).

pipeline in the discovery of new antibiotic substances, antibiotic-resistant bacteria can now kill. As the Center for Disease Control and Prevention (CDC) reports: ‘Each year in the United States, at least 2 million people become infected with bacteria that are resistant to antibiotics, and at least 23,000 people die each year as a direct result of these infections’ (‘Antibiotic/antimicrobial resistance’, 2015). The two human microbiome science projects led by microbial ecologist Dr. Maria Gloria Dominguez-Bello (Chapters 3, 4, and 5) that I conducted ethnographic fieldwork on under the research design of ‘feminist para-ethnographies of human–microbe relations’ (Chapter 2) are part of the current race in biomedicine against microbial resistance to antibiotics (Chapter 4).

The immune system, the human microbiome, and antibiotics—the latter as a therapeutic linkage between the aforementioned biomedical categories—constitute the three areas of scientific knowledge production that I examine in this thesis. In the next section, I explain the rationale, scope, and research questions this thesis tackles.

On interdisciplinarity and microbiomisation: Questions and scope

Interdisciplinarity

While I was studying for my undergraduate degree in Molecular Biology and Biotechnology at the University of Santiago de Compostela (Spain), I often felt overwhelmed by the practicalities, methods, and procedures that I had to go through. Biology studied in university classrooms and laboratories at that time was almost entirely focused on empirical evidence and technical knowledge concerning the manipulation of biological entities and chemical substances by the deployment of the operational devices available in the lab.

It was about instrumentality.

I have also learnt, although in a tacit manner, that to ‘see’ or to bring an object into ‘presence’ (let’s say the antibody X of rat 5) is determined by the previous setting of the experimental conditions, such as the type of calibrator or the quantity of acid chloride used. However, at that time, I did not reflect further on the metaphysical implications of the multiple factors that condition a scientific experiment, such as the manipulation of experimental settings, previous literature, or researchers’ subjectivity. Rather, my only wish was to abandon what I considered to be the constraints of the scientific method (i.e. rationality, causality, objectivity) and to become fully dedicated to my long-standing passion: cultural theory.

In my master’s degree in Cultural Studies, I had the opposite experience. The standards of scientific rigour (read ‘rationality, causality, and objectivity’) no longer applied. What is more, they were regarded as the socio-historical by-products of the (Western) oppressive, patriarchal, and (post)colonial capitalistic machine. This view, which to a certain extent still nourishes my conceptual makeup, provoked an intellectual liberation with repercussions in both my personal and academic life. I studied philosophical theories and their ramifications in various areas of knowledge, followed by the interpretation and critical analysis of them. This included a subsequent interpretation of the

interpretations that other authors developed from the 'original' interpretation of a metaphysical concept or particular aspects of culture, society, science, art, or history. A substantial part of the cultural theory I encountered was embedded in a 'postmodern', and as such 'pluralistic' or 'perspectival' way of understanding the world.

Clearly, this brief narrative about my educational background reflects the polarisation of my academic experience and training: on the one hand, the reductionism of the scientific method; on the other, the relativism of some sectors of the humanities. Whereas the former is more grounded in practical matters, the latter's foundations are conceptual speculation and critical thought. But are there also places in-between, that is, at the margins of both relativism and reductionism?

As the work of several social sciences and humanities scholars shows (Blackman, 2012; Haraway, 1988, 1991; Latour & Woolgar, 1979; Latour, 1987, 1988, 1993; Mol, 2002; Stengers, 1997, 2000, 2010, 2018), it is indeed possible to go beyond extreme scientific empiricism as well as epistemology, and thus the prevalence of representation, without renouncing scientific empiricism or the humanities' critical standpoint. In fact, this thesis is situated between the positivist empiricism of my undergraduate training and contemporary microbiome research and the critical and perspectival relativism of my cultural studies postgraduate curricula.

This thesis is an interdisciplinary study of the human microbiome. I frame issues around interdisciplinarity in four interlocking ways:

- 1) First, in relation to my academic background. In similar ways to medical anthropologist Annemarie Mol (2002), I present myself as both insider and outsider, having received training in molecular biology and biotechnology as well as in cultural studies. A critical science study of the human microbiome involves a mobilisation of my previous knowledge of and experience in biology.
- 2) Second, interdisciplinarity is key to the subject matter of my thesis: the human microbiome. Microbiome science is characterised by a 'big science' approach (Vermeulen, 2016) that materialises in large-scale projects such as the HGP (1990–2003). The HGP or similar and more recent initiatives such as the Human Epigenome Project (HEP) or the Earth Microbiome Project (EMP)⁶ are public-private partnerships. Human microbiome research usually involves various scientific experts:

⁶ The Human Epigenome Project (HEP) is a multinational consortium which aims to identify all human genes' methylation patterns. The Earth Microbiome Project (EMP) is a non-governmental international project to collect and sequence microbial DNA around the globe.

Microbiologists and microbial ecologists with expertise in microbial communities and microbial ecosystems, bioinformaticians capable of interpreting the genomic data once it is out of the next-generation sequencing (NGS) machines, environmental scientists, nutritionists, clinical scientists, and physicians specialising in a particular condition or disease. Likewise, the ethnographic fieldwork I conducted in San Juan and New York in 2014 involves a microbiome expedition in the Peruvian and Brazilian Amazon between 2011 and 2013, led by microbial ecologist Dominguez-Bello as part of the Sloan Foundation-funded project ‘Microbiomes of Homes across Cultures’ (MHC), an investigation at the intersections of microbial ecology, environmental sciences, and architecture (Chapter 3).

- 3) Third, the conceptual framework I develop in this thesis is also interdisciplinary, as it is situated at the intersections of three main bodies of literature and fields of research: body studies, STS, and anthropology of science. This thesis makes a theoretical contribution to the disciplines above, and more specifically, to the social and cultural studies of microbes and the cultural studies of immunity, both interdisciplinary fields of knowledge production in themselves (Chapter 1).
- 4) Fourth, I reformulate the concept of the para-ethnographic—that is, ‘a way of dealing with contradictions, exceptions, and facts that are fugitive’ (Holmes & Marcus, 2008, p. 596)—as a feminist intersectional and situated practice that entangles embodied experiences with ‘fugitive’ qualitative data in technoscientific claims and quantitative (microbiome) research. I refer to this method as ‘feminist para-ethnographies’. As well as a contribution to research methods on embodiment, selfhood, and biological identity and the colonial history of science and cultural studies of immunity, feminist para-ethnographies are interdisciplinary interventions in the field of science studies. This method involved a multi-sited ethnography of microbiome science, which included following an interdisciplinary team of scientists working on the human microbiome; interviews with scientists; analysis of their published work; attention to how their work circulated beyond the institutional networks into the public sphere via online microbiome community and personalised medicine platforms, media news, and popular science literature; attending microbiome and epigenetics conferences as both data collection and research training; and science policy analysis.

Interdisciplinarity is, therefore, a compulsory point of passage for this thesis. This thesis is not about interdisciplinarity, but it is interdisciplinary in nature, and it tangentially touches debates on the topic (Chapter 5). Against celebratory claims and perspectives

portraying postgenomics as a new biosocial paradigm in the life sciences characterised by harmonious collaborations, this thesis concurs with Callard and Fitzgerald (2015) in that interdisciplinarity is a ‘historical and sociological artefact, an object that offers numerous openings as well as constraints’ (p. 4); therefore it can also be seen as ‘practices of subjugation’ (p. 96). It is for this reason that we, as social sciences and humanities scholars, are compelled to ensure that ‘engaged research involves experimentation in and an evaluation of the kinds of relationships that are productive and sustainable’ and that ‘new forms of evidence can be made public, gain traction, and effect change’ (Hinchliffe et al., 2018, p. 8) (Chapter 5).

Microbiomisation

My main interest and central aim in this thesis is to examine how and to which extent scientific research on the human microbiome is shaping and reconfiguring biomedical practice and experimentation and older scientific and popular ideas associated with the immune self. Is microbiome science qualifying alternative modes of scientific knowledge production that include more-than-humans (i.e. microbes, environment)? Are there vestiges of the immunological past (i.e. biological essentialism, liberal subject) percolating the epistemic, ontological, and empirical values of microbiome research?

Results from my ethnographic fieldwork on human microbiome science research and my science policy and popular science literature analysis on the topic indicate that social categories of difference—specifically race, gender, and class—are being re-enacted in microbiome research. I refer to the process of biologisation and molecularisation of social categories of difference as ‘microbiomisation’, a neologism originally coined by anthropologist of science Stefan Helmreich (2016). This thesis will argue and demonstrate why attending to the microbiomisation of categories of difference is important.

I theorise microbiomisation as the process by which microbiome science takes social groups as pre-existing, ‘natural’ phenomena and biologises them by creating and attributing microbes and microbial profiles to them. By correlating certain microbial species and diversity with women, hunter-gatherers, or high-income families, for example, social categories of difference become microbiomised. Unlike other biological-social interplays—such as the personification of cells (Martin, 2006), in which biomedicine writes and speaks about cells as if they were interchangeable with persons—in the process of microbiomisation, the ‘social’ is the main element that animates

scientific research on microbes (see Figure 2). In other words, many microbiome studies start with a non-scientific assumption or question about social differences: What is the difference between Western and indigenous (microbial) populations (Chapter 3)? What is the microbial composition of women of different socio-economic status across different populations (Chapters 4 and 5)?

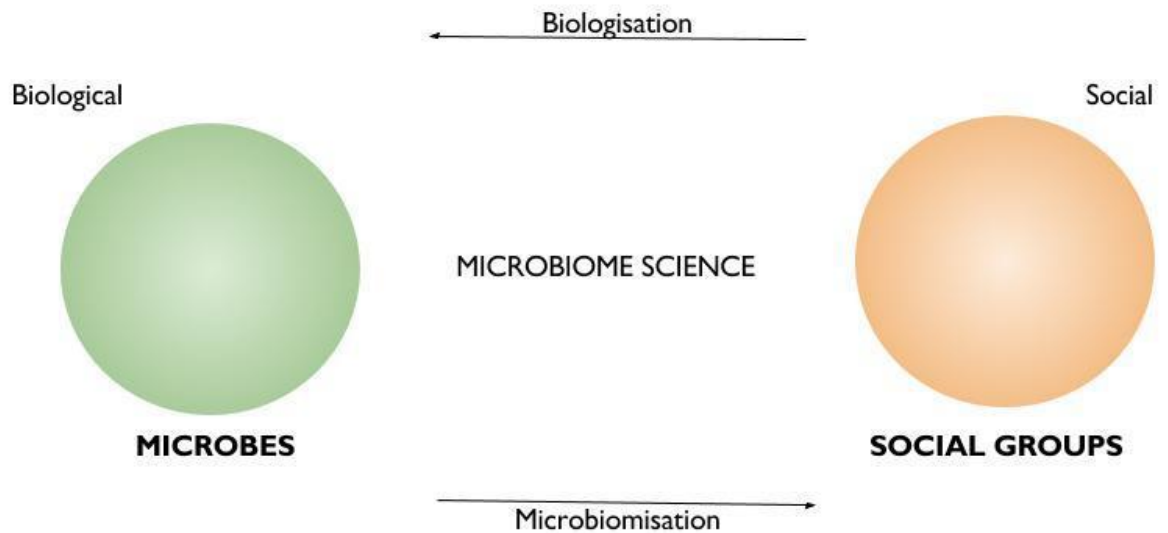


Figure 2. Diagram of the process of microbiomisation, by the author.

In the process of microbiomisation, socio-cultural practices such as cleaning frequency, architecture, and family size along with assessments of age, diet, and kinship are essentialised into racial, gender, class, and nationality categories when microbial species are used as markers of population differences. Importantly, I argue that microbiomisation is an intersectional phenomenon, often involving the biologisation of several categories of difference (Chapter 5). For example, in 2012, Dominguez-Bello took part in a landmark cross-cultural and cross-geographical human microbiome study entitled ‘Human gut microbiota viewed across age and geography’. The aim of the study was to lay the foundations of human genetic and metabolic variation through the characterisation of the human microbiota. The study used faecal samples from three different populations: ‘Amerindians from the Amazonas of Venezuela, residents of rural Malawian communities, and inhabitants of USA metropolitan areas’ (Yatsunenکو et al., 2012, p. 222). The authors note that:

Pronounced differences in bacterial species assemblages and functional gene repertoires were noted between individuals residing in the USA compared to the other two countries. ... In addition, the similarity of fecal microbiomes among family members extends across cultures. These findings underscore the need to

consider the microbiome when evaluating human development, nutritional needs, physiological variations, and the impact of Westernization (p. 222).

Here, the authors group human populations into two different categorisations, one based on race/ethnicity (i.e. ‘Amerindian’) and the other based on nationality/country of residence (residents of the United States (US) and residents of Malawi).

By encapsulating my findings under the framework of ‘microbiomisation’, I want to explore ‘how social structures get under the skin’ (Meloni, 2015, p. 136). Microbiomisation is similar to what environmental scientist Becky Mansfield (2012) calls ‘epigenetics biopolitics’, which involves shifting ‘the responsibility of exposure to chemicals towards the ‘abnormal’ diets of women of colour instead of blaming contamination itself’ (p. 352). However, in contrast to Mansfield’s ‘epigenetics biopolitics’, the specificity of the process of microbiomisation involves two interlocking elements:

- 1) Neocolonialism, which is sustained by bioprospecting microbial biodiversity from non-Western peoples and territories (Chapter 3).
- 2) Bioinequalities, a reformulation of Foucault’s classical theory of biopower and biopolitics by medical anthropologist and physician Didier Fassin (2009). Bioinequalities is ‘not merely a politics of population but is about life and more specifically about inequalities in life’ (2009, p. 57).

This thesis will demonstrate that ‘individualised optimisation’ of the human microbiome in neoliberal societies is ‘a gendered and racialized demand’ (Mansfield, 2012, p. 369) fundamentally sustained by the bioprospection of microbial DNA from non-Western populations (Hayden, 2003; Shiva, 1997; TallBear, 2013) (Chapter 3).

It might be objected that the process of microbiomisation is based on an ‘interaction effect’, that is, a (simplified) cause–effect mechanism between microbes and social groups (see Figure 2). While its scope is limited to one aspect of microbiomisation (i.e. how microbiome science biologises social categories of difference), this thesis will also shed light on and establish the basis for further research into process(es) of microbiomisation. Microbiomisation, as an analytical device to critically examine human–microbe relations, serves to analyse how individual microbiome science is shaped and reshaped by self-governing practices of the body (Rabinow & Rose, 2006; Rose, 2007) and citizen science projects (see Chapter 3), for example.

The main argument I develop in the thesis is that, while the human microbiome is displacing older ideas of immunity as a guarantor of biological identity and individuality,

it instantiates new forms of difference, particularly immunitary privilege based on a higher microbial diversity, and reproduces old ones in terms of neocolonial practices of expropriating nature (microbes in this case) and structural differences in (Western) societies. Human microbiome science brings human agency together with environmental effects and socio-cultural habits and traits in processes of pathologisation, medicalisation, and optimisation. This is especially evident in how biomedicine intervenes to define a ‘healthy’ microbiome and how strategies to improve health through the human microbiome are articulated: via the microbial genetic makeup of non-Western(ised) communities, societies, and locales (Chapter 3); and individual economic, social, and cultural capital in neoliberal societies (Chapters 4 and 5). Likewise, contrary to some romantic and uncritical views in more-than-human literature (see Hird, 2009; Kirksey & Helmreich, 2010), my argument is that microbiome science ‘re-enacts’ an immunitarian model of inclusion and exclusion, self and other.

The verb ‘to re-enact’ and the noun ‘re-enactment’ that I use in the thesis title require some specification. These terms are a deliberate reference to STS scholars Annemarie Mol and John Law’s ‘Embodied action, enacted bodies’ (2004). In this influential paper, Mol and Law examine the different ways in which hyperglycaemia (high blood glucose level) *acts* and *enacts* in the human body. Hyperglycaemia, they show, is measured as blood sugar levels; it is felt as swelling, for example; it is also countered, avoided, and produced (pp. 50–51). As Mol and Law explain, the implications of this argument relate to the complicated ways in which enacting and acting go together (p. 51). This means that bodies too—not only diseases—are enacted differently. For example, for people with asthma or those who practice yoga, breathing acquires a special dimension (p. 54). Through the case of hyperglycaemia, Mol and Law provide a basis for producing ‘knowledge-in-practice’ about the ‘body-in-action’ (p. 51).

Although this thesis is not about how microbes and microbiome are enacted differently in human bodies, my framework for the analysis of human–microbe relations is inspired by this body of work, in particular by the important realisation that bodies are ‘semi-permeable’ (p. 54) to their surroundings, including other humans and non-humans such as microbes and environments. However, as I have argued earlier, my key concern is with the fact that environments are rarely neutral or ‘just’ environments. This means that ‘surroundings’, ‘environments’, and consequently, (leaky) bodies are sites of constraint, control, and subjugation as well as sites of contestation and resistance. While with ‘microbiomisation,’ I want to reflect the first dimension of (leaky) bodies in what

we might call ‘biosocial surroundings’, ‘feminist para-ethnographies’ takes up the dimension of resistance and contestation (Chapter 5) through my embodied experiences of human–microbe relations in childbirth and as a sufferer of recurrent urinary tract infections (UTIs). Furthermore, my proposition of ‘feminist para-ethnographies’ has very much to do with the ‘ethnographic turn’ Mol and Law call for as part of a ‘multi-voiced form of investigative story telling’ (2004, p. 59) (Chapter 5).

Contributions to knowledge

- 1) I develop and propose the ‘microbiomisation of social categories of difference’ as a social sciences and humanities conceptual and empirical framework through which to critically examine the repercussions and implications of human microbiome science in society.
- 2) I develop a conceptual framework of analysis at the intersection of three main bodies of literature: body studies, (feminist and decolonial) STS, and anthropology of science. Also, I include a decolonial analytical framework by focusing on theories of *Buen Vivir* (‘Living Well’) (see Chapter 1). This interdisciplinary theoretical repertoire in the social and cultural analysis of the human microbiome and human–microbe relations is a novel approach, since existing literature on the topic has focused on multispecies ethnography/studies (Chapter 2). Furthermore, this is the first social and cultural study of the human microbiome that incorporates immunity as an analytical category. Therefore, this thesis is also updating cultural studies of immunity.
- 3) I introduce and develop the concept of ‘feminist para-ethnographies’, an intersectional method that entangles embodied experiences with ‘fugitive’ qualitative data in technoscientific claims and quantitative research. I argue that this method, in turn, challenges ‘more-than-human’ methods of multispecies ethnographies and updates existing literature on postgenomics and the biosocial by focusing on how ‘biology is lived out’ (Riley, 1983, p. 40). The main feature of my reconceptualisation of the para-ethnographic (Holmes & Marcus, 2008; Nading, 2016) is the incorporation of embodied experiences as feminist research tools. The inclusion of embodied experiences and the analysis of qualitative claims and ‘impressions’ made by scientists about the human microbiome in other public media than scientific publications is an innovative methodological intervention in the cultural and social study of human–microbe relations. A para-ethnographic approach also entails

granting an active role to social sciences and humanities scholars as co-producers (together with scientists), rather than as ‘commentators’ or ‘interpreters’ of qualitative evidence and emergent categories (e.g. microbes) in contemporary life science (Nading, 2016, p. 578) (see Chapter 2).

- 4) I demonstrate that human microbiome science relies on comparative studies of genetic (microbial) variation in human populations. The microbiome of ‘uncontacted peoples’ such as the high Oricono Yanomamis of Venezuela or the Peruvian Amerindians of Checherta is a reservoir for microbiome science. In fact, the microbiome of non-Western peoples and territories is not a side project or a specific ‘approach’ within the field. Rather, this thesis shows that it constitutes a key element of this new area of scientific knowledge production. Likewise, one of the principal contributions of this thesis is to show that ‘the microbiomisation of race’ is constituted within a nexus between bioprospection and bioinequalities (Chapter 3) and establishes the basis of the ‘microbiomisation’ of other social categories of difference, particularly of class (Chapter 4) and gender (Chapter 5).
- 5) I demonstrate how the phenomenon of antimicrobial resistance (AMR), as a by-product of the human microbiome’s ‘dysbiosis’ or microbial de-entanglements, is not merely biological. Rather, AMR illuminates the articulation of capitalist political economy in the biological. Against the globality and homogeneity of (Grand) theories of the Anthropocene, this thesis provides a theoretical intervention in the phenomenon of AMR, adopting a political economy perspective (Chapter 4).
- 6) Beyond its methodological application (Chapter 2), I develop ‘feminist para-ethnographies’ as a material-semiotic device to make available and register ‘socialised biology’ (Riley, 1983). As a biosocial intervention aimed at the socialisation of care and the delivery of health justice through the transformation of silenced and private embodied experiences into shared experiences, feminist para-ethnographies has the potentiality, I suggest, of assisting the tackling of antibiotic overuse, AMR, and biome depletion (Chapter 5).
- 7) I advance new avenues of research for the development of an ‘engaged research’ (Hinchliffe et al., 2018) and a ‘critical friendship’ (Rose, 2013) between the social sciences and humanities and the life sciences. I discuss this aspect in relation to alternative solutions to AMR and biome depletion more broadly in the context of my proposition of ‘feminist para-ethnographies’ (Chapter 5). In this sense, the central argument I make in this thesis—which focuses on the significance of the

microbiomisation of social categories of difference—sheds light on scientific processes of social divisions and on how to (co-)produce scientific knowledge that becomes more sensitive and responsive to its social implications (Stengers, 2018).

Organisation of the thesis

Chapter 1 situates the thesis within three main bodies of literature: body studies, (feminist and decolonial) STS, and anthropology of science, outlining how I will build on and go beyond the existing literature. It tackles previous work of social sciences and humanities scholars engaged with immunology, particularly with metaphors of immunity, and introduces debates in social and cultural studies of microbes through the lens of two works by emerging figures in the critical social and cultural studies of science: ‘Homo immunologicus’ (Sloterdijk, 2013; Goffey, 2015) and ‘Homo microbis’ (Helmreich, 2016).

In **Chapter 2**, I outline the methodology and research design of the thesis. Contrary to a positivist way of conducting ethnographic fieldwork, I complement the ethnographic study of human–microbe relations with the use of embodied experiences as feminist research tools. I do so by reformulating the concept of the para-ethnographic, that is, ‘a way of dealing with contradictions, exceptions, and facts that are fugitive’ (Holmes & Marcus, 2008, p. 596) as a feminist intersectional method that entangles embodied experiences with ‘fugitive’ qualitative data in technoscientific claims and quantitative research. I call this method ‘feminist para-ethnographies’. I then delineate the research design using as framework ‘feminist para-ethnographies of human–microbe relations’, and outline the scope and limitations and the research ethics.

Drawing on the ethnographic fieldwork I have conducted with microbial ecologist Dominguez-Bello and her research team in San Juan (Puerto Rico) and New York (US), interviews with influential microbiome scientists in London (UK), attendance of microbiome conferences, and analysis of scientific publications along with a microbiome online community, **Chapter 3** develops what I call the ‘microbiomisation of race’, establishing the basis of the ‘microbiomisation’ of other social categories of difference, particularly of class (Chapter 4) and gender (Chapter 5). I propose that what I call ‘the microbiomisation of race’ is constituted within a nexus between bioprospection and bioinequalities. I particularly focus on Dominguez-Bello’s research ‘Microbiomes of Homes across Cultures’ (MHC) to demonstrate how the operationalisation of race along with cultural relativism produces human microbiome scientific discourse and evidence.

MHC's experimental core is based on the bioprospection of microbes from biodiversity-rich locales and peoples of the Peruvian Amazon, in search of 'ancient microbes' as a potential solution to restore the microbiome of Western and westernised societies. MHC has several online and offline ramifications; I also follow those networks and examine the microbiome online community associated with the American Gut Project (AGP), a personalised medicine initiative, and its affiliated projects: The Human Food Project (HFP) and British Gut (BG).

Chapter 4 proposes what I call the 'microbiomisation of class' as a speculative 'proposition'—what philosopher of science Isabelle Stengers calls 'innovative fiction'⁷ (1997)—informing microbiome science. I do so by bringing together insights from my ethnographic fieldwork, science policy analysis of contemporary bioeconomy, and analytical perspectives from the work of feminist science studies scholars Hannah Landecker (2016), Melinda Cooper (2008), and Isabelle Stengers (2018). I particularly focus on the links between microbiome science and AMR, an understudied theme in social and cultural studies of (postgenomic) science. My argument is that a diverse microbiota, as crucial as it is for overall health and immunity, as microbiome science indicates, is not accessible to everyone. The more affluent, the more microbial diversity and the less susceptibility to AMR, and vice versa. This social stratification of microbes and immunities, in turn, reflects the ways in which entanglements between neoliberal capitalism and the life sciences are lived and experienced differently in and by different bodies.

Finally, **Chapter 5** asks: how to foster a 'critical friendship' (Rose, 2013), that is, a friendship able to generate assemblages between the sciences and the social sciences and humanities, between scientists and people, overall, between 'matters of concern' and 'matters of fact' (Despret, 2004; Latour, 2004; Stengers, 2018)? Here I draw on ethnographic fieldwork on Dominguez-Bello and her team's research on the microbiology of human reproduction, also known as 'vertical transmission of microbes'. The microbiology of reproduction is a controversial field of research. I illustrate these controversies through the lens of my embodied experience as a woman in labour and Group B *Streptococcus* (GBS) carrier in pregnancy. These experiences are important because they offer a 'lived' and 'socialised biology' (Riley, 1983), an example of the

⁷ Stengers (1997) defines an 'innovative fiction' as a proposition that 'makes a new phenomenon, or a phenomenon in a new mode, intervene in discussions' (p. 140).

‘microbiomisation of gender’ and of how the latter is caught up between two competing theories in the microbiology of reproduction: the (Pasteurian) ‘sterile womb paradigm’ and the (post-Pasteurian) ‘in utero colonisation hypothesis’. What I frame in the previous chapters as the ‘microbiomisation of race’ (Chapter 3) and the ‘microbiomisation of class’ (Chapter 4) becomes entangled here with the ‘microbiomisation of gender’. In fact, the case of GBS reflects the intersectionality of microbiomisation processes. Bringing together this empirical material with feminist literature on scientific knowledge production (Despret, 2004; Latour, 2004; Stengers, 2000, 2018), I develop ‘feminist para-ethnographies’, beyond its methodological application (Chapter 2), as a caring, ‘slow science’ (Stengers, 2018) and ‘engaged research’ (Hinchliffe et al., 2018) intervention in the biomedical field of microbiome science. Feminist para-ethnographies aim at the socialisation of care and the delivery of health justice through the transformation of silenced and private embodied experiences into shared experiences. They make ‘available’ (Despret, 2004), I will argue, new relationships and alliances between humans and microbes, clinicians/medical staff and patients/people, and social scientists and life scientists. Ultimately, as a social justice–driven tool to counter biome depletion and bioinequalities (Fassin, 2009), the role of feminist para-ethnographies is biome restoration across socio-economic classes and groups to alleviate health disparities produced by microbiome science (Chapters 3 and 4).

CHAPTER 1. Literature review: Contesting ‘Homo immunologicus’ and ‘Homo microbis’

1.1 Introduction

This first chapter introduces the conceptual fields and the lines of argument I will be developing throughout the thesis. In the first part, I provide a historical background of immunity as self-preservation and self-defence by drawing on Ed Cohen’s concept of ‘immunity-as-defence’ (2009) and Bruno Latour’s work on pasteurisation (1988). I then engage with previous work of social sciences and humanities scholars engaged in immunology, particularly with metaphors of immunity, paying attention to ontological, epistemological, and methodological aspects. The third part of the chapter focuses on a recent debate on the critical analysis of immunology initiated by Andrew Goffey in his essay ‘Homo immunologicus: On the limits of critique’ (2015). Goffey’s argument on the immuno-logic driving the pre-existing separation between discourse and practice, between the sciences and the humanities, offers an opportunity, I argue, to devise meaningful knowledge practices through which to circumvent his own ‘limits of critique’. Addressing Goffey’s limitations, I situate this thesis within three main theoretical and empirical frameworks of influence: body studies, STS, and anthropology of science.

Contrasting with the individualism of ‘Homo immunologicus’ (Goffey, 2015), the fourth part of the chapter focuses on the figure of the ‘Homo microbis’ (Helmreich, 2016). ‘Homo microbis’ has recently been taken up in the social sciences and humanities literature amid postgenomic research on human microbiome science. It has been largely encapsulated by the cultural anthropology subfield of ‘multispecies studies/ethnography’ (Kirksey & Helmreich, 2010).⁸ I then draw on the work of sociologists of science Hannah Landecker and Aaron Panofsky (2013) and Maurizio Meloni (2014a, 2014b, 2015), among others, and bridge new scientific research on the human microbiome, epigenetics, metabolism, and AMR to the concept of the biosocial. Using cultural theorist and poet Denise Riley’s concept of ‘socialised biology’ (1983), I reformulate the notion of the ‘biosocial’. Attending to ‘more-than-human’ (Braun & Whatmore, 2010) lives in ‘more-than-Western worlds’ and devising alternatives to neoliberal capitalism’s embodied inequalities, in the last section of the literature review I outline feminist theories of care

⁸ I will elaborate ‘multispecies ethnographies’ further in connection to the research methods of the thesis in Chapter 2.

(Martin, Myers, & Viseu, 2015; Mol, 2008; Murphy, 2015; Puig de la Bellacasa, 2011, 2012, 2015) along with decolonial theories of *Buen Vivir* (De La Cadena, 2010; González & Vázquez, 2015; Gudynas, 2011; Harding, 2016; Lanza, 2012; Leon, 2012; Walsh, 2010) as part of the critical analysis of microbiome science. I argue that care as *Buen Vivir* is an insightful social justice and alternative political framework to biome depletion. Remarkably, care as *Buen Vivir* compensates well multispecies ethnography/studies and the biosocial literature's insufficient engagement with non-neoliberal politics.

1.2 A history of immunity: Self-preservation and self-defence

1.2.1 'Immunity-as-defence'

The first use of the word 'immunity' in medicine appeared in 1775, when Dutch physician Van Sweiten deployed the term 'immunitas' for describing variolation⁹ (Tauber, 2012). The term 'immunity' has for two millennia, from before its contemporary usage within a biomedical context, referred to the condition of being exempt from duties or obligations. The Latin *immunis* refers to someone who is free from public services and communal responsibilities (*munus*) of various kinds, be they 'personal, fiscal, or civil' (Esposito, 2011, p. 5). The juridico-political origins of immunity and its modern transposition to human biology are at the core of Ed Cohen's book, *A body worth defending* (2009). Cohen traces a historical, philosophical, political, and biomedical genealogy of the migration of immunity from a legal and political context to a completely distinct frame of reference: biology.

According to Cohen, apart from its judicial and political connotation, which originated in the Roman *polis* (immunity-as-exemption), from the end of the nineteenth century onwards, 'immunity' has constituted a ubiquitous biomedical paradigm, one that he terms 'immunity-as-defence'. With this term, Cohen (2009) refers to the emergence of the 'modern body', since before the nineteenth century there was no clear distinction between the biological body and the legal, political, and economic body. From this moment in history, the biological body starts to be understood as distinct from other bodies and entities in order to keep its boundaries undamaged. This radical alteration of

⁹ Variolation was an inoculation method used to treat smallpox (*Variola*), a virus which solely targets humans as a host, and which, apart from having terrible physical consequences such as the characteristic pimples covering all body surfaces and mucosa, is highly deadly. The technique consisted of extracting fluids from a smallpox pustule on a sick person and, using venous access, infecting another, healthy person in order to induce protection against the virus. At the end of the eighteenth century, the physician Edward Jenner transformed variolation into a safer technique: vaccination.

previous conceptions of nature and culture is what Cohen argues defines the birth of biopolitical individualisation (p. 15). Thus, the mutation of the term ‘immunity’ from a legal and political context to a biological one presupposed the onset of the dissociation between the organism and its environment, as well as the association between ‘defence’ and biological functions, namely the immune system itself.¹⁰

In 1881, Russian zoologist Élie Metchnikoff (1845–1916), discoverer of the immune cells known as phagocytes, aligned immunity with the mechanism of self-defence (Cohen, 2009, p. 3). Metchnikoff’s insights constitute the most remarkable precedent of our current conception of the immune system. Biological scientists describe the immune system as a variety of organs and tissues, each one contributing in a specific manner to its specialised functions: the recognition of antigens (substances that trigger the production of antibodies) and the subsequent reaction to them. This understanding of immunity, which emanates from Metchnikoff’s ‘biological self-defence’, is widely known as the self/non-self model, proposed by F. M. Burnet in the 1950s.

As I will further elaborate in the next section, the self/non-self paradigm is based on the idea that the immune system’s function is to pinpoint the ‘Other’ which has ‘intruded’ the boundaries of the ‘self’, and subsequently ensure its ‘annihilation’. Although it was later proven that antigens are both exogenous and endogenous to the body (Jerne, 1974), the discourse that permeates various media and the educational health system is still based on this militarised narrative: The immune system is the ‘patrolling police’ of our bodies; that which guarantees a correct and healthy functioning following the established order and/or the reinforcement of ‘boundaries’. It is thus what ‘defends’ and ‘protects’ us from disease. As such, the heterogeneous cells that make up the immune system exist in a ‘battlefield’, engaged in constant ‘war’, ‘fighting’ against the ‘external invaders’.

Cohen (2009) is interested in disclosing this militarised provenance of immunity and examining whether the latter has something to tell us about the vital processes of the body (p. 31). Accordingly, in order to untangle why immunity stands in a rigid dichotomy between ‘endogenous self’ (that which must be preserved through perpetual defence) and ‘exogenous other(s)’, Cohen signals the Habeas Corpus Act of 1679 as a possible origin of its militaristic portrayal. According to Cohen, with the Habeas Corpus Act, ‘the body

¹⁰ The longer histories that Cohen explores are useful for establishing why immunity-as-defence has taken on a ‘truth value’ or ‘veridicality’, as Foucault would say.

replaces the soul as political subjectivity's foundation', thereby becoming 'the legal location of the person' (pp. 76, 81). Habeas Corpus (meaning 'you have the body') aimed to lessen the excessive royal power, during the reign of Henry II of England, in regard to unlawful detention. It basically claims that 'the sovereign cannot imprison people unless it can show that it has a lawful reason to do so' (Cohen, 2009, p. 79).

In the establishment of a 'corporeal personhood', in other words, the understanding of the body as a form of *possession*, the English political philosopher Thomas Hobbes (1588–1679) was the ideologist *par excellence*. Hobbes's *Leviathan* (1651) was one of the principal narratives that instigated a secular 'body politics' in which natural law and rationality were the basis for social cohesion, establishing 'self-defense as the first natural right by defining the body as a physical and hence natural locus for legal and political personhood' (Cohen, 2009, pp. 76–89). Cohen and the Italian philosopher Roberto Esposito¹¹ argue that Hobbes's writings and the Habeas Corpus Act have inaugurated an 'individualistic paradigm' that together with a mechanistic mode towards vital processes has considerably influenced scientific epistemology (Esposito, 2008, pp. 46–47, 2011, p. 114).

1.2.2 The body-as-organism: *Milieu intérieur* versus pasteurisation

Starting at the beginning of the eighteenth century, with the West's incorporation of techniques of inoculation against smallpox (variolation) and its subsequent development into a safer technique (vaccination), the body as legal locus began to be translated into the biological body. Prophylaxis in two formats—immunisation via vaccination and public hygiene measures—was focused on populations. Immunity ('the power to preserve life') here meets with politics ('the instrument for keeping life alive') in the guise of a Hobbesian logic of self-defence against 'foreign' and invisible 'invaders' (Esposito, 2008, p. 46; see also Bashford, 2001). As Cohen (2009), referring to Foucault, argues, in the genesis of a biopolitical realm, medicine starts 'to reimagine the living body itself in relation to the collective manifestations of disease' and to move forward 'as essential social knowledge both of the individual and of the collective' (pp. 160–161; see also Cohen, 2008).

¹¹ I discuss the work of Esposito in relation to the biopolitics of immunity later in the chapter.

1.2.2.1 *Milieu intérieur*

The attention to populations, using sanitary surveillance against contagion (mainly for cholera and smallpox), was however challenged by the concept of '*milieu intérieur*', postulated by the French physiologist Claude Bernard (1813–1878). Bernard's epistemology questions the focus on populations by developing a self-regulating and self-sufficient vision of the organism. Freedom and independence from the environment are what, in Bernard's view, characterise life. Therefore, public health investments should be directed towards the individual rather than the populace (Cohen, 2009, pp. 133, 201).

In his magnum opus, *An introduction to the study of experimental medicine* (2003), Bernard embarks on the development of one of the most important concepts of nineteenth-century physiology: the *milieu intérieur*, or internal environment, which is expanded in his posthumously published *Leçons sur les phénomènes de la vie communs aux animaux et aux végétaux* (1979). The key feature of Bernard's *milieu intérieur* is that it not only transforms the body into unity but also guarantees its perfect functioning in isolation from its external environment, granting freedom and independence to the organism because 'the *milieu intérieur* surrounding the organs, the tissues and their elements never varies' and therefore 'atmospheric changes cannot penetrate beyond it' (Fulton, 1996, as quoted in Cooper, 2008, p. 422). As Bernard (1927) explains:

The functions of man and of higher animals seem to us ... independent of the physico-chemical conditions of the [external, ANC] environment, because its actual stimuli are found in an inner, organic, liquid environment. What we see from the outside is merely the result of physico-chemical stimuli from the inner environment; that is where physiologists must build up the real determinism of vital functions (p. 79, as quoted in Cooper, 2008, p. 421).

Hence, following Bernard, physiologists are compelled to disregard factors beyond that of the inner functioning of the organism. However, this only applies to what he refers to as 'higher animals' or 'higher vertebrates'. Under this hierarchical vision of the living being, all invertebrates and cold-blood vertebrates would lack this balancing, harmonious, and emancipatory 'fluid' that is the *milieu intérieur*. Moreover, Bernard believed that any disruption or perturbation of the regulatory activities of the *milieu* would lead to disease (Cooper, 2008, p. 422). For Bernard, the orchestrator of the self-regulatory quality of the interior of 'higher animals' was the nervous system, specifically the autonomous nervous system, a thought that dominates a substantial part of the physiology of the first half of the twentieth century (Cooper, 2008, p. 421). Another notable aspect of the influence of the *milieu intérieur* is the numerous conceptual by-products which developed during the

twentieth century, the most relevant being the notions of homeostasis and autopoiesis, as defined in the next section.

Drawing on Bernard's *milieu intérieur*, the American physiologist Walter B. Cannon coined the concept of 'homeostasis' in 1929. Cannon's homeostasis, that is, the compensatory or regulatory system that keeps the internal constants of the organism stable, overcomes the principal weakness of the *milieu intérieur*, recognising the indissociability of the organism and the external environment as well as the fact that the internal environment is not 'fixed', as Bernard believed, but rather fluctuates within 'narrow limits' (Cooper, 2008, p. 424). Examples of homeostasis mechanisms include, for instance, the pH of the bloodstream or body temperature. Moreover, proponents of the Gaia hypothesis of the biosphere maintain that what guarantees life on earth is a complex self-regulating system (Margulis & Sagan, 1995). Homeostatic imbalance is related to several pathologies, such as diabetes or hypo- and hyperglycaemia.

But perhaps the most ubiquitous term derived from Bernard's *milieu intérieur* and Cannon's homeostasis, which is often transposed from biology to cultural and social theory, is 'autopoiesis'. Proposed in 1972 by the Chilean biologists Humberto Maturana and Francisco Varela, the term 'autopoiesis' refers to a network of processes that has the ability to create and destroy elements of its own system in response to environmental perturbations (Maturana & Varela, 1980). As Varela (1996) described it:

Autopoiesis attempts to define the uniqueness of the emergence that produces life in its fundamental cellular form. It's specific to the cellular level. There's a circular or network process that engenders a paradox: a self-organizing network of biochemical reactions produces molecules, which do something specific and unique: they create a boundary, a membrane, which constrains the network that has produced the constituents of the membrane. This is a logical bootstrap, a loop: a network produces entities that create a boundary, which constrains the network that produces the boundary. This bootstrap is precisely what's unique about cells. ... It is, by itself, a self-distinction. It bootstraps itself out of a soup of chemistry and physics (p. 212).

Clearly, Varela is careful to overemphasise the fact that autopoiesis is occurring within a cellular environment; it refers to the self-creation of cellular membranes. However, that the membranes of the cells are formed by autopoiesis does not mean that the cells are autonomous entities or bounded unities. This is because cellular membranes are characterised by permeability and are thus constantly exchanging nutrients with the

surrounding environment, an indispensable condition for cellular survival. Cells, as bodies, are ‘leaky’ (Mol & Law, 2004).¹²

With respect to the immune system, I suggest that the *milieu intérieur* is key to understanding discourses on immunity, since it can be seen as the bedrock of an individualistic conception of selfhood, grounded in self-preservation and self-defence, and has influenced both empirical immunology research and its theoretical basis on the one hand, and non-scientific representation and socio-cultural imaginary of the immune system on the other. In fact, some authors go further than this, arguing that much of the current neoliberal rhetoric of the body and immunity takes up Bernard’s notion, consciously or not, as a source of ontological and epistemological inspiration (see Cohen, 2009).

When Bernard carried out his research, biology was largely restricted to physiology, and it was not until the 1930s and 1940s when, mainly due to the development of high-resolution technologies such as the electron microscope or gel electrophoresis,¹³ molecular biology started to evolve, gaining influence and displacing other subdisciplines such as ecology or ethology at the end of the twentieth century. However, it is notable that the ‘molecular gaze’ (Rose, 2007; Abi-Rached & Rose, 2010) that has dominated the life sciences, and the associated deterministic approaches that characterise a neo-Darwinian perspective on vitality, emanate from Bernard’s epistemology.¹⁴

¹² Although this exceeds the scope of the chapter and my own expertise, it is worth mentioning that Bernard’s notion of the *milieu intérieur* has several conceptual consequences for twentieth-century biology (Cannon’s homeostasis and Maturana and Varela’s autopoiesis), additionally permeating other disciplines such as cultural and critical theory (Deleuze and Guattari’s ‘body without organs’ and ‘machinic assemblages’) and sociology (Luhmann’s System Theory).

¹³ An electron microscope is a type of microscope that uses an electron beam instead of light (achieving a higher resolution than the light microscopes) to reveal the structure of smaller objects, including biological and inorganic specimens. Gel electrophoresis is a biochemical method for the separation of macromolecules (DNA, RNA, and proteins), depending on their charge and/or size. This technique, relatively simple and economical, was vital for the rise of molecular biology since, for the first time, it was possible to analyse the properties and characteristics of single macromolecules and their fragments. It is used by a wide range of scientific disciplines as preliminary method for further analytical purposes, such as DNA sequencing or cloning.

¹⁴ To put it another way, the ‘molecular revolution’ in the life sciences, with its focus on the biochemistry of cellular processes to the detriment of other factors of influence, such as ecological and psychosocial, follows the epistemological and ontological assumptions of Bernard’s *milieu intérieur*. That is, it adopts the inner (micro) components of the body as the unique foci from which to combat disease but also from which individual identity, tied to a discourse of the genetic, can be determined. For further details on these debates around the history of immunology as a scientific discipline, see Appendix A.

1.2.2.2 Pasteurisation

Coming back to how the first vestiges of what is known today as the ‘immune system’ were articulated in the nineteenth century’s biomedical realm, Bernard’s *milieu intérieur* was partially displaced when a redefinition of health and disease prevention was introduced by Louis Pasteur (1822–1895) and his postulation of the ‘microbe’ in the social realm (Cohen, 2009, p. 236; Latour, 1988, p. 61). As Bruno Latour says:

You cannot build economic relations without this ‘tertium quid’ since the microbe, if unknown, can bitter your beer, spoil your wine, make the mother of your vinegar sterile, bring back cholera with your goods, or kill your factotum sent to India. You cannot build a hygienist social movement without it, since no matter what you do for the poor masses crowded in shanty towns, they will still die if you do not control this invisible agent (as quoted in Martin, 1994, p. 189).

Thus the microbe signalled a crucial shift in how to understand vitality, finitude, and human relationships with the environment. Pasteur’s discovery revolutionised approaches to health and disease, first by demonstrating that bacteria come from the environment, thereby displacing theories of spontaneous generation, and second by providing empirical confirmation of the germ theory of diseases.¹⁵

The reason Pasteurianism refocused public health’s investment in populations, breaking with Bernard’s *milieu intérieur* and its exclusive concern with the individual body, was in part due to its focus on the *invisible* or, as Latour (1988) points out, by controlling ‘this invisible agent’ that is the microbe. The control of the microbe was achieved by the alliance of two elements: the laboratory, in which Pasteur was able to recreate the ideal conditions for isolating microbes, thereby controlling infectious microorganisms; and the hygienist movement, by which the control of disease was directed towards a series of measurements applicable to populations (pp. 61–68). One could not be achieved without the other, since ‘all the great macroscopic problems of hygiene, it was believed, had been found to be solvable by the Pasteurians on the small scale of the laboratory’ (p. 67). Importantly, since Pasteur’s achievement, science starts to be concerned with *visibility* (pp. 61–63). With the deployment of visual technologies (such as the microscope), nineteenth-century science attempts to make visible the otherwise invisible agents that put the integrity of the body in danger. Thus, while physiologists like Bernard focused on the internal equilibrium of the body, disregarding

¹⁵ Before germ theory was formulated during the nineteenth century (most famously by Louis Pasteur and Robert Koch), the miasma theory of disease transmission was the predominant explanation for diseases such as cholera or chlamydia. Miasma, Greek for ‘pollution’ or ‘bad air’, was thought to originate in rotting organic matter and to be the cause of epidemic diseases. For a detailed account, see Latour (1988).

the nature and effects of external pathogens in human biology as well as the application of the latter to medical praxis, Pasteur, along with the hygienist movement, developed a holistic approach to combat disease (p. 61).

With ‘Pasteurianism’, guaranteeing human vitality consisted in the interconnection between the macro (population-driven strategies) and the micro (study of the microbe). However, ‘pasteurisation’ was not simply focused on controlling and combating disease, but also on the reorganisation of society, since hygiene involved a ‘mixture of urbanism, consumer protection, ecology (as we would say nowadays), defense of the environment and moralisation’ (p. 23). Prophylactic measures, from sewage treatment and compulsory vaccinations to the encouragement of personal hygiene, are the population-driven strategies that, since Pasteur, are aimed at the protection of individuals and collectives from the pervasiveness of ‘exogenous’ microbes which reach the porous barriers of bodies.

Since the immune system could ‘fail’, preventive techniques, which denote acquired immunity in the broadest sense (i.e. not only vaccination but also personal care, hygiene, diet, etc.), supplement the body’s ‘natural barriers’ to ensure its optimal molecular functioning.¹⁶ Moreover, as Esposito (2011) argues with reference to Derrida, prophylaxis, especially in the form of the vaccine (using the substance that resembles the disease-causing organism), represents a modern incarnation of the old Platonic *pharmakon* (poison and remedy at one stroke): *pharmakon* ‘is opposed to its other not by excluding it, but, on the contrary, by incorporating and vicariously substituting it’ (p. 127).

In summary, this first section of the chapter has outlined a historical overview of the origins of immunity. Drawing on the work of Ed Cohen (2009), I have argued that since the eighteenth century onwards, the juridico-political and scientific lexicons of immunity have permeated one another. Particularly, the shared common ground of ‘immunity-as-exemption’ and ‘immunity-as-defence’ is prevention: the former from communal responsibilities; the latter from death and disease. During the eighteenth and nineteenth centuries, the immune system was approached from a physiological

¹⁶ In immunology, the immune system is divided into innate immune system (non-specific response and the first line of defence, including inflammation, leukocytes and phagocytes, NK cells, and gamma/delta cells) and the adaptive immune system (specific recognition of antigens, including B and T lymphocytes and immunological memory by B and T cells). Here, I am referring to acquired immunity through hygiene practices and vaccination.

standpoint, and its study did not constitute a scientific discipline per se. However, Claude Bernard's *milieu intérieur* and Louis Pasteur's microbiological advancements would radically transform the discourse, practice, and experimentation of the immune system, leading to the transition from a physiological focus to a molecular focus. In this sense, I suggest that, on the one hand, Claude Bernard's *milieu intérieur* can be interpreted as the bedrock of an individualistic conception of selfhood that, grounded in self-preservation and self-defence, has been influencing both empirical immunology research and its theoretical basis, and non-scientific representation and the socio-cultural imaginary of the immune system. On the other hand, Pasteurianism, by diverting the focus from physiology towards the (invisible) microcauses of disease, stands as the modern antecedent of the molecular focus that has been driving immunological research. The insights of both Bernard and Pasteur have led to the emergence of the science of the immune system: immunology.

1.3 The 'immune self' metaphor

There are several coexisting theories and models of immune function (see Appendix A), yet its most common and pervasive understanding derives from the clonal selection theory, colloquially known as the self/non-self model postulated by Australian virologist Frank Macfarlane Burnet in 1957. What this model proposes is the recognition and elimination of pathogens or the 'non-self', such as viruses and bacteria, as the core function of the immune system. Accordingly, the immune system is 'protecting' and 'preserving' the integrity of the organism. Although it was later on proven that antigens are both exogenous and endogenous to the body (Jerne, 1974), this ubiquitous discourse is based on a militarised narrative: The immune system is the 'patrolling police' of our bodies; that which guarantees a correct and healthy functioning by the established order and/or the reinforcement of 'boundaries'. It is thus what 'defends' and 'protects' us from disease. As such, the heterogeneous cells that make up the immune system exist in a 'battlefield', engaged in constant 'war', 'fighting' against the 'external invaders' (Immune system research, 2016).

Despite its widespread influence, Burnet's theory has been contested by immunologists (Coutinho, 1989; Jerne, 1974; Matzinger, 1994) as well as by critical theorists and philosophers of science with various orientations, albeit predominantly from feminist post-structuralism, STS, philosophy, and anthropology of science (Brown, Machin, & McLeod, 2011; Cohen, 2001, 2003, 2008, 2009; Esposito, 2008, 2011;

Haraway, 1991; Hird, 2009; Howes, 2008; Lock, 2002; Martin, 1994; Martin, 2010; Moulin, 2001, 2012; Napier, 2003, 2012; Pradeu, 2012; Shildrick, 2010; Tauber, 1994, 2001, 2008; Weasel, 2001). While many of these accounts draw on the self/non-self discrimination as a metaphor for the dynamics of contemporary societies (Cohen, 2001, 2003, 2009; Esposito, 2008, 2011; Sloterdijk, 2011), the work of several critical theorists and science studies scholars deals with the immunological rhetoric by attending to scientific practice and experimentation (Brown et al., 2011; Haraway, 1991; Lock, 2002; Martin, 2010; Moulin, 2001; Pradeu, 2012; Shildrick, 2010; Tauber, 2008). Some works that used ethnographical modes of inquiry (Lock, 2002; Martin, 1994; Napier, 2003) have widely influenced this thesis.

In the section that follows, I review in depth the aforementioned debates and works of social sciences and humanities scholars engaged in immunology, particularly in metaphors for immunity, paying attention to ontological, epistemological, and methodological aspects.

1.3.1 The immune self metaphor in early work on immunity

Despite the fact that I do not intend to base my research on metaphorical analyses, the large-scale application of the ‘self’ metaphor in critical studies of immunity (Cohen, 2001, 2003, 2009; Derrida, 2003; Esposito, 2008, 2011; Haraway, 1991; Hird, 2009; Howes, 2008; Martin, 1994; Martin, 2010; Moulin, 2001; Sloterdijk, 2011; Weasel, 2001) makes the latter an indispensable point of passage. In reframing the immune system within a non-identitarian scope, philosopher of science Alfred I. Tauber’s *The immune self: Theory or metaphor?* (1994) is a milestone in oppositional approaches to the common interpretation of immunity (i.e. Burnet’s self/non-self model). Tauber analyses different philosophical modalities of selfhood that permeate through immunology, unveiling the indebtedness of this scientific discipline to different philosophical traditions. For instance, he suggests that the Nietzschean quest for freedom of the self stands as the philosophical origin of Metchnikoff’s immunological research (p. 290). For Tauber, the metaphor ‘points the inquiry toward its strategy and object but cannot precisely [detail] the phenomena of concern’ (p. 8). But perhaps Tauber’s main contribution to the logic of immunity is precisely its reversal. For him, the immune self is ‘neither subject nor object, but is actualized in action; the self becomes, in this view, a subject-less verb’ (p. 295). Therefore, immunity is ‘a *process* that always involves an open system of self-definition that consistently produces self and other’ (Esposito, 2011,

p. 169). The self is hence an echo chamber, transforming from one moment to the next; it is not one but many, not singular but plural (Blackman, 2012; Nancy, 2000).

Immunologist Paul Ehrlich's 'horror autotoxicus'¹⁷ and subsequent theory of autoimmunity (i.e. an organism's immune system reacting against its own tissues) (see Silverstein, 2014) is a source of inspiration for philosopher Jacques Derrida (2003). The interest of Derrida in autoimmunity lies in the fact that 'an autoimmune act does not close the immune body within a process of excessive defence, rather it destroys a living being's ability to protect itself and opens it to infection and contamination' (Andrews, 2011, pp. 14–15). Derrida's insights into autoimmunity as the human body's ability to relate to 'otherness' are especially elucidatory when read through the actual lens of human microbiome science (i.e. microbial–human entanglements).

Autoimmunity is also relevant in terms of the importance that biographical narratives have in achieving the management of chronic illnesses, such as multiple sclerosis or arthritis. Drawing on biographies of autoimmune patients and published accounts, historian of science Warwick Anderson's and immunologist Ian Mackay's *Intolerant bodies* (2014) shows that accommodating sufferers' feelings of loss and social isolation requires constant biographical work (see also Cohen, 2004, 2017; Hsu, 2017). The importance of a dialogic relation between medical treatments and patients' experiences of disease (and health) reverberates in my proposition of feminist para-ethnographies as a material-semiotic device to register, document, and analyse 'socialised biology' (Riley, 1983), particularly embodied experiences of human–microbe entanglements (Chapter 5).

The seminal works on the immune system by biologist and feminist theorist Donna Haraway (1991) and anthropologist Emily Martin (1994) attend to the 'self' metaphor and also to its underlying militaristic rhetoric, endeavouring to dismantle the sovereign (Western) notion of selfhood deployed by scientific and non-scientific discourse on immunity. Donna Haraway's *The biopolitics of postmodern bodies: Constitutions of self in immune system discourse* (1991) pinpoints the centrality of the immune system in the dialectics of Western biopolitics, suggesting that the latter appears as a strategic material and symbolic icon to 'construct and maintain the boundaries for what may count as self and other in the crucial realms of the normal and the pathological'

¹⁷ 'Horror autotoxicus' literally refers to the horror of self-toxicity.

(p. 204). In Haraway's account, biopolitics runs parallel to the technicisation of life ('techno-biopolitics'), a question that Foucault was unable to grasp.¹⁸ Hence, bodies are not biologically pre-given, but are generated in a dynamic of amalgamation with technologies and semiosis (p. 208, 209). Following Haraway's argument, the semantics of the immune system also take the 'differences' that dominate other areas of knowledge as part of its rhetoric. That means that there is no longer a single centre of control but a 'pastiche of multiple centres and peripheries' which nevertheless are not free, as Haraway indicates, from problems (p. 207). As she posits:

The hierarchical body of the old has given way to a network-body of truly amazing complexity and specificity. The immune system is everywhere and nowhere. Its specificities are indefinite if not infinite, and they raise randomly; yet these extraordinary variations are the critical means of maintaining individual body coherence (p. 218).

The 'network-body' Haraway is referring to is based on Jerne's immune network (1974). Jerne articulates the immune system as a complex, self-regulating network in constant interaction, in which the adaptability of antibodies (being able to function also as antigens) and their specificity are its core features. However, despite the inherent flexibility that the network theory bestows on the immune system, and in contrast to classical forms of immunity (i.e. the self/non-self model), Haraway is suggesting that the ends are the same: the maintenance of 'individual body coherence'. In fact, for Haraway, biology is still based on 'recognition and misrecognition, coding errors, the body's reading practices' (p. 211); and the network theory does not change this reality, because it is conceived as a system of maintenance based on boundary-making practices.

However, it should be remarked that Haraway's essay dates from a period—late 1980s and early 1990s—in which new theories of the immune system and human–microbe entanglements like in microbiome science were not yet developed/initiated. In the light of new, non-reductionistic avenues of research opened up by women such as

¹⁸ As Paul Rabinow and Nikolas Rose have argued in their influential 'Biopower today' (2006), Foucault's concepts of biopolitics and biopower are complicated, unfinished notions. In order to address this gap, Rabinow and Rose have proposed that biopower and biopolitics need to be reinterpreted and used as 'operational tools for critical inquiry' (p. 197). Focusing on three examples (race, reproduction, and genomic medicine), the authors have reformulated biopower and biopolitics in relation to contemporary biomedicine. Biopolitics, they write, can be used to 'embrace all the specific strategies and contestations over problematisations of collective human vitality, morbidity and mortality' (p. 197). Biopower, on the other hand, is conditioned by the presence of these elements the authors propose: 'One or more truth discourses about the "vital" character of living human beings; 'Strategies for intervention upon collective existence in the name of life and health'; 'Modes of subjectification, through which individuals are brought to work on themselves' (p. 197).

immunologist Polly Matzinger with her danger model (1994),¹⁹ some authors go even further, suggesting the possibility of a ‘feminist science’ founded on antideterministic ontological, epistemological, and ethical values (see Weasel, 2001). Regardless of this main contextual difference, the fact that Haraway looks beyond the initial celebration of the network theory, in contradistinction to the fixity of the self/non-self model, can be related to my position regarding the status of immunology in relation to the emergence of microbiome science. In other words, is human microbiome science breaking with the sovereign (Western) bounded body?

Coming from similar socio-historical contingencies, in her ethnographic study on the immune system *Flexible bodies* (1994), social anthropologist Emily Martin explores the hermeneutic changes of the immune system as well as ‘the logic of health, and of fitness of survival’ that its redefinition implies (p. 13). Her main argument is that with the advent of liberal democracies and their emphasis on readjusting to constant change as an indicator of competitiveness (her analysis is exclusively focused on the US under the Clinton administration), it follows that the prerequisites of personalities and bodies are also to become adaptable and flexible. Simply put, newly flexible corporations and establishments demand new flexible bodies and souls. Drawing on pioneering and extensive ethnographic fieldwork on the interpretations of the immune system by four different loci (media, non-scientists, alternative practitioners, and scientists), Martin’s insights also suggest that, in correlation with liberal democracies’ ethos of ‘flexibility’ (at the workplace and in the body), neither does biology rely on a mechanistic logic nor is the body immutable. Instead, complex systems in constant flux are what define ‘flexible bodies’ (p. 150). She nevertheless calls for careful consideration of the passage from a rigid body to flexible bodies and the inherent risk of taking for granted flexibility as ‘liberatory’ (pp. 247–248), suggesting that the configuration of bodies as flexible entities coexists with a post-Darwinian ideology, namely the ‘survival of the fittest’ (pp. 229–250). In this respect, regardless of the fact that many scientists and non-scientists understand the immune system’s ‘performance’ as a set of adaptable qualities that can be maximised with multiple forms of ‘training’ and ‘education’ (e.g. vaccination, healthy lifestyle, meditation...), as her research demonstrates, much of the current biomedical discourse relies on the genetic standpoint (pp. 235–238). Hence, while Martin’s work is

¹⁹ The danger model is an immunological theory that proposes that the immune system makes decisions based on alarm signals from injured tissues or cells. For further details on this model, see Appendix A.

situated within the socio-political US economy of the mid-1990s, I suggest that her reflections on flexible bodies can be partially transposed to contemporary ‘advanced liberal’ societies (Rose, 2007). Similarly, in the light of human microbiome science, my research will suggest that an ecological approach to human immune systems is not only a consequence of a post-Darwinian ideology. The current relational and ecological epistemologies of human–microbe relations also involve the optimisation of microbes and, more broadly, life-managing processes, aligned with the individualisation of the body and the personalisation of medicine (Chapter 3). Also, Martin’s multi-sited ethnography is more consonant with the methodological foundations of this thesis (Chapter 2).

In sum, despite the accounts developed by Tauber (1994, 2001, 2008), Haraway (1991) and Martin (1994) being intimately grounded in the rhetoric of the self metaphor and, particularly, in the case of Haraway’s and Martin’s, belonging to very different times and contexts, this thesis tackles and reformulates some of the questions that these authors have posed.

1.3.2 The immune self metaphor in contemporary biopolitics

The immune self metaphor has been reinstated in contemporary biopolitics through the work of several social scientists, philosophers, and cultural theorists.

As I have explained earlier in the chapter (see Section 1.2.1), apart from its judicial and political connotation, which originated in the Roman *polis* (immunity-as-exemption), from the end of the nineteenth century onwards, ‘immunity’ has constituted a ubiquitous biomedical paradigm, one that Ed Cohen terms ‘immunity-as-defence’. With this term, he refers to the emergence of the ‘modern body’, since before the nineteenth century there was not a clear distinction between the biological body, on the one hand, and the legal, political, and economic body, on the other. The mutation of the term ‘immunity’ from a legal and political term into a biological one presupposed the onset of the dissociation between the organism and its environment, as well as the association between ‘defence’ and biological functions, namely the immune system itself.

From a biopolitical angle as well, philosopher Roberto Esposito (2008, 2011) has called for a ‘non-immunised life’ or an affirmative politics of life grounded in relationality. In his books *Bios: Biopolitics and philosophy* (2008) and *Immunitas: The protection and negation of life* (2011), Esposito brings the apparently opposed terms of ‘immunity’ and ‘community’ into dialogue. He claims that the discourse of immunity—

and by extension, modern biopolitics—in the juridico-political as well as in the biological lexicon is built on a semantics of negation. Thus, for him, ‘immunisation’ is ‘an explanatory model for understanding the core dynamics of contemporary societies’ (Tauber, 2012). Following Esposito, immunity is protection but, most importantly, it is also a negation of life—what he calls ‘thanatopolitics’—since its ultimate purpose is the protection from the common (*munus* = shared responsibilities and contributions to the community).

Drawing on Canguilhem’s *The normal and the pathological* (1991), Esposito (2011) brings into discussion a reversal of the meaning of the preservation of life and its contrary, disease. What defines the ‘normal’ of an organism is ‘the ability to change its own norms’ or ‘the power to create new norms’ (p. 143). By contrast, disease supposes the inability to take risk and to confront changes. Disease presupposes ‘not a lack, but an excess of protection’ (p. 143). Bringing Haraway (1991) back into the discussion, this is in fact correlated to her request for an acknowledgement of ‘vulnerable life’. Disease results from excessive preservation, or immunisation, for trying to be invulnerable to the other. Thus, to be ‘normal’ is to take risks by embracing the ‘vulnerable life’:

Immunity and invulnerability are intersecting concepts, a matter of consequence in a nuclear culture unable to accommodate the experience of death and finitude within available liberal discourse on the collective and personal individual. Life is a window of vulnerability. It seems a mistake to close it. The perfection of the fully defended, ‘victorious’ self is a chilling fantasy (Haraway, 1991, p. 224).

Haraway (1991) contingently considers this question further—vulnerability as an affirmative attribute of life—by suggesting the possibility of an ‘oppositional/alternative/liberatory approach’ that recognises the ‘vulnerability, multiplicity, and contingency of every construct of individuality’ (p. 220). Despite the fact that she does not explicitly reveal how this ‘liberatory approach’—one that could break with the accepted immunological discourse of defence and attack and the self/other dichotomy—could possibly take shape, she nevertheless gives us a hint which involves taking into consideration the diverse cultural and technoscientific representations of the immune system (p. 221). In more general terms, Esposito’s proposition of a ‘non-immunised life’ or an affirmative politics of life (2008, 2011) means that, in the face of the increasingly contagious and genetic risk in which contemporary individuals are immersed as a result of the current biomedical discourse (Rose, 2007), we should not simply accept the necessity of contamination and we should learn to coexist under this

susceptible panorama, but more remarkably, to recognise that the ‘Other’ is not purely external to the self, or ‘foreign’ to the self, but is the self itself.

As we will see in the next section of the chapter, several authors have made similar arguments regarding the self/other dichotomy by drawing on contemporary biomedical research (Hird, 2009; Martin, 2010). However, before reviewing the social sciences and humanities literature on contemporary scientific accounts of immunity, in the next section of the chapter I engage with a recent debate on the critical analysis of immunology initiated by Andrew Goffey in his essay ‘Homo immunologicus: On the limits of critique’ (2015).

1.4 ‘Homo immunologicus’

‘Homo immunologicus’, a term coined by philosopher Peter Sloterdijk (2013) and recently taken up by sociologist Andrew Goffey (2015), amounts to an atomistic vision of the human, by which the traffic between the sciences and the humanities is limited to a symbolic and excessively discursive exchange in terms of warfare and protection. In this section, I first engage with Goffey’s account on the limits of a social and cultural critique of immunology. I claim that Goffey’s analysis of the existing literature on immunity is coming from a very selective reading, restricted to a biopolitical perspective on the topic. As such, Goffey excludes a vast body of (predominantly feminist) literature engaged with experimental immunology. In response to his text, in the second part of this section I situate this thesis within three different yet interlocking bodies of literature: body studies, STS, and anthropology of science. I complement each of these subfields in the cultural and social study of science with an empirical case study of immunity. In doing so, my objective is twofold: First, to counteract Goffey’s linear and limited account in ‘Homo immunologicus’ (2015), and second, to explain the bibliographic references and feminist citation politics that I draw on, and that influence and shape this thesis.

1.4.1 On the limits of Goffey’s critique

In ‘Homo immunologicus: On the limits of critique’ (2015), sociologist Andrew Goffey develops a critique of the pre-existing separation between discourse and practice, the sciences and the humanities. Drawing on philosopher of science Isabelle Stengers’s *modern knowledge practices* (2000) and focusing on the traffic between immunology, philosophy of science, and critical studies of immunity—particularly on the work of Haraway (1991), Martin (1994), Tauber (1994), Esposito (2008, 2011), Cohen (2009),

and Sloterdijk (2013)—Goffey (2015) aims to challenge ‘the abstractedly general understanding of scientific knowledge that has largely prevailed in the philosophy of science, and which is replicated across other disciplines’ (p. 13). He is here referring to the rhetoric of immunity in relation to its ‘problematic connections with culture more broadly’ (p. 13). ‘Such discussions’, Goffey continues, ‘do little to convey the uncertainties operative within immunology considered as a practice, and they do little to address the problems that they do disclose other than by referring that immunology to another court of judgement’ (p. 13). For Goffey, critical analyses of immunity are dominated by a biopolitical reading, with little investment in ‘practical’ forms of inquiry. In fact, immunity constitutes ‘a philosophical rather than a scientific problem’ (p. 11). The social sciences and humanities are still approaching the sciences as ‘the enemy to be contested’ (p. 8). Thus, like ‘we have never been modern’ (cf. Latour, 1993), neither have we ever stopped being in a ‘science war’. Inspired by the work of Stengers, Goffey claims that scientific truths ‘must be addressed in such a way as not to push out of the picture the singular quality of the practices that enable that achievement’ (p. 13). Likewise, he concludes with a plea for a deeper engagement with the empirical work of life scientists.

One of the main objectives of ‘Homo immunologicus’ is to signal and advance future avenues of critical social sciences and humanities scholarship on immunity. My claim is that it is exactly this very goal that makes the piece extremely problematic and misleading. The problem, I argue, springs from Goffey’s inattention to an already existing, vast body of contemporary social, cultural, and anthropological research dealing with experimental immunology and innovation at the intersections of other life science subdisciplines, such as microbiology, neuroscience, or epigenetics. In fact, this failure to take into account the existing literature on the empirical side of the rhetoric of immunity has pervaded the most popular contemporary accounts on the topic, particularly those developed by philosophers Roberto Esposito (2008, 2011), Peter Sloterdijk (2013), and cultural theorist Ed Cohen (2009).

Against this background, it could be argued that the work of the scholars above belongs to a very different tradition of thought, concerned with continental philosophy under a Foucauldian framework. But this does not apply to Goffey’s ‘Homo immunologicus’. In other words, the reason behind the incomplete mapping of critical studies of immunity in Goffey’s text cannot be seen as the result of disciplinary constraints, since these are not mentioned and, importantly, the article is in itself a review of the existing literature on the topic. Therefore, by ignoring existing work on empirical

aspects of immunology and by creating a divide between theory and practice, discourse and empiricism, Goffey falls into the very same ‘limit of critique’ he signals as haunting critical accounts of immunity. As a mode of response to Goffey’s ‘Homo immunologicus’ (2015), the following section situates the cultural and social study of immunity within the three bodies of knowledge practices that I draw upon and am inspired by.

1.4.2 Situating immunity: Influences

1.4.2.1 Body studies

Sociologist and feminist scholar Lisa Blackman, editor of the first body studies journal in anglophone academia, *Body & Society*, writes that body studies or body theory ‘takes the body as a central locus of concern and analysis in relation to broader questions related to power, ideology, technologies, agency and so forth’ (Blackman, 2008, p. 20). Body studies is characterised by transdisciplinarity, and so it ‘crosses over the borders and boundaries between psychology, sociology, cultural theory, anthropology and sociology’ (p. 7). Discourse and critical perspectives on the self are a central theme of concern for body studies. In this sense, sociologist Chris Shilling (2012) points out that ‘the body provides a firm foundation on which it is possible to reconstruct a reliable sense of self’ (p. 4).

Body studies is a relevant source of literature for this thesis for four main reasons. First, in connection to the self, which, as I have previously explained, is a constitutive element of immunology since the birth of the discipline in the 1960s (Moulin, 1989) and a fundamental concern for this thesis: With the emergence of the human microbiome in biomedicine, what happens to the self and, in particular, to Cohen’s concept of ‘immunity-as-defence’ (2009)? (Chapter 3). Second, its transdisciplinary nature is consonant with the varied sources that this thesis draws upon and is inspired and shaped by. A substantial part of the literature I draw on falls into an ‘interdisciplinary’ category, by which authors navigate through scientific facts and several traditions of thought, such as postmodernism or biopolitics. Third, body studies is relevant because of its mixed-methods approach. Body studies takes feminist innovative transdisciplinary methodology as its core feature. Medical personal narratives, autoethnography, or storytelling are situated embodied practices of body studies. Likewise, this thesis combines my embodied experiences of health and disease with anthropological methods such as ethnography and interviewing and sociological methods such as critical analysis of science and policy. As I will explain in the next chapter, I develop my interdisciplinary research methods under

the methodological framework of ‘feminist para-ethnographies’ (Chapter 2). Fourth, I argue that body studies acts as a catalyst for mingling an eclectic body of experimental and critical (mostly) feminist literature engaged with contemporary bioscience. As such, the work of several feminist science/body studies scholars has incorporated the material reality of research and experimentation of the immune system into their theoretical agenda (Hird, 2009; Lock, 2002; Martin, 2010; Moulin, 2001; Shildrick, 2002, 2010; Weasel, 2001; see also *Body & Society*’s ‘New biologies’ special issue, Blackman, 2016b). Although the common ground of these perspectives is also the dismantling of normative accounts of autonomous selfhood, the empirical cases they draw upon, as well as the theoretical and methodological orientations, are quite heterogeneous. Likewise, the work of sociologist Aryn Martin (2010) is particularly relevant for this thesis because it provides a renewed vision of immunology by bridging scientific research with critical studies of science through the lens of the phenomenon of microchimerism.

Case: Fetal-maternal microchimerism

Aryn Martin’s ‘Microchimerism in the mother(land): Blurring the borders of body and nation’ (2010) brings highly specialised immunological research into transdisciplinary debate. Using a material-semiotic perspective—inaugurated by feminist technoscientist Donna Haraway—that places the body in a mediated reality co-constituted by language, technology, and flesh, Martin (2010) is interested in the potential of the phenomenon known as ‘microchimerism’ for dismantling predominant atomised views of the body. Fetomaternal microchimerism refers to ‘the “bidirectional cell trafficking” between fetal and maternal bodies’ through the placenta (p. 24). Questioning the self/non-self model, exchanged cells can multiply, migrate to other organs, and persist in the mother’s body for several decades.

Combining metaphor analysis with field research—she conducts interviews with scientists working in microchimerism-related research—Martin (2010) focuses on an ontological shift in the immunological discourse: ‘from contained selfhood to relational coexistence’, that is, from a militaristic nation-state body to a relational one (p. 44). Drawing upon Barbara Duden’s account on the modern construction of fetus (1993) and Benedict Anderson’s similar view on the nation (1991), Martin asks ‘how did the fetus come to be a nation?’ (2010, p. 24). Tracing back the beginnings of microchimerism research to the early 1990s and Diana Bianchi’s group (Bianchi, Flint, Pizzimenti, Knoll, & Latt, 1990; Bianchi, Zickwolf, Weil, Sylvester, & DeMaria, 1996), Martin (2010)

suggests that with it, a set of new metaphors such as ‘trafficking’ and ‘migrants’ were introduced in the immunological field, consequently reinstating a rhetoric by which the body became a nation, and cells citizens (pp. 28, 38).

Martin also touches on some controversies provoked by the phenomenon of microchimerism. For instance, part of the scientific community at that time aligned fetomaternal trafficking with autoimmune disorders such as diabetes type I, rheumatoid arthritis, celiac disease, or lupus erythematosus—what Martin calls ‘bad fetal cell theory’ (p. 32). It was later on proven that while in some autoimmune disorders fetal cells might worsen the mother’s state, in others they can contribute to her health’s improvement, even having therapeutic use (p. 34). In the light of this, the ‘bad fetal cell theory’ was partially substituted by the ‘good cell theory’ (p. 43). Martin refers to immunologist Polly Matzinger’s ‘Danger model’ (1994)²⁰ as one of the main theses that propelled the epistemic change towards the ‘good cell theory’. Following Martin, by correlating the immune system’s core goal with damage rather than with otherness, Matzinger’s model ‘shift[s] the focus from the *identity* of cells or tissues to their *function*’ (2010, p. 41).

The phenomenon of microchimerism demonstrates that body boundaries are blurred rather than rigid. It shows that our immune systems function by ‘symbiotic generosity’ rather than by self-defence; that we are socially, culturally, and most importantly, biologically, co-constituted by a heterogeneous range of ‘others’. Likewise, Aryn Martin’s research suggests that ‘our personal DNA profile is not as inviolable as we have been led to believe’ (Shildrick, 2010, p. 16), since our own cells are not the only ones inhabiting our bodies; other humans’ as well as viral and bacterial DNAs coexist with ours. Organ transplantation, and as a result, the embodied experience that such an ‘intruder’ generates in its ongoing negotiation with the common milieu, that is, the body (see Blackman, 2010; Lock, 2002; Nancy, 2008; Varela, 2001), figures as another phenomenon that challenges conventional immunology. Similarly, I argue that microbiome science enacts immunity differently.

Martin’s article is a good example of body studies research engaged with the experimental scientific minutiae of contemporary immunology; a perspective and style consonant with this thesis. However, I contend that the work of Martin (2010), along with other feminist scholars, excessively emphasises molecular aspects (fetal DNA in the case

²⁰ See Appendix A for more details on Matzinger’s ‘danger model’ (1994).

of Martin's account of microchimerism), disregarding other (non-molecular) factors that would make their arguments more compelling and less problematic (Brennan, 2004; Martin, 2010), for example by including the gender-race-class configurations of biomedical onto-epistemologies and technologies.

Against Goffey's vision of 'the abstractedly general understanding of scientific knowledge' (2015, p. 13), the work of Aryn Martin on fetal-maternal traffic demonstrates that his critique is grounded in eliding a vast body of literature of a feminist orientation. Importantly, acknowledging and accounting for this less-cited and therefore less-known literature on immunity constitutes a political act: it counteracts the hegemonic politics of citation, a politics of reproduction by which predominantly Western, white males appear to be the sole representatives, experts, and gatekeepers of academic knowledge. I concur here with feminist and critical race studies scholar Sara Ahmed in that the 'reproduction of a discipline can be the reproduction of *these techniques of selection*, ways of making certain bodies and thematics core to the discipline, and others not even part' (2013).

The social and cultural study of immunity is eclectic and goes well beyond biopolitical narratives written by a handful of continental (male) philosophers (see Esposito, 2008, 2011; Sloterdijk, 2013). In addition, beyond critical engagement with the immune system, the work of feminist scholars like Lisa Blackman (2001), Anne Pollock (2012), or Amy Hinterberger (2012a, 2012b) refutes Elizabeth Wilson's (and Goffey's) argument that the 'aversion to biological data is widespread in feminist theories of all stripes' (Wilson, 2015, p. 3). However, it is also important to remark that I concur with Wilson that feminist theories have failed to bring their engagement with and analysis of biological experimentation and scientific minutiae more broadly to the forefront of the discussion, making it an evident and central part of their argument. This limitation, as it applies to this thesis as well, is an aspect I would like to address in my future research.

1.4.2.2 *Science and technology studies*

Cultural and social critique of immunity is not limited to philosophical biopolitical-oriented diatribes (as Goffey, 2015, argues). This is one of the key arguments underscored in this chapter. The topic of immunity in the social sciences and humanities is wide-ranging and dispersed. Science and technology studies (STS)—a term I use interchangeably with (critical) science studies, technoscience, and science, technology, and society—has addressed several aspects of immunity in the past (Haraway, 1991; Latour, 1988) and in the present (Brown et al., 2011; Brown & Nettleton, 2016, 2017).

STS ‘starts from an assumption that science and technology are thoroughly social activities’ (Sismondo, 2010, p. 10). STS studies the relationship between technology, science, and society.

The study of science, technology, and society in the anglophone world can be traced back to two main schools of thought: sociology of scientific knowledge (SSK) and sociology of science. Emerging in the 1970s, SSK, as opposed to the (North) American sociology of science inaugurated by the work of Robert K. Merton (1942), considers the content of science, and not just scientists, crucial to a sociological account. More contemporary accounts of STS, however, particularly actor-network theory (ANT), regard SSK as essentialist and anthropocentric (Collins & Yearley, as cited in Pickering, 1992). Its material-semiotic approach distinguishes ANT. The influence of feminist scholar Donna Haraway, along with its anti-essentialist ethos through the inclusion of non-humans (characteristic of Haraway’s work as well) makes ANT a relevant interdisciplinary approach for this thesis.

Developed in the early 1980s by Bruno Latour, Michel Callon, and John Law, ANT reflects preoccupations of post-structuralism, especially about the multiplicity of material-semiotic realities. Authors associated with ANT, such as John Law (2004) and Annemarie Mol (2002), show that ‘realities *overlap and interfere with one another*. Their relations, partially co-ordinated, are complex and messy’ (Law, 2004, p. 61). Accordingly, there are multiple, coexisting realities. Crucial to this argument is the fact that reality is *enacted* (Law, 2004; Mol, 2002). This means that reality does not pre-exist ‘out-there’, with the role of the knowing subject being to decipher it by empirical and discursive devices.

Annemarie Mol’s ethnography of lower-limb atherosclerosis, *The body multiple* (2002), is a research milestone in accounting for enacted realities. In contrast to both relativist and reductionist narratives of medical sociology and anthropology, Mol’s ethnography traces the hybrids and multiplicities of socio-material assemblages in the enactment of lower-limb atherosclerosis. Hence, rather than attending to perspectives and interpretations of medical specialists and patients, Mol focuses on how atherosclerosis is enacted (i.e. produced) differently in the various hospital’s locations as well as through the physical constraints that the latter bring to the patient’s daily life. As a result, she shows that even though ‘there are different atheroscleroses in the hospital’—for instance, the one the pathologist makes is distinct from the one made by the radiologist—these ‘are

connected’: ‘*The body multiple* is not fragmented. Even if it is multiple, it also hangs together’ (p. 55).

Consonant with the body of work developed by authors such as Bruno Latour (1988, 1993, 2005), Donna Haraway (1988, 1991, 2008), and Isabelle Stengers (1997, 2000, 2010), Mol’s *The body multiple* pleads for an ‘ontological politics’ that can account for human and nonhumans. As she writes:

Shifting from understanding objects as the focus point of various perspectives to following them as they are enacted in a variety of practices implies a shift from asking how sciences represent to asking how they intervene. ... a philosophical shift in which knowledge is no longer treated primarily as referential, as a set of statements *about* reality, but as a practice that interferes with other practices. It therefore participates *in* reality (pp. 152–153).

Mol’s ontological politics is in fact in line with Goffey’s critique of the excessively theoretical take on immunity by social scientists and humanities scholars (2015). I concur with Mol that reality is multiple, enacted/produced differently by different practices, and through knowledges as well. And this is where the problem with this kind of approach lies, I argue. I distance myself from privileging practice, materiality, and objects over knowledge, discourse, subject, representation, and interpretation. Knowledge and practice come together. For instance, consider a knowledge practice that I have become familiar with in the process of this thesis: writing a doctoral thesis. A thesis is not (just) about knowledge. To produce academic knowledge, you need a lot of practice. Writing is a form of practice. Your writing schedule, writing environment, together with your drafts, data storage, and management: all of this requires practice. Crucially, you need practice in mapping the epistemic fields in which your thesis is situated. You need the practice to manage knowledge. Moreover, if you write in a second language as I do, you need even more practice. To practice the language, building sentences, grammar, and expressions. To separate practice from knowledge is, in my opinion, counterproductive.

I prefer to use the adjective ‘material-semiotic’ or the noun ‘material-semiosis’ rather than ‘enactments’ or ‘hybrids’ because I believe that Haraway’s concept encapsulates the entanglement of knowledge and practice altogether. Importantly, for Haraway (2004), theory and knowledge are corporeal:

So while the late twentieth-century immune system, for example, is a construct of an elaborate apparatus of bodily production, neither the immune system nor any other of biology’s world-changing bodies—like a virus or an ecosystem—is a ghostly fantasy. Coyote is not a ghost, merely a protean trickster. ... Overwhelmingly, theory is bodily, and theory is literal. Theory is not about matters distant from the lived body; quite the opposite. Theory is anything but disembodied (p. 68).

Similarly, and more recently, feminist scholar Sara Ahmed (2017) has emphasised the need of pulling theory away from abstractions by bringing theory back to daily life, to embodied experiences. Theory, she writes, ‘can do more the closer it gets to the skin’ (p. 10).²¹

Influenced by STS, my research takes up an ethos by which reality, rather than fixed and pre-existing, is produced differently by different knowledge practices. Haraway’s material semiosis of the immune system and Latour’s work on vaccines (1988) provide the bedrock of STS scholarship on immunity. More contemporary accounts of STS studies on immunity include the work of Nik Brown and colleagues (2011), drawing on the umbilical cord–blood market. As I show in the following section, this work is particularly helpful for the theoretical framework of this thesis, as it attends to situated accounts of science while being theoretically inspired by biopolitical concerns.

Case: Cord blood market

In ‘Immunitary bioeconomy’ (2011), sociologists of science Nik Brown, Laura Machin and Danae McLeod interrogate the economisation of the cord blood (CB) market. Using ethnographic qualitative data from interviews with CB stakeholders along with policy data, the authors provide a compelling analysis of the economic dimension of the CB market by bringing race to the core of critical debates on immunity.

Human CB stem cells, the authors explain, are important bio-objects (Vermeulen Tamminen, & Webster, 2012) because they produce the entire body’s immune system and blood (Brown et al., 2011, p. 1115). CB stem cells have been used as an alternative to bone marrow since the late 1980s. Compared to bone marrow donation, which involves an invasive surgical procedure, CB is easily collected from newborns (pp. 1115–1116). CB is also valuable in the field of regenerative medicine (Brown, Kraft, & Martin, 2006). CB banks grew rapidly in the early 1990s. Public CB banks are based on an ‘allogeneic regime’ fuelled by ‘social solidarity’, where blood circulates among unrelated yet immunologically compatible donors and recipients. Private CB banks, on the other hand, are kinship-based and so ‘autologous (self-to-self)’, more in tune with individualistic neoliberalism (p. 1115). As Brown et al. point out, ‘CB is a high-value commodity frequently trading at £15,000 to £20,000 per unit’ (p. 1116).

²¹ I will come back to Ahmed’s evoking sentence in the next chapter (Chapter 2), where I explain methodological repertoire, including my embodied experiences of health and disease.

While their focus is the economisation of CB, a perspective, they argued, with important gaps in the social critique of the life sciences (p. 1117), their analysis of the CB market avoids the public versus private debate by concentrating instead on the international trade between different institutions situated within the public domain. Their aim to avoid simplistic dichotomies (i.e. private versus public) is theoretically motivated by philosopher Roberto Esposito's affirmative biopolitics of immunity. Following Esposito, their interest lies in new forms of (immunitarian) circulation, in the 'trade in immunotypes, an internationalized political economy built upon the capitalisation and globalisation of 'diasporic immunity'' (p. 1116). For Brown et al. (2011), the concept of 'diasporic immunity', that is, 'the dispersal and heterogenisation of populations upon which the CB trade is based' (p. 1116) is key to the bioeconomy of CB banking and market.

The CB banking sector was originally established to solve the alarming under-representation of non-Caucasoid populations in bone marrow registries (p. 1117). As the authors demonstrate throughout the article, the economisation of CB stem cells originates in racial differences. As an example, most East Asian countries are internally homogeneous; therefore, their supply is limited to the domestic market. Europe and North America are, on the contrary, ethnically/racially heterogeneous, reflecting 'globalised histories of migration and immunitary diversity' (p. 1120). The US is the country that exports the highest number of units because of the 'ethnic/racial diversity of individual banks'. Hence, the 'global patterning of the CB bioeconomy directly reflects population heterogeneity'. Put differently; the 'immunitary trade significantly advantages those racially heterogeneous countries able to supply globally dispersed populations' (p. 1121), which are built on slavery and empire.

'Immunitary bioeconomy' cogently shows that 'immunitary globalisation' is 'historically structured through outbred diasporic migration' (p. 1122), including forced migration and slavery. Tackling race, immunity, and global economy through the lens of CB stem cells is an insightful perspective for this thesis, as I also merge colonial histories, race (Chapter 3), bioeconomy (Chapter 4), and contemporary biomedicine through the framework of 'microbiomisation' (Chapters 3, 4, and 5). Also, the text is an illustrative example of how biopolitical theory (through the work of Esposito) entangled with a situated account of present-day immunity, defying, in turn, Goffey's 'Homo immunologicus' (2015).

1.4.2.3 *Anthropology (of science)*

Within social and cultural anthropology, the highly specialist subfield of medical anthropology (also known in European academia as ‘anthropology of health’, ‘anthropology of illness’, or ‘anthropology of medicine’) has been key for the development of the theoretical framework of this thesis. Originating in cultural and social anthropology, medical anthropology, and anthropology of science, it understands aspects of science and medicine such as health, illness, specific diseases, health technologies and infrastructures, healthcare, and healthcare access and inequalities as broader elements of culture and society. Some authors use the term ‘medical anthropology’ to refer to their disciplinary domain, while others prefer the wider ‘anthropology of science’. In addition, because of the transdisciplinary nature of STS, some academic programmes integrate anthropology of science in an STS perspective.²²

In this thesis, I use the term ‘anthropology of science’ to refer to the literature outlined below. I believe that the word ‘science’ is more inclusive (i.e. includes medicine) than the word ‘medicine’ (i.e. the clinical application/translation of science). Anthropology of science encapsulates, for instance, Emily Martin’s seminal work on the immune system (1994) as well as the more recent research of Alex Nading on dengue fever in Ciudad Sandino, Nicaragua (2013, 2014, 2015b). Although Nading’s work falls within medical anthropology (i.e. dengue fever is a medical condition), his later work (2016)—together with the work of other anthropologists engaged with various aspects of immunity (Fischer, 2012; Moulin, 2012)—is broader than the discipline of medical anthropology. Moreover, the expanding subfield of ‘anthropology of microbes’ (Benezra et al., 2012)—also conceptualised as ‘multispecies ethnography’ (Kirksey & Helmreich, 2010)—is, as I will show in the next section of the chapter, situated within anthropology of science.

Anthropology of immunity

Anthropology of science has indeed been a very prolific field in the social and cultural study of immunity in the past decade. Medical anthropologist A. David Napier is one of the key exponents in the field. In his 2003 book *The age of immunology: Conceiving a future in an alienating world*, Napier uses as inspiration the non-Cartesian cosmology of the Balinese to argue that there are alternatives to the neoliberal and individualist ethos

²² See, for instance, the doctoral programme offered at MIT in History, Anthropology and Science, Technology, and Society (HASTS), at <http://web.mit.edu/hasts/index.html>.

of immunology, namely the ‘recognition and elimination of difference’ (p. xxiii). For Napier, immunology’s mantra is indeed a premise of modern life (p. xxiii). By contrast, the non-modern and non-Western Balinese culture engages with ‘otherness, rather than cultivating *avoidance*’ (p. 31). For example, ‘in the Balinese view, we do not contract cancer when pathogenic cells gain control; we all have cancers which must be negotiated, or they become pathogenic’ (p. 31). Napier’s attention and approach to metaphors as ‘the basic building blocks used for making new discoveries’ rather than as ‘humanistic “flaws of science”’ (p. 65) provide an interesting framework from which to pursue ‘other’ immunities.

In a similar line, the 2012 special issue of the journal *Cultural Anthropology* provides rich material on the role of metaphors of immunity. The issue is structured around Napier’s article ‘Nonselves help: How immunology might reframe enlightenment’ (2012). Following his previous thesis, developed in *The age of immunology* (2003), Napier insists on the ethnographic record of others’ (read non-Western cultures’) ‘assimilation of difference’ (pp. 131, 134) as a solution to neoliberal conceptions of selfhood. Napier’s article is followed by a series of responses by renowned social and cultural anthropologists.

George E. Marcus (2012) takes Napier’s article as an invitation to outline a thought experiment on ethnographic practice. Reversing the ‘principles’ of ethnography, Marcus’s idea consists of overtheorising the ‘self of the other’ and undertheorising the ethnographer self (p. 172). Consequently, the others would become ‘counterparts or ‘epistemic partners’ to the research, rather than its informants or subjects’ (p. 172). Paul Stoller (2012) takes a different perspective by drawing on his embodied experience of non-Hodgkin’s lymphoma. To make sense of his own ‘in-betweenness’ with cancer, Stoller uses Sufi mysticism as inspiration. Immunologist and historian Anne Marie Moulin (2012) criticises Napier’s attempts to parallel science and culture, arguing that ‘culture leads science and not vice versa’ (p. 160). Similarly, drawing on the work of Hannah Landecker on tissue cultures (2007) and Lily Kay’s historical reading of the cracking of the genetic ‘code’ by biochemists (1999), Michael Fischer’s response shows that metaphors do impact biological experiments (2012, pp. 145–146). Interestingly, Fisher also points out the obsolescence of the self/non-self-model amid contemporary biological research:

Just like identity politics, perhaps self–nonself has run its course, useful for certain contexts but not generally viable amid growing biological and ecological sensibilities (p. 150).

This is a significant quote because, following Sara Ahmed’s view on the dangerous ‘overing’ of identity politics (2017), the main argument of this thesis is the exact opposite of what Fischer is suggesting: the self/non-self, in its multiple and varied guises, is still present in contemporary biomedicine. Identity politics is articulated in postgenomics; particularly, I argue, in microbiome science, in what I refer to as the ‘microbiomisation of social categories of difference’ (Chapters 3, 4, and 5).

Case: Dengue fever

The work of medical and environmental anthropologist Alex Nading on dengue fever and microbiome research (2013, 2014, 2015a, 2015b, 2015c, 2016) has widely influenced the anthropological take I develop in this thesis. Nading’s approach is more concordant with mine, especially when compared to the cultural anthropology of immunity metaphors I have outlined earlier.

In ‘From critique to practice: A response to Andrew Goffey’ (2015), Nading tackles the vagueness and ambiguity of Goffey’s ‘Homo immunologicus’ (2015) by offering a situated account of his research on dengue. Dengue fever is a mosquito-borne infection caused by one of the four dengue virus serotypes. All the serotypes ‘are capable of playing an insidious trick on the immune system’ (p. 14). The viral infection causes high temperature, headache, and muscle, joint, and bone pain. Because bone pain is one of the most common symptoms, dengue is colloquially known in English as the ‘breakbone fever’. Nading links dengue with immunity by detailing the ‘original antigenic sin’, namely an immunological reaction that explains why secondary dengue infection is more serious, even deadly, than a first-time infection. Moving beyond metaphors of immunity (i.e. ‘sin’), Nading focuses instead on the ethical conundrum of the tetravalent Dengue Vaccine Initiative (DVI). The global public-private DVI has brought visibility and capital investment to dengue research, an area of research that previously received little attention. The tension between the for-profit vaccine and experimental research on the immunology of the dengue virus is an aspect that preoccupies dengue scientists, as Nading explains. Yet, it is indeed this ‘perplexity’ that offers an opportunity to medical humanists to ‘get involved in experiments and clinical interventions (even those in which capital has taken a heavy hand)’ as well as ‘to give

voice to the ethical, political reflections of scientists' (p. 14). 'To do this job well', Nading continues,

medical humanists must become comfortable with the idea that science is neither an explanatory device nor a device to be explained. Rather, like culture and politics (and vaccines and viruses), it is just one of the material-semiotic constructions that emerges out of human engagements in a perplexing world (p. 15).

Hence, following the work of Stengers (2000, 2010), Nading's consideration departs from purist precepts of science. Science is not an uninfluenced practice. It is not divorced from social, political, and economic influences. His response to Goffey's 'Homo immunologicus' is a call for social sciences and humanities scholars to feed into that reality, to amplify the spectrum of inquiry by including the partiality of science and their interlocutors.

Likewise, in his book *Mosquito trails: Ecology, health and the politics of entanglement* (2014), Nading follows the material and semiotic networks of dengue fever in Ciudad Sandino, Nicaragua. Against the universal conceptions of health and disease that populate global health (p. 13), Nading's ethnographic work concentrates on the management of dengue by community health workers known as *brigadistas*. *Brigadistas*, predominantly female and poor, conceive 'disease control as a search for ways to *open* bodies to new forms of attachment' (p. 9). The classic precept of immunology based on the recognition and elimination of difference (Napier, 2003) is fundamentally in conflict with how dengue control operates in Ciudad Sandino. As Nading observes, 'a lack of entanglement was perhaps the unhealthiest thing that could befall an urban Nicaragua' (p. 25). Ensuring the health of the community was about 'building quality attachments' between 'human bodies, mosquitoes, and viruses' (p. 26). Between bodies, knowledge, and infrastructures.

Nading's findings strongly resonate with my research. Scientific evidence in microbiome science correlates autoimmune and inflammatory diseases in Northern nations and the steady rise in AMR globally with a lack of microbial diversity or, in Nading's terms, a 'lack of entanglement' (Chapter 5). Also, the influence of Nading's situated account of immunity through the lens of dengue fever surpasses the ethnographic dimension. His work on entanglements and dengue also links with two key theoretical frameworks I draw on: multispecies studies and the biosocial.

Likewise, contrasting with the individualism of 'Homo immunologicus' (Goffey, 2015; Sloterdijk, 2013), in the next section of the chapter I briefly outline how the figure

of ‘Homo microbis’ (Helmreich, 2016) has been recently taken up in social sciences and humanities literature amid current postgenomic research on microbial ecology and the human microbiome (Haraway, 2008, 2016; Helmreich, 2009, 2016; Hinchliffe, 2015; Kirksey & Helmreich, 2010; Kohn, 2007; Lorimer, 2016; Nading, 2013, 2014, 2016; Paxson, 2008; Tsing, 2015; Yates-Doerr, 2012, 2015). I then draw on the work of sociologists of science Hannah Landecker and Aaron Panofsky (2013) and Maurizio Meloni (2014a, 2014b, 2015), connecting their analysis of new scientific research of the human microbiome, epigenetics, metabolism, and AMR to cultural theorist and poet Denise Riley’s concept of ‘socialised biology’.

1.5 ‘Homo microbis’: The new role of microbes in the social and cultural studies of science

Influenced by feminist scholar Elizabeth Wilson, Helmreich (2016) defines the figure of ‘Homo microbis’ as ‘a weird back-to-the-bio move’ that ‘might provide critical resources for exploring the flexibility of bodily identities and processes’ (p. 63). Against neutral or celebratory explanations of the human microbiome, he claims that

there are not immediately obvious—and uncontestable—meanings for the microbiome. A clear politics of the ‘human’ do not necessarily follow from redescriptions of the biological. Such redescriptions can be progressive, retrogressive, liberatory, oppressive, strange, and familiar, all at once (p. 66).

This is more evident in the current scientific re-instantiation of race through microbial genomics, what Helmreich has coined the ‘microbiomization of race’ (p. 67). I borrow the term ‘microbiomisation’, proposing and developing a more specific meaning of Helmreich’s neologism, namely the ‘microbiomisation of social categories of difference’, the central argument of the thesis. The process of microbiomisation, I will argue, involves the scientific production of molecularised, unidimensional, and essentialist social categories of difference (including race, but also gender, class, and nation) through the characterisation and classification of microbial diversity.

As I will examine in detail in Chapter 3, a substantial volume of scientific publications and research on the human microbiome looks at geographical and ethnic differences between microbiomes (Ghose et al., 2002; Dominguez-Bello & Blaser, 2011). This type of biomedical research is based on population (microbial) genomics. It involves the comparison and classification of different populations (often non-Western versus Western) according to their microbial profile, which is often defined by the abundance or absence of certain microbial species. As Helmreich also observes, the same applies to

gender. Drawing on my ethnographic fieldwork on microbiome science and the analysis of scientific literature on the topic, there is a substantial body of human microbiome literature on the female and pregnant bodies, featuring the vagina as the ‘preferred harvesting’ body site (Chapter 5).

Helmreich’s ‘Homo microbis’, as a figure springing from biomedical knowledge and practice in microbial ecology, is an insightful conceptual framework for this thesis. If the human is ‘more-than-human’ (Braun & Whatmore, 2010), a phrase that has become over-reiterated in the light of the human microbiome, ‘the biological is more than biological’ (p. 72), Helmreich concludes. I share Helmreich’s preoccupation about the retrogressive meanings of the human microbiome. Clearly, race, gender, nation, and class, I argue, attain a new relevance in the light of the human microbiome. As I will demonstrate, medical interventions to improve health through the human microbiome widely depend on economic, social, and cultural capital (Chapter 4).

The current postgenomic shift from destiny to plasticity is far from liberatory (see Landecker, 2005; Pitts-Taylor, 2010; Sanabria, 2016). This is because postgenomics is still indissociable from neoliberal notions of choice (see Sanabria, 2016). The difference with respect to genetic onto-epistemologies lies in that the postgenomic discourse rests on the entanglement of the social with the biological, or, to put it in Helmreich’s words, in that ‘the biological is more than biological’. This central aspect of postgenomic science has recently been encapsulated by social sciences and humanities scholarship as the ‘biosocial’.

1.6 Socialised biology: An alternative to the ‘biosocial’

Over the last decade, there has been a growing interest in how habits such as smoking or drinking, sleep patterns, diet, pollutants, and stages of antenatal, postnatal, and early life development affect gene expression without altering the physicality of the DNA sequence. In postgenomic science, this field of research is called epigenetics. Epigenetics emphasises ‘how environments come into the body and modulate the genome’ (Landecker & Panofsky, 2013, p. 349).

Sociologist Maurizio Meloni (2015) explains that epigenetic and developmental approaches have already started to elaborate a model by which social conditions and material contexts experienced by past generations may become biologically embedded and somatically transmitted in specific social groups (p. 133).

This novel field of life science research and experimentation implies new ways of understanding ‘social life as part of the biology of the life course’ (Landecker & Panofsky, 2013, p. 346). Epigenetics entails ‘the deepening of the notion of embodiment ... the erasure of any residual distance between the biological and the social in the ontology of human beings’ (Meloni, 2015, p. 141). At the same time, the lack of consensus in epigenetics, especially in terms of transgenerational epigenetics, brings issues around ‘uncertainty’ and ‘responsibility’ as two of the principal (qualitative) features in the field (Pickersgill, 2016).

Contemporary sociological and anthropological literature has conceptualised the nature-culture or social-biological interplay that inhabits epigenetics with the adjective ‘biosocial’ (Ingold & Palsson, 2013; Meloni, 2014a, 2014b, 2014c, 2015; Lock, 2012, 2013a, 2013b) (Chapter 3). Sociologist Maurizio Meloni (2014a) claims that ‘a “social turn” in the life-sciences is taking shape’, ‘the new social biology’ (pp. 594–595, 603). Meloni (2014a, 2014b, 2014c, 2015), along with other contemporary commentators (Dupré, 2012; Fox-Keller, 2010; Ingold & Palsson, 2013) has recently argued that ‘biology has become porous to social and even cultural signals to an unprecedented extent’ (Meloni, 2014a, p. 594).

However, I argue that the biosocial literature often assumes (mostly tacitly) that the biosocial is a novel conceptual development in both the life sciences and the social sciences and humanities. Is the biosocial literature adopting the concept of ‘biosocial’ from life science research? Is it a social sciences and humanities heuristic device? Or is it both? Against this lack of specificity and detail in the biosocial literature, my argument is that biology has always been porous to the social, and vice versa. The novelty lies not so much in ‘biology’ itself as in its discourse and empirical settings, particularly in the areas of epigenetics and microbiome science. On the other hand, while the divisions between the social and biological, nature and nurture, and so forth have been a recurrent concern for scholarship in the social sciences and humanities as much as for this thesis, I contend that the existing body of literature on the biosocial ignores a vital and elucidatory precursor of the concept of the biosocial: feminist writer and poet Denise Riley’s notion of ‘socialised biology’ (1983).

1.6.1 Socialised biology

Through a critical analysis of British developmental psychology and childcare policies at the end of the Second World War, Riley’s ‘socialised biology’ (1983) demonstrates that

‘the opposition of the biological to the social’(p. 31) can be undone by acknowledging that

most of what is understood as biology is *lived out* by the individual in a social form—though this is not to say that, for example, one is aware of one’s blood circulating—that, as with questions of health and illness, of nutrition, of mental disturbance, of fertility, sexuality, reproduction, what we might try calling socialised biology is as accessible to the same sort of analysis as any other experiences (p. 31).

Socialised biology, in other words, is biology ‘lived within particular lives’ (p. 40). Riley’s notion provides a situated account of embodied biological experience in everyday life. Remarkably, the embodied quality of ‘socialised biology’ served Riley to develop a critique of the narrowness of the ‘social’, particularly in the field of developmental psychology. As she writes:

It could be objected that appeals to a concept of social biology still leave biology unanalysed and out in the cold, and that socialised biology will only give a more dense account of ‘social factors’, and push back biology to a point of regression. This may turn out to be true. But what is important here is that biology, as lived within particular lives, has for too long been neglected. The account of what is social as we have it is both too wide in its compass and too narrow in its definition; tacking on a ‘biological’ category, like illness, to the cluster of ‘social factors’ is inadequate: assimilation is not a critical process (p. 40).

‘Socialised biology’ not only serves as a heuristic device to supplement the ‘biosocial’ literature; I also incorporate Riley’s concept in my methodological core, in what I call ‘feminist para-ethnographies’ (see Chapter 2). In Chapter 5, I propose ‘feminist para-ethnographies’ as a material-semiotic device to register ‘socialised biology’, using my embodied experiences of childbirth and recurrent urinary tract infections (UTIs) as empirical material. Contrasting with more general and unspecific ‘biosocial’ approaches, ‘socialised biology’ offers an insightful framework through which to incorporate embodied experiences as part of empirical data.

As I demonstrate in what follows, there is a growing body of literature in social and cultural studies of epigenetics and AMR (Chapter 4) more attuned to Riley’s ‘socialised biology’ and thereby to the kind of approach I develop in the thesis in relation to human microbiome science.

1.6.2 Embodying inequalities: The example of epigenetics biopolitics

Environmental studies scholar Becky Mansfield’s research on race and epigenetics is inspirational. Through the case of the environmental chemical methylmercury and its hazardous effect on fetal neurodevelopment, Mansfield (2012) develops the term

‘epigenetic biopolitics’. ‘Epigenetic biopolitics’ involves regulatory bodies, such as the US agency in her case study, that shift the responsibility of exposure to chemicals towards the ‘abnormal’ diets of women of colour, instead of blaming contamination itself. It is then ‘the reproductive woman who is racialized and who, through her actions, produces embodied race’ (p. 352). Therefore, she argues, ‘an epigenetic understanding of biology as plastic can intensify race by relying on—and ascribing responsibility for upholding—racialized norms of behavior and bodily outcomes’ (p. 353; see also Pickersgill, 2016).

Similarly, Landecker and Panofsky (2013) claim that the epigenetic model ‘has led to the search for the genetic variation underlying racial differences in health outcomes’ (p. 346). In fact, their review of environmental epigenomics complements Mansfield’s ‘epigenetic biopolitics’. Gender (and class) is also a driver of epigenetic processes. As the authors explain, folic acid, a B vitamin implicated in fetal neurodevelopment, is prescribed in pregnancy—especially during the first trimester, when the fetus’s neural tube develops—and is added to food by government mandate in several countries. However, they argue, eating patterns are highly varied across gender, age, class (and race), therefore

a consumer economy of fortified or ‘functional’ foods, such as nutrition bars marketed as designed especially for women, further contours the terrain of who is ingesting how much folic acid, which in turn may have important and unknown consequences, via methylation, for the genomes of individuals and their offspring (p. 346).

In fact, AMR, one of the key topics in contemporary biomedicine, shares many conceptual lines with the epigenetic discourse. In this sense, as I will elaborate in Chapter 4, Landecker’s concept of the ‘biology of history’ (2016) as ‘the physical registration of human history in bacterial life’, not confined to singular bodies (p. 1), not only applies to AMR but also to epigenetics.

Policy, social, and economic differences together with identity politics are embodied and perpetuated as a complex of the biological and the social. Epigenetics as the ‘deepening of the notion of embodiment’ entails ‘how social structures get under the skin’ (Meloni, 2015, pp. 136, 141). Inequalities then, are embodied, turned into biological variability. Medical anthropologist Didier Fassin’s bioinequality, a reconceptualisation of the classical Foucauldian notions of biopower and biopolitics, offers a helpful conceptual framework for understanding the new biosocial biology of epigenetics and the human microbiome (Chapter 4). As Fassin (2009) explains:

Biopolitics is not merely a politics of population but is about life and more specifically about inequalities in life which we could call bio-inequalities (curiously ‘inequality’ is a word that never appears in Foucault’s writings): it is about not only normalizing people’s lives, but also deciding the sort of life people may or may not live (p. 49).

Following Fassin, Mansfield’s case of methylmercury and the intensification of race as an example of epigenetics is not so much about the normalisation (or ‘whitening’) of bodies of colour, but about the production of inequalities through the intervention in lives (p. 44), that is, about policies and medical advice regarding the diet of pregnant and breastfeeding women and the (transgenerational epigenetic) consequences of non-compliance (Chapters 4 and 5).

In sum, this body of work on epigenetics and metabolism (see also Landecker, 2011) provides an insightful framework of analysis by demonstrating how epigenetics re-embody questions of structural differences in society (race, gender, and class). This is the central argument—the microbiomisation of social categories of difference—I develop throughout the thesis in relation to immunity and the human microbiome (Chapters 3, 4, and 5). Another important remark to make, in relation to the wider scientific and public debates around the porosity of the social and the biological, is that it opposes the individualist rhetoric of what Goffey (2015) calls ‘Homo immunologicus’ (see Section 1.4).

Attending to ‘more-than-human’ (Braun & Whatmore, 2010) lives in ‘more-than-Western worlds’ and devising alternatives to neoliberal capitalism’s embodied inequalities, in the following and last section of the literature review, I engage with feminist theories of care and read them along with decolonial theories of *Buen Vivir*. I read them as alternative and sustainable propositions for the critical analysis of microbiome science.

1.7 *Thinking with care and care as Buen Vivir in multispecies entanglements*

1.7.1 *Care: Thinking with*

Medical anthropologist Annemarie Mol’s work on care (2008) has inaugurated a new focus in feminist theory. Contributing to the postcolonial literature, Mol juxtaposes the logic of choice in healthcare with the logic of care. While the logic of choice is based on the Western precepts of autonomy and rationality, the logic of care, Mol proposes,

counter[s] the internal colonisation of all kinds of Western traditions by the single idea of choice and the rationalism that it is tied up with. ... Within the logic of choice ‘disease’ is a strange exception, it has nothing to do with ‘us’, while the logic of care starts out from the fleshiness and fragility of life (pp. 5, 7).

The fragility and vulnerability of care are aspects that sociologist Maria Puig de la Bellacasa (2011) also emphasises in her work; after all, ‘care connotes attention and worry for those who can be harmed by an assemblage but whose voices are less valued, as are their concerns and need for care’ (p. 92). Complementing Bruno Latour’s notion of ‘matters of concern’ and Haraway’s multispecies entanglements or becomings (with),²³ Puig de la Bellacasa develops a framework for knowing and thinking with care in the technosciences (2011, 2012, 2015). Caring, for her, ‘is not an option but a vital necessity in our technoscientific world, and that nothing holds together in a liveable way without caring relationships’ (2011, p. 100).

The question of care (what is care, who cares, how to care [Puig de la Bellacasa, 2011]) is complex. Care has long genealogies in feminist political theory (Martin et al., 2015; Rose, 1994)—genealogies that surpass the aims of the thesis and my own expertise.²⁴ Care as a feminist proposition in the sciences (Rose, 1994) and critical STS scholarship (Puig de la Bellacasa, 2011) should not be confused with harmonious, idealised, and romantic visions of care that neglect the ‘troubles of interdependent existences’ (Puig de la Bellacasa, 2012, p. 199). Or, as Mol (2008) insists, care is not about ‘tender love’ (p. 5). ‘Caring or being cared for is not necessarily rewarding or comforting’, Puig de la Bellacasa argues (2012, p. 199). Similarly, in a special issue on care for the academic journal *Social Studies of Science*, feminist science studies scholars Aryn Martin, Natasha Myers, and Ana Viseu (2015) call for a non-innocent formulation of care (Murphy, 2015). For the authors, it is ‘by staying in the thick of things, by analyzing care’s non-innocent politics that our responses can be slowed down enough to make them more *care-ful*’ (Martin et al., 2015, p. 12).

²³ Bringing together Latour’s concept of matters of concern and Haraway’s becoming with, Puig de la Bellacasa articulates the notion of ‘matters of care’ as ‘a proposition to think with’. ‘Rather than indicating a method to unveil what matters of fact are, it suggests that we make of them what is needed to generate more caring relationships. It is thus not so much a notion that explains the construction of things than a suggestion on how those who study things can participate in their possible becomings. I have said that the commitment to care can be a speculative effort to think how things could be different’ (Puig de la Bellacasa, 2011, p. 100).

²⁴ Care onto-epistemologies and, in particular, care as resistance connect to my proposition of ‘feminist para-ethnographies’ as a ‘slow science’ (Stengers, 2018) and ‘engaged research’ (Hinchliffe et al., 2018) intervention in microbiome science (Chapter 5).

One of the most relevant aspects of new theorisations of care in STS for this thesis has to do with its opposition to the productivist model of capitalism. Capitalism occludes care, it invisibilises it. Capitalism naturalises care by situating it in the sphere of maternal love (Mol, 2008; Puig de la Bellacasa, 2012, 2015). Care, or ‘unwaged reproductive labour’ in Federici’s terms (2004), was a necessary precondition for the development of capitalism in Europe (Federici, 2004). Recent feminist literature, however, confers a new meaning to care, situating it in the sphere of resistance. That is, care can also be understood as an anti-capitalist and decolonial practice (Mol, 2008; Puig de la Bellacasa, 2011, 2012, 2015). ‘Understanding caring as something we do extends a vision of care as an ethically and politically charged *practice*, one that has been at the forefront of feminist concern with devalued labours [e.g. childcare, domestic work, ANC²⁵]’ (Puig de la Bellacasa, 2011, p. 90).

Puig de la Bellacasa encapsulates this concern and commitment of feminist theories of care with the example of ‘making time for soil’ (2015). In contrast to an ‘exploitative and instrumentally regimented care’, ‘immersed ecological care’ in human–soil relations ‘require[s] material, ethical and affective ecologies that thicken the dominant timescape with a range of relational rearrangements’ (pp. 699, 706). In other words, soil as a living multispecies community requires different temporalities than those based on innovation, productivism, and profitability. Likewise, my argument is that human–microbe entanglements, particularly in relation to the human microbiome, also require different logics and temporalities (Chapters 2 and 5). This thesis shows that the current configuration of human microbiome science is sustained by an immunitary neoliberal logic: through the microbiomisation of social categories of difference, knowledge-making in the field benefits privileged strata of rich societies (Chapter 4). This is because the underlying tenet of microbiome science in terms of knowledge production and innovative biomedical applications has to do with turning human–microbe relations, by definition based on the well-being of multispecies communities, into individualised medical outcomes and biovalue (Chapter 3). This approach, in my view, goes entirely against the multispecies relationality that sustains human–microbe relations. It goes against the long-term sustainability of the human microbiome.²⁶

²⁵ ANC stands for Andrea Núñez Casal and is used when I clarify something in a quotation.

²⁶ Inspired by this body of feminist literature on care and the recent work by philosopher of science Isabelle Stengers (2018), this thesis calls for a very different science. My own contribution, as I elaborate in Chapter 5, is feminist para-ethnographies as an intervention in microbiome science.

The alternative timescale that Puig de la Bellacasa (2015) proposes is about restoring as well as building up affective and ecological attachments and commitment across multispecies levels. This entails an everyday labour of maintenance (2011, p. 100), as she argues:

These include adjustments according to cycles, present-embedded time and different ecological time-scales. Feminist sociologies of caring practices can support this observation, for they expose them as labours of everyday mundane maintenance, and as repetitive work, requiring regularity and task reiteration (for recent STS perspectives, see Mol, 2008; Mol et al., 2010; Singleton & Law, 2013). But anybody who has been involved in caring for children, pets or elderly kin knows that the work of care takes time and involves making time of a particular kind. Care time can be enjoyable and rewarding, but also tiresome, involving a lot of hovering and adjusting to the temporal exigencies of the cared-for (2015, p. 707).

Fundamentally, however, having²⁷ (more than making) time for inter- and intraspecies care requires organising wage labour differently, living life differently, which is pretty much an impossibility in neoliberal capitalism. However, as countries like Ecuador and Bolivia show, it is possible to make time for (and create a politics of) care. Care is a constitutional right in these two countries. It not a privilege that money can buy through the outsourcing of care work, which, in turn, involves the precarisation of (mostly) racialised women. It is at these intersections where feminist theories of care coalesce with decolonial theories of *Buen Vivir* (living good).

1.7.2 Decolonial theory of *Buen Vivir*

Decolonial theory is predominantly coming from Latin American scholarship. Decolonial theorists propose a co-production between modernity and coloniality beginning in 1492 (Dussel, 1995), with the arrival of Christopher Columbus to the Americas and the subsequent colonisation of the continent, a geopolitical move sponsored by the Crown of Castile (Spain). Feminist STS scholar Sandra Harding (2016) explains that the Spanish and Portuguese colonisation of the Americas has shaped the ‘modern social orders’ and therefore the co-production, development, and evolution of sciences and technologies (p. 1066; see also Dussel, 1995). Central to decolonial theory is the idea of scientific pluralism, by which different epistemologies and ontologies of science coexist (Mol, 2002). Against unidirectional ways of understanding and disseminating scientific and

²⁷ I am writing the verb ‘having’ instead of ‘making’, because using the latter suggests that caring (‘making the time for caring’) is an individual choice. However, having (or not) the time to care cannot be dissociated from policies on gender equality, dependency, and working rights.

technological innovation (i.e. North to South), decolonial theorists have insisted on restoring and providing visibility to South-to-North and South-to-South innovation, both in the past and the present (see Harding, 2016; Rajão, Duque, & De', 2014)²⁸. Decolonial theorists have focused on countering the universality of European colonialism and modernity through devising alternative forms of knowledge and being. Influenced by the writings of Gloria Anzaldúa, Frantz Fanon, Anibal Quijano, and Enrique Dussel, cultural theorist Walter Mignolo (2007) explains that

the practice of liberation and de-colonization is initiated with the recognition, in the first place, that the colonialization of knowledge and being consisted of using imperial knowledge to repress colonized subjectivities and the process moves from there to build structures of knowledge that emerge from the experience of humiliation and marginalization that have been and continue to be enacted by the implementation of the colonial matrix of power. ... For decolonization to be fully operative, we must create alternatives to modernity and neo-liberal civilization. We must begin to imagine such alternatives from the perspectives and consciousnesses unlocked in the epistemic, ethical and political domain of the geo- and the bio-political loci of enunciation and of action (p. 492).

Mignolo refers to this practice of decolonisation as the 'grammar of de-colonization', which involves a 'de-colonization of knowledge and of being—and consequently of political theory and political economy' (p. 492). In this sense, as I outline below, the *Buen Vivir* ('Living Well') movement is a decolonial social, environmental, and political-economic alternative to neoliberalism and new forms of colonialism (see Chapter 5). This is a real organic example, I argue, of what Mignolo calls the 'grammar of decolonization'.

1.7.3 *Buen Vivir*

The term *Buen Vivir* connotes 'the Spanish words used in Latin America to describe political alternatives to development²⁹ focused on the good life in a broad sense' (Gudynas, 2011, p. 441). *Buen Vivir* stands as an alternative to development 'beyond the modern Western culture' (p. 442). It is usually categorised as 'decolonial, post-neoliberal, and post-developmental'; 'post-capitalist' and 'post-socialist' (González & Vázquez, 2015, p. 315; Gudynas, 2011, p. 446).

Buen Vivir emerged in Latin America in the early 2000s as a critique of Western individualism and capitalist economy as well as a proposal for ecological awareness

²⁸ This is a very relevant point because, as I demonstrate (Chapters 3 and 4), microbiome science rest upon the embodied knowledges and practices of non-Western societies and communities, particularly for the development of innovative treatments for non-communicable diseases (NCD) predominantly affecting richer, Northern nations.

²⁹ On a socio-cultural critique of development, see the work of anthropologist Arturo Escobar (2008).

(Lanza, 2012, p. 5). As a concept springing from Indianist ideology, *Buen Vivir* has been implemented in public policies and is now a constitutional right in Ecuador (2008) and Bolivia (2009). *Buen Vivir* as a constitutional right includes nature or ‘sentient beings’ such as mountains, soil, or air in the ‘public political arena’ (De La Cadena, 2010, p. 363). Nature is ‘broadly understood as the constitutive conditions and practices—sociocultural, territorial, spiritual, ancestral, ethical, epistemic, and aesthetic—of life itself’ (Walsh, 2010, p. 18). According to Martha Lanza (2012), in the *Buen Vivir* paradigm, the ‘alternative to market economy would be to make the community the nucleus of economic organisation, where the industrial community would only be complementary’ (p. 6). Crucially, the revaluation of care is an essential (feminist) reformulation of productivity for *Buen Vivir*. In this sense, the 2008 Ecuadorian constitution acknowledges care as part of the economy, referring to ‘organization of forms of family and home production, as well as self-consumption labour and human care as productive activities’ (p. 28).

I argue that theories of *Buen Vivir* complement well theories of care and vice versa. On the one hand, one of the main weaknesses I see in the feminist theories of care relates to its focus on Western onto-epistemologies and policies. In this sense, *Buen Vivir* brings a non-Western standpoint (Harding, 2004) to the feminist theories of care. On the other, despite *Buen Vivir* incorporating indigenous concepts that seek complementarity between women and men (i.e. Chacha-Warmi in Bolivia), women’s rights and gender equality are not central concerns of *Buen Vivir*, as some feminist scholars have pointed out (Lanza, 2012). For feminist economist Magdalena Leon (2012), a feminist vision and reformulation of *Buen Vivir* entails revaluing contributions and potentialities of indigenous women. This means ‘moving from an emphasis on the deficiencies of those actors to an emphasis on the contributions they make, even when they take place in situations of inequity and disadvantage’ (p. 25).

My engagement with *Buen Vivir* simultaneously reveals what I see as one of the principal limitations of my conceptual approach. That is, this thesis exhibits a lack of non-Western, non-native-English-speaking authors. The term ‘anglophone’ is important because the debates I engage with in this thesis are mostly coming from anglophone academia, rather than from ‘Western’ thought or ‘Euro-American’ discourse (because the latter would include academics from countries other than the UK and the US, such as Spain, Greece, Portugal, Poland, and so forth). Admitting that I am mostly drawing on the anglophone discourse and wishing that I would have come across decolonial theories earlier in my PhD, my compliance with anglophone academia reflects its hypocrisy. In

other words, despite claims against imperialism, colonialism, and appeals to critical thinking, British and North American critical theory (including body studies, STS, and anthropology of science, the three bodies of literature I draw upon) is made of a set of knowledge practices mostly performed by native English speakers and their non-native speakers' adepts. My engagement with *Buen Vivir* is partly a modest response to this reality and partly an early draft destined at overcoming such limitations in my future research.

In conclusion, *Buen Vivir* rests on principles of sovereignty and emancipation from the biopolitical and colonial projects of modernity. Notwithstanding its various weaknesses outlined above, the new developments that *Buen Vivir* proposes, including 'quality of life, democratisation of the State, and attention to biocentric concerns' (Walsh, 2010, p. 18), are valuable propositions for biosocial knowledge practices of (microbial) coexistence and decoloniality (Chapter 5). Beyond the potential of *Buen Vivir* for a biosocial practice of microbiome science, on a more personal plane the decolonial framework is closer to me. This is because my national identity is imbued with colonial and family histories and stories about Spanish imperialism and brutality in Latin America. I feel compelled—as both an act of historical responsibility and as a feminist situated practice (Haraway, 1988)—to engage with decolonial debates rather than using a postcolonial framework (which responds to the cultural legacy of British and French colonialism and imperialism). In addition, the decolonial theory of *Buen Vivir* also responds to the situatedness of my ethnographic fieldwork: my fieldwork was partly conducted in the Caribbean island of Puerto Rico, and my epistemic partners (Holmes & Marcus, 2008),³⁰ in their majority, are Latin Americans (Chapter 2).

1.8 Conclusion

This first chapter has introduced the conceptual fields and lines of argument I will be developing throughout the thesis. After providing a historical background of 'immunity-as-defence' (Cohen, 2009) and tackling previous social and cultural studies on immune metaphors, I have reviewed Andrew Goffey's 'Homo immunologicus' (2015). Here I have argued that by ignoring existing work on the empirical aspects of immunology (predominantly coming from a feminist tradition) and creating a divide between theory

³⁰ I use the term 'epistemic partners' (Holmes & Marcus, 2008) instead of 'research participants'. For more detail on this see Chapter 2.

and practice, Goffey falls into the very same ‘limit of critique’ that he argues haunts critical accounts of immunity. As a mode of response to ‘Homo immunologicus’, I have then situated the thesis within three bodies of literature: body studies, STS, and anthropology of science. Contrasting with the individualism of ‘Homo immunologicus’, I have engaged with the figure of ‘Homo microbis’ (Helmreich, 2016). ‘Homo microbis’ has been recently taken up in the social sciences and humanities literature amid postgenomic research on human microbiome science. Beyond this framework, I have contended that the critical social study of the human microbiome can be also understood as ‘socialised biology’ (Riley, 1983) rather than as a ‘biosocial’ phenomenon. The biosocial, I have argued, is about a new scientific relational ontology and epistemology by which social experiences are always already embedded in the biological. Yet, this does not say enough about the functioning and qualities of such entanglements, or, in the case of epigenetics, it does not say enough about the promises of plasticity (Landecker, 2005; Pitts-Taylor, 2010; Sanabria, 2016), of what it means to go ‘beyond the gene’. In this sense, I have shown how the work of Mansfield, Meloni, and Landecker and Panofsky on epigenetics and metabolism brings up how epigenetics reinstates questions of structural differences in society (race, gender, nation, and class); the central argument of the thesis in relation to immunity and the human microbiome (Chapters 3, 4, and 5). Finally, in the last section, I have shifted from ‘more-than-human’ (Braun & Whatmore, 2010) to ‘more-than-Western’ worlds. Here, I have outlined existing feminist theories of care (Martin et al., 2015; Mol, 2008; Murphy, 2015; Puig de la Bellacasa, 2011, 2012, 2015) along with decolonial theories of *Buen Vivir* (De La Cadena, 2010; González & Vázquez, 2015; Gudynas, 2011; Harding, 2016; Lanza, 2012; Leon, 2012; Walsh, 2010) as part of the critical analysis of microbiome science. As a social justice and political alternative framework to capitalism-driven biome depletion, ‘care as *Buen Vivir*’ complements well the biosocial literature’s and multispecies’ studies³¹ insufficient engagement with non-neoliberal politics.

³¹ I will elaborate this aspect further with respect to multispecies ethnographies in the next chapter.

CHAPTER 2. Methodology and research design: Feminist para-ethnographies

2.1 Introduction

In this chapter, I outline the methodology and research design of the thesis. The ethnographic study of microbes has been encapsulated in the cultural anthropology subfield of ‘multispecies ethnography’ (Kirksey & Helmreich, 2010). In the first part of chapter, I engage with this conceptual and methodological field of social and cultural research, outlining its limitations. In multispecies ethnographies, I argue, the richness of the ethnographic detail leaves little to no room for more analytic and less descriptive views. I demonstrate how the work of several authors brings biome depletion and multispecies ecologies together with capitalist political economy (Haraway, 2016; Tsing, 2015) and examines socio-economic relations in the ‘making’ of interspecies health (Hinchliffe, 2015). The aforementioned perspectives are more attuned to the approach I develop in the thesis. Against a positivist way of conducting ethnographic fieldwork, in the second part of the chapter I complement the ethnographic study of human–microbe relations with the use of embodied experiences as feminist research tools. I do so by reformulating the concept of the para-ethnographic—that is, ‘a way of dealing with contradictions, exceptions, and facts that are fugitive’ (Holmes & Marcus, 2008, p. 596)—as a feminist intersectional method that entangles embodied experiences with ‘fugitive’ qualitative data in technoscientific claims and quantitative research. I call this method ‘feminist para-ethnographies’. In the third part of the chapter, I outline the research design of the thesis using the framework of ‘feminist para-ethnographies of human–microbe relations’. First, I discuss embodied experiences along with more conventional qualitative data. I then explain the details of the exploratory pilot project I conducted, and I describe the main aspects of the fieldwork of human microbiome science, involving semi-structured interviews and conversations with microbiome scientists and immunologists; lab visits and observations; participation in international microbiome conferences and meetings; a digital media analysis of the online microbiome community; and critical analysis of microbiome scientific and popular science literature. The last part of the chapter deals with the research ethics.

2.2 Multispecies ethnographies

Over the past decade, multispecies sensitivities have become a very prolific theme of social and anthropological research. An ‘anthropology of microbes’ has been proposed as a transdisciplinary field of research to ‘reevaluate the way we view our human biological and cultural diversity’ as well as to investigate how our “‘indigenous” microbial populations (microbiota) are shaping human health and how they could impact clinical practice’ (Benezra et al., 2012, p. 6378). ‘Homo microbis’ has been largely encapsulated in the anthropological subfield of ‘multispecies ethnography’ (Kirksey & Helmreich, 2010).

Multispecies ethnography goes beyond the proposed ‘anthropology of microbes’ as it includes other, non-microbial human animals. In ‘The emergence of multispecies ethnography’ (2010), anthropologists Eben Kirksey and Stefan Helmreich (2010) define multispecies ethnography as a method which ‘centers on how a multitude of organisms’ livelihoods shape and are shaped by political, economic, and cultural forces’ (p. 545). Influenced by Eduardo Kohn’s ‘anthropology of life’ (2007), that is, an anthropology ‘concerned with the effects of our entanglements with other kinds of living selves’ (p. 4, as cited in Kirksey & Helmreich, 2010, p. 545), the authors delineate multispecies ethnography as interdisciplinary studies coming from animal and environmental studies and STS (p. 566). The biosociality of microbes involves disparate aspects, for example, their implication as actors in economic development and marketing campaigns (bioremediation, probiotic products such as yogurts); new social and cultural practices (the rise of so-called ‘natural’ food and pro- and prebiotic consumption); new medical practices (therapies with microbes such as faecal transplant or newborn ‘re-colonisation’); and pharmaceutical and policy changes (from antibiotics to pro- and prebiotics) (Chapters 3 and 4). ‘Multispecies ethnographers’, they write, ‘are studying contact zones where lines separating nature from culture have broken down, where encounters between *Homo sapiens* and other beings generate mutual ecologies and coproduced niches’ (p. 546).

In *The origins of sociable life: Evolution after science studies* (2009), one of the seminal multispecies studies works, sociologist of science Myra J. Hird develops a ‘microontological’ approach to sociality by engaging with bacterial competences for perception, communication, and communal organisation. Bringing together philosophy and biology, Hird touches on what is problematic about discourses on immunity, and

instead of the typical approach of self-defence and preservation, she proposes an understanding grounded in what she defines as ‘symbiotic generosity’. Symbiotic generosity integrates Rosalyn Diprose’s concept of ‘corporeal generosity’, ‘the debt that a body owes to other bodies’ (p. 80), and Lynn Margulis’s ‘symbiogenesis’³² as a means to challenge ‘immunological integrity’ (p. 78). Hird shows, as do Haraway and Esposito (Chapter 1), that far from ensuring the body’s integrity, the immune system’s vulnerability to the other (bacteria, viruses, parasites...) is the ‘norm’, is what guarantees its evolution, and, thereby, what ensures life. Hird’s ‘symbiotic generosity’ is a romantic and conjectural view as well as a very selective reading of human–microbe entanglements.

Less naively, in *Alien ocean: Anthropological voyages in microbial seas* (2009), Stefan Helmreich explores ‘the governance of relations among entangled living things’, what he calls symbiopolitics (p. 15). *Alien ocean* reflects the unfamiliarity of marine microbiologists with sea microorganisms amid the paradigm shift from a single organism to a ‘network of connections’ (p. 8). In this shift, Helmreich shows how bioinformatics, genomics, and molecular biology becomes key for unravelling the microscopic life of the sea. He does so through a deep engagement with marine microbial life, in which a classical laboratory ethnography of methane-eating microbes and a scientific expedition in sea volcanoes coexist with more speculative queries on the origins of life, the future of life, bioprospection, and (neo)colonialism. Instead of seeing them as a relatively independent issue, as in Helmreich’s account, I argue that neocolonial practices of bioprospection are a key element of the process of microbiomisation (see Chapter 3).

Helmreich illustrates how concerns in anthropology of science (kinship, evolution, colonialism, capitalism) overlap with concerns in contemporary microbiology (horizontal gene transfer, astrobiology, biotech industry, climate change, and extinction). His concept of symbiopolitics comes from anthropologist Heather Paxson’s notion of microbiopolitics (2008): ‘the creation of categories of microscopic biological agents ... and the elaboration of appropriate human behaviors vis-à-vis microorganisms engaged in infection, inoculation, and digestion’ (p. 17).

In ‘Post-Pasteurian cultures: The microbiopolitics of raw-milk cheese in the United States’ (2008), Paxson examines the revival of artisan cheese making in the US.

³² Symbiogenesis or endosymbiotic theory postulates that eukaryotic cells (e.g. human cells) come from prokaryotic cells (e.g. bacteria).

Contrary to the Pasteurian (hygienist) views on raw-milk cheese as a potential biohazard (legally supported by the Food and Drug Administration's ban on unpasteurised milk aged less than sixty days), the post-Pasteurians (probiotics), Paxson explains, believe that 'raw-milk cheeses may actually be safer to eat than pasteurized ones, for what protects the cheese can protect us' (pp. 31–32). Post-Pasteurianism focuses on the probiotic (beneficial bacteria for human health) nature of microorganisms to improve health (via e.g. fermented food) rather than on a hyperhygienic environment, and pasteurised and antimicrobial products. In fact, cultivating 'good bugs' has recently gained adepts and importance in the light of the 'global threat' of antimicrobial resistant bacteria to antibiotics (Paxson, 2008) (Chapter 4).

With a similar concern, geographer Jamie Lorimer's 'Gut buddies: Multispecies studies and the microbiome' (2016) explores helminth therapy, 'the controlled (re)introduction of ... parasitic worms into human bodies', as a potential solution to non-communicable diseases (NCD) such as inflammatory and autoimmune disorders as well as allergies (p. 59). According to Lorimer, helminth therapy implies 'an ecological model of immunity as involving a multispecies community' (p. 69) and it offers 'new ways of thinking companionship and hospitality as more-than-human, but not posthuman, achievements'. (p. 59). However, what he describes as an 'ecological model of immunity' is discussed only vaguely.

2.2.1 Limitations of the multispecies approach

This thesis supports the view that the study of the human microbiome involves a shift in the scientific and popular understanding of immunity towards a more ecological and relational approach. Yet, I argue that this does not mean that an immuno-logic of inclusion and exclusion is not still and widely at play. The fact that helminth therapy constitutes another form of 'lively capital' (Sunder Rajan, 2012) in Northern richer nations could have been further explored by Lorimer. This, in turn, means that he also overlooks non-biomedical ways in which helminth therapy functions, especially in non-Western contexts. In this sense, Alex Nading's ethnographic research of dengue fever and its control by community health workers in urban Nicaragua fills that gap (2014, 2015b, 2015c, 2016) (see Chapter 1). I concur with Lorimer in that, contrary to posthumanist hopes of decentring the human (see Esposito, 2008, 2011; Hird, 2009), the 'human' of the human microbiome remains the goal of multispecies ethics and therapies (Chapters 3 and 5). Multispecies ethnography/studies is a very human area of scholarship, theorised

and practised by humans. The sociality of microbes, in other words, is dependent upon humans. As Nading (2016) argues, ‘microbes become social when people draw them into explanations about behavior, health, politics, and economics’ (p. 525). In addition, as any other scientific domain, evolutionary theories are in a constant revision process. Therefore, the species of multispecies is problematic. Medical anthropologist Emily Yates-Doerr (2015) has cogently argued that the term ‘species’ involves conventional modes of classifying identity:

The call for multispecies ethnography, if taken as a call to focus anthropological attention on other-than-human (Linnaean) species, runs the risk of similarly reasserting homogenizing, and ontologically violent, modes of ordering (p. 310).

For Yates-Doerr, a more fluid approach based on the transformation of divisions and connections would be more appealing and less problematic (p. 309). My view is in line with what Nading (2016) and Yates-Doerr (2015) argue. That is, while I share multispecies and more-than-human sensibilities about decentring the human from ethnographic accounts (i.e. human exceptionalism) and about the blurring between the natural and the social and cultural, my reticence regarding multispecies ethnography has to do with the fact that microbial accounts in theory and practice are produced by humans, along with their instruments and methodologies. The main ‘actors’ of my fieldwork of human microbiome research are microbiome scientists, not microbes. My ethnographic fieldwork is on scientists, scientific theories, and scientific systems. Likewise, my argument is that many of the current research projects under the umbrella of ‘multispecies’ are, instead, more attuned to classical sociological and/or anthropological theoretical and methodological frameworks. In other words, the category of multispecies in the vast majority of social and cultural research dealing with non-humans does not justify itself—with the exception of Haraway (1991, 2008), Tsing (2015), and Despret (2004, 2016), whose works bridge animal and body studies. Another main weakness of a multispecies approach relates to its depoliticisation, I suggest. In multispecies ethnographies, the richness of the ethnographic detail leaves little to no room to more analytic and less descriptive views. The work of feminist technoscience scholars, Haraway (2016) and Tsing (2015) in particular, figures as an exception. In what follows, I engaged with this recent body of multispecies literature.

2.2.2 Resisting Anthropos: Politicising multispecies

Biome depletion or, in other words, the loss of microbial diversity is a common theme in multispecies studies. Kirksey and Helmreich (2010) connect this aspect of multispecies

ethnography to the Anthropocene. The Anthropocene is a neologism used in the environmental and social sciences alike to describe the impact of human activities on the biochemistry of planet Earth; a proposed geological epoch after the Holocene, in which the devastating human trace seems to be indelible. Multispecies ethnography, they note, ‘involves writing culture in the Anthropocene, attending to the remaking of Anthropos as well as its companion and stranger species on planet Earth’ (p. 549). Biome depletion and AMR as central themes of this thesis could be well framed within the topic of anthropogenic (i.e. damaged) biologies. Yet, I resist and distance myself from apocalyptic myths associated with the buzzword ‘Anthropocene’ (Chapter 4). Instead, the theoretical repertoire through which I analyse these issues is motivated by the recent work on multispecies and disturbed ecologies by Donna Haraway (2016) and Anna Tsing (2015).

The work of feminist technoscience scholar Donna Haraway has provided both the theoretical and the empirical background for the fertilisation of multispecies ethnography/studies. Making space for animal-human encounters and ‘companion species’ in feminist critical theory, Haraway’s *When species meet* (2008) is indeed a seminal work on multispecies. In her latest book, *Staying with the trouble: Making kin in the Chthulucene* (2016), she attends to processes of extinction and troubled multispecies entanglements. She does so by reconceptualising apocalyptic narratives of the Anthropocene through the ‘speculative fabulation’ (SF)³³ of the Chthulucene. For Haraway, the catastrophism associated with the Anthropocene is autopoietic, self-enclosed, autonomous. On the contrary, the Chthulucene is sympoietic. Rejecting human exceptionalism, the Chthulucene requires making-with, becoming-with companion species (pp. 10, 33). The Chthulucene involves ‘ongoing multispecies stories and practices of becoming-with in times that remain at stake, in precarious times’ (p. 55). My understanding of the Chthulucene has to do with repair and regeneration. The regeneration of ecological damage and disturbance requires to *stay with the trouble*, to care.³⁴ Ultimately the Chthulucene is a call ‘to cultivate the capacity of response-ability’ (p. 35), to *stay with the trouble* as a positive response to capitalism, extinction, and destruction instead of relentlessly looking away: ‘We require each other in unexpected

³³ Haraway (2016) encapsulates the ‘string figures’ of ‘speculative fabulation’, ‘science fact’, and ‘speculative feminism’ under the abbreviation of ‘SF’. SF, she writes, ‘is practice and process; it is becoming-with each other in surprising relays; it is a figure for ongoingness in the Chthulucene’ (p. 3). As a method to follow events and practices, SF is dedicated to the ‘cultivating of multispecies justice’ (p. 3).

³⁴ I engage with the feminist literature on care in Chapter 1 (Section 1.7.1).

collaborations and combinations, in hot compost piles. We become-with each other or not at all' (p. 4).

The idea of cultivating alliances and kin through cross-species entanglements in times of loss of diversity, contamination, precarity, and growing inequalities resulting from rampant capitalism resonates with another recent work on multispecies by anthropologist Anna Tsing: *The mushroom at the end of the world: On the possibility of life in capitalist ruins* (2015). In the book, Tsing examines the 'possibilities of coexistence within environmental disturbance' through an ethnographic study of matsutake mushrooms commerce and ecology (p. 4). For Tsing, precarity, 'life without the promise of stability' (p. 2), precarious livelihoods and environments, 'is the condition of our time' (p. 20). Following the supply chain of matsutake from pickers in the forests of Oregon to consumers in Japan, Tsing develops the concept of 'salvage capitalism', that is, 'taking advantage of value produced without capitalist control'. The concept applies to 'living things made within ecological processes [that] are co-opted for the concentration of wealth' (pp. 62–63). Tsing's salvage capitalism and capitalist accumulation are very helpful concepts for understanding one of the key elements of microbiome scientific knowledge production: microbial DNA data mining from non-Western communities and societies (Chapter 3). As Tsing writes: 'The ship sails because of capitalist financing. The conversion of indigenous knowledge into capitalist return is salvage accumulation' (p. 64).

While Haraway's Chthulucene is grounded in the rhetorical figures of 'SF', science fiction, speculative feminism, etc., a source of inspiration for this thesis, the relevance of Tsing's ethnographic research on multispecies lies in that she situates political economy at the heart of discussions on multispecies, overcoming one of the principal limitations of authors working in human–animal entanglements and, more generally, more-than-human literature.

In a similar line, the work of geographer Steve Hinchliffe on interspecies health (2015) is exemplary. Hinchliffe focuses on the cross-disciplinary initiative of One World One Health (OWOH) to argue against its singular approach, its 'one world metaphysics' (Law, 2011), which concentrates on disease contamination and transmission. Attending to 'contingent, local and practical engagements' (p. 31) through field cases about influenza surveillance and contagion and safety in chickens and pigs—conducted in UK farms and laboratories with a varied range of actors—Hinchliffe foregrounds the importance of the socio-economic configuration of health and disease. Bridging animal,

environmental, and human health, he suggests, is key to attending to ‘how different knowledges are brought together’ (p. 28). For Hinchliffe,

this is not to say that health is culturally relative, but it is to recognize and value the continuous work that is carried out on farms, in laboratories and elsewhere in order to produce healthy outcomes. This requires a new common sense, one that brings together and interrogates rather than romanticizes the various knowledge practices that make health possible across these domains [farms, laboratories... ANC] (p. 34).

Likewise, my aim is to interrogate and bring together different practices of knowledge production on immunity and the human microbiome (laboratories, popular science, scientific literature). Significantly, Hinchliffe’s compelling ethnography can be complemented by a significant knowledge practice for this thesis: the researcher’s own embodied experiences while conducting empirical fieldwork.

2.2.3 Embodied experiences as a feminist tools

Over the past thirty years, feminist scholars have been contributing to feminist methodologies across disciplines in the social sciences and humanities (see Barad, 2007; Blackman, 2012; Haraway, 1988; Harding, 1987; Hughes & Lury, 2013; Smith, 1999). Ahmed’s proposition that ‘theory can do more the closer it gets to skin’ (2017, p. 10) perfectly encapsulates the notion of embodiment and the feminist idea of embodied knowledge. As she writes:

Theory can do more the closer it gets to the skin ... The personal is theoretical. Theory itself is often assumed to be abstract: something is more theoretical the more abstract it is, the more it is abstracted from everyday life. To abstract is to drag away, detach, pull away, or divert. We might then have to drag theory back, to bring theory back to life (p. 10).

Embodiment ‘is not just a location for society and culture, however, but *forms a basis for* and *shapes* our relationships and creations’ (Shilling, 2012, p. 15). Embodied knowledge as a feminist epistemology (ways of knowing) uses lived experiences as the basis on which challenge scientific objectivity and positivism (Hesse-Biber, 2008, p. 336). Scientific objectivity, as historians of science Lorraine Daston and Peter Galison (2007) demonstrate through their study of the atlas of scientific images, has a history. Emerging in the mid-nineteenth century, objectivity

preserves the artifact or variation that would have been erased in the name of truth; it scruples to filter out the noise that undermines certainty. To be objective is to aspire to knowledge that bears no trace of the knower—knowledge un-marked by prejudice or skill, fantasy or judgment, wishing or striving. Objectivity is blind sight, seeing without inference, interpretation, or intelligence (p. 17).

Daston and Galison go further to argue that objectivity is inseparable from subjectivity, as they emerge together in the mid-nineteenth century. Subjectivity, they write,

was the enemy within, which the extraordinary measures of mechanical objectivity were invented and mobilized to combat. It was no accident that these measures often appealed to self-restraint, self-discipline, self-control: it was no longer variable nature or the wayward artist but the scientific self that posed the greatest perceived epistemological danger (pp. 197-198).

Likewise, feminist methodologies bring subjectivity and the embodied (scientific/academic) self to the forefront of critical analyses, not just to fulfil the requirement of reflexivity but, fundamentally, to conduct genuine research that departs from what Donna Haraway (1988) calls ‘White Capitalist Patriarchy’ (p. 592). Feminist methodologies combat value-free science, binaries—mind/body, objectivity/subjectivity, self/other, and so forth—and therefore disembodied accounts of qualitative research.

In her celebrated and influential essay ‘Situated knowledges: The science question in feminism and the privilege of partial perspectives’ (1988), Donna Haraway calls for the transformation of ‘objectivity’ towards ‘situated’ and ‘partial’ accounts of knowledge-making. Situated knowledges, Haraway explains,

require that the object of knowledge be pictured as an actor and agent, not as a screen or a ground or a resource, never finally as slave to the master that closes off the dialectic in his unique agency and his authorship of ‘objective knowledge’ (p. 592).

Adapting Katie King’s term, the ‘apparatus of literary production’, Haraway’s ‘apparatus of bodily production’ is a tool through which to produce embodied and thereby situated empirical feminist research. Here, bodies ‘as objects of knowledge are material-semiotic generative nodes’ (p. 585). More recently, Hughes and Lury (2013) have reshaped feminist situated practice, including ecological and ‘more-and-other-than-human’ sensibilities. As the authors explain, ecological epistemology and the concept of patterning—that is, ‘processes of repetition and differentiation that are at issue in the creation of situated knowledge’—‘seek to de-privilege the weight given to reflexive accounts of identity in the production of situated knowledge’ (pp. 786, 797). Although I concur with Hughes and Lury in that ecological epistemology is needed as a feminist situated practice, their description does not provide, in my view, novel insights into what such an approach would look like, or how it might differ from Haraway’s situated knowledges, which also includes ecology as a core theme of feminist knowledge practice.

Moreover, as I have also argued in Chapter 1 in relation to the work on the self metaphor by anthropologist Michael Fischer, what Hughes and Lury define as ‘fixed’ and

‘reflexive’ perspectives on identity (politics) constitute a homogenising view of identity. As Blackman, Cromby, Hook, Papadopoulos, & Walkerdine (2008) claim, ‘subjectivity is always unfinished, partial, non-linear’ and ‘there is not a tight fit or homology between subject positions and subjectivities’ (pp. 16, 17). Likewise, against the notion of a unitary and rational subject, Henriques, Hollway, Urwin, Venn, & Walkerdine’s *Changing the subject* (1984) demonstrates the multiple facets of subjectivity. Showing the complexity of culture and psyche in the production of identity and subjectivity (p. x), *Changing the Subject* established the foundations of critical and feminist psychology.

In summary, in this first section of the chapter, I have engaged with literature using the framework of ‘multispecies ethnographies’. I have then addressed the limitations of this approach, particularly in terms of depoliticisation and a lack of engagement with embodied experiences of human–microbe relations. In contrast with ‘more-than-human’ (Braun & Whatmore, 2010) claims, I suggest, multispecies ethnographies is a very orthodox and very ‘human’ area of social sciences and humanities scholarship. Moreover, while in this section I have also provided a theoretical rationale for the methodological use of my embodied experience as part of a feminist situated practice, I will come back to a detailed description of my embodied experience later in the chapter as part of the research design of the thesis: ‘Feminist para-ethnographies of human–microbe relations’ (see Section 2.4).

In what follows, I outline the term of multi-sited fieldwork. As a response to multispecies ethnography and inspired by medical and environmental anthropologist Alex Nading’s (2016) reformulation of Holmes and Marcus’s concept of the para-ethnographic (2008), I then develop the notion of ‘feminist para-ethnographies’ and situate my fieldwork within this category of empirical inquiry. Feminist para-ethnography is an intersectional method that entangles embodied experiences with ‘fugitive’ qualitative data in technoscientific claims and quantitative research.

2.3 Against multispecies ethnography: Feminist para-ethnographies

2.3.1 Multi-sited fieldwork

The term ‘multi-sited fieldwork’ refers to an anthropological practice introduced by anthropologist George Marcus (1995) and developed by Appadurai (1986) and Taussig (1987) (among others), in which traditional single-site location, conventionally ‘contextualised by macro-constructions of a larger social order, such as the capitalist

world system', moves to 'multiple sites of observation and participation that cross-cut dichotomies such as the "local" and the "global", the "lifeworld" and the "system"' (Marcus, 1995, p. 95).

Certainly, my field was constantly shifting as I carried out the research. I have engaged in field sites that seemed inter- and disconnected on multiple scales. I have attended scientific conferences. I have analysed heterogeneous documents such as science policy documents and specialised scientific literature on the human microbiome. I have conducted fieldwork on scientists working on microbiome research at an actual or offline (Puerto Rico, New York) and virtual or online (personalised medicine website 'American Gut') level. I have partaken in AMR workshops, using them as learning sites and sites of data gathering on the latest research on AMR and interdisciplinarity. 'Multi-sited ethnography' then captures the multiple scenes or sites of data collection that comprise my fieldwork.

In an updated account of multi-sited ethnography, anthropologist Matei Candea (2007) interrogates the limitlessness, complexity, and expansion inherent in the idea of multi-sited fieldwork, and instead emphasises the importance of an 'arbitrary location' as a means of making the 'cut' necessary to define one's field. By highlighting limitation as a decision on the part of the anthropologist, an arbitrary location is 'premised on the realization that any local context is always intrinsically multi-sited' (p. 175). At the same time, it also refuses to take that multi-sitedness as a totalising discourse itself. Likewise, since I started the exploratory pilot project in June 2013,³⁵ I have made several 'cuts' (Barad, 2007) that gave shape to and defined both my field site and fieldwork. One of the ethnographic moments that have crucially determined the course of the thesis occurred during the conference 'Infectious Disease Genomics & Global Health', organised by the Wellcome Trust between 16 and 18 October 2013 in Hinxton, Cambridge, during which I first met and established contact with microbial ecologist Dominguez-Bello (Chapter 3).

My ethnographic fieldwork is principally influenced by anthropology of science (see Chapter 1). One of the problems posed to and by the anthropology of science is that of how one might talk about the universal, the global, reality, or a totality at all in a disciplinary idiom that apparently no longer permits it (Choy, 2005). If, on the one hand,

³⁵ See Section 2.4.2.

science is that domain of Western knowledge that in a large part bases itself on the necessary premise that universals are not created but given, and that aspires to totality, and if, on the other hand, anthropology/sociology is that domain that aspires to countenance partiality and particularity, then the anthropologist of science is forced into a trap (Wagner, 1981). This arises from the difficulty of deciding exactly where to locate the ‘native’ in this relation in the first place, for as Wagner writes, ‘the former alternative, we are told, is superstitious and unobjective; the latter according to some, is “science”’ (p. 30). When studying scientists, the two sides seem to collapse into one another. In privileging the particular, situated, and contingent—the ‘unobjective’—anthropology and social studies of science are supposedly engaged precisely in moving away from its natural scientific, Western tendencies (see Franklin, 1995; Ingold, 2000).

Yet, Western methodologies such as ethnography should also converge with the decolonising move of adopting and acknowledging other knowledge practices apart from Western ones (Smith, 1999). In the following section, I develop what I call ‘feminist para-ethnographies’, an intersectional method with the aim of inventing and shaping a decolonising and ‘de-patriarchalising’ qualitative set of methodologies.

2.3.2 Feminist para-ethnographies

In my fieldwork, entanglements of scientific concepts and instruments such as next-generation sequencing (NGS) technologies cross paths with elements and events that are often erased from ‘scientific’ accounts, such as the embodied experience of the researcher. Failed research plans, slow bureaucratic processes together with gossip, love, friendship, and political positions define, as much as immune and microbial cells do, the messy realities that arise from social qualitative research. I distance my research methods from the tendency to delimit ethnographic research to a handful of categories of analysis such as ‘actants’, ‘networks’, ‘systems’, ‘non-humans’, and so forth, as occurs in STS. While some basic premises of STS, such as the inclusion of non-humans in social theory and social research methods, have indeed influenced and inspired the development of the thesis, I nevertheless consider that through single analytical frameworks alone my research project would not grasp the complexity I have encountered during the fieldwork. Thus, in order to retain the complexity and contradictions I encountered and co-produced in the fieldwork, I do not erase but acknowledge them as necessary elements of the data collection and data analysis.

This view is not new. It has been conceptualised differently by social scientists and humanities scholars (Fassin, 2014; Haraway, 1991, 1997; Latour, 1999; Taussig, 1980, 1987). For example, Bruno Latour has called for the acknowledgement and inclusion of ‘anecdotes’ in the production and architecture of the ‘reality of science studies’ (1999). Another recent example is the work of anthropologist Didier Fassin (2014). For Fassin, the current value of ethnography has to do with ‘the ultimate evidence of its fragile solution to the difficult problem of bringing life into the text through the writing itself’ (p. 53). As I have mentioned previously, feminist scholar Sara Ahmed (2017) has also emphasised the importance of daily life and bodily experiences to ‘bring theory back to life’ (p. 10).

Assuming that Cartesian bifurcations only exist in theory (Latour, 1993), I do not enter into sterile arguments that confront the material and discursive, natural and cultural, fictional and factual. Rather, this thesis considers reality, ethnographic or otherwise, as always already entangled. In this sense, the concept of para-ethnography is extremely insightful for this thesis.

2.3.3 The para-ethnographic

Anthropologists Holmes and Marcus (2008) coined and defined the ‘para-ethnographic’ as ‘a way of dealing with contradictions, exceptions, and facts that are fugitive’ (p. 596). Furthermore, the ‘para-ethnographic’ is

a self-conscious critical faculty operating in diverse domains as a way of dealing with contradictions, exceptions, and facts that are fugitive, suggesting a social realm and social processes not in alignment with conventional representations and reigning modes of knowledge and analysis. The para-ethnographic operates as a kind of social thought—expressed in genres such as the anecdotal, hype, and intuition (p. 596).

Para-ethnography, they point out, was originally formulated to address ‘the challenges of pursuing anthropological ethnography within new contexts of fieldwork ... in settings dominated by scientific knowledge and/or a technocratic ethos’ (p. 595). Importantly, in para-ethnographies, the ‘researched’ are not research ‘participants’, ‘subjects’, or ‘informants’. They are rather ‘epistemic partners’, a term that denotes the co-production of knowledge between researcher and ‘researched’. Epistemic partners, Holmes and Marcus write, ‘are not merely informing our research but ... participate in shaping its theoretical agendas and its methodological exigencies’ (p. 595). I borrow and use the term epistemic partners as a way to recognise the intellectual labour and generosity of the scientists I have collaborated with in this thesis.

In a reformulation of Holmes and Marcus's concept, Alex Nading (2016) develops the term of 'evidentiary symbiosis' as a para-ethnographic tool in the study of the human microbiome. For Nading, 'evidentiary symbiosis is the form that microbial sociality takes' (p. 565). Going beyond the passivity of 'cultural interpretation and social documentation of scientific practice' and 'avoiding cultural and scientific reductionism' (pp. 561, 562) requires

taking seriously not only the technoscientific claims that experts make about microbes in scholarly papers but also the qualitative claims (those about the existence of a 'microbial community' as well as those about the human 'publics' within which they circulate) that they make in blogs, popular writing, and public engagement. These qualitative claims—easily written off as hype or simplification—are, I argue, evidence. Human-microbe relations can sometimes be measured numerically, but they cannot be fully explained with quantitative tools. Bacteria and viruses mutate, they avoid capture, and they destabilize social orders (p. 562).

Significantly, he insists, adopting a para-ethnographic approach means granting an active role to social scientists and humanities scholars as co-producers (together with scientists), rather than 'commentators' or 'interpreters' of qualitative evidence and emergent categories (e.g. microbes) in contemporary life science (p. 578).

I concur with Holmes and Marcus (2008) and Nading (2016) about the inclusion of forms of qualitative data often discarded from the ethnographic detail,³⁶ particularly technoscientific data that does not appear in scientific publications but in other channels of dissemination, especially in online and offline popular and public domains such as popular science literature, blogs, and public engagement events (Chapters 4 and 5). Yet, my problem with Holmes and Marcus's (2008) and Nading's (2016) accounts of the para-ethnographic is that qualitative data still operates within normative precepts. This is because the para-ethnographic is restricted to the claims of epistemic partners and even their 'gut feelings', but fails to take into consideration (and analysis) the researcher's experiences in the co-production of knowledge.

In order to complement what counts as para-ethnographic data, I develop the concept of feminist para-ethnographies. I conceive feminist para-ethnographies as an intersectional method that entangles embodied experiences with 'fugitive' qualitative data in technoscientific claims and quantitative research. The main feature of my

³⁶ In this sense, the concept of the para-ethnographic is similar to Lisa Blackman's concept of 'haunted data' (2015), which aims at dissolving distinctions between big and small data as well as 'to explore what leaves the frame if we exclusively focus on metrics, quantification and digital methods based on counting, measuring and aggregating numbers' (p. 5).

reconceptualisation of the para-ethnographic is the incorporation of embodied experiences as feminist research tools. Feminist para-ethnographies takes up Riley's 'socialised biology' (1983) ethos of accounting for how 'biology is *lived out*' in all its embodied and, crucially, political senses (p. 30). As Riley writes,

to overlook the particular forms in which biology is lived out is to overlook the fact that this biology is simultaneously biography—and that lives differ in ways which general categories of the socio-economic do not capture. For women in particular it is evident that an extremely significant portion of social experience *is* socialised biology—reproductive experience, for instance. Because it is so vulnerable to inroads—changes in abortion laws, for example—it has a clear *political* dimension. The question of the conditions for a real control of fertility are of obvious concern here. And this is why feminism in particular cannot avoid thinking through the problems about what meaning can be given to the biological and the social (p. 40).

As I have previously argued, I conceive embodied experiences as part of situated feminist practice. Feminism is political. Furthermore, feminist para-ethnographies aims at being intersectional (Crenshaw, 1989) inasmuch as it acknowledges the multidimensionality of identities (i.e. you can be brown, female, middle class, and disabled) and how homogeneous perceptions of womanhood (e.g. white, able-bodied, middle class) contribute to a monolithic understandings of women's realities. As Nira Yuval-Davis (2006) points out, 'each social division has a different ontological basis, which is irreducible to other social divisions' (p. 195). A multiplex vision of social categories of difference is an important perspective to take, because it offsets 'microbiomisation'.

It is worth mentioning the parallels between para-ethnography and autoethnography. The definition of autoethnography as 'ethnographic research, writing, story, and method that connects the autobiographical and personal to the cultural, social, political' (Ellis, 2008, p. 48) fits well into my reformulation of the para-ethnographic. However, I privilege the term para-ethnography over autoethnography because the former is broader than the latter. While autoethnography refers to personal (including bodily) experiences of the researcher, para-ethnography includes the experiences of epistemic partners (scientists, in this case), and not just their technoscientific claims in interviews and scientific publications. Furthermore, my version of the para-ethnographic comprises other forms of qualitative data from conference attendance, workshop participation, and policy analysis as part of the fieldwork. In an autoethnography, the researcher becomes the focus or main lead of the narrative. On the contrary, the narratives I bring together in this thesis are distributed. The voices are plural.

In summary, through the inclusion of embodied experiences and an analysis of qualitative claims and ‘impressions’ made by scientists about the human microbiome in public media other than scientific publications, what I call ‘feminist para-ethnographies’ is a novel methodological intervention in the cultural and social study of human–microbe relations, and therefore one of the main contributions I make in this thesis.

2.4 Research design: Feminist para-ethnographies of human–microbe relations

In this section of the chapter, I outline the research design of the thesis under the framework of ‘feminist para-ethnographies of human–microbe relations’. In the first part of the research design, I outline a rationale for the methodological use of my embodied experiences as part of a feminist situated practice. Here, I catalogue my embodied experiences during the research process according to a twofold thematic: 1) embodied experiences of health and disease in UTIs, pregnancy, and childbirth; and 2) embodied national identity as a point of reflexivity and connection with my epistemic partners as well as a point of resistance to the precepts of anglophone academia. I then outline the details of my exploratory pilot project, scientific conferences attendance, ethnographic fieldwork on human microbiome research, digital media analysis of the online microbiome community, and critical analysis of complementary documents—which includes science policy and scientific analysis, and popular science literature. The aforementioned different methods of data gathering and analysis constitute what I call ‘feminist para-ethnographies of human–microbe relations’. Here, embodied experiences mingle with both qualitative and technoscientific claims about the human microbiome by life scientists as well as other types of qualitative data resulting from science policy and scientific and popular science analysis.

2.4.1 Embodied experiences

2.4.1.1 Embodied experiences of health and disease: UTI, pregnancy and childbirth

Contrary to my recurrent UTIs at the point when I started my PhD, my pregnancy came at a time when my research was relatively advanced, in late 2015. By that time, I had gathered all the data and I was in the process of data analysis and writing up. This period was interesting from an intellectual viewpoint. On the one hand, in human microbiome studies, pregnant and breastfeeding female bodies are biomedically valuable due to the major shifts in microbial communities in both the woman’s and the infant’s body. On the other hand, pregnancy carries an increased risk of UTI, especially for those women with (unexplained) recurrent UTIs. According to classical immunological theory, in pregnancy, the immune system weakens in order to

'tolerate' the fetus. And this is the reason why infections are more common. What might be a minor and very mild infection in non-pregnant women might become serious and with long-term consequences for the pregnant woman and the fetus. Prenatal infections are associated with preterm delivery, stillbirth, and sepsis, to name a few. Importantly, there is an unknown burden of antimicrobial resistance (AMR) on women's health, especially in poorer countries (Chapters 4 and 5).



Figure 3. Above, one of my many visits to A&E due to acute UTIs. Below, one of my many visits to pharmacies, in this case in Campinas (Brazil), looking for an alternative UTI treatment only available in certain countries. Photos by the author.

I conceive of my embodied experiences associated with UTI, pregnancy, and childbirth as crucial situated knowledge practices. This is because my embodied experiences of health and disease have animated and informed this thesis since its very inception and have co-evolved with the research process. These experiences include GP appointments and countless urine cultures, research on UTI alternative treatments to antibiotics, the purchasing of alternative treatments in pharmacies outside the UK, and online searches of microbiome research in pregnancy.

2.4.1.2 *Embodying the nation: Reflexivity and resistance*

Reflexivity

The convergent genealogical history between microbial ecologist Dominguez-Bello—the key epistemic partner of this thesis (Holmes & Marcus, 2008)—and me became a key source of access and contributed to the establishment of trust. I am originally from the autonomous community of Galicia, in north-west Spain. My maternal family is from Ferrol, where I grew up. Ferrol, a city in northern Galicia, is situated in the province of A Coruña, a locale still haunted by being the birthplace of Francisco Franco Bahamonde, the fascist dictator of Spain from 1939 until his death in 1975. My paternal family is from Vigo, a larger city in the province of Pontevedra, south-west Galicia (Figure 4).



Figure 4. Map of Galicia

Galicia, traditionally a rural society based on agriculture and fishing, was the Spanish region historically more affected by emigration during the nineteenth and twentieth centuries. South America, and mostly Argentina, Venezuela, and Brazil were the countries most Galicians emigrated to. My paternal grandparents were part of those millions of Galicians who were forced to leave their land for labour, economic, or political reasons. The economic stagnation of rural Galicia during Francoist Spain was the dominant factor that precipitated the exodus of my grandparents.

At that time, without the mobile and online technologies that populate our contemporary world, the choice of destination was not made based on informed facts, carefully selected information on the host country's employment opportunities, or as a result of an a priori job position. By contrast, word of mouth played a crucial role. My

grandmother often tells the story of how an acquaintance of my grandfather living in Brazil encouraged him to join him in a business in the fishing industry, together with other Galician workers living in São Paulo. Despite the business not being a reality yet but just a mere idea, a few months later, in May 1955, my grandparents packed a few belongings and crossed the Atlantic Ocean by sea towards São Paulo. They brought with them their four-month-old baby, my father, leaving their two-year-old daughter behind in Vigo, in the care of family members. Their journey lasted two weeks. Once in São Paulo, they settled in San Bernardo, a peripheral neighbourhood, nowadays absorbed in the megalopolis. They lived there for nearly a decade. As soon as their economic situation improved, they returned to Vigo and reunited with the rest of the family.

The story of my family was commonplace in those days of mid-twentieth-century Galicia. This socio-historical reality of my hometown turned one of my first electronic correspondences with Dominguez-Bello into the initial development of bonding and trust between us. Dominguez-Bello's maternal family is from the same city as my paternal family, Vigo. Her mother (who I presume is slightly younger than my grandmother) emigrated to Caracas, Venezuela, where Dominguez-Bello was born and lived until she moved to Aberdeen, UK, to conduct her doctoral studies in microbiology. This relatedness through descent (i.e. kinship) with Latin America as the epicentre of our biographies figures as the background of my fieldwork of microbiome research.

During my fieldwork, my body became a proxy of the nation. Examining contemporary immunology through the phenomenon of fetal-maternal microchimerism, Aryn Martin (2010) points out that foreign cells metaphors have shifted 'from invaders to insurgent foreigners to assimilated productive immigrants' (p. 23). Microchimerism destabilised dominant ontologies of the body as bounded and fixed. Yet, simultaneously, microchimerism is imbued with a nationalistic rhetoric which portrays 'cells as migrants and bodies as nations' (p. 44). Similarly, I found myself embodying the nation.

My national identity was a point of contact and trust with my epistemic partners but also of colonial history during the ethnographic fieldwork. My body, my presence, became a reminder of the brutal imperialist and colonial rule of Spain in Latin America. A reminder of racism, sexism, and centuries of slavery and subjugation inflicted by my ancestors on the indigenous inhabitants of what it is now Latin America. Hence, the shameless bloody history of my country has influenced how I relate to my epistemic partners. Kinship was key to establishing initial contact with Maria Gloria Dominguez-Bello, but it was also key to developing trust with her research team, mainly formed by

young Puerto Rican and Venezuelan scientists. I soon realised that my national identity was valued by the research team, even admired. I felt like the character of Fitzcarraldo in Werner Herzog's 1982 homonymous film, that is, as if I was embodying the colonial being of a nineteenth-century (white, male) European explorer/coloniser. I was very uncomfortable in this position. As a way of coping, I decided to be open about my political views on colonialism and new forms of colonialism (neocolonialism). Yet my anti-colonial comments were somehow blurred, even dissolved, into narratives about their family history in relation to European descent or about the gastronomic influence of Spain on Puerto Rican cuisine. I was frustrated about my inability to approach and address this situation differently. After all, adopting a critical, anti-colonial discourse might not have been the most useful and truthful attitude as it might carry with it a condescending effect. Yet, as an inexperienced ethnographer, being open and honest with my epistemic partners about my political ideology was the only way forward I envisioned at the time.

Resistance

On a briefer note, my embodiment of the nation also acts as a point of resistance to anglophone academic standards.

As some feminist scholars have pointed out regarding situated knowledge practices of (gender, race, class, and sexual) difference, those analyses 'often ignore the diversity among women with regard to their particular geographical and cultural placement across the world' (Hesse-Biber, 2008, p. 337). What Hesse-Biber calls 'geographical and cultural placement' includes, in my view, non-native-English speakers and other-than-English language accounts, along with resistance to the term 'Western' as an all-encompassing notion (the same applies to the term 'Euro-American') when it just denotes anglophone academia.

As I have argued in the previous chapter in relation to the decolonial literature (Chapter 1), one of the principal limitations of the thesis is its insufficient engagement with non-anglophone debates and scholarship. My engagement with decolonial theories of *Buen Vivir* is partly a modest response to this reality and partly an early draft destined at overcoming such limitation in my future research. Importantly, decolonial thinking responds to my own situatedness (in the form of embodied narratives) as a Spanish

national both doing a PhD in the UK as well as conducting short ethnographic fieldwork on the Caribbean island of Puerto Rico.³⁷

As a Spanish female researcher, I am not only dealing with a past of colonial history (previous section). I am also trying to resist dominant academic precepts by dismantling the mind-body split through a situated and embodied account of my research process. In turn, I also see embodied experiences as a way to resist normative (anglophone) stylistic and cultural aspects of academic knowledge production. Through a significant part of my PhD I have tried to ‘behave’ (including my writing) as if I were a native speaker, an attitude that is often encouraged at UK universities (targeted at non-native speakers’ students). In doing so, I adopted a certain tone and register. I had to relearn how to write academically, which is, in itself, learning another culture (another culture to add to my original disciplinary scientific culture). For example, in Spanish language, it is common to write long sentences and to use more adjectives. Paragraphs are usually longer and structured differently. Part of doing a PhD in the UK Higher Education system, I believe, passes by adapting and adopting its own academic writing. Yet, at some (late) point of my PhD I arrived at the conclusion that it would be naive on my part to ‘pretend’ I am a native speaker or even bilingual. When I arrived in the UK back at the end of 2008, I could barely speak in English. A second language competence is a lifelong learning process, I believe. ‘Faking’ my writing was counterproductive. I could not find ‘my voice’. I could not believe what I was narrating and how I was writing it. In these circumstances, being more flexible in terms of the writing style (while maintaining academic standards) and, crucially, entangling and bringing into presence my embodied experiences during the research and writing of this thesis, have proven, in my opinion, a successful way of managing my linguistic disadvantages as well as a way to resist homogenisation by anglophone academia.

In summary, it would be a deceptive practice to erase my embodiment from the main narrative of the thesis. My academic analysis of immunity and the human microbiome cannot be isolated from my embodied experiences of microbes during the research process. These had provided extremely rich and novel insights and had supplemented more conventional critical analyses on the topic. Life, theory, research, and practice are, in this thesis, entangled. Fieldwork, therefore, goes beyond classical anthropological accounts. This is what my reformulation of the para-ethnographic

³⁷ I will come back to this point later in the chapter.

captures: Embodied experiences as meaningful qualitative data originating at the fieldwork which add to more conventional data such as technoscientific claims by scientists as well as to less conventional and thus more ‘fugitive’ evidence, such as their ‘impressions’, ‘intuitions’, or ‘gut feelings’. This form of conducting research is radically opposed to scientific objectivity and positivism. For me, objectivity and subjectivity are indissociable; therefore, the research methods and research design should reflect that entwined reality.

In stylistic terms, I try to incorporate and mix thick descriptions of my embodied experiences together with otherwise more conventional forms of qualitative research. I bring both accounts as close together as I possibly can in order to make evident their entanglement. I present my embodied experience in a ‘raw’ yet integrated manner in a response to Sara Ahmed’s call for bringing ‘theory back to life’ (2017, p. 10).

2.4.2 Exploratory pilot project

After spending the first six months of my doctoral research familiarising myself with and researching the theoretical foundations of the immune system in both critical theory and biomedical literature, I conducted an unstructured and open-ended pilot study during the period June 2013–October 2013, which mainly consisted of attending two scientific conferences on microbiome research organised by the Wellcome Trust³⁸:

- **Exploring Human Host–Microbiome Interactions in Health and Disease**, organised by the Wellcome Trust, took place between 8 and 10 July 2013 at Fitzwilliam College, Cambridge, UK.
- **Infectious Disease Genomics & Global Health**, organised by the Wellcome Trust, took place between 16 and 18 October 2013 at the Wellcome Trust Genome Campus, Hinxton, Cambridge.

My initial purpose in attending these conferences was to gain access to the microbiome scientific community in the UK and to update my previous undergraduate education in molecular biology and biotechnology with new insights in the emerging field of microbiome research.

³⁸ ‘The Wellcome Trust is a biomedical research charity based in London, United Kingdom. It was established in 1936 with legacies from the pharmaceutical magnate Sir Henry Wellcome to fund research to improve human and animal health ... The Trust has been described by the *Financial Times* as the United Kingdom’s largest provider of non-governmental funding for scientific research and one of the largest providers in the world. In the field of medical research, it is the world’s second-largest private funder after the Bill & Melinda Gates Foundation’ (Wikipedia, 2014).

On the other hand, the reason that I chose to attend these two conferences, both organised by the Wellcome Trust, was twofold: First, the Wellcome Trust Foundation is one of the most prestigious institutions that organise scientific events and advanced scientific courses and conferences at a national and international level. In fact, ‘Exploring Human Host–Microbiome Interactions in Health and Disease’ was the second international meeting on the topic organised by the Wellcome Trust. Two panels of the ‘Infectious Disease Genomics & Global Health’ conference were on microbiome research. The conference interested me because the theme combined infectious diseases and global health with microbiome research, a novel and multidisciplinary approach. At this conference, I met and established the first contact with microbial ecologist Dominguez-Bello.

Second, these two conferences were the only conferences on the microbiome in the UK and abroad, apart from the 4th International Human Microbiome Consortium conference in Hangzhou, China, held between 13 and 15 September 2013, which due to financial constraints I did not consider attending.

2.4.3 Ethnographic fieldwork

In the influential *Laboratory life* (1979), anthropologist Bruno Latour and sociologist Steve Woolgar conducted a laboratory ethnography at the Salk Institute (US) about the ways in which ‘the daily *activities* of working scientists lead to the construction of facts’ (p. 40). Their study deconstructed the perception of science as field of discovery. Instead, Latour and Woolgar demonstrated how ‘objects ... are constituted through the artful creativity of scientists’ (p. 129). As they have insisted, the scientific construction of a protein, for example, ‘is not to deny its solidity as a fact. Rather, it is to emphasise how, where, and why it was created’ (p. 127).

My ethnographic fieldwork with microbiome scientists has informed the central argument of the thesis—the microbiomisation of social categories of difference—and shares their ethos regarding the construction of facts as well as similarities as to how they delineated their case study of the peptide TRF:

We do not attempt to produce a precise chronology of events in the field, nor to determine what ‘really happened’. Nor do we attempt a historical exposition of the development of the speciality of ‘releasing factors’. Instead our concern is to demonstrate how a hard fact can be sociologically deconstructed (p. 107).

Likewise, I ‘deconstruct’ the idea that the human microbiome is about scientific evidence that contributes to the decline of the pervasive social, political, and scientific discourse

based on an immuno-logic of exclusion and inclusion. On the contrary, I argue that human microbiome discourse and practice reinforces the naturalisation of fixed and unidimensional social categories of difference through the classification and characterisation of microbial diversity, a process I describe as the ‘microbiomisation of social categories of difference’.

Laboratory life inaugurated a genre within science studies, namely that of lengthy and thick descriptions of scientific laboratories, or laboratory ethnographies. By contrast, however, this thesis is not an anthropological study of human microbiome research. As such, its ethnographic dimension is not based on lengthy laboratory fieldwork, as is common in anthropology of science and in STS. As I have tried to demonstrate throughout this chapter, my ethnographic fieldwork of microbiome scientists is one of the elements constituting ‘feminist para-ethnographies of human–microbe relations’. In fact, the different methods that compose feminist para-ethnographies reflect the multi-sitedness of human microbiome research and so the impossibility of capturing and understanding the field by a single-method approach. I was perplexed the first time I visited Dominguez-Bello’s laboratory at the UPR. It looked like a storage site. The gas chamber was used to pile emptied boxes. Scientists there were working on their laptops (see Figure 15 in Chapter 3). The scene was the antithesis to what I was expecting to find and to what I was used to as a laboratory worker during my undergraduate years.

Dominguez-Bello and her team’s empirical work is not conducted in a biology laboratory in a conventional way. Their microbial research, as mine, is multi-sited. One of the most important stages of microbiome research is the gathering of microbial samples. And, unlike classical microbiology, in which microbes were cultured in Petri dishes and so the work was done purely at the benches, the study of microbes is conducted in the natural environment in which they reside (which is literally everywhere). This approach is known as ‘metagenomics’.³⁹

Although I would have preferred to establish a collaboration with Dominguez-Bello and her team, there were several reasons that impeded the development of reciprocity and partnership. Dominguez-Bello’s research was already in an advanced

³⁹ ‘Metagenomics’, also called ‘ecogenomics’ or ‘environmental genomics’, refers to ‘the study of genetic material directly extracted from an environmental sample’ (Rhodes, Gligorov, & Schwab, 2013, pp. 35–36), such as various parts of the human and animal bodies like the gut, mouth, and so on, soil, solid surfaces of a house, trees, etc. I will return to metagenomics and next generation sequencing methods in Chapter 3, Section 3.3.2.

process of data analysis when I visited her laboratory at the UPR and NYU. My presence and role was conceived by her and the research team as one of a classical ethnographer or 'reporter': observing, asking questions, familiarising myself with their work and experimental settings, and generating trust. Reflecting on my own 'presence' in the field, I consider two principal reasons why collaboration did not materialise. One is pragmatic and concerns Dominguez-Bello. She is one of the leading scientists working in microbiome studies and as such, she is an extremely busy scholar.⁴⁰ She spends half of the time living in San Juan and the other half in New York. She is also engaged in microbiological research in South America and has recently signed contracts with research institutes in Venezuela, her home country, and Ecuador. In addition, she is a regular collaborator with several universities in Brazil and Tanzania, countries in which she also conducts microbiological research. Therefore, my presence, motivations (PhD research), and expectations (collaborative fieldwork) were, understandably, minor matters for her compared to her research agenda. Besides, the fact that I am a young PhD student conducting research in the social sciences and humanities tacitly contributed to my 'subaltern' presence. Second, I believe that my lack of experience in conducting ethnographic fieldwork played a part in the development of the research. Despite having previously read several classics in the field (Geertz, 1973; Malinowski, 1922; Mintz, 2010), manuals and anthropological readers included, I learnt that it is impossible to be completely prepared for the unexpectedness of the fieldwork. Looking back, I could have, in various ways, managed the situations I encountered and my own presence differently. But, simultaneously, I believe that too much control and standardised variables constrain relationships.

Because on my previous undergraduate training that was in biology, and my specialisation in molecular biology and biotechnology, I did not feel alien to most of the practices and lexicon I have encountered during the course of this project. Instead, this fieldwork served as an intensive updating of the technologies and knowledge of immunology, microbiology, and ecology. Moreover, I have also come across recent developments and concepts that were not available or developed when I was a biology student, such as NGS technologies and 'metagenomics'.

⁴⁰In 2010, Dominguez-Bello published a landmark study on the microbiome of newborns. She compared children delivered through caesarean section and children delivered vaginally. The results were surprising: children born through C-section were more prone to suffer inflammatory and autoimmune diseases (see Chapter 5).

2.4.3.1 *Semi-structured interviews*

While I was conducting fieldwork in San Juan and New York, Dominguez-Bello introduced me to her collaborators. Earlier, before travelling to Puerto Rico and New York—where I conducted formal interviews and informal conversations—I did background research on the team. I have also contacted other collaborators through a ‘snowballing’ method. In doing so, I always informed Dominguez-Bello of my intentions. She supported and agreed with my actions. All the interviews were conducted at the workplace, at the UPR in San Juan and NYU. Once I came back to London, I established regular contact with some members of the team. I spent four entire days with Dominguez-Bello. I followed her from the morning, when we went to the university, and at noon when we had lunch together with her graduate students. She also invited me to partake of an informal dinner with one of her collaborators (Dr. Humberto Cavallin).

I complemented the interviews with Dominguez-Bello’s team and collaborators with an interview with Professor Tim Spector, a leading scientist in microbiome research and epigenetics. In 2014, Spector set up BG—an online participatory network of scientists and citizens—in collaboration with Rob Knight, Dominguez-Bello’s key collaborator in the American Gut Project (AGP) and more recently, in 2017, Map My Gut (MMG) (see Section 2.4.5 for further details). I also interviewed Professor Graham Rook, a prominent UK immunologist who has developed the ‘old friends mechanism’, a competing theory of ‘microbial dysbiosis’, with Martin Blaser’s reformulation of the hygiene hypothesis developed in his 2014 book *Missing microbes*.⁴¹

2.4.4 **Scientific conferences⁴² and AMR workshops attendance**

Between July 2013 and June 2014, I attended six international conferences. As I explained at the beginning of the chapter, two of these conferences were part of the exploratory pilot project I conducted between June and October 2013. The other four conferences I attended were not limited to the Wellcome Trust Advanced Scientific Conferences.

- **Epigenomics of Common Diseases**, organised by the Wellcome Trust, took place between 7 and 10 November 2013 at the Wellcome Trust Genome Campus, Hinxton, Cambridge. At this conference, I started establishing regular contact with Dr. Heba

⁴¹ See Appendix B for further details on semi-structured interviews and informal conversations.

⁴² I have paid a registration fee to all the conferences I have attended, except for the 1st Microbiome Meeting, which I access by invitation.

Saadeh, a bioinformatician at Babraham Institute, Cambridge. Saadeh and I have had regular personal and professional correspondence since we met at the Epigenomics conference. She has helped me to grasp the basics of the complex field of epigenomics. Moreover, I established initial contact with Tim Spector (see Section 2.4.5.).

- **British Society for Immunology Congress**, organised by the British Society for Immunology, took place between 2 and 5 December 2013 at Arena and Convention Centre, Liverpool. Attending this congress provided me with a valuable insight into present-day immunological theory and research.
- **Exploring Human Host–Microbiome Interactions in Health and Disease**, organised by the Wellcome Trust, took place between 14 and 16 April 2014 at the Wellcome Trust Genome Campus, Hinxton, Cambridge, UK. This conference was a follow-up of the previous one I attended in July 2013 as part of my exploratory research project.
- **The 1st London Microbiome Meeting**, organised by the Department of Twin Research, KCL, took place on 12 June 2014 at the Prideaux Lecture Theatre, St Thomas' Hospital, London. Compared to the previous scientific meetings, this was a small-scale, yet compelling conference. I gained access by an invitation from Tim Spector, who I had met on two earlier occasions at the Wellcome Trust conferences and who I interviewed (finally) in 2017. Almost all speakers were clinicians and thus their attention was more directed to the therapeutic dimension of the microbiome compared to the other two Wellcome Trust microbiome conferences, that were based on scientific experimental research.

Overall, at these meetings, I attended talks and poster sessions, spoke to researchers between sessions, and participated in informal conversations at mealtimes and breaks (all scientists and biotech representatives I mention in the thesis agreed for me to use their real name). These were important research moments, as they allowed glimpses of the social interactions among researchers and of modalities for presenting content that differed from interviews and the published literature.⁴³

⁴³ Chapters 3 and 4 draw on data gathered at conferences.

2.4.4.1 *AMR workshops*

Between August 2016 and June 2017, I was invited to three workshops on AMR held in the UK:

- **The Constructing of Antimicrobial Resistance: A Workshop**, London School of Hygiene and Tropical Medicine and Wellcome Trust, Latimer Place, Chesham, UK, took place on 3 August 2016.
- **Interdisciplinary Research & Antimicrobial Resistance Workshop**, University of Bristol and ESRC, Engineer's House, Bristol, UK, took place on 2–3 March 2017.
- **AMR as a Sustainable Development Challenge in Low- and Middle-Income Countries**, University of Nottingham, UK, took place on 27 June 2017.

Participating in these workshops provided the theoretical and methodological scaffolding for Chapter 4. I integrate my impressions and discussions about AMR in these three settings as part of para-ethnographic data on AMR.

2.4.5 **Digital media analysis: Online microbiome community**

Since 2013, I have followed and documented the news and public statements made by microbiome scientists in several online platforms. This mostly includes the American Gut Project (AGP) and, to a lesser extent, the Human Food Project (HFP), British Gut (BG), and Map My Gut (MMG) (see Chapter 3).

The AGP is a not-for-profit microbiome initiative led by Rob Knight,⁴⁴ a leading figure in microbiome studies, particularly in the sequencing of microbial samples. He is the main collaborator in Dominguez-Bello's MHC research. Dominguez-Bello is an adviser of the AGP. The microbial DNA samples gathered by Dominguez-Bello and her team collected in the Amazon are sent to sequence at Knight's Lab at the University of California in San Diego (US), where they are sequenced. Knight's Lab is also where the AGP is conducted.⁴⁵

In addition, I have conducted participant observation of a six-week massive open online course (MOOC) offered by the research team leading the AGP at the University of Colorado Boulder.⁴⁶ I obtained a large quantity of material, which includes a comprehensive review of microbiome research, along with a detailed description of the

⁴⁴ Rob Knight is a leading scientist in microbiome research and a key collaborator of the scientific community I follow (Chapter 3).

⁴⁵ I provide an overview of the AGP in Chapter 3 (see section 3.5.1).

⁴⁶ Previously, Knight's Lab was based at the University of Colorado Boulder, before moving to the University of California, San Diego. See Appendix C for certificate of attendance.

laboratory procedures behind the sequencing of microbial DNA data through NGS methods, its digitalisation, and its visual representation through charts and 3D software.

My analysis of the microbiome online community also includes three other virtual spaces—the HFP, BG, and MMG—offshoot microbiome initiatives of the AGP. Anthropologist and popular science writer Jeff Leach’s HFP examines the relationship between diet and microbial diversity. Jeff Leach is also part of Tim Spector’s AGP-affiliated microbiome initiative BG. The difference between the two lies in the provenance of the samples (AGP from North American citizens and/or residents while BG is from British). More recently, Spector started another microbiome endeavour, MMG, a similar initiative to BG and AGP, although its focus is on gut microbiome analysis and interpretation through accredited health professionals, a service that is neither offered by AGP nor BG.

2.4.6 Policy, scientific, and popular science literature critical analysis

- **Science policy documents:** In Chapter 4, I analyse the ‘National bioeconomy blueprint’ (NBB), published in 2012 by The White House; and, to a lesser extent, ‘A new biology for the 21st century’ (NB), published by the US National Academy of Sciences in 2009; and The European Commission’s ‘Innovating for sustainable growth: A bioeconomy for Europe’, published in 2012. I consider these policy reports as valuable data to examine the political and economic motivations behind the emergence of microbes in postgenomic science. I selected these three documents on the basis that microbiome science was initially a US initiative of the NIH starting in 2007, two years before the publication of the NB. Although research on the human microbiome has become global over the years—including ambitious projects in Brazil and China⁴⁷—North America and Europe figure as the main players in the field. Therefore, it is also sensible to include in the policy analysis a document by the European Commission (EC) on bioeconomy and featuring microbial potential, published the same year as its US counterpart (NBB).

Since June 2013, I have compiled information about the microbiome from varied sources. I have classified the information as follows:

⁴⁷ I am referring here to the Brazilian Microbiome Project (BMP) (<https://www.brmicrobiome.org/>) and The Ten Thousand Microbial Genomes Project in China (<https://db.cngb.org/10kp/>).

- **Popular science:** Information from newspapers and popular science books, blogs, and websites on microbiome research and related topics such as AMR. Usual sources are the websites of *The Guardian* (<http://www.theguardian.com/uk/environment/>, sections on health, science, and the environment); *El Pais* (<http://elpais.com/elpais/ciencia.html/>, section on science and technology); and *Popular Science* (<http://www.popsci.com>). I have selected the aforementioned media sources for the quality and reliability of the information and in-depth analysis of scientific issues. I access these websites on a regular, weekly basis. In addition, I focus on the public work of anthropologist Jeff Leach, particularly his 2015 book *Rewild*; microbiologist Martin Blaser's *Missing microbes* (2014a); and geneticist Tim Spector's *Identically different* (2012) and *The diet myth* (2015).
- **Scientific literature:** The basis of the scientific literature I gathered consists of scientific articles of Dominguez-Bello's research team, along with articles authored by her collaborators in scientific journals such as *Nature*, *Science*, *Cell*, *Immunity*, and *American Association for the Advancement of Science*, the *ISME Journal*, and *PLOS Biology*.

I complement the articles published by Dominguez-Bello and her lab members and collaborators with key literature on the microbiome. This body of additional scientific literature has helped me to familiarise myself with the field of human microbiome research and microbial ecology. I selected this literature by gathering reference data at scientific conferences, asking Dominguez-Bello for references, as well as doing basic searches of keywords such as 'microbiome' or 'resistance' on Scopus, a citation database of peer-reviewed literature. Apart from literature on the microbiome, I have also gathered literature on epigenetics and AMR (Chapter 4). Similarly, I use references I collected from scientific conferences and workshops (see Section 2.4.4.1) and basic searches on Scopus. Following my development of 'feminist para-ethnographies of human-microbe relations', the thesis does not dedicate a chapter to an analysis of scientific publications. Rather, I merge it in the text (Chapters, 3, 4, and 5) along with other types of data, such as embodied experiences (Chapters 4 and 5), science policy analysis (Chapter 4), and ethnography (Chapters 3 and 5).

2.4.6.1 *Scribble—Fieldnotes and notational techniques*

During my doctoral programme, I have constantly been taking notes. These notes were of two kinds: based on the gathered data and dismembered thoughts about the research,

its organisation, etc. Together with the field trip diaries (i.e. field notes from the ethnographic fieldwork on microbiome research and scientific conference attendance), these informal notes were archived every month since June 2013 in a new Word document.

As noted by historian of science Hans-Jorg Rheinberger (2010), ‘the generative function of such documents in the overall order of knowledge production has been neglected’ (p. 244). Rheinberger refers to this type of annotation technique as ‘the economy of the scribble’. Despite using that term to refer to knowledge production in the research culture of laboratory science, I suggest that scribbles are equally important for the social sciences and humanities in facilitating ‘condensation and accretion of meanings’ (p. 248).

2.5 Research ethics

2.5.1 Reliability, validity, and generalisability

‘Reliability is concerned with the extent to which research findings are reproducible. Validity is the extent to which the research produces an accurate version of the world.’ And ‘generalizability is the degree to which conclusions are appropriate to similar populations and locations outside of the study area’ (Bloor & Wood, 2006, p. 148). This thesis differentiates itself from positivistic ‘measures of rigour’ (p. 148). I am confident however, that what I refer to as the ‘microbiomisation of social categories of difference’ is generalisable to social and cultural studies of microbiome research. In other words, it is a finding that can be used as a framework for future critical science research on different aspects of microbiome research.

Despite the broad scope of the thesis, its ‘nature’ is particular, situated, and contingent. This thesis is precisely engaged in moving away from natural scientific, Western tendencies, an approach that Donna Haraway (1988) perfectly encapsulates:

Here is the promise of objectivity: a scientific knower seeks the subject position, not of identity, but of objectivity, that is, partial connection. There is no way to ‘be’ simultaneously in all, or wholly in any, of the privileged (i.e., subjugated) positions ... I am arguing for politics and epistemologies of location, positioning, and situating, where partiality and not universality is the condition of being heard to make rational knowledge claims (p. 589).

In an insightful reformulation of Haraway’s ‘situated knowledges’ (1988)—along with feminist theorists Sandra Harding’s concept of ‘standpoint’ (2008) and Sheila Jasanoff’s

co-production (2004)⁴⁸—feminist indigenous studies scholar Kimberly TallBear (2013) develops the concept of ‘feminist objectivity’ (2013). With a similar concern to Harding’s ‘view from women’s lives’ and looking at ‘science from below’ (2008), TallBear sees in the views of women and marginalised peoples ‘in a society stratified by gender, class, race, sexual orientation, and other factors’ the possibilities of producing ‘empirically more accurate and theoretically richer explanations than conventional research that treats the views from some lives and not others as bias’ (p. 24). Concurring with TallBear’s ‘feminist objectivity’, this thesis’s interests are ‘concerned with the lives of women but do not limit their focus to women’, calling out ‘sciences that do not account for their partiality and for representing their views as universal and objective, or value-neutral’ (pp. 22, 24).

2.5.2 Ethical issues and ethnographic fieldwork

Mostly, the ethical issues of the thesis have resulted from the ethnographic fieldwork. As I have already outlined in previous sections, all participants agreed and signed the informed consent form and all semi-structured interviews were recorded digitally. The interviews I conducted in Puerto Rico were in Spanish, while the ones conducted in New York and London were in English. I have been regularly informing my participants about the progress of my research and I have promised to offer them a summary of the research findings and a copy of the thesis once completed.

Presumably, some of the research findings could be interpreted negatively by Dominguez-Bello and her research team. I am particularly referring to my argument derived from the ethnographic fieldwork on the biovalue of DNA data mining of indigenous communities, and the correlation I establish between the production and distribution of (bio)inequalities (Farmer, 1999; Fassin, 2009) and the contemporary focus of biomedicine and so-called ‘New Biology’ on individual health monitoring in high-income countries (Chapter 4 and 5).

While I am deeply indebted to Dominguez-Bello’s generosity in sharing her time and expertise with me, I cannot overlook a reality that was not searched for or anticipated,

⁴⁸ Sheila Jasanoff’s (2004) ‘co-production’ refers to the ‘ways in which we know and represent the world (both nature and society) are inseparable from the ways in which we choose to live in it. Scientific knowledge ... both embeds and is embedded in social practices, identities, norms, conventions, discourses, instruments and institutions’ (pp. 2–3). Sandra Harding’s ‘standpoint’ (2008) calls for the inclusion of the views and experiences of women and marginalised groups in the epistemic and empirical production of science.

but that spontaneously emerged from the ethnographic fieldwork on microbiome research: the microbiomisation of social categories of difference.

2.6 Conclusion

In this chapter, I have explained the methodology and research design of the thesis. I first discussed the cultural anthropology subfield of ‘multispecies ethnography’ (Kirksey & Helmreich, 2010) and outlined its limitations. In multispecies ethnographies, I argued, the richness of the ethnographic detail leaves little to no room for more analytic and less descriptive views. I have demonstrated how the work of several authors brings biome depletion and multispecies ecologies together with capitalist political economy (Haraway, 2016; Tsing, 2015) and examines socio-economic relations in the ‘making’ of interspecies health (Hinchliffe, 2015). The aforementioned perspectives are more attuned to the approach I develop in the thesis. I have then complemented the ethnographic study of human–microbe relations with the use of embodied experiences as feminist research tools.

Contrary to defining what ‘fieldwork’ counts for and to a positivist way of conducting ethnographic fieldwork, in the second part of the chapter I have reformulated Holmes and Marcus’s concept of the para-ethnographic (2008), that is, ‘a way of dealing with contradictions, exceptions, and facts that are fugitive’ (p. 596). In doing so, I have introduced and developed the concept of ‘feminist para-ethnographies’, an intersectional method that entangles embodied experiences with ‘fugitive’ qualitative data in technoscientific claims and quantitative research. In addition, this approach challenges ‘more-than-human’ methods of multispecies ethnography. These first two parts of the chapter were theory-driven and have provided the conceptual methodological rationale of the research design of the thesis.

Subsequently, in the third part of the chapter I have formulated the research design of the thesis using the framework of ‘feminist para-ethnographies of human–microbe relations’. Here, I explained the type of embodied experiences I will be drawing on as well as more conventional forms of data gathering and analysis. I then outlined the details of the exploratory pilot project and the ethnographic fieldwork on human microbiome science I have conducted. This involved semi-structured interviews and conversations with microbiome scientists and immunologists; lab visits and observations; attending international microbiome conferences and meetings; participating in AMR workshops; a digital media analysis of the online microbiome community; and a critical analysis of

microbiome scientific and popular science literature. The last part of the chapter dealt with the research ethics.

CHAPTER 3. Hunting microbes: The microbiomisation of race

3.1 Introduction

In this chapter, I develop what I call the ‘microbiomisation of race’, establishing the basis for the ‘microbiomisation’ of other social categories of difference, particularly of class (Chapter 4) and gender (Chapter 5). I do so by drawing on ethnographic fieldwork with microbial ecologist Maria Gloria Dominguez-Bello and her research team in San Juan (Puerto Rico) and New York (US), interviews with influential microbiome scientists in London (UK), my attendance of microbiome conferences, and an analysis of scientific publications and the microbiome online community.

I begin the chapter with a speculative rumination on the links between Werner Herzog’s *Fitzcarraldo* (1982) and Dominguez-Bello’s expedition to and human microbiome research in the Brazilian and Peruvian Amazon. This semi-fictional vignette allows me to pose questions that transverse social studies of science. Here, neocolonial biomedical practices bring to the surface biographical elements of European imperialism and the colonial history of Latin America. In the second part of the chapter, I provide a detailed ethnographic account of Dominguez-Bello’s research project ‘Microbiomes of Homes across Cultures’ (MHC). MHC’s experimental core is based on the bioprospection of microbes from biodiversity-rich locales and peoples of the Peruvian Amazon. Among the principal aims of MHC is the search for ‘ancient microbes’ as potential solutions for restoring the microbiome of Western and westernised societies.⁴⁹ In the third part, I argue that the bioprospection of microbial ‘populations’ from human and non-human populations is a key element of the process of microbiomisation. As Hinterberger puts it, ‘the population imagination has not faded in the post-genomic era’ (2012a, p. 76). However, the individual dimension of human microbiome science, although sustained by microbial DNA data from human populations through bioprospecting practices, gains meaning through informal online networks of pseudoscientific microbial-related evidence.

⁴⁹ This echoes the turn to indigenous cosmologies (including *Buen Vivir*) to ‘solve’ problems of the Anthropocene. I discuss these debates in relation to the human microbiome and antimicrobial resistance in Chapter 4.

MHC has several online and offline ramifications. In the fourth and last section of the chapter, I follow those online ramifications and examine the para-ethnographic evidence (non-scientific) of the microbiome online community associated with the American Gut Project (AGP) mostly, but also with AGP's affiliated initiatives: the Human Food Project (HFP) and British Gut (BG). Drawing on empirical data from these online microbiome initiatives and material from interviews, I show that the process of microbiomisation not only rests upon (1) the bioprospection of DNA from human and non-human populations, but also, and equally importantly, on (2) the economic, social, and cultural capital of consumers (mostly from Northern, richer nations) of microbiome profiling online platforms such as AGP. I associate this second trend of the process of microbiomisation with what medical anthropologist Didier Fassin calls 'bioinequalities' (2009), a reformulation of the Foucauldian notion of biopolitics and biopower. The concept of bioinequalities is 'not merely a politics of population but is about life and more specifically about inequalities in life' (2009, p. 57; see also Povinelli, 2011).⁵⁰

In summary, through the lens of the 'microbiomisation of race', this chapter establishes the basis of what I call the 'microbiomisation of social categories of difference': a social sciences and humanities conceptual and empirical framework through which to critically examine the repercussions and implications of human microbiome science in society. The microbiome challenges the tenet of a fixed and self-contained human nature by recognising the role of microbes along with environmental and lifestyle factors in the shaping of the immune function. Does this mean that the material-semiotic paradigm of the immune self, or immunity-as-defence (Cohen, 2009), is obsolete? My argument is that, contrary to romantic and uncritical debates in the 'more-than-human' (Braun & Whatmore, 2010) literature (including 'multispecies' approaches) (Hird, 2009; Kirksey & Helmreich, 2010; Lorimer, 2016), microbiome science re-enacts an immunity model of inclusion and exclusion, self and other. I substantiate this by demonstrating that the microbiomisation of race is constituted within a nexus between bioprospection (i.e. population genomic research) and bioinequalities (personalised medicine projects).

⁵⁰ I examine this second dimension of 'microbiomisation' in terms of production and reproduction of structural differences and embodied inequalities in relation to class and gender in Chapters 4 and 5 respectively.

3.2 Explorers

3.2.1 Fitzcarraldo

Sinking comfortably into my office chair, I am doing a google search of Manaus, Brazil. My little knowledge of the capital of the Amazon comes from Werner Herzog's classic 1982 film *Fitzcarraldo*. One of the first images in the film is the Manaus Opera House (Figure 5), otherwise known, more exotically, as the Amazon Theatre. Soon after the sequence of the grandiose Renaissance architecture of the opera house contrasting with a tropical background, the main character, Fitzcarraldo (Klaus Kinski), an Irishman living in Iquitos, appears, rowing a small boat with a dandy look. When the boat approaches the theatre, he impatiently takes the hand of his female companion, Molly (Claudia Cardinale), and, with fervour, cries out 'Caruso!', the surname of the opera tenor Enrico Caruso.



Figure 5. The Manaus Opera House. Source: commons.wikimedia.org.

Herzog's film is an adventure drama based on the historic figure of Carlos Fitzcarrald, a nineteenth-century Peruvian rubber baron notorious for enslaving and exploiting natives as workforce. The film depicts the delirious story of Brian Sweeney 'Fitzcarraldo' Fitzgerald, an enigmatic and eccentric character who dreams of erecting an opera house in Iquitos. In doing so, Fitzcarraldo's plan is to partake in the rubber boom or *ciclo da borracha* (1879–1912).⁵¹

⁵¹ On the historical conditions and political history of Manaus, see Seráfico and Seráfico (2005).



Figure 6. Two still images from the film *Fitzcarraldo* (1982). Left: Amazonian natives pushing the steamship by a pulley system. Right: Fitzcarraldo on top of the mountain that cuts across both rivers.

The Amazon rubber boom was a vital moment in the social and economic history of Brazil. Among other things, it brought on the expansion of European colonisation to diverse areas of the Amazon basin, and with it, the enslavement and torture of hundreds of thousands of indigenous people.⁵² In the aftermath of the Industrial Revolution in Europe, the latex produced by rubber trees⁵³ was a lucrative material. In fact, the Manaus Amazon Theatre itself, built from the fortunes of rubber barons such as Carlos Fitzcarrald, symbolises the legacy of the brutal history behind the early European and North American capitalist economy. In Herzog's *Fitzcarraldo*, however, the main character's involvement in the rubber industry of the epoch has an aesthetic, rather than a monetary purpose. In fact, Fitzcarraldo's ambition of bringing Caruso's tenor voice from the muddy waters of the Amazon river to the city of Iquitos not only touches the aesthetic realm but also divine or spiritual ecstasy. With the financial help of his lover, Fitzcarraldo acquires a 320-tonne old steamship, which will allow him to gain access to an unclaimed rubber parcel between two tributary rivers of the Amazon basin: Ucayali River and Pachitea River.⁵⁴ The film reaches its apotheosis when the colossal steamship is physically pushed by natives over the mountain that separates the two rivers (Figure 6). At the end of the film, Fitzcarraldo does not bring back any rubber to Iquitos and his dream of building an opera house in the city crumbles. Yet, he does fulfil the aim of his delirious expedition, although not exactly as he planned: the old steamship replaces the opera house to perform, live and with Caruso himself, the tenor's repertoire.

⁵² For more information on the Amazon rubber boom, see Lima, C. A. (2002). *Coronel de Barranco*. Manaus: Valer. On its consequences for Amazonian communities, see <http://www.survivalinternational.org/news/7092>.

⁵³ Rubber trees were only found in the Amazon, until the British planted them in South East Asia.

⁵⁴ These two tributary rivers are fictional. The filming of *Fitzcarraldo* involved twenty different locations in Peru and Brazil, especially regions of the Amazon basin, including the main cities of Iquitos and Manaus. For more information, see http://www.imdb.com/title/tt0083946/locations?ref_=ttspec_sa_6.

One month earlier, when I started thinking of Manaus and recalling Herzog's *Fitzcarraldo*, I was at an 'Infectious Disease Genomics & Global Health' conference organised by the Wellcome Trust and held in the Genome Campus in Hinxton (Cambridge, UK) between 16 and 18 October 2013.

3.2.2 The conference: Microbes and transculturation

I am listening to Maria Gloria Dominguez-Bello's lecture about the effects of certain anti-microbial practices associated with Western lifestyles and their detrimental impact on the human microbiome. Dominguez-Bello is a leading microbial ecologist at NYU Langone Medical Center in New York City and the University of Puerto Rico in San Juan. Her research focuses on human host–microbiome interactions in different environments and how these interactions 'drive microbial evolution, diversity and symbiosis' (Maria Gloria Dominguez-Bello's Lab, 2018). In the lecture, she explains that in all mammals, the mother is 'an important source of microbiome constituents'. 'Modern practices' such as 'C-section, which precludes the new-born from obtaining the original inoculum, and further impacts ... exerted via bottle feeding, antibiotics, processed foods, etc. ... disrupt the microbiome transmission and sustainability' (Dominguez-Bello, 2013). Dominguez-Bello suggests that the 'restoration of the lost [microbial] diversity' in Western and westernised populations could potentially come from the 'microbiomes of unimpacted peoples, presumably more similar to our ancestral state'.

Despite the focus of the meeting being on population genomics, genomics of bacterial diseases, epidemiology, and public health, on the last day there was a panel dedicated to the microbiome.⁵⁵ Dominguez-Bello was the co-chair of the session and the first to intervene. I read in the conference programme the title of her paper: 'Genomics and global health in the context of transculturation'.

The word 'transculturation'⁵⁶ immediately caught my attention. It called to my mind the 1947 book *Cuban counterpoint: Tobacco and sugar* by the anthropologist Fernando Ortiz. Influenced by the classic ethnographic writings of Bronislaw Malinowski and against the term 'acculturation'—arguing that it evidences a unidirectional

⁵⁵ For further information on the conference, see https://registration.hinxton.wellcome.ac.uk/display_info.asp?id=358.

⁵⁶ Transculturation is also an interesting concept from the standpoint of the history of botanical transfer. In this sense, Jill Casid's *Sowing Empire* (2004) analyses the formation of colonial, gendered subjects in the plantation system. I provide a genealogy of this word in the context of Dominguez-Bello's study later in the chapter (Section 3.4.1).

acquisition of a culture—Ortiz coined the term ‘transculturation’, alluding to ‘two phases, the loss or uprooting of a culture (“deculturation”) and the creation of a new culture (“neo-culturation”)’ (Coronil, 1995, p. xxvi). He applied the term to the complex colonial reality of Cuba:

There was no more important human factor in the evolution of Cuba than these continuous, radical, contrasting geographic transmigrations, economic and social, of the first settlers, the perennially transitory nature of their objectives, and their unstable life in the land where they were living, in perpetual disharmony with the society from which they drew their living. Men [*sic*], economies, cultures, ambitions were all foreigners here, provisional, changing, ‘birds of passage’ over the country at its cost, against its wishes, and without its approval (Ortiz, 1995, p. 101).

Following Ortiz, such ‘intense’ and ‘complex’ social events, ‘all in a state of transition’, cannot be understood without ‘the most important personages of Cuban history’: sugar and tobacco (1995, p. 103). For Ortiz, sugar and tobacco are not mere commodities, but social actors in the shaping of social identities and colonial and neocolonial narratives of the island (Coronil, 1995, p. xxx). Hence, much earlier than the cultural theorist Zygmunt Bauman popularised the idea of liquidity (2000) as a notion through which to understand the changeable dynamics of modern societies, Ortiz already showed that fluidity, instead of fixity, is an attribute of these non-Western contexts. This is particularly so in the shaping of neocolonial narratives and identities in the Caribbean. In fact, Ortiz’s thought fits with the ethos of contemporary bioscience about the plasticity (Bhandar & Goldberg-Hiller, 2015; Landecker, 2005; Pitts-Taylor, 2010; Sanabria, 2016) and malleability of cells (e.g. epigenetics) and cooperation and co-evolution of life forms (see Introduction).

Curiously enough, if Fitzcarraldo in Herzog’s film navigated through the Peruvian and Brazilian Amazon river in search of rubber as a way through which to bring Caruso’s voice to his hometown in Iquitos, Dominguez-Bello herself and her research team are following a very similar route to the one Fitzcarraldo took through the Amazon basin (see Figure 12 further down in this chapter). They do not seek rubber, however, but the microscopic life of microbes to determine the impact of westernisation on microbial diversity.

Blending the fiction of the film with the factuality of the scientific conference and research serves to pose questions which go beyond science itself. They bring to the surface a colonial historical past which intermittently roots/routes aspects of the documented scientific present. While I could elaborate more on the daydream-like speculative thinking regarding the links between Fitzcarraldo, the delirious colonial

explorer, and Dominguez-Bello, the microbial hunter or the ‘microbial anthropologist’ as she likes to call herself,⁵⁷ my approach is more mundane and ethnographically grounded. I found myself immersed in an ambiguous lexical world in which ‘scientific’ words such as microbiota, microbiome, resistome, and antibiotic-resistant genes (AR) were tangled up with anthropological categories such as ‘transculturation’, ‘unimpacted peoples’, ‘westernisation’, ‘modern practices’ and ‘globalisation’. Was the use of such idiosyncratic rhetoric evidencing something novel in the life sciences, particularly in relation to the traffic between nature and culture? For instance, was the term ‘transculturation’ an occult reference to the anthropologist Fernando Ortiz?; Could microbes be compared to sugar and tobacco and thus be seen through the lens of Ortiz, as both non-human social actors and commodities transforming the collective identities and social history of contemporary societies?; Could Dominguez-Bello be considered as a representative of a new way of approaching biological questions in which culture and emancipation (as a non-Western woman scientist) go in hand? Yet, are there vestiges of the immunological past (i.e. biological fixity, autonomy, and determinism) percolating the new epistemological, ontological, and empirical values of microbiome research?

All these questions intrigued me during and after Dominguez-Bello’s talk. What I gleaned from her intervention at the conference was that her microbiome research is part of a growing body of scientific literature and research at the intersections of immunology, microbiology, and ecology that is reformulating established assumptions about the immune system as a guarantor of self-defence and individuality. The social-biological interplay of her intervention fascinated me. I wanted to know more about her research.

3.2.3 The microbial hunter: Dominguez-Bello

Dominguez-Bello is a key actor in the international human microbiome research. Her research has been published in renowned scientific journals such as *Science*, *Nature*, and the *Journal of Clinical Microbiology*. She is an extremely busy scientist. In addition to her academic appointments as a Professor at the University of Puerto Rico and Associate Professor in the Division of Translational Medicine in the Department of Medicine at the NYU Langone Medical Center, she has recently signed a longed for contract with the Venezuelan Institute for Scientific Research (IVIC), and started a collaborative research project on the microbiome of newborns in Guayaquil (Ecuador). In addition, she is a

⁵⁷ In 2016, Dominguez-Bello published a personal written piece in the scientific journal *Cell*, entitled ‘A microbial anthropologist in the jungle’ (pp. 588–594). I will discuss this piece later in the chapter.

founding and advisory member of the crowdfunded, personalised microbiome project American Gut (see Section 3.5) and also sits on the scientific advisory board of the American Microbiome Institute (AMI). Beyond the scientific world of microbiome research, her work is generating remarkable media attention. The numerous interviews she has given to diverse media in different countries—such as the international television channel NTN24, BBC News (Collen, 2015), *The Guardian* (Molloy, 2015), and *El Pais* (Criado, 2015), together with the Smithsonian Channel’s documentary *Aliens inside us* (Cohen, 2013) on her microbiome expedition in the Peruvian Amazon—are only a handful of the many examples evidencing the repercussion of her research in non-specialist contexts.



Figure 7. Left: still image from the short clip *The healthy truth about traditional childbirth* (2013), The Smithsonian Channel, May [online]. Retrieved from <http://www.smithsonianmag.com/science-nature/microbes-the-trillions-of-creatures-governing-your-health-37413457/>. Right: still image from the NTN24 Channel interview ‘El microbioma intestinal’, YouTube video [online] added by Luís Quevedo. Retrieved from <https://www.youtube.com/watch?v=48Aij--mqCs>.

Following the Wellcome Trust conference in October 2013, I established initial (electronic) contact with Dominguez-Bello, expressing my interest in conducting ethnographic fieldwork on her microbiome research. Soon after, unexpectedly, she invited me to take part in the next expedition she and her research team were organising to Manaus (Brazil), between 8 and 19 December 2013. There, they would be conducting microbial DNA sampling of surfaces, house objects, and the skin of humans and non-human animal inhabitants of ten modern apartments. The DNA data gathering that Dominguez-Bello’s research team would perform in Manaus is part of a larger innovative research project entitled ‘Microbiomes of Homes across Cultures’ (MHC), funded by the Sloan Foundation Programme ‘Microbiology of the Built Environment’. Sadly, due to financial constraints (the flights and hotel would have cost over £4,000), I could not join the scientific team in Manaus. I was lucky that Dominguez-Bello proposed to me, as an alternative, to visit her laboratory at the University of Puerto Rico, Río Piedras Campus (UPR-RP), in San Juan.

Because of the aftermath of Hurricane Sandy at NYU, she suggested I visit her at the UPR-RP. Hurricane Sandy severely affected her lab facilities at NYU and, more than one year after Sandy hit New York at the end of October 2012, some of the offices and labs were not fully operative, still suffering important and expensive losses in research equipment and material.

At the UPR-RP, she planned to introduce me to her graduate students and collaborators working on two research lines: (1) how modern practices associated with Western lifestyles (i.e. antibiotics, caesarean section, processed food) impact the microbiome in relation to the microbiome of indigenous societies; (2) how modes of delivery (vaginal versus caesarean section) alters the microbiome of newborns (Chapter 5).

3.2.4 Puerto Rico and ‘la upi’

The archipelago of Puerto Rico lies in the north-eastern Caribbean (Figure 8). Puerto Rico is the fourth largest island in the Caribbean after Cuba, the Dominican Republic, and Haiti and Jamaica. Its territory also includes three other small islands: Vieques, Mona, and Culebra. According to the latest US federal census, Puerto Rico has over three million five hundred thousand inhabitants. The total area of the island is 3,435 square miles (9,000 square kilometres). It has a mountainous interior surrounded by a wide coastal plain, where most of the population lives. Puerto Rico is in the tropics. Temperatures do not change drastically during the year, averaging 23°C in winter and 27°C in summer. The main languages are Spanish (official) and English, although the former is used predominantly.



Figure 8. Puerto Rico Island. Source: https://en.wikipedia.org/wiki/Puerto_Rico#/media/File:Rico_%281%29.png.

Weeks before flying to San Juan, I conducted an online search of travel recommendations. However, the political status of Puerto Rico, officially the Commonwealth of Puerto Rico, also known as the 'Free Associated State of Puerto Rico', complicated my search. The island, currently and since 1952 an 'unincorporated territory' within the US, 'became colonial in 1509, and has never been politically independent' (Mintz, 2010, p. 5). Puerto Rico, writes the anthropologist Sidney Mintz, 'is both a new colony and an old one' (p. 35).

First settled by Spain in 1508, Puerto Rico became a prize of war in 1898. Though it has since experienced several transitions, it remains firmly attached to the United States. Its people are United States citizens, though they cannot exercise all of a citizen's rights when living in Puerto Rico itself (Mintz, 2010, p. 35).

Because of this historico-political circumstance, it is difficult to find travel advice on the island per se, as this is usually absorbed into information about the US. The scarce yet relevant facts on health I did retrieve from the Internet reinforce an immuno-logic of travelling in the context of non-Western tropical geographies. As occurs in several regions of Latin America, dengue fever and chikungunya virus are the major non-preventable risks in Puerto Rico.⁵⁸ Moreover, schistosomiasis is endemic to parts of the island. Schistosomiasis is one of the deadliest parasitic neglected tropical diseases (NTD),⁵⁹ transmitted by contact with infected fresh water (rivers, lakes, ponds) inhabited by snails carrying one of the five varieties of the parasite. Interestingly, schistosomiasis embodies Puerto Rico's colonial past. The parasite 'came to Puerto Rico with the slave trade' and it increased as 'the change from a coffee economy ... to sugarcane cultivation' took place at the end of the nineteenth century (Berry-Cabán, 2013, p. 1). Yet, despite these endemic diseases being prevalent, the 'exceptional' political status of Puerto Rico as a US territory (especially when compared to other regions of the American continent, such as jungle areas or locales in close proximity to the Amazon like Manaus) moderates what Priscilla Wald calls the 'outbreak narrative' (2008).⁶⁰ As Wald points out, 'contagion is more than an epidemiological fact', since it also explains 'how beliefs circulate in social interactions' (p. 2).

⁵⁸ In December 2013, there was a chikungunya outbreak in the Caribbean, which continues today. For more detail on the chikungunya virus in the Caribbean, see National Travel Health Center and Network (2015).

⁵⁹ The World Health Organisation (WHO) defines neglected tropical diseases (NTD) as 'a diverse group of diseases with distinct characteristics that thrive mainly among the poorest populations' (WHO, 2015a). Schistosomiasis mostly affects the African continent and some parts of Venezuela, Brazil, and Puerto Rico. For more information on the disease, see WHO (2015b).

⁶⁰ I will return to Wald's notion of the 'outbreak narrative' in Chapter 4, in relation to the apocalyptic official discourse around antimicrobial resistance (AMR).

3.2.4.1 *Convergences*

General information about a country often includes demographic data on the population distribution, emigration and immigration, and population genomics. The World Directory of Minorities and Indigenous Peoples' website reports that population genomics studies have concluded that 'the three largest components of the Puerto Rican genetic profile are in fact indigenous Taino, European, and African with an estimated 62 per cent of the population having an indigenous female ancestor' (World Directory of Minorities and Indigenous Peoples, 2005). The website adds that this biogenetic information on ancestry contrasts with the fact that 'the majority of Puerto Ricans regard themselves as being of mixed Spanish-European descent'. But beyond kinship merely understood as biogenetic knowledge and identity or, in other words, as consanguinity and procreation, the historical past of the island, shaped by Spanish colonialism, further reveals the co-implications and connections between knowledge and responsibility. In this sense, the colonial history of Puerto Rico, along with the convergent genealogical stories between Dominguez-Bello and me, figure as a ghostly background to my fieldwork.⁶¹ This being related through descent (i.e. kinship) with Latin America as epicentre of our biographies brought to the surface European imperialism and colonialism, but, at the same time, it provided a source of access and contributed to the establishment of trust with Dominguez-Bello, as discussed in Chapter 2.

3.2.4.2 *La upi*

The UPR-RP, known by locals, students, and university workers alike as 'la upi', is the main public research university on the island, with more than eighteen thousand students (see Figure 9).

⁶¹ I elaborate on this in Chapter 2, section 2.4.1.2.



Figure 9. Map of San Juan, the capital of Puerto Rico. In red circles: on the right the International Luís Muñoz Marín Airport and on the left UPR-RP. Source: http://graduados.uprrp.edu/images/img/mapa_san_juan.jpg.

The campus was built in the beginning of the twentieth century, and the first thing I recognised when we entered it was the emblematic clock tower, *la torre*, the landmark of the university (see Figure 10). Dominguez-Bello’s lab is located at the Faculty of Biology. Approaching the entrance of her lab, I distinguish three persons: two young women—one of them holding a baby, the other in the last trimester of pregnancy—and a young man pushing a buggy. Dominguez-Bello walks towards them effusively; they are some of her students: Jean Ruiz Calderon (‘Gina’, now Dr.), Kassandra de Jesus, and Carlos Lopez Ortiz. Ruiz Calderon’s six-month-old baby seems to recognise Dominguez-Bello, who affectionately refers to her as her ‘first grandchild’. Their intimacy surprises me. Dominguez-Bello’s role looks like that of a caring academic mentor who everyone admires.



Figure 10. On the top: left, the clock tower of the UPR, partially hidden by a palm tree. Right, entrance to the Faculty of Biology. On the bottom: left, entrance to the Biology Research Centre. Right, door of Dominguez-Bello's microbial ecology laboratory. Photos by the author.

Since she obtained an Assistant Professor position at the NYU Langone Medical Centre in 2013, she travels to the UPR once per month, usually at the end of the month, to supervise undergraduate, graduate, and research students and meet with some of her collaborators based in San Juan. Apart from Ruiz Calderon, a biologist conducting her doctoral studies on the MHC project, Kassandra, a graduate student working on the microbiome of newborns, and Carlos, undergraduate in medicine and research assistant on various of Dominguez Bello's research projects, there are three more students at the lab: Selena Rodriguez and Bryan Rios Nieves are both undergraduates in medicine and research assistants on several microbiome projects, and Daniela Vargas Robles is a doctoral researcher currently conducting fieldwork in Puerto Ayacucho (Venezuela) on the correlation between the high prevalence of cervical cancer in indigenous women and the human papillomavirus (HPV) (see Figure 11).

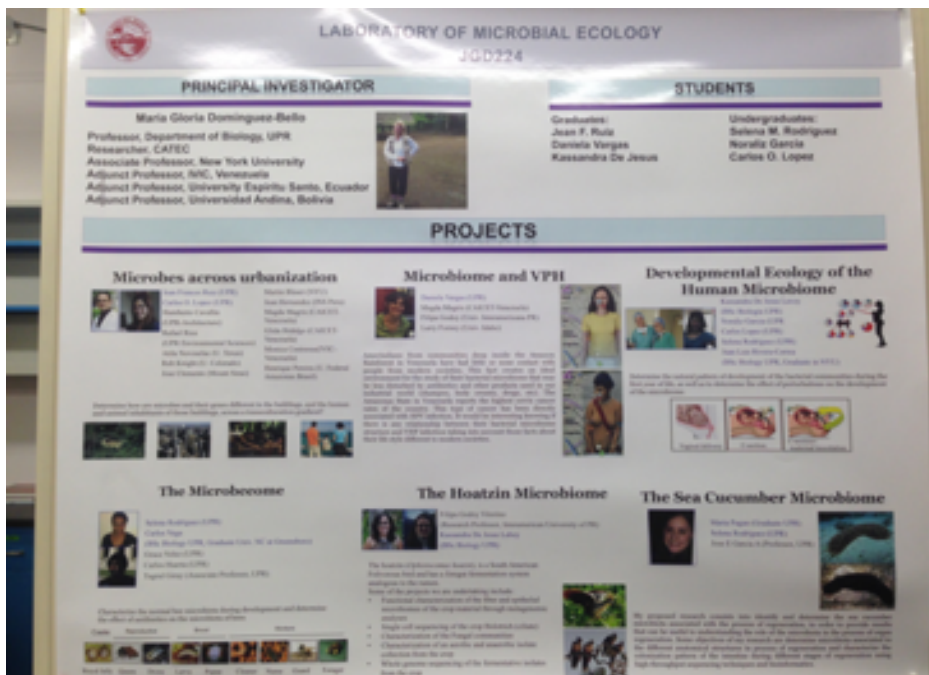


Figure 11. Poster showing the six different projects at Dominguez-Bello’s lab: Microbiome across Urbanization (or ‘Microbiomes of Homes across Cultures’, MHC); Microbiome and HPV; Developmental Ecology of Human Microbiome; The Microbecome (bee microbiota); The Hoatzin Microbiome; The Sea Cucumber Microbiome. Photo by the author.

3.3 Microbiomes of Homes across Cultures

Dearest Father Luigi,

We returned from our trip at the end of August and every week I thought about writing to you! How are you? I hope you are as well as when we left. I’m sending you pictures of you and us. This is a long letter because I have a lot to tell you as well as to ask about. So, I divide it into sections.

I’m sending you paper and pens, a notebook, and a book about New York (where I am living now), which contrasts so much with the pristine environment where you live ... these are the contrasts that take away my sleep, what is between Checherta and New York, and what is the significance of those differences.

Personal correspondence of Maria Gloria Dominguez-Bello with Father Luigi Bola, 6 October 2012, my translation

Father Luigi Bola, known as ‘Yankuam Jintia’ in Achuar, is a Catholic missionary from the Salesian Congregation in Peru. “Luigi was the main gatekeeper of the Achuar community of Checherta (Peru), where he spent forty years before he died in Spring 2015, and was a valuable informant of Dominguez-Bello there. The above excerpt is from a letter Dominguez-Bello sent to Father Luigi in October 2012. In the letter, Dominguez-Bello enclosed a twenty-six-questions questionnaire touching on issues of child mortality, breastfeeding, fertility, longevity, and diet in Checherta. Two months earlier, Father Luigi

and Dominguez-Bello met for the first time in Checherta, where she and her research team gathered microbial, architectural, and environmental samples as part of the MHC project. Dominguez-Bello's emphasis in the letter on the high contrast between Checherta and New York encapsulates the main aim of the MHC project: 'To characterise the microbiome in multiple body sites across a gradient of urbanisation within the same latitude, from a hunter-gatherer community to a developed urban city' (Ruiz-Calderon, 2015, p. 37).

MHC is an Alfred P. Sloan Foundation⁶²-funded interdisciplinary microbiome research project on the changes in the human microbiome in relation to the evolution of lifestyles. MHC officially started in January 2012 and lasted until January 2014. All the data and metadata⁶³ gathered has already been analysed and partially published in several scientific publications and media news articles (see next section). The total budget of the research was approximately \$600,000. As stated in the proposal, the objective of the project was to 'determine how are microbes and their genes different in the buildings, and the human and animal inhabitants of those buildings, across a transculturation gradient from a remote jungle village with indigenous populations (Checherta) to rural settings (Puerto Almendras), mid-size cities (Iquitos) to a modern metropolis (Manaus)' (Dominguez-Bello, 2013, see also Figure 12).

⁶² The Alfred P. Sloan Foundation is a not-for-profit institution based in New York City. 'Established in 1934 by Alfred Pritchard Sloan Jr., then-President and Chief Executive Officer of the General Motors Corporation, the Foundation makes grants in support of original research and education in science, technology, engineering, mathematics and economic performance.' Further details available at <http://www.sloan.org/>.

⁶³ The word 'metadata' refers to 'a set of data that describes and gives information about other data' (Oxford Dictionary: Oxford University Press, 2014).



Figure 12. Google Earth still images showing the four locations at the same latitude of the Peruvian and Brazilian Amazon where Dominguez-Bello and her research team sampled microbial DNA. From West to East (in a gradient of transculturation—less to more westernised): huts of isolated Achuar villages (Checherta); rural settlement of an Amerindian-mestizo town (Puerto Almendros), mestizo cities (Iquitos), and mestizo modern buildings (Manaus).

MHC is part of the emerging interdisciplinary area in the study of human–microbe entanglements in human constructed environments known as ‘microbiology (also “microbiomes”) of the built environment’. This field encompasses studies of microorganisms and various types of built environment, including houses, vehicles, hospitals, water systems, and clothing. It is therefore an interdisciplinary area of study and expertise. Biologists collaborate with architects, designers, and doctors. More recently, particularly in relation to AMR and the built environment (mainly hospitals and operating theatres), humanities and social sciences scholars are collaborating with scientists, designers, and architects to reimagine ways in which building design, technologies, processes, and behaviours lessen the dependency on antibiotics (Chapter 4). MHC’s sponsor, the Sloan Foundation, has been the principal funding body of this field, although its growing importance is also attracting more funding. As Dominguez-Bello insists, humans spend most of their time in indoor environments—especially in Western (and I would add Northern) societies—and building design determines microbiological communities. Hence, microbiome initiatives studying indoor and built environments bridging architecture, design, sociology, ecology, and microbiology, for instance, can potentially mitigate nosocomial⁶⁴ diseases and bacterial infections, as well as improve the air quality of homes and public transport systems, for example.

⁶⁴ The adjective ‘nosocomial’ refers to a disease originating in a hospital.

The expedition is meant to develop Dominguez-Bello's main thesis, and her objective is to investigate whether the built environments (i.e. open-air huts) of Checherta—along with their inhabitants' diet (non-processed food) and lack of exposure to antibiotics—correlate with a more diverse composition of their human microbiome as well as their environmental microbes. The principal contention of Dominguez-Bello is that 'modern lifestyle has led to changes in microbial patterns in humans and their environments, with reduced microbial diversity ... [producing] profound changes transmitted by descent, and perpetuated in future generations' (2012). Besides Western lifestyle practices and trends associated with diet, modes of delivery at birth (Dominguez-Bello et al., 2010a), or antibiotic usage (Bisgaard et al., 2011), the MHC project is exploring changes in the pattern and composition of microbiota associated with the quantity of time spent indoors and the lack of 'natural' ventilation of modern architectural designs (Dominguez-Bello, 2012, p. 3). In indoor environments, 'humans are exposed to surfaces with a bacterial content that reflects the space and object uses' and they 'also shed microbes to the environment, and ventilation greatly affects microbial transmission by aerosol, which is of special interest in hospital design' (p. 3) Dominguez-Bello argues that both 'the microbiome and environmental microbes need to be viewed as an entity integrated in their physical and biological dimension to fully assess the impact of modernisation on human biology' (p. 3).

3.3.1 The expedition

The first day is for greetings, explanations, presentations in a formal way, with the community council or the whole community. Our team leader, a national of the country, first introduces the team, and then we introduce ourselves. We tell them what we want. They are familiar with intestinal worms, some of which are visible. We explain that there is tiny life smaller than worms—microbios in Spanish and Portuguese—in the intestine, mouth, skin, vagina—a few bad ones and mostly good ones—and that we still don't understand their function. We let them know that traditional peoples like them seem to have a more diverse set of microbes than we do, and that we want to understand why (Dominguez-Bello, 2016, p. 589).

Dominguez-Bello and Ruiz-Calderon tell me about the fascinating expedition they endured back in the summer of 2012. The first locality they visited was the jungle hunter-gatherer community of Checherta (Peru), with approximately three hundred inhabitants. Checherta is an 'isolated' Achuar Amerindian community without drinking water or electric services, accessible only by taking an aeroplane to a jungle strip in Nuevo Andoas (Peru), plus a two-day boat trip towards the border with Ecuador. On one boat, there were Dominguez-Bello, Ruiz-Calderon, and the rest of the team members: Humberto Cavallin

(architect, UPR-RP); Atila Novoselac (environmental engineer, University of Texas at Austin); Oscar Noya-Alarcon, MD and public health researcher at the Amazonian Centre for Research and Control of Tropical Diseases (CAICET), Puerto Ayacucho, Venezuela); and Professor Martin J. Blaser (MD and director of the NYU Human Microbiome Programme, NYU Langone Medical Centre). In addition, they were joined by a filming crew (camera and sound engineer) from the Smithsonian Channel. On the second boat, they brought the scientific and filming equipment along with food, medicines, and a few personal belongings.

Arriving at the canoe port, locals, especially children, ran towards the team. The community had previously approved their visit through the mediation of a local interpreter and Father Luigi, who negotiated the details of the visit with the *Apu* (chief). But because this was a first-time visit, they had to wait several hours outside the village. The Checherta community distrusts foreigners. The Achuar and other Peruvian and Brazilian indigenous communities have been fighting against oil companies, defending their land and environment for decades. Over the past four decades, oil companies have been hiding contaminants, spilling oil, and dumping barrels of toxic products in Peru's northern Amazon. These criminal practices have created an unprecedented health and environmental crisis, especially in the northern Amazon.⁶⁵ Checherta has not been as badly affected by industrial and petroleum operations as other Peruvian communities, such as Samurillo or Nuevo Andoas.

Dominguez-Bello talks about Checherta as an 'uncontacted' indigenous community. However, missionaries like Father Luigi made their way to Checherta and other previously uncontacted Amerindian tribes over the years. She argues that, although Father Luigi has been living with the Checherta peoples and other Achuar communities for forty years, Checherta is a valid population for her microbiome research. They have 'never confronted antibiotics, touched antibacterial soaps, or breathed conditioned air; as a result, their microbiomes are relatively pristine' (M. G. Dominguez-Bello, personal communication, January 28, 2014). She wants to study the differences in the microbial community between people living 'ancestral' lifestyles and Western lifestyles. As she explains to me:

⁶⁵ This *Guardian* article provides a complete overview of the disaster: <https://www.theguardian.com/environment/andes-to-the-amazon/2017/aug/03/us1-billion-oil-perus-amazon>.

While our ancestors are no longer there, and studying their remains has important limitations, we can alternately study indigenous or African hunter-gatherers. These are cultures close to those of our ancestors, and we can compare them with urban lifestyles, because both are contemporary (M. G. Dominguez-Bello, personal communication, January 28, 2014).

Hence, while I will return to this central theme later in the chapter, I want to highlight that, in Dominguez-Bello's project, the microbiomisation of race starts at the very beginning: with the project itself. In other words, it is co-produced with scientific lines of inquiry about microbial diversity.



Figure 13. Microbiologists Maria Gloria Dominguez-Bello and Martin Blaser gathering microbial DNA samples in a hut in Checherta in 2013. Photo courtesy of Dominguez-Bello.

Once they got access to Checherta, Dominguez-Bello and her team took DNA samples from surfaces of objects, floors and walls, and humans (skin, nose, mouth, and anal swabs) and animals. After the team collected DNA samples with sterile cotton swabs, these were immediately stored in liquid nitrogen (-80°C), and kept frozen until the team extracted DNA in the lab (see next section). The idea is that combining microbiological with architectural (e.g. room area, windows, and doors per room, sample height) and environmental measurements (relative humidity, temperature, light, air exchange rate, wind speed, ultrafine air particles, CO , CO_2), the researchers can determine the composition and geography of microbes and how we are changing them in the West. Prior to the expedition, Dominguez selected ten homes (or 'huts' in the case of Checherta) per four communities at the same latitude in the Amazon basin, with different degrees of urbanisation: Checherta (jungle), Puerto Almendras (rural), Iquitos (town), and Manaus (city) (see Figure 14).



Figure 14. The four different types of housing architecture across the ‘transculturation gradient’. Courtesy of Jean Ruiz-Calderon.

The lifestyle and habits of the Checherta are very different from those in Western or westernised towns or cities, Dominguez-Bello and Ruiz-Calderon tell me passionately. They live in open huts (twenty-one) made of natural materials (wood and reed). The huts are single open-plan spaces, with two functional areas: a dormitory (for all the family) and a fire area for cooking and socialising. Apart from vaginal birth, breastfeeding until the babies are 2 years old, and a plant-rich diet, the Checherta community has natural light and ventilation, and close contact with animals. From when they are around 10 or 11 years old, members of the community practice a ritual known as ‘wayusear’, in which they consume a leaf-infused tea (Wayusa tea) that induces vomiting. The community ‘wayusear’ every morning as a body-cleaning ritual. In addition, they consume masato, a pre-Columbian traditional beverage prepared with yucca and served in different degrees of fermentation. Masato is consumed daily by men and less frequently by women and children from seven months of age. The ritual of ‘wayusear’, together with the consumption of masato, Dominguez-Bello suspects, also have an effect on the microbial diversity.

After three days with the Checherta community, during which all the scientists slept in hammocks, they travelled to Puerto Almendras by boat and by road. Puerto Almendras is a rural town with around two hundred inhabitants, with a water reservoir, some family water tanks, electricity, and a healthcare centre. The houses have external walls, made of natural and industrial materials. The majority of the houses are not internally subdivided. The team spent four days in Puerto Almendras with a local family, before travelling to the next location, Iquitos, approximately an hour’s drive West.

The town of Iquitos, known as the ‘capital of the Peruvian Amazon’, with circa 371,000 inhabitants, is the largest town in the world without road access. Iquitos has an airport, tap water, electricity, road infrastructure, and commercial activity. After spending six days collecting DNA, architectural, and environmental samples from ten families, the team came back to the US from where they had flown to Peru together.

Months later, in December 2013, Dominguez-Bello organised the last expedition to Manaus, the final location of the MHC project. If Iquitos is the ‘capital of the Peruvian Amazon’, Manaus is the ‘capital of the Brazilian Amazon’. Manaus is a cosmopolitan city of 1.8 million inhabitants, with an international airport, a major river harbour, and industries. It was hard for the scientific team to recruit participants for the microbiome study. Unlike the Peruvian locations of the study, socio-economic (SE) differences in Manaus are staggering (Ruiz-Calderon et al., 2016). They decided to limit the samples to middle class families, although they also took samples from low and high socio-economic profiles for future research. Despite their efforts and collaboration with a scientist from the Federal University of Amazonas (UFAM), they could only get sixteen participants in Manaus, while in Checherta, the participants were twenty-seven, in Puerto Almendras twenty-one, and in Iquitos twenty-six. After nine days in Manaus, they came back to the US, concluding their fieldwork.

3.3.2 Deciphering diversity: Ghost labs

I was perplexed the first time I entered Dominguez-Bello’s laboratory at the Faculty of Biology of the UPR-RP. It looked like a storage site. The gas chamber was used to pile emptied boxes. There were posters of past projects that took place, hung on the walls. Scientists were working on their laptops. The scene was the antithesis of what I was expecting to find and of what I was used to as a laboratory worker during my undergraduate years. I used to do experiments in immunology and molecular anthropology laboratories. These were organised spaces, full of bakery, Petri dishes, microscopes, fume hoods, refrigerators... with the sound of centrifuges in the background. Here, they were not manipulating DNA or any other bio-object (Vermeulen et al., 2012). Furthermore, the outfits of the scientists did not make it obvious that they were biology and medical students. None of them wore coats. Neither gloves. They could be taken for social or computer scientists (see Figure 15).



Figure 15. The lab as storage. Dominguez-Bello's laboratory at the University of Puerto Rico. Photos by the author.

3.3.2.1 *Metagenomics*

Dominguez-Bello and her team's empirical work is not conducted in a biology laboratory in a conventional way. Their microbial research, as mine, is multi-sited. One of the most important stages of microbiome research is the gathering of microbial samples. And, unlike classical microbiology, in which microbes were cultured in Petri dishes and so the work was purely done at the benches, the study of microbiomes is conducted in the natural environment in which microbes reside (which is literally everywhere). This approach is known as 'metagenomics'. 'Metagenomics', also called 'ecogenomics' or 'environmental genomics', refers to 'the study of genetic material directly extracted from an environmental sample' (Rhodes et al., 2013, pp. 35–36), including various parts of the human and animal bodies such as the gut, mouth, and so on, but also soil, the solid surfaces of a house, trees, etc. Culture-independent analysis of microbiomes using a metagenomics approach has revealed an overwhelming microbial diversity in natural environments such as lakes, as well as in and on the bodies of humans and non-human

animals. Traditional methods in microbiology, which primarily consist of cultivating cloned cultures, were not able to disclose the vast array of trillions of different microbial communities that populate our planet, the living and the non-living, the organic mostly, but also the inorganic. Sequencing the entire DNA of a microbial community taken directly from the environment to identify species present in the human body or in a body of water, for instance, is technically possible through methods of DNA sequencing or high-throughput sequencing (HTS) technologies, also known as ‘second -generation’ or ‘next-generation’ sequencing (NGS). The metagenomics approach is about identifying ‘communities’ of microbes (i.e. populations of bacteria) through the DNA, rather than individual bacterial ‘colonies’.

3.3.2.2 *High-throughput sequencing*

Shortly after the human genome was sequenced and completely in draft in 2001, the US National Human Genome Research Institute (NHGRI) invested \$70 million in DNA sequencing technology initiatives, which resulted in the meteoric emergence of different high-throughput sequencing (HTS) platforms (Reuter, Spacek, & Snyder, 2015). HTS methods are technologies that ‘parallelize the sequencing process, producing thousands or millions of sequences concurrently’ (Church, 2006). ‘Next-generation high throughput sequencing technologies became available at the onset of the 21st century. They are continually improved to become faster, more efficient and cheaper’ (Barba, Czosnek, & Hadidi, 2014, p. 106). Importantly, HTS methods have made large-scale metagenomic studies possible and are currently revolutionising biomedical and bioinformatics research due to the significant advantages they offer in comparison to culture-based methods (i.e. Petri dishes with microbes laboriously cultivated in a laboratory): they are much cheaper (and becoming even more so); they produce thousands or millions of times more sequence data; and they do not require a cloning step (PCR: polymerase chain reaction) (Rhodes et al., 2013, p. 36). The use of HTS, apart from microbiome sequencing, includes mapping regulatory information and the 3D organisation of the genome, cancer genome sequencing, and genome sequencing of rare diseases (Rhodes et al., 2013). Biomedical consortia-based projects—such as the Human Microbiome Project (HMP), the Roadmap Epigenomics Project, the 1000 Genomes Project, and the Human Immunology Project Consortium—use HTS for cataloguing, characterising, and describing genomic data associated with human health and disease (Rhodes et al., 2013). There are several

commercially available HTS technology. Dominguez-Bello uses the most common one, Illumina.

In the classic *Making PCR: A story of biotechnology* (1996a), anthropologist of science Paul Rabinow cogently showed how biotechnology is an industry that emerged in the early 1980s. In the book, Rabinow ‘examines “the style of life” or form of “life regulation” fashioned by the young scientists who chose to work in this new industry rather than pursue promising careers in the university world’ (1996a, p. 2). Examining the invention of PCR,⁶⁶ Rabinow argues that it is ‘a tool that has the power to create new situations for its use and new subjects to use it’, which has reshaped ‘the practices and potentials of molecular biology through vastly extending the capacity to identify and manipulate genetic material’ (pp. 2, 7). Two decades after the ‘making of PCR’, HTS is the new way of deciphering genetic material. It is more efficient, cheaper, and faster than PCR. HTS, as I have shown earlier, is transforming the biosciences, producing new avenues of research at the intersections of biotechnology, genomics, and big data science. Ruth McNally and Adrian Mackenzie note that:

The availability of NGS [HTS, ANC] data is catapulting sequence data to the forefront of biological experimentation, where it is used to address questions about gene function and regulation, explore genome diversity, and study gene-environment interaction. As a result, biological, biomedical and environmental research are converging on genome sequence data as the main data type (2012, p. 83).

As McNally and Mackenzie suggest, genome sequence data is the main data type of today’s biomedicine. Similarly, anthropologist Amber Benezra has recently shown how ‘microbial functions are datafied through metagenomics and how subsequently, microbiome data is connected to the diets, health and lives of humans’ (2016, p. 4).

I would go further to argue that large-scale, data-driven genomic projects such as the HMP, as well as small-scale ones such as Dominguez-Bello’s MHC, entail a different way of making science, of producing scientific knowledge. Following Rabinow’s analysis of PCR, I suggest that HTS, as PCR did back in 1980s, has the potential of creating ‘new situations for its use and new subjects to use it’ (1996a, p. 2). This is not to say that human microbiome science is just a product of technological development. The human microbiome emerged at the intersections of technological development, scientific practice, and several Euro-American policy-led strategic plans on bioeconomy (Chapter

⁶⁶ PCR is the acronym for polymerase chain reaction, which since the 1980s is the most widely used technique in molecular biology to replicate segments of DNA.

4). Distancing myself from technical determinisms, I argue that data-driven microbiome science inaugurates a new regime of visibility of microbes (Latour, 1988), together with a new microbiology research culture in which the dominant approach is based on comparative population genomics,⁶⁷ an argument I will develop in the next section of the chapter.

Yet, this new way of accounting for microbial communities has important limitations, and so it is the subject of controversies in microbiome science. The scientific literature highlights that these limitations mostly have to do with the complex management of large datasets or ‘big data’ produced, the insufficient scope of visualisation software, and the strong demand for bioinformaticians specialised in HTS and able to develop new methods for retrieving biological data and conducting data analysis (H. Saadeh, personal communication, April 15, 2013). In addition, HTS lacks accuracy across the genome (Ross et al., 2013) and the technology cannot be integrated into the clinic (i.e. translational research) because of the ‘cost and the timescales associated with storage and interpretation of genome data’ (Reuter et al., 2015, p. 594). This is an important drawback, because data-driven microbiome science is cataloguing microbial variation in humans with the main goal of rapid translational outcomes in the form, for example, of probiotics, prebiotics, and synbiotics (i.e. a combination of probiotics and prebiotics) (Benezra, 2016).

Beyond these documented limitations of HTS, some scientists argue that the current methods of microbiome analysis miss a great number of microbial species, jeopardising the reliability of microbiota data and data analysis.⁶⁸ In an interview, Graham Rook, immunologist and medical microbiologist at University College London (UCL), summarised the methods of study of the microbiome as follows:

They used methods normally used for soil organisms, which means to say they took DNA swabs and they beat it up with mechanical means, and they boiled it and then they beat it up again, then they put in enzymes and they boiled it and they beat it. I mean, they really bashed it around (G. Rook, personal communication, April 21, 2017).

According to Rook, the mechanical and technical means used in metagenomics wipe out a huge amount of relevant microbial data. For example, the stomach lumen of mammals is very rich in spore-forming environmental microbes. However, as Rook notes, HTS

⁶⁷ See the next section for a further discussion of population genomics.

⁶⁸ I will return to Rook’s criticism of microbial data analysis later in the chapter, in relation to the American Gut Project (AGP).

methods do not pick up spore-forming microorganisms. This is an important limitation for microbiome research, especially for studies that, like Dominguez-Bello's MHC, focus on the interplay between the human and environmental microbiomes. Rook's point is very remarkable, because there is hardly any criticism with regard to microbiome methods of analysis among the human microbiome scientific community, as he repeatedly complained (G. Rook, personal communication, April 21, 2017).

3.3.3 The transnational traffic of microbial DNA

Microbiome projects such as MHC are increasingly collaborative and multi-sited. The multi-sitedness of microbiome science is partly conditioned by the varied expertise that interdisciplinary projects like MHC need, and partly because of the maintenance cost of HTS and the space these machines require. Following sociologist of science Amy Hinterberger's argument in relation to the scientific practice of human genome science, I suggest that the 'laboratory is only one of many places' where human microbiome science 'accrues value, meaning and relevance' (2012a, p. 72). Assumptions about social categories, microbes, the environment in which microbes reside, the nation state, human and non-human bodies, online platforms, along with DNA, metagenomic data, and HTS, constitute this field of research. The scientific configuration of the human microbiome is thereby constituted within a circulation between different research sites and labs, between exchanges of DNA microbial material and gene sequences. A circulation between flesh and information (Rosengarten, 2009; see also Mitchell & Thurtle, 2004). Ruiz Calderon, the doctoral researcher of the MHC project, helped me make sense of this new assemblage of contemporary biological research.

During the MHC project, scientists first collected the microbial DNA samples from humans, non-humans (including pets and objects), and homes. They collected skin, nose, mouth, and anal swabs from ninety-four humans (thirty-seven men and fifty-three females) (Ruiz-Calderon, 2015, p. 37). They took microbial samples from the floors and walls of the living rooms, kitchens, bedrooms, and bathrooms of each household (forty in total, ten per location). Immediately after the collection, they stored the swabs in liquid nitrogen (-80°C). The team brought with them a questionnaire to collect additional information or 'metadata', including anthropometric and dietary information, surface material, sample height (walls), cleaning frequency, and the presence of pets in the home. The architect, Humberto Cavallin, drew sketches of the houses with measurements the team collected in the field (e.g. the dimension of spaces, level of openness, human

density) and took photographs of each household. Atila Novoselac, the environmental engineer of the study, gathered environmental variables such as temperature and relative humidity through a machine called ‘HOBO Micro Station Data Logger’, which made it possible to record two-minute-interval data on temperature and relative humidity. The purpose of recording these measurements, as Ruiz Calderon explained to me, was to account for variations in environment between the four locations they studied (J. Ruiz Calderon, personal communication, January 28, 2014). To determine and compare variations in architecture and environment between the four locations, they used the SPSS programme. In addition, on the architectural side, they produced three-dimensional representations of each sampled house. 3D models are useful to map the spatiality of microbes in built environments. In microbiome parlance, this method is called ‘microbial biogeography’, an aspect I will highlight in what follows.

The genetic material the team gathered at the four locations was directly shipped by air from Peru and Brazil to the US. These are very different times compared to when Dominguez-Bello was a doctoral student at the University of Aberdeen, back in the second half of the 1980s. Sponsored by the British Council, Dominguez-Bello conducted her PhD in microbiology on the bacteria found in the rumen of sheep. She recalls how she often brought bacterial samples in her hand luggage from Venezuela, where she conducted her fieldwork, back to the UK. In sharp contrast, the samples of MHC follow a different and highly bureaucratised route. From the Peruvian and Brazilian Amazon basin, they reach their destination at the Rob Knight Lab at the University of Colorado Boulder.

Rob Knight is one of the leading figures of human microbiome research, contributing to over sixty journal articles on microbiome studies per year.⁶⁹ He is well known in the field because of the computational and technological capacity of his laboratory. He is also the co-founder of the American Gut Project (AGP), one of the largest online platforms for the study of the human microbiome (see Section 3.5). Once the samples arrive in Knight’s Lab, the scientists extract the genetic material using a DNA isolation kit called MoBio Power Soil. MoBio Power Soil is a patented method for extracting DNA from environmental samples. The steps the scientist follows are given by the manufacturer’s instructions.

⁶⁹ Data from Scopus, 2016.

Once they extract the DNA from the microbial sample, they follow, what in microbiome science is known as the ‘16S-based approach’. The 16S rRNA gene is an essential, highly conserved, and universal component of bacterial ribosome (prokaryotic). The 16S rRNA sequences ‘serve as a proxy for the entire genome’ (Rhodes et al., 2013, p. 37). This is because by looking at ‘the diversity and distribution of 16S rRNA sequences in an environment, researchers can quickly and easily ascertain the diversity and distribution of microorganisms in that environment’ (p. 37). At the laboratory, the scientists amplify and sequence the 16S rRNA gene using HTS (HiSeq Illumina platform). For the analysis of the sequences resulting from HTS, they use the Qiime (pronounced ‘chime’) pipeline, an open source bioinformatic software package developed by Knight’s laboratory in 2010. Qiime gives qualitative analysis of microbial communities. It creates graphics that “allows users to interact with the data” (Caporaso et al., 2010). Qiime performs the entire 16S analysis, which identifies microbial species as well as the relative abundance of species within a sample.

Once the 16S is complete, the Knight Lab sends the results back to Dominguez-Bello’s laboratory at UPR-RP via web links, generally using cloud computing. Once they have the 16S rRNA gene sequence, Dominguez-Bello’s team analyses and interprets the sequences by comparing them with a repository of ‘sequence of reference’. This means that sequences obtained by the 16s rRNA analysis are classified by similarity, using a 97 per cent similarity threshold (97 per cent 16S rRNA sequence similarity). Sequences are then clustered into what is known as operational taxonomic units (OTU). ‘From the OTU cluster, a single sequence is selected as a representative sequence. The representative sequence is annotated using a 16S classification method and all sequences within the OTU inherit that same annotation’ (Nguyen, Warnow, Pop, & White, 2016, p. 1). As Graham Rook points out, the problem with this approach is that

if a sequence doesn’t occur in the existing database, you ignore it. And so, every time a new organism appears in the database, it’s the cause of every disease for the next six months because it suddenly appears in everybody’s work. So, there are an awful lot of problems (G. Rook, personal communication, April 21, 2017).

Since clustering similarity based on a single representative sequence is the main shortcoming of microbiome data generation, critics in the field have called to change the paradigm, moving towards ‘more accurate and phylogeny-based methods’ (Nguyen et al., 2016, p. 6).

3.3.4 Results: ‘Walls talk’

Very dear and remembered Maria Gloria,

Going down to St. Lorenzo de Marañón, I found your letter and the questionnaire. For the sixty years of missionary life, I decided to pay a visit to my three brothers in Italy at the end of May ... It is almost certain that your negative judgment on the Achuar stove, in spite of good intentions, was a mistake. With walls or without walls, the smoke passes through the leaves of the ceiling, drying the humidity of the leaf, allowing greater duration. The walls are a great defence in the violent storms of several seasons of the year and keep the heat at night, especially when the tribe has the flu and the nocturnal cold affects especially the children.

Father Luigi Bola, 3 January 2013, my translation

Father Luigi Bola, ‘Yankuam Jintia’ in Achuar, replied to Dominguez-Bello’s letter and completed the questionnaire about the Checherta’s lifestyle three months after he received the correspondence. In the above extract of his response, Luigi is alluding to the presence of walls in one of the homes in Checherta. Out of the twenty-one homes in the village, there is only one with walls: the house of the teacher. Teachers study in towns or cities and they return to work in Checherta and other Amerindian villages of Peru. During their visit, Dominguez-Bello and her team hypothesised that the presence of walls, as opposed to open-plan huts built with raw natural materials, correlates with a decreased microbial diversity. For Luigi, however, this assumption elicits the importance of walls for hunter-gatherer communities. Walls, as he narrates, are vital for shelter and for keeping dry and warm during rainy seasons. Missionaries and governmental bodies see open huts and sand roads alike as elements of a backward lifestyle, Dominguez-Bello points out. That explains that walls, along with other processes of urbanisation such as paved roads, are conceived as improvements for indigenous communities.

Dominguez-Bello proved her hypothesis about house walls later, in the research article, ‘Walls talk: Microbial biogeography of homes spanning urbanisation’ (Ruiz-Calderon et al., 2016). ‘Walls talk’ is one of the resulting publications of the human microbiome MHC project. The main contention of the article is that ‘the bacteria from the surfaces of house walls are informative of the level of urbanisation based on architectural design’ (p. 5). ‘The presence of walls dividing functional spaces acquires function-dependent microbes, mostly of human origin’ (p. 5). For example, the bathrooms walls present human oral microbes, while kitchens have traces of water-associated microbes.

Unsurprisingly, the scientists found major changes in microbial diversity and composition between the two extremes of the urbanisation gradient (i.e. Checherta, hunter-gatherer village, and Manaus, urban city). Diversity was lower in the city, except for the oral microbiome, which was lower in the rural town of Puerto Almendras, suggesting that ‘changes in the host lifestyles are associated with microbiota changes on all body sites, to a lesser extent in the mouth’ (Ruiz-Calderon, 2015, pp. 35–36). This finding in relation to oral microbiota is striking, because the scientific team expected that Checherta peoples’ consumption of Wayusa tea would alter their oral microbiome. They also assumed that hygiene factors (e.g. toothpaste) would reduce the diversity of the oral microbiome of inhabitants of urbanised towns and cities (Iquitos, Manaus). On the other hand, the results on the skin microbiome met the predictions of Dominguez-Bello. The human skin microbiome is important because it ‘reflects environmental microbes that the subjects are exposed to. Also, skin microbes are one of the main source of bacteria in the indoor environment in urban societies (Klepeis et al., 2001, as cited in Ruiz-Calderon, 2015, p. 53). In fact, the characterisation of ‘the skin microbial community structure is vital to reduce exposure of harmful bacteria indoors’ (p. 53). As the authors note, MHC is the first human microbiome study to compare and to observe loss in microbial diversity in the skin microbiome.

Overall, the MHC research is unique because, to date, it is the first and only microbiome study to compare microbial communities in different bodies and living sites across an ‘urbanisation gradient’. The study’s results showed that ‘urbanized spaces uniquely increase the content of human-associated microbes—which could increase transmission of potential pathogens—and decrease exposure to the environmental microbes with which humans have coevolved’ (Ruiz-Calderon et al., 2016, p. 1).

The microbial changes documented in the MHC research might translate ‘into differences in microbial exposure that might have developmental health implications for humans’, more likely ‘immune and metabolic disorders that have become the new disease paradigm in the industrialised world’ (Ruiz-Calderon et al., 2016, p. 5).

3.4 The microbiomisation of race

In this part of the chapter, I interpret and conceptualise the MHC research as part of what I call the ‘microbiomisation of race’. I refer to microbiomisation as the process by which microbiome science takes social groups as pre-existing, ‘natural’ phenomena and biologises them by creating microbes and microbial profiles and attributing these to them.

I first outline a genealogy of ‘transculturation’, an intriguing and key concept of the MHC research, often interchangeable with ‘westernisation’ and ‘urbanisation’. I argue that these sociologically rooted concepts (‘transculturation’, ‘westernisation’, and ‘urbanisation’) embody and establish the basis of the microbiomisation of race. This is because the experimental design of MHC and similar human microbiome projects starts from a non-scientific assumption about cultural and social differences in populations. Engaging with the science studies literature on race (El-Haj, 2007; TallBear, 2013; Wade, Lopez Beltran, Restrepo, & Ventura Santos, 2014), I then elaborate on the concept of the ‘microbiomisation of race’, which is enacted (i.e. practised) by the bioprospection of biological material from non-Western populations and territories.

3.4.1 A genealogy of the word transculturation

Over the course of this thesis, I have documented a conceptual evolution of Dominguez-Bello’s MHC research. The word ‘transculturation’ from Dominguez-Bello’s abstract title ‘Genomics and global health in the context of transculturation’ first caught my attention at the conference ‘Infectious Disease Genomics and Global Health’ (2013), organised by the Wellcome Trust and held at the Genome Campus at Cambridge (UK). This intriguing word, I learnt at the conference, was an analytical tool to describe the degree of westernisation, from ‘unimpacted peoples’ to communities adopting a Western lifestyle (Dominguez-Bello, 2013).

I traced the genealogy of the word ‘transculturation’ back to the work of anthropologist Fernando Ortiz in his 1947 book *Cuban counterpoint: Tobacco and sugar*. In the aftermath of Spanish colonialism in Cuba, Ortiz suggests the term ‘transculturation’ to refer to the converging of two cultures and the creation of a new one (neo-culturation), in contrast to the unidirectional acquisition of another culture (acculturation). At this first contact with Dominguez-Bello’s human microbiome research, I speculated on the reformulation of the concept within a scientific emancipatory process: a female scientist bringing a Latin American concept (i.e. transculturation) to the forefront of international microbiome research.

In San Juan (Puerto Rico) in early 2014, I met the anthropologist Waleska Sanabria Leon. Sanabria Leon is a biological anthropologist specialising in cultural anthropology at the University of Puerto Rico. At that time, she had just become the anthropologist of the MHC project. She noted that acculturation was the preferred

terminology in the first draft of the MHC Sloan Foundation proposal (W. Sanabria Leon, personal communication, January 28, 2015):

A set of cases will be selected from a continuum of settings that represent typical dwellings of the environments in a gradient of acculturation from isolated villages to cosmopolitan cities: isolated jungle communities/rural jungle settlements and small city/cosmopolitan city. We propose to choose villages in gradient of acculturation in Peru (Fig 1), and include a Latino community in Manhattan as the metropolis in the most acculturated end (Dominguez-Bello, 2012, p. 7).

In view of the negative connotation of ‘acculturation’ as a unidirectional process of cultural acquisition, Sanabria Leon proposed the alternative term ‘transculturation’. However, to my surprise, she was not referencing Ortiz’s transculturation. She was alluding to the work of Arjun Appadurai. Yet, interestingly, transculturation does not appear in Appadurai’s work. Sanabria Leon then clarified to me that the processes of fluidity and ‘non-localised quality’ of Appadurai’s work (1996) were an inspiration for her reformulation of acculturation as transculturation in the MHC research. Her point was to remark on the unsettled nature of cultures. The provenance of the reference for the use of transculturation was, and still is, unclear and cryptic (see also Casid, 2004).

Progressively, transculturation, westernisation, and urbanisation became interchangeable concepts in the MHC research, as the following quote reads:

While the world is converging toward Western lifestyles (a process known as transculturation/Westernization), there is a need to characterize the changes that occur during this convergence, and to provide insights into which factors may contribute to specific immunologic and metabolic diseases ... We observed important dietary changes across the villages in the transculturation/urbanization gradient. From plant-rich natural product diet in the jungle village, void of dairy products, to a more diverse, high-caloric, high sugar processed diet consumed less frequently but in bigger meals (Ruiz-Calderon, 2015, pp. 19, 29).

In the journal article versions, however, transculturation no longer appears. Here, the experimental design and rationale of the MHC research is framed in terms of urbanisation, understood as an outcome of westernisation:

Westernization has propelled changes in urbanization and architecture, altering our exposure to the outdoor environment from that experienced during most of human evolution. These changes might affect the developmental exposure of infants to bacteria, immune development, and human microbiome diversity ... This study addresses the associations between architectural design and the microbial biogeography of households across a gradient of urbanization in South America (Ruiz-Calderon et al., 2016, p. 1).

The progressive substitution of transculturation with the concepts of urbanisation and westernisation, I argue, elicits the socio-cultural and anthropological dimension of the

MHC research, moving towards an architectural context under the framework of microbiology of the built environment. Talking about ‘urbanisation’, I suggest, sounds more technical and is less problematic in terms of research ethics (access to indigenous communities, sampling DNA, etc.). In other words, talking about buildings and design (i.e. urbanisation) instead of race, nation, and ethnicity (i.e. transculturation, westernisation) is a way to ‘sanitise’ scientific discourse, avoiding controversies and criticism.

The socio-cultural starting point of the MHC research is interesting for me because it echoes my own academic interplay and ‘interdisciplinarity’ in the life sciences and the social sciences and humanities. In Dominguez-Bello’s MHC research, the socio-cultural and biological interplay is in an incessant process of making and remaking. The point, for me, is not to evaluate which one came first (i.e. the social or the biological) or the extent to which the biological is social and vice versa. This is because I understand the social-biological interplay as a co-production (Jasanoff, 2004) or intra-action (Barad, 2007), as biology always already socialised, as ‘socialised biology’ (Riley, 1983). Rather, my interest lies in examining the critical and sociological relevance of MHC with regards to the paradigm of immunity (i.e. self versus non-self) and, consequently, its implications in terms of the production and distribution of inequalities in health and disease.

I suggest that the evolution of the concept of transculturation in the MHC research—how it travels, transforms, and ‘normalises’ itself as part of more common and accepted concepts in contemporary scientific discourse (i.e. ‘westernisation’, ‘urbanisation’)—is important because it links microbiome science and race. Before turning to how microbiome science reifies race, in what I call the ‘microbiomisation of race’, it is relevant to highlight that the links between race and science have a long history. More precisely, race is part of the very constitution or ‘invention’ of ‘modern science’ (Stengers, 2000).

3.4.2 From race science to postgenomics

The concept of race emerged as early as the thirteenth and fourteenth centuries in Europe to refer to ‘lineage, breed, or stock in animals and humans’ (Wade et al., 2014, p. 3). Represented by ‘naturalists’ Carl Linnaeus (1707–1778) and Comte de Buffon (1707–1788), among others, taxonomy developed as part of the Enlightenment project during the eighteenth and nineteenth centuries. It was a way of ordering and classifying plants and human and non-human animals according to their physiological characteristics

(Wade et al., 2014, p. 4). The hierarchical taxonomic systems developed at that time, part of what we might call ‘race science’ or ‘raciological science’ (TallBear, 2013) have made their way to our time (El-Haj, 2007). As several social scientists have demonstrated (El-Haj, 2007; Wade et al., 2014), race as a biological concept was not fully abandoned, even after the emblematic UNESCO Statements on Race (1950), a series of documents produced by the United Nations (UN) in the aftermath of the Second World War. As El-Haj argues, the ‘documents did not deny the reality of race as a biological concept’ (2007, p. 286). Instead, the concept of race was gradually substituted with the concept of ‘populations’ (El-Haj, 2007; TallBear, 2013; Wade et al., 2014). In an idiom of ‘percentages and allelic frequencies’, physical traits, the phenotype, were gradually replaced by genetic information, the genotype (Wade et al., 2014, p. 227). El-Haj refers to the embeddedness of race in population genomics as the ‘molecularisation of race’ (2007) in reference to sociologist Nikolas Rose’s influential notion of ‘molecularisation’⁷⁰ (of the life sciences) (2007).

With the emergence of population genomics in the second half of the twentieth century, the fact that all humans share 99.9 per cent of their genome reached an iconic status. This, in turn, gave rise to several genomic projects aimed at the understanding the 0.1 per cent difference among different human populations (via the data mining of their genomes). For example, in 1991 the Human Genome Diversity Project (HGDP) began in Stanford University (US), directed by the influential geneticist Luigi Cavalli-Sforza. The HGDP has established a landmark in population genomic research in terms of biological research on human evolution and migration. The database of the HGDP is in use today (Wade et al., 2014, p. 5). In an epoch of unprecedented environmental damage and extinctions, the HGDP—along with other genomic initiatives such as the International

⁷⁰ Rose’s influential concept of ‘molecularisation’ refers to a new form of governmentality (of sovereign power) involving the individualisation of risk and the creation of a ‘new “somatic” self’ (Braun, 2007, p. 6; Novas & Rose, 2000). In an interesting reconceptualisation of Rose’s notion, geographer Bruce Braun (2007) reads ‘molecularisation’ along with biosecurity discourses. Braun argues that looking at the emergence of different diseases in the world and the subsequent biosecurity alerts that they generate, provides a more particular and less universal framework of the concept of ‘molecularisation’: ‘At the very least, we must see Rose’s ethopolitics as something more particular and less universal, as perhaps a form of biopolitics within globalization that is specific to the zone of “liberal peace” in the affluent spaces of the West. But more important, we must ask whether the conditions of possibility for ethopolitics for secure bodies that are open to “improvement” include the extension of sovereign power elsewhere in the name of biological security. For not only does the global South lie outside the technoscientific and cultural networks that compose the ethopolitical for Rose, but arguably biological existence there is increasingly subject to projects that seek to pre-empt risk through new forms of sovereign power. We are faced with the troubling thought that in the molecular age, what appears to us in terms of an ethics of “care of self”, and as a pressing problem of democracy, may appear to others as yet another expression of empire’ (Braun, 2007, p. 25).

Hapmap Project (2002–2009) or the more recent Human Microbiome Project (2007) and the 1000 Genomes Project (2008–2015)⁷¹—aims at studying and generating DNA databases of populations of humans and non-humans (especially plants and microbes) before it is too late; before they disappear (Dominguez-Bello, 2013).⁷²

As scientists exploring the co-evolution of humans and microbes, the practices of population genomics are also present in the research of Dominguez-Bello and her collaborators. For example, in an influential article on the use of the bacterium *Helicobacter pylori* as a marker of ancestry and migrations, Dominguez-Bello and Blaser (2011) argue that ‘these microbes [*H. pylori*, ANC] are mostly vertically transmitted, they have evolved within each human group and provide a view of human ancestry’ (Dominguez-Bello & Blaser, 2011, p. 451) Furthermore, they suggest that because ‘human mixing affects microbial phylogeographic signals, and lifestyles impact the human microbiome population structure’, this approach can be useful as a way to gain ‘insights into the population structure of the human microbiome’ (p. 451).

Ancestry genomics is in fact one of the biomedical areas that better reflects the contemporary imbrication between race and the life sciences. In the book *Native American DNA* (2013), feminist indigenous studies scholar Kim TallBear shows how ‘the DNA profile helps to reconfigure the concept of tribe’ (p. 4). Linking population genomics with colonialism, TallBear argues that ‘without “settlers”, we could not have “Indians” or “Native Americans”—a panracial group’ (p. 5). This is because

scientists who trace human migrations do not tell a story from the standpoint of those peoples who were encountered; they tell a story from the standpoint of those who did the encountering—those who named and ordered many thousands of peoples into undifferentiated masses of ‘Native Americans’, ‘Africans’, ‘Asians’, and ‘Indo-Europeans’ (p. 5).

Similarly, in *Mestizo genomics* (2014), Peter Wade and colleagues theorise ‘mestizaje as an ideology of national identity’ (p. 211). Analysing the several laboratories of ancestry genomics in three Latin American countries (Brazil, Mexico, and Colombia), *Mestizo genomics* provides an insightful account of local differences in the scientific knowledge production of genomic lineages. Emphasising ‘local biologies’ (Lock & Nguyen, 2010),

⁷¹ The Hapmap Project (2002–2009) was a multinational organisation created to develop a haplotype map (i.e. HapMap) of the human genome, to describe the common patterns of human genetic variation. The 1000 Genomes Project has developed a catalogue of human genetic variation.

⁷² I will return to these debates in terms of personalised microbiome initiatives in Section 3.5 of the present chapter. I will engage with debates on the Anthropocene in relation to antimicrobial resistance (AMR) and what I call the ‘biology of capital’ in Chapter 4.

the authors show how, for example, in Mexico, harvesting population DNA is a question of national sovereignty. In Brazil, by contrast, national population genomics programmes rest on a narrative of mixture, which, in turn, finds itself justified in ancestry genomic data (see also Kent et al., 2015).

Both TallBear's (2013) and Wade et al.'s (2014) studies show how biological knowledge connects to several forms of citizenship(s) and identities, a process sociologist Adriana Petryna coined 'biological citizenship' (2002; see also Novas & Rose, 2005; Rose, 2007) and sociologist Nicholas Rose refers to as 'vital politics' (2001) (El-Haj, 2007).⁷³ Crucially, 'Native American DNA' (TallBear, 2013) and 'mestizo genomics' (Wade et al., 2014) 'how new versions of race are being assemblaged globally through local practices' (Wade et al., 2014, p. 238). This is to say that, mainly through population genomics projects, postgenomics reauthorises and reifies race (El-Haj, 2007; TallBear, 2013; Wade et al., 2014). Likewise, in what follows, I argue that human microbiome science, as an area of postgenomics, also involves the reinscription of race in biological experimentation and knowledge about human–microbe entanglements. I conceptualise these processes as the 'microbiomisation of race'.

3.4.3 The microbiomisation of race

In the process of microbiomisation, socio-cultural practices such as cleaning frequency, architecture, family size, along with assessments of age, diet, and kinship are reduced and essentialised to racial categories when microbial species are used as markers of population differences. For example, in 2012, Dominguez-Bello took part in a landmark cross-cultural and cross-geographical human microbiome study entitled 'Human gut microbiota viewed across age and geography'. The aim of the study was to establish the foundations of human genetic and metabolic variation through the characterisation of the human microbiota. The study used faecal samples from three different populations: 'Amerindians from the Amazonas of Venezuela, residents of rural Malawian communities, and inhabitants of US metropolitan areas' (Yatsunenکو et al., 2012, p. 222). The authors note that:

⁷³ While in *Life exposed* (2002), Petryna locates 'biological citizenship' in post-Soviet societies as 'a massive demand for but selective access to a form of social welfare based on medical, scientific, and legal criteria that both acknowledge biological injury and compensate for it' (p. 6), Novas and Rose offer a broader definition of the concept: 'all those citizenship projects that have linked their conceptions of citizens to beliefs about the biological existence of human beings, as individuals, as families and lineages, as communities, as population and races, and as a species' (2005, p. 440).

Pronounced differences in bacterial species assemblages and functional gene repertoires were noted between individuals residing in the USA compared to the other two countries ... In addition, the similarity of fecal microbiomes among family members extends across cultures. These findings underscore the need to consider the microbiome when evaluating human development, nutritional needs, physiological variations, and the impact of Westernization (p. 222).

Here, the authors group human populations into two different categories: one based on race/ethnicity (i.e. 'Amerindian') and the other based on nationality/country of residence (residents of the US and residents of Malawi).

As I have previously argued, in the MHC research, the biologisation of the social and cultural is exemplified through the words transculturation, westernisation, and urbanisation. However, published versions of the research avoid invoking social and cultural explanations as well as categorisation into racial/ethnic groups by focusing on differences in the built environments:

Urbanized spaces uniquely increase the content of human-associated microbes—which could increase transmission of potential pathogens—and decrease exposure to the environmental microbes with which humans have coevolved (Ruiz-Calderon et al., 2016, p. 1).

By contrast, drawing on results from the MHC research, several other journal articles co-authored by Dominguez-Bello deliberately focus on nationality and race of the human samples. In an article entitled 'The microbiome of uncontacted Amerindians' (Clemente et al., 2015), the authors state that the 'Yanomani[s] harbor a microbiome with the highest diversity of bacteria and genetic functions ever reported in a human group' (p. 1). As a result, the article insists on 'the need for extensive characterisation of the function of the microbiome and resistome in remote non-westernized populations before globalization of modern practices affects potentially beneficial bacteria harbored in the human body' (p. 6).

The microbiome of 'uncontacted peoples', such as the high Oricono Yanomamis of Venezuela or the Peruvian Amerindians of Checherta, is a reservoir for microbiome science. While I will come back to this point later in the chapter in relation to neocolonialism and bioprospection, I would like to highlight the importance of this point. Microbiome science relies on comparative studies of genetic (microbial) variation in human populations. Harvesting the microbiome of non-Western peoples and territories is not a side project or a specific 'approach' within the field. Rather, it is the key element which constitutes this new area of scientific knowledge production.

The comparative study of the human microbiome in non-Western versus Western populations is indeed the principal research line of Dominguez-Bello. More recently, she has conducted fieldwork in Tanzania, together with her usual collaborator, biochemist and HTS ‘guru’ Rob Knight, and anthropologist Jeff Leach, cultural anthropologist and pizza business entrepreneur turned microbiome scientist. He is the co-founder (together with Rob Knight) of the AGP and the founder of the HFP (see Section 3.5). In the research article ‘Seasonal cycling in the gut microbiome of the Hadza hunter-gatherers of Tanzania’ (Smits, et al., 2017), the authors demonstrate how the Hadza’s human microbiota shifts according to seasonal changes. The study compared the Hadza microbiome profile of 350 stools collected (by Leach) longitudinally over more than a year, with ‘data collected from 18 populations in 16 countries with varied lifestyles’ (p. 802). The results clearly correlate the racial/ethnic category of the Hadza with the *Prevotellaceae* (bacteria) family and ‘industrialised populations’ (read Western) with the *Bacteroidaceae* family:

During the cyclic disappearance of taxa, the Hadza microbiota shifts to a state with increased similarity to those of industrialized microbiotas (fig. S1). Conversely, some OTUs within microbial families common to both traditional and industrialized populations are less seasonally volatile (fig. 1F and fig. S3, C and D; $P = 7 \times 10^{-13}$, Wilcoxon). Second, the Prevotellaceae, a member of the Bacteroidetes phylum, is a common family in the Hadza microbiota, leading us to wonder about its relationship to the Bacteroidaceae, a dominant family in industrialized populations, which is also a member of the Bacteroidetes phylum (Smits, et al., 2017, p. 804).

It is interesting to note how the designation of social categories of difference varies among different human microbiome studies. While the Tanzania study uses the racial category of the ‘Hadza’ and the socio-economic category of ‘industrialised’, or the study by Yatsunencko et al. (2012) combines racial/ethnic categories (i.e. ‘Amerindians’) with nationality (i.e. US, Malawi), other studies use political categories to signify race/ethnicity. For instance, De Filippo et al. (2010) is a highly cited study on the impact of diet on the gut microbiome that compares ‘European’ children and Burkina Faso children:

BF [Burkina Faso, ANC] children showed a significant enrichment in Bacteroidetes and depletion in Firmicutes ($P < 0.001$), with a unique abundance of bacteria from the genus Prevotella and Xylanibacter, known to contain a set of bacterial genes for cellulose and xylan hydrolysis, completely lacking in the EU children. In addition, we found significantly more short-chain fatty acids ($P < 0.001$) in BF than in EU children (2010, p. 14691).

Clearly, comparing populations within a political and economic ‘consortium’ of nation states (i.e. Europe) with a single nation state (i.e. Burkina Faso) is an unequal and problematic comparison. This is accentuated by the fact that neither this study nor the previously mentioned ones provided any explanation about the criteria followed for the categorisation of populations (see also Wade et al., 2014).

There is also microbiome literature that uses the term ‘Caucasian’. In ‘The interpersonal and intrapersonal diversity of human-associated microbiota in key body sites’ (Ursell et al., 2012), co-authored by some of Dominguez-Bello’s collaborators, the authors outline the inter- and intrapersonal microbial variation of five body sites across several populations: gut, skin, vagina, mouth, and nose. Summarising the results of the vaginal microbiome, they write:

The vaginal communities of Asian and Caucasian women were most often dominated by lactic-acid producing *Lactobacillus* than Hispanic and African American women, possibly causing the lower vaginal pH levels found in Asian and Caucasian women (Ursell et al., 2012, p. 1204).

While the terms ‘Asian’ and ‘Hispanic’ are blurry racial/ethnic categories, denoting geographic provenance and colonial history respectively, the word ‘caucasian’, as the paediatrician Dennis Fortenberry (2013) points out, ‘is a peculiar—but commonly used—racial term because it originates in 18th-century European assumptions of beauty, intelligence, and natural superiority’ (p. 166). In fact, Fortenberry continues, ‘a word steeped in such assumptions amplifies the stigma of sexuality and sexually transmitted infections often associated with racial and ethnic minorities’ (p. 166). Similarly, Wade et al. (2014) argue that *mestizaje* ‘is a sexualised and gendered practice and ideology’ (p. 19). Genomic research ‘often finds evidence in today’s populations that reflects early colonial matings between European men and indigenous or African women’ (p. 19). The indissociability of race from other social categories of difference, as Fortenberry and Wade et al. demonstrate, is a remarkable point I will expand on in relation to class and gender in Chapter 4 and Chapter 5, respectively.

3.4.3.1 *Microbiomisation of race as a nexus between bioprospection and bioinequalities*

Beginning with non-scientific assumptions about cultural and social differences associated with certain populations and geographies (i.e. diet, sanitation, family size, architecture, antibiotic use, child-rearing), microbiome science turns these differences into a heuristic device based on microbial taxonomy. It is then that Tanzanian ‘hunter-gatherers’, ‘Burkina Faso’ children, or simply ‘Hispanics’ have more *Lactobacillus* or

Bacteroidetes than ‘industrialised populations’ or ‘EU children’. This process involving the biologisation of social groups as pre-existing ‘natural’ phenomena is what I call ‘microbiomisation’. In this sense, microbiomisation entails what philosopher Alfred North Whitehead calls ‘the fallacy of misplaced concreteness’ (1997), also known as the ‘fallacy of reification’, that is ‘the tendency to assume that categories of thought coincide with the obdurate character of the empirical world’ (Duster, 2005, p. 1050).

There is a characteristic of microbiomisation that is easy to go unnoticed. This has to do with the fact that Western categories of difference are often broader than non-Western ones. Take for example, comparing Burkina Faso children with European children (De Filippo, et al., 2010). Or ‘industrialised’ populations versus ‘traditional’ ‘Hadza’ hunter-gatherers (Smits et al., 2017). The Western category is not only broader, but is also blurrier. Following a universal and colonial logic, I argue, the Western (microbiome scientists, in this case) defines others (‘hunter-gatherers’, ‘Hispanic’, ‘Amerindians’, and so forth), but does not need to define itself.

By encapsulating my findings under the framework of ‘microbiomisation’, I want to tell a story about ‘how social structures get under the skin’ (Meloni, 2015, p. 136). Microbiomisation is similar to what environmental scientist Becky Mansfield calls ‘epigenetics biopolitics’, which involves shifting ‘the responsibility of exposure to chemicals towards the “abnormal” diets of women of color instead of blaming contamination itself’ (2012, p. 352). However, in contrast to Mansfield’s ‘epigenetics biopolitics’, the specificity of the process of the microbiomisation of race (and microbiomisation more broadly) involves two interlocking elements articulated at population and individual levels.

- 1) **Bioprospection** refers to neocolonial practices of data mining and expropriation of microbial biodiversity from non-Western peoples and territories (i.e. **populations**) (see Section 3.3.1).
- 2) **Bioinequalities** is a reformulation of the Foucauldian concepts of biopolitics and biopower by medical anthropologist Didier Fassin (2009). Going beyond ‘a politics of population’, it is about ‘life and more specifically about inequalities in life’ (Fassin, 2009, p. 57). I associate the **individualisation** of microbial profiles with the production and reproduction of ‘bioinequalities’ in microbiome science.

In the following sections of the chapter (3.4.4 and 3.5), I discuss these two elements of the process of microbiomisation of race. Social studies of science tend to associate

postgenomics with the individualisation of medicine (El-Haj, 2007; Wade et al., 2014). Some discordant voices, however, have recently suggested that postgenomics is still very much about populations (Fox-Keller, 2010; Hinterberger, 2012a, 2012b). My argument is that microbiome science, as an area of postgenomic science, is about individuals as much as it is about populations. This is because, through bioprospecting practices, microbiome science relies on comparative studies of genetic (microbial) variation in human populations. These studies are then used, as I will show, to create individual microbial profiles via online personalised medicine projects (Section 3.5). Yet, those who can access to their ‘microbial profile’ belong to privileged strata of (predominantly Western) societies (Chapter 4). In other words, this means that bioprospecting populations is indissociable from the bioinequalities that the individualisation of microbiome data produces and reproduces.⁷⁴

3.4.4 Bioprospection

The term bioprospection refers to the search and commercialisation of biological resources or bioproducts. In addition, bioprospection is a form of piracy or ‘biopiracy’, ‘leading to a loss of power of indigenous people over their own resources’ (Cluis, 2006). In her ethnographic study of bioprospection in Mexico (2003), sociologist of science Cori Hayden points out that bioprospecting ‘is the new name for an old practice: it refers to corporate drug development based on medicinal plants, traditional knowledge, and microbes culled from the “biodiversity-rich” regions of the globe—most of which reside in the so-called developing nations’ (2003, p. 1). Similarly, in an extensive ethnographic study of marine microbes, anthropologist Stefan Helmreich sees the extraction of aquatic molecules and cells by US scientists from the Hawaiian sea as ‘controversial’ because

organizations scouting for intriguing organisms often hail from northern industrialized nations, whereas the biota in which they are interested are frequently sited in so-called developing nations in the tropics and global South. ... Some opponents [see Shiva, 1997, ANC] have seen in bioprospecting the legacy of colonial relations, terming the activity ‘biopiracy’ (Helmreich, 2009, p. 135).

As Helmreich points out, it is not a matter of opinion but a fact that ‘the biota in which they [scientists, ANC] are interested are often sited in so-called developing nations in the tropics and global South’ (p. 135). This is mainly because there is significantly more

⁷⁴ In the fourth and last section of this chapter, I explain how bioinequalities articulate through personalised microbiome projects in high-income countries (the US and UK in particular).

biodiversity in those geographies than in any other across the globe. The biodiversity these places harbour translates into biovalue for contemporary science. The Amazon basin is an excellent ‘living lab’ for Dominguez-Bello’s microbiome research due to the vast quantity of microbes that flourish there, along with the little exposure (especially of remote and inaccessible areas) to the influence of modern urban life and biomedicine. Biodiversity and bioprospection, richness of life, and bioeconomic value are indeed interdependent. Elaborating on the alliance between ecology and economy, Helmreich insists on the polyvalent meaning of biodiversity:

We should pause over this enthusiasm for diversity, for it is a key support for biotech capitalism. *Biodiversity* began its life as *biological diversity*, a term advanced by conservationists to describe nature as a store of variety that might be measured and valued, in both ecological and economic terms. Since its coinage, *biodiversity* has become infectiously polyvalent (2009, p. 110).

Beyond biodiversity and bioeconomy,⁷⁵ Hayden cites the manifold meanings, functions, and facets of biodiversity:

an ecological workhorse, essential raw material for evolution, a sustainable economic resource, the source of aesthetic and ecological value, of option and existence value, a global heritage, genetic capital, the key to the survival of life itself (Hayden, 2003, p. 52, as cited in Helmreich, 2009, p. 111).

Bioprospection is neither an exclusive phenomenon of the twenty-first century nor does it only relate to cells and DNA. As I have previously shown at the beginning of the chapter, through the lens of Werner Herzog’s *Fitzcarraldo*, the rubber boom or *ciclo da borracha* at the end of the nineteenth and beginning of the twentieth century already involved the extraction and commercialisation of biological products such as rubber in a context of colonialism. The depletion of natural resources from the Amazon jungle was tied to the exploitation and slavery of its inhabitants.

Recently, in 2016, Dominguez-Bello published a short comment in *Nature Microbiology* entitled ‘Ethics of exploring the microbiome of native peoples’. The article was co-authored by a heterogenous group, including an anthropologist from the Venezuelan Institute of Scientific Research (IVIC) (Caracas, Venezuela), a Hadza villager from Lake Eyasi (central Rift Valley, Tanzania), and a leader member from the Yekwana village of Kanadakuni, Upper Caura (Bolívar State, Venezuela). In the article, the authors argue that the microbiota of indigenous communities provides a ‘reservoir’

⁷⁵ I discuss issues around bioeconomy and biocapital (see Helmreich, 2008; Sunder Rajan, 2006, 2012) in relation to the ‘microbiomisation of class’ in Chapter 4.

for Western populations and that DNA mining should be conducted according to ethical practices:

If urban-related factors impact the human microbiome in ways that cause or perpetuate disease states, leading to the extinction of microbionts in industrialized societies, then solutions might depend crucially on the microbionts of people untouched by Western lifestyles. Their microbiota might provide the reservoir to help us replace the microorganisms we have lost, but restoration will require far more research about the best strains, best practices, cultivation and, importantly, safety (Dominguez-Bello et al., 2016, p. 2).

In contrast with arguments on bioprospection, using the microbiome of indigenous peoples as a ‘reservoir’ for the restoration of ‘Western’ human microbiomes recalls what the paediatrician and Minister of Health of Rwanda Agnes Binagwaho and colleagues call ‘reverse innovation’⁷⁶, that ‘some insights from low-income countries might offer transferable lessons for wealthier contexts’ (2013, p. 1). Drawing on epidemiological data on the successful implementation of antiretroviral therapy (ART) in Rwanda, the authors of the study elaborate on the viability of fair healthcare through the development of wider channels of communication South–North and South–South. They remark that ‘AIDS-related deaths have declined by 83.1% since 2000—even more steeply than the comparable post-ART period after 1996 in Europe and North America’ (pp. 1, 2). Clinical innovation through health tools and care based on local needs and strategic transnational collaborations were key for the dramatic decline. This case is more relevant in light of the 1994 Rwandan Genocide. From this situated approach towards clinical innovation the concept of ‘reverse innovation’ offers, I started the chapter by asking whether Dominguez-Bello stands as a representative of a new way of approaching biological questions, in which culture and emancipation (both through ‘reverse innovation’ and through her identity as a non-Western woman scientist) go hand in hand. As I will argue in what follows, Dominguez-Bello’s MHC research does not belong to an emancipatory process of ‘reverse innovation’. Her scientific profile and persona, attuned to the capitalist demands of outcome-based, highly cited, and ‘translatable’ scientific research, contrast with her personal sensitivities towards disadvantaged researchers and the rights of indigenous peoples.

⁷⁶ It is worth noting that, according to anthropologist Abadia-Barrero (2018), ‘reverse innovation’ in global health has become a business concept and model that can both solve global health problems and boost multinational corporations’ profits (p. 384).

3.4.4.1 *Bioprospection as inclusion*

The extensive work of Dominguez-Bello on the human microbiome at the intersections of biology and anthropology is remarkable.⁷⁷ As she expressed regarding her initial work on the bacterium *Helicobacter pylori* as a marker for migrations of individuals and populations (see Dominguez-Bello & Blaser, 2011), ‘the work on *H. pylori* transformed my career; I became a microbial anthropologist, a field that does not yet formally exist’ (Dominguez-Bello, 2016, p. 590). For her, the human microbiome is ‘an anthropological field focused on intimate interactions between microbes and human function and evolution’ (Dominguez-Bello & Blaser, 2011, p. 457). As an (microbial) anthropologist then, Dominguez-Bello is concerned with the ethical implications of her research practices. On the compensation that science should offer to indigenous communities for the mining of their microbiomes, Dominguez-Bello and colleagues suggests that ‘scientists should acknowledge in publications the origins of microbiome data and/or microorganisms derived from native peoples, as potential beneficiaries from future technological developments’ (Dominguez-Bello et al., 2016, p. 2). In addition, they highlight the importance of empowerment and emancipation for the ‘natives’:

Native peoples must decide their own destinies, but it is our responsibility to provide recognition and safe technologies towards materializing their freedom to choose to remain in their lands, to live their traditional way, and to continue being the guardians of their unspoiled micro- and macro-habitats. *If they do, it will be for the benefit of humanity* (p. 2, my emphasis).

It is worth noting the ambivalence of the discourse. On the one hand, *their* microbiome is a crucial (microbial) ‘reservoir’ for the restoration of *our* own. On the other, on the more ‘ethical’ side, *they* ‘must decide their own destinies’. ‘*If they do*’ choose to keep their ‘traditional’ lifestyles, the benefit will be universal (i.e. ‘humanity’), they argue. Clearly, I argue, the bioprospection of biodiversity from indigenous places and territories conflicts with the emancipatory ethics expressed by the scientist.

This tension in contemporary biomedical research on populations is often approached from a perspective of inclusion. In the book *Inclusion: The politics of difference in medical research* (2007), sociologist Steven Epstein traces the origins of biomedical research on population differences in North America. In what he refers to as the ‘inclusion-and-difference paradigm’, Epstein documents the policies, practices, and ideologies behind the medical inclusion of underrepresented social groups. Medical

⁷⁷ See also Chapter 5 on interdisciplinary collaborations in microbiome science.

inclusion, he shows, is a recent phenomenon. It was during the mid-1980s when reformers pointed out the dangerous flaws of ‘one-size-fits-all’ research (which mostly included white, middle-aged male bodies). The criticism translated into changes in science and pharmaceutical industry policy. Epstein argues that, while certain aspects of these medical reforms improved disparities in health and disease, the inclusiveness of these policy changes and reforms also brought unintended consequences:

By approaching health from the vantage point of categorical identity, they ignore other ways in which health risks are distributed in society. By valorizing certain categories of identity, they conceal others from view. By focusing on groups, they obscure individual-level differences, raising the risk of improper ‘racial profiling’ or ‘sex profiling’ in health care. By treating each of the recognized categories in a consistent fashion, they often ignore important differences across them. And by emphasizing the biology of difference, they encourage the belief that qualities such as race and gender are biological in their essence, as well as the mistaken conclusion that social inequalities are best remedied by attending to those biological particularities (p. 11).

These are all important points signalling the biologisation—or, in this case, ‘microbiomisation’—of social categories of difference (race, class and gender) under frameworks and practices of ‘inclusion’. Furthermore, ‘inclusion’ in postgenomics is not only a policy in science and the pharmaceutical industry, as Epstein (2007) signals, but a societal demand from underrepresented minority groups:

The political impetus for including race, for insisting on diversity in the conduct of postgenomic medicine, comes in large part from people who organize or identify as minorities (including physicians/researchers) and who demand the right to equal treatment: Medicine has met identity politics, and out of that meeting point novel practices of both race and medicine (as ‘expertise’) have been borne (El-Haj, 2007, p. 292).

Sociologist Amy Hinterberger argues that ‘the solution to the dilemmas raised by the unsettled histories of group classification and their increasing entanglement with the futures of genomic medicine is not to stop using categories of differences’ (2012b, p. 220). This is because, among other aspects, measuring and monitoring health disparities would become even more challenging (Epstein, 2007; Hinterberger, 2012b, p. 20). Yet, biomedical research should address race disparities in ‘all their biosocial complexity’ (Duster, 2005). As Duster proposes, a tentative solution to counteract the reification of race in science—what Whitehead (1929) calls the ‘fallacy of misplaced concreteness’—is that researchers conducting population genetics studies ‘always attach a caveat or warning label that could read something like this, “allelic frequencies vary

between any selected human groups—to assume that those variations reflect ‘racial categories’ is unwarranted” (2005, p. 1050).⁷⁸

The microbiomisation of race is indeed a result of the ‘inclusive’ science policy framework that Epstein documents and analyses in *Inclusion* (2007). Human microbiome research comparing citizens or residents in different countries (i.e. ‘biological citizenship’) (Petryna, 2002; Novas & Rose, 2005), is clearly designed using the lens of an inclusionary practice of difference (see for instance De Filippo et al., 2010; Yatsunenکو et al., 2012). However, in human microbiome science, not all differences and populations belong to a framework of inclusion. This is evident in Dominguez-Bello’s MHC study. Here, the Achuar population of the Peruvian village of Checherta were not selected as participants following an inclusionary practice. The Checherta peoples do not get any medical benefit out of the MHC research, simply because their microbiome is the gold standard for the microbiomes of other populations. Studying their microbiome then is not about inclusion and cannot be explained under that framework. It is rather a question of bioprospection. This is not to say that a scientist like Dominguez-Bello is not well intentioned. The point is that, although Dominguez-Bello and her collaborators provide an ethical framework in which to situate their practice (i.e. bioprospecting biodiversity) (see Dominguez-Bello et al., 2016), the ultimate outcome of the latter is to address a medical problem (i.e. a lack of diversity of microbiomes leading to metabolic, inflammatory, and autoimmune diseases) that affects a specific segment of populations/countries (high-income, fundamentally Western countries). In this sense, knowledge about the microbiome of indigenous communities ‘is evaluated in terms of how well it correlates to orthodox scientific and technological thought, rather than in terms of the belief system that supports it’ (Last & Chavunduka, 1986, p. 217).

To summarise my argument, I have contended that the process of microbiomisation of race starts with a non-scientific assumption about social groups and cultural differences. This is then materialised by bioprospecting microbial biodiversity. I argue that the microbiomisation of race reproduces an old politics of (neo-)colonial practices encapsulated in the bioprospection of microbial DNA of indigenous communities for the exclusive benefit of certain individuals (see Section 3.5),

⁷⁸ I develop my own response and contribution to this in Chapter 4 by informing microbiome science of the (unexpected and unintentional) bioinequalities produced in this area of scientific experimentation and knowledge production, as well as in Chapter 5 by proposing ‘feminist para-ethnographies’ as a material-semiotic intervention in microbiome science based on care and decoloniality.

predominantly from high-income (Northern) countries. Bioprospection is indeed indissociable from what anthropologist Arturo Escobar calls ‘global coloniality’ and ‘imperial globality’, which is about:

The defense of white people worldwide. By *white privilege* I mean not so much phenotypically white, but the defense of a Eurocentric way of life that worldwide has historically privileged white peoples (and, particularly since the 1950s, those elites and middle classes around the world who abide by this outlook) at the expense of non-European and colored peoples. This is global coloniality at its most material (2008, p. 20).

Finally, it is important to highlight that the MHC research, and microbiome science more broadly, is about (bioprospecting) populations. As Hinterberger puts it, ‘the population imagination has not faced in the post-genomic era’ (2012a, p. 76). I concur with Hinterberger that ‘we [as social scientists and humanities scholars, ANC] should opt for an approach that interrogates what is at stake in population constructions’ rather than transcend them (pp. 76–77). Following Hinterberger’s suggestion on critically examining contemporary population genomics research, I will argue in the section that follows that human microbiome science does not only operate at the level of populations, contradicting what Hinterberger (2012a, 2012b) and other authors (see Fox-Keller, 2010) have argued in relation to genomics and postgenomics medicine. Instead, I argue that the individual dimension of human microbiome science, although sustained by microbial DNA data from human populations through bioprospecting practices, gains meaning through informal, online networks of pseudoscientific microbial-related evidence.

3.5 Online microbiome community

MHC has several online and offline ramifications. In this last section of the chapter, I follow those networks and examine the para-ethnographic evidence (non-scientific) of the microbiome online community associated with AGP mostly, but also with AGP’s affiliated initiatives: the HFP and British Gut (BG).

3.5.1 Overview of the American Gut Project

The American Gut Project (AGP) is a not-for-profit microbiome initiative co-founded by anthropology-trained entrepreneur Jeff Leach and scientist Rob Knight⁷⁹ in 2012. Back

⁷⁹ As I have explained earlier in the chapter, Knight is one of Dominguez-Bello’s main long-term collaborators. The microbial DNA samples gathered by Dominguez-Bello and her team as part of the MHC research in the Amazon were sent for sequencing to Knight’s Lab. This lab at the University of California in San Diego (US) is also where the AGP is conducted.

in 2011, Jeff Leach, who at the time was in Australia planning to conduct a microbiome study on Australian Aboriginals, approached Rob Knight about the idea of setting up a crowdfunding project with the aim to build large-scale microbial data sets. The AGP website (<http://americangut.org/>) narrates the beginnings of the initiative as follows:

At the time, the idea seemed a little bit crazy but with a bit of hard work on the part of Rob and others in his lab, the American Gut Project went live Thanksgiving of 2012. The American Gut Project enables participants to learn about their own body's microbes while also contributing to the greater scientific effort to learn how the human microbiome is associated with various aspects of our health—from associations with diet to the amount of alcohol someone drinks to whether or not someone has autism or IBS [Irritable Bowel Syndrome, ANC]. Because all de-identified data are made freely available, researchers from all over the world can access the data to ask questions about the microbiome and its association with a variety of health and lifestyle factors (retrieved from <http://americangut.org/about/>).

The AGP, as its website informs, is one of the largest 'crowdsourced citizen science' projects in the US (AGP, 2018). The project has 'many more samples representing more groups of people than other studies, such as the Human Microbiome Project, Global Gut, or Personal Genome Project' (AGP, 2018). During the four years that the initiative has been running, over ten thousand contributors have participated and over \$1.5 million was raised. The AGP has processed and sequenced around eight thousand samples from different ages, diets, and BMIs (body mass indexes). The results so far have shed light on how the human microbiome varies across age and changes in microbial diversity in relation to antibiotic consumption (which translates in less diversity) and alcohol consumption (increased diversity).

The AGP aims to explore, sequence, and map the human microbiome (Costandi, 2013). Participants receive a kit for providing samples from the body site(s) of their preference and send the kit back along with a personal survey, detailing their diet and whether they are taking any medication. Once the samples are analysed, they are provided with the results—together with information on how their sample correlates to other profiles, what this data means, and the latest articles and scientific research that relates to their profile. AGP's strategy uses a technical lexicon and develops an open-data model, through which all the sequenced data is made public and accessible to anyone. Interestingly, this so-called 'Science 2.0' project uses the popular term 'citizen science' for describing their ethos and procedures, despite charging between \$69 and \$99 for their most basic service.

Participation in the AGP is straightforward. The donation of certain amounts of money typically comes with ‘perks’, which in the AGP means the characterisation of the human microbiome. Participants can or cannot choose a perk for their monetary contribution. There are different perks at different prices (the cheapest is to sequence the gut microbiome for \$99). Participants can also choose ‘family packages’, which include three and four family members, including dogs. Faecal samples are processed and sequenced at Knight’s Lab at the University of California, San Diego, formerly at the University of Colorado Boulder.

Knight’s Lab is a reference in the field, and not only for researchers like Dominguez-Bello and Blaser in the context of North American microbiome science. In an interview, Tim Spector—a successful and multifaceted geneticist, director of TwinsUK, physician, and popular science writer on epigenetics and microbiome science—explained the scale of Knight’s Lab: ‘Rob Knight has set up a very big system, so you can measure 800 samples in one go, which halves the cost of the whole process’ (T. Spector, personal communication, June 29, 2017). Together with Jeff Leach, Spector launched BG in 2015, a subsidiary project of the AGP. All the samples from BG participants are sent to Knight’s Lab to sequence, not because Spector’s department at KCL lacks HTS, but because of its insufficient infrastructure to make the processing of the samples fast and cheap and software to interpret the data (T. Spector, personal communication, June 29, 2017).

The AGP’s purpose is to build a large data set of microbial profiles as well as provide a personalised medicine-like platform in which individual participants (North American) can explore their microbial profile by comparing it with the microbiome of different populations. As I will elaborate in what follows, the individual dimension of human microbiome science, although sustained by microbial DNA data from human populations, gains meaning through informal online networks of pseudoscientific microbial-related evidence represented by AGP along with its affiliated initiatives (the HFP and BG).

3.5.2 Microbes and the ‘ancestral blend’: NakedPizza

On our way to ‘la upi’ (University of Puerto Rico) from Old San Juan, where Dominguez-Bello lives when she visits her students once per month, she tells me about the background of her involvement with the AGP, featuring not only microbes but, curiously enough, pizza.

In 2006, Jeff Leach founded NakedPizza, formerly the World's Healthiest Pizza, in New Orleans. Defined by Leach as an 'immune boosting pizza' (Miller, 2008), NakedPizza is the first delivery pizza which includes prebiotics (insoluble fibre that promotes the growth of beneficial microorganisms in the gut) and probiotics (beneficial bacteria for health). First, Leach created a pizza dough called 'Prebiotic Multi-Grain Crust'. In 2008, the Geneden Labs joined Leach's business venture with their patented probiotic GenedenBC30 (*Bacillus coagulans* GBI-30, 6086). Leach explained that the addition of probiotics to the 'Prebiotic Multi-Grain Crust' will make the pizza even healthier, without affecting its flavour. Adding probiotics, Leach expressed, 'is a big deal for our business and consistent with our mission to demonstrate that pizza can be part of a healthy lifestyle' (Miller, 2008). In fact, Leach describes his contribution to improve the lifestyle of Americans as a 'social mission' (Miller, 2008).⁸⁰

Leach, Dominguez-Bello tells me, started to research about gut microbiota and nutrition and came up with the idea of NakedPizza after his daughter was diagnosed with type 1 diabetes. By 2014, there were several NakedPizza branches in the US, including in New Orleans, Boston, New York, and Seattle. Leach moved to London to study microbiology at the London School of Hygiene and Tropical Medicine (LSHTM) in 2015. By that time, NakedPizza business in the US sank, except for the Seattle branch. In 2017, Leach opened the first UK branch in Edinburgh (takeaway only), after establishing the new brand and business, now NKD Pizza, in Dubai. The crust of NKD Pizza is now called 'Ancestral Blend of 10 Grains' and it features a 'naked tomato sauce' made from sun-ripened tomatoes. As the former NakedPizza, NKD Pizza includes prebiotic agave fibre and probiotics.

Besides the pizza business and the AGP, Leach is also the founder of the HFP. The HFP is an AGP-affiliated, not-for-profit project examining the association between diet and microbial diversity. In 2012, Leach launched the HFP website (<http://humanfoodproject.com/>) with the aim of redefining what food is in the 'postmodern era of squeaky-clean food and hand sanitizers' (Leach, 2012) and of reconnecting with or 'rewilding' (Leach, 2015) 'our ancestral/microbial past':

Nobody tells a giraffe how to eat. But for the first time in history, humans don't know what to eat. We no longer know what human food is ... The Human Food Project is an effort to understand modern disease against the backdrop of our ancestral/microbial past. Through a better understanding of human ecology at

⁸⁰ Information available at <http://npseattle.com/index3.html>.

different time scales, the coevolution of us and the trillions of microbes that live on and in our bodies is likely to open new doors to understanding. Fingers crossed (HFP, 2018).⁸¹

Over the years, Leach has become a key player in microbiome science. He is a usual collaborator with and ‘gatekeeper’ for the teams of Dominguez-Bello and Blaser in East Africa. He is also a visiting research fellow in the Department of Twin Research and Genetic Epidemiology at KCL. Together with Tim Spector, a leading geneticist and head of the Department, he launched BG in 2015, the UK version of the AGP. Also in 2015, Leach started another small microbiome entrepreneurial business: the Human Food Bar. The Human Food Bar is a nutrition bar sold through the HFP website. ‘Nutrition from the inside out. You’re 99% microbe. It’s time you start eating like it. “Hadza food”. Science’ are the slogans printed on the wrapper of the bar. Microbiome science blends with capitalism, an argument I will develop in the next chapter (Chapter 4).

Leach’s entrepreneurial and pseudoscientific uses of the idea of an ‘ancestral/microbial past’ capture the central theme of the microbiome online community I document. The ‘ancestral’ acts as racial, para-ethnographic data.

3.5.3 The ancestral as racial para-ethnographic data

In December 2014, I completed ‘Gut check: Exploring your microbiome’, a six-week online course authorised by the University of Colorado Boulder and the University of Colorado System and offered through Coursera, an education-focused technology platform (Appendix C). The course material consisted of mini lectures videos, key readings, and quizzes. ‘Gut Check’ provided me with a broad overview of microbiome science. The topics revolved around the microbial diversity of the human body, microbiome research methods—including generating and analysing microbial data—the main factors impacting gut microbiota, and microbes-human host interactions in terms of immune and nervous systems. The last week of the programme was dedicated to the AGP.

In the first video lecture on the AGP, Rob Knight (co-founder of the AGP together with Jeff Leach) explained its rationale. According to Knight, the National Institutes of Health (NIH)-funded Human Microbiome Project (HMP) has a very restrictive selection criterion and accommodates a small number of participants, 242 in total. ‘242 people is a tiny fraction of the over 300 million people in the US. So, what about the rest of us?’, asks Knight in the video. The AGP aims to fill that gap, since ‘the more people participate,

⁸¹ Information available at: <http://humanfoodproject.com/about/founder-jeff-leach/>.

the more informative the results would become' (Knight, 2014). The crowdsourced and crowdfunded model of the AGP 'enables everyone to participate as a citizen scientist to better understand how the microbiome affects health'. Knight concludes the video lecture. Following Knight's plea for inclusion and democratisation in human microbiome research, the AGP website uses casual language to emphasise the importance of individual participants:

The problem is humans are so darn complicated. What we need to be able to do is to compare large numbers of people, people who differ in many ways, to be able to sort out which variables are sometimes a little important and which ones are the big deal. Is a vegan gut very different from a vegetarian one? Does eating yogurt make a big difference? Do the effects of a C-section birth last forever? These questions require us to compare many people, which is where you come in. Your sample gives us context and it gives you context too. It won't be terribly exciting on its own (you will know which ancient lineages you have dividing and thriving inside you. OK, that is pretty cool on second thought), but it will be very exciting in context. Where do you fall relative to fish eaters, sick people, healthy people, hunter-gatherers, or even your dog? You will know and we will know (AGP, 2018).

The point, as the quote suggests, is that the human microbiome of different populations provides context to individual samples. In that way, 'you will know which ancient lineages you have'. Invoking the ancestral and, in turn, racialising human populations is, I argue, a central element of these initiatives (AGP, HFP).

For medical anthropologist Alex Nading, moving beyond the passivity of 'cultural interpretation and social documentation of scientific practice' requires 'taking seriously not only the technoscientific claims that experts make about microbes in scholarly papers but also the qualitative claims ... that they make in blogs, popular writing, and public engagement' (2016, pp. 561, 562). With this aim, Nading develops the framework of 'evidentiary symbiosis' (2016), a reformulation of Holmes and Marcus's para-ethnography, that is, 'a way of dealing with contradictions, exceptions, and facts that are fugitive' (Holmes & Marcus, 2008, p. 596) (see Chapter 1). Evidentiary symbiosis is a para-ethnographic tool in the study of the human microbiome.

The category of the 'ancestral', or 'ancestrality', acts as (racial) para-ethnographic data. It involves the deployment of qualitative, non-scientific claims about microbial diversity in relation to an 'ancestral past' or to certain (racialised) human populations living traditional lifestyles (e.g. 'Hadza' hunter-gatherers). For example, the following statement that Jeff Leach wrote for the HFP website captures the importance that an 'ancestral/microbial past' has to producing para-ethnographic data about the human microbiome in the microbiome online community:

I can't help but think that us 'moderns' moving through our squeaky-clean lives—obsessing over every bite of food we eat—might be suffering *oh so slightly* from a detour or full blown exit from the microbial super highway that once dominated so much of our evolutionary history. Though the Hadza and presumably our ancestors didn't directly consume each other feces or that of the animals on the landscape in a deliberate way on a frequent basis, clearly our hunter-gatherer ancestors had a more intimate involvement in the total microbial metacommunity of the environments they inhabited than we do in the concrete jungles we call home (Leach, 2013).

These assertions about the higher microbial diversity of the Hadza in comparison with 'us "moderns"' plays a nostalgic and exclusionary role. As Nading points out, 'ecological nostalgia is selective; it engages with the bodies of colonized others while insisting that they occupy a space beyond "global" environmental or economic life' (West, 2006, as cited in Nading, 2016, p. 572). Against ecological (imperial) nostalgia and the reification of 'ancestrality' in microbiome research, popular science writer Ed Yong writes:

The Hadza ... are not ancient people, and their microbes are not 'ancient bacteria' ... They are modern people, carrying modern microbes, living in today's world, and practicing traditional lifestyles. It would be misleading to romanticize them and to automatically assume that their microbiomes are healthier ones' (Yong, 2015, as cited in Nading, 2016, p. 572).

On a similar note, in an interview, immunologist and microbiologist Graham Rook goes further than Yong's critique of the 'ancestrality' of the Hadza by questioning population genomic studies that compare non-Western to Western populations and vice versa. He notes:

So, you go to Africa, there's some wonderful papers... there's some wonderful Italian groups [De Filippo et al., 2010, ANC] ... The microbiota was so totally different. And particularly, of course, African people have lots of spirochetes and strange things that they have that we don't have at all. But, I mean, how do you ... what do you do with that information? Because it's quite clear that the African microbiota is what it is, at least in part, because of things like helminth, because of maybe things like these spirochetes. Do we need spirochetes? I doubt it. Do we need helminth? I doubt it (G. Rook, personal communication, April 21, 2017).

For Rook, the extrapolation of DNA microbial data from African to American or European populations is problematic, because these studies overlook evolutionary adaptations to local biologies (Lock & Nguyen, 2010) and, importantly, epigenetic mechanisms. Humans, Rook argues, have developed enormous flexibility through epigenetics. He illustrates this abstract biological idea with a specific case in pregnancy. If a woman with helminths (intestinal parasitic worms) is treated (with an antiparasitic drug) during pregnancy, her baby has a considerably increased likelihood of having allergic disorders, even in communities and populations where allergic diseases are not prevalent. This mechanism is 'almost certainly epigenetic' (G. Rook, personal

communication, April 21, 2017). This shows, Rooks explains, that helminths protect from developing non-communicable diseases (NCD). Yet, he emphasises that these epigenetic mechanisms also mean that ‘after a few generations in the United States without helminths, helminths are no longer necessary’ and their re-introduction in Western populations would not mean a decrease in NCD.

Rook’s argument contrasts with advocates of biome restoration, which refers to the controlled reintroduction of parasites or bacteria into the human body. DIY biome restoration through helminths and similar therapies such as faecal transplantation are popular among certain (online) communities, predominantly in the US. Geographer James Lorimer has documented and elaborated on the issue in the article ‘Gut buddies: Multispecies studies and the microbiome’ (2016). Looking at online networks of helminths therapy users, along with the literature on immunity, he points out that the ‘driving energy for the subsequent growth of helminthic therapy comes from a vibrant network of online support groups’ (p. 64). Contrary to Rook’s argument, Lorimer subscribes to the idea of helminth therapy as a potential solution to NCD (2016, p. 59). According to Lorimer, helminth therapy implies ‘an ecological model of immunity as involving a multispecies community’ (p. 69) and it offers ‘new ways of thinking companionship and hospitality as more-than-human, but not posthuman, achievements’ (p. 59).

I concur with Lorimer in that, contrary to posthumanist hopes of decentring the human (see Hird, 2009; Esposito, 2008, 2011), the ‘human’ of the human microbiome remains the goal of multispecies ethics and therapies. However, I argue that biome restoration through helminths is not about an ‘ecological model of immunity’, as he suggests, but about a delocalised model of immunity based on qualitative, para-ethnographic data (pseudoscientific). Here, the (ancestral) role of helminths in traditional cultures and societies is the principal element (para-ethnographic data) sustaining DIY experiments with helminths in the West via an empowered online community. This model of immunity is, in fact, articulated in exclusion (‘us’, moderns, versus others, traditionals) and nostalgia for a (better and healthier) evolutionary past (see TallBear, 2013).⁸²

Similarly, despite the scientific epistemology of microbiome science resting upon a discourse of ‘ecological holism’, co-evolution, and harmonious balance between

⁸² I elaborate this point in Chapter 4 in connection to what I call the ‘biology of capital’ and the ‘microbiomisation of class’.

microbes and humans, Dominguez-Bello's MHC project, along with its online ramifications, operationalises the microbiome of indigenous human and non-human communities. It is not about holism, but about a disembodied knowledge practice based on the expropriation (via bioprospection) of 'ancestral microorganisms'. This is, in fact, very much a neoliberal capitalist model of microbiome research, based on the individualisation and privatisation of biological knowledge production, therefore distant from the delivery of universal and public health (see Chapter 4 and 5).

As I will elaborate in the next and last section of the chapter, the exclusionary and nostalgic role of the AGP becomes explicit through the results that participants obtain for their monetary contribution to the project (see Figure 16).

3.5.4 From populations to individuals: Bioinequalities

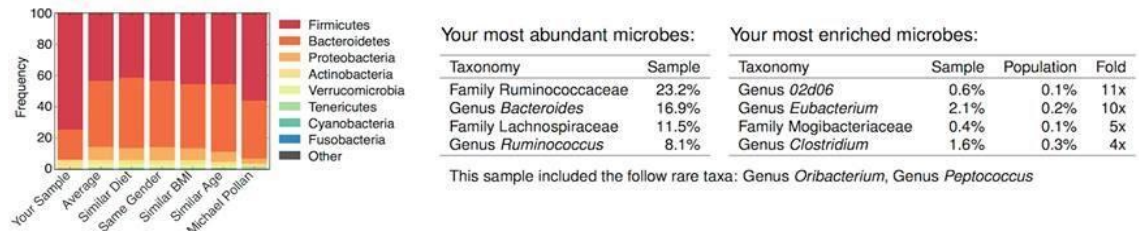
Jessica Metcalf, Senior Research Associate at the AGP, explains the importance of population trends and meta-analysis to produce human microbiome data as follows:

The real power of the AGP lies in the huge numbers of participants, thousands of them. When we look at so many people we can start to see trends. For example, relationships between what people eat and their microbes in their gut. We can also compare people who participate in the AGP with participants in other studies, in what is called a 'meta-analysis', which combines data from multiple studies to discover even more patterns (Metcalf, 2014).

Meta-analysis is a key element of the AGP. A 'meta-analysis' means that Dominguez-Bello's data of the MHC project, for example, can be used for the AGP to 'contextualise' and 'interpret' results from individual profiles. This is made possible through microbial databases. The microbial genomic data obtained from population genomic studies such as MHC, as well as from AGP's participants, is anonymised and added to the database of the Earth Microbiome Project (EMP). The EMP is a massive, open-source and open-access global microbiome study founded by Rob Knight, whose aim is to catalogue the microbial profiles of the Earth's ecosystems. This nexus between population genomics data of the human microbiome and an individual microbial profiling acquires meaning through the visualisation of the results participants receive in a PDF file after the samples are processed and sequenced at Knight's Lab (see Figure 16).

JEFF LEACH

What's in your American Gut sample?



How do your gut microbes compare to others?

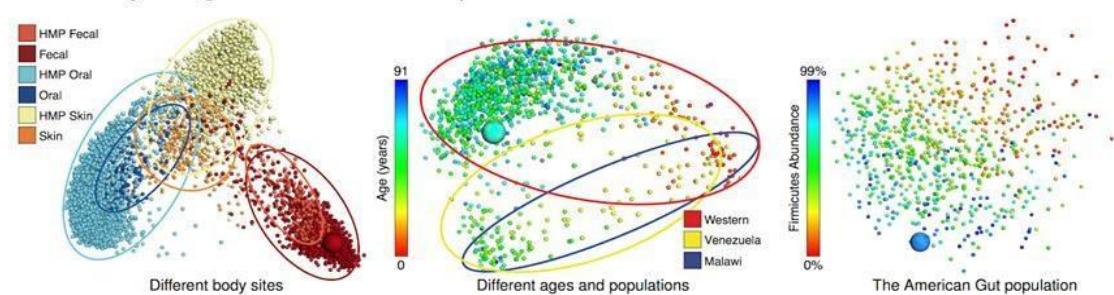


Figure 16. Jeff Leach's results from his participation in the AGP.

These results are from Jeff Leach, founder of the HFP and co-founder of the AGP. They were part of the course material of 'Gut Check'. Results are divided into two (microbial) perspectives: the first, above in the PDF file, deals with the bacteria taxa of the faecal sample. This includes percentages of the most abundant and most enriched microbes, as well as less common or 'rare' taxa. The second perspective, on the bottom of the figure, includes three graphs representing how the (individual) gut sample compares to other populations: Venezuelan, Malawi, and Western. The first graph on the left situates these three populations in relation to the microbial composition of different body sites. The biggest red dot represents Leach's samples, which fall in the 'Western' category (red circle). The graph in the centre situates the individual sample in relation to different ages and populations (Leach's sample is represented by the biggest turquoise dot). Lastly, the right graph situates the AGP participants in relation to the abundance of *Firmicutes*, a bacteria phylum which constitutes a large portion of the human gut microbiome. Leach's sample (represented by the biggest blue dot) has a low abundance of the bacteria.

The results of AGP pose two main problems that occur 1) in relation to the value of the results for the participants of the project; 2) in relation to the microbiomisation of social categories of difference.

Recalling how he got involved in the study of the human microbiome, co-founder of BG (together with Jeff Leach) Tim Spector explains that comprehending nutrition as a move away from what is on the label (i.e. calories, fat, carbohydrates, and protein content) is why he turned his interest to the human microbiome. His aim was ‘to understand what really is food, how does it help me, how does it help my microbes, how can I become my own expert’ (T. Spector, personal communication, June 29, 2017). Yet, he soon became disappointed with BG. The criticism of Spector has to do with issues related to a lack of involvement of participants, an important point since BG and the AGP are so-called ‘citizen science’ initiatives, and with the limited information participants get from their gut sample:

I got fed up with people complaining to me when I gave talks ... And I joined it slightly on not understanding, that I thought it was more of a citizen science project than it is, but actually, most people who do it can't interpret their results or get much out of it; so, I'm not totally happy with the project (T. Spector, personal communication, June 29, 2017).

Out of his disillusionment with BG, Spector founded a small spin-off company in 2017 called Map My Gut (MMG). MMG provides a more individualised analysis and interpretation of results and dietary and lifestyle recommendations; services that neither BG nor the AGP provide. MMG works with nutritionists to provide a fifteen-page report explaining ‘exactly what’s going on, and with a personal interpretation by a microbiome expert on what’s going on. It costs three or four times as much, but you get what you pay for’ (T. Spector, personal communication, June 29, 2017).

The other issue springing from the microbial information that makes up the results of the AGP has to do more directly with the focus of this thesis and, more specifically, with the interplay between population genomics and individual microbial profiling—or, in other words, between racialised microbial populations and individualised whiteness.

As I have previously argued in relation to Dominguez-Bello’s MHC research, the population categories (i.e. Western, Venezuelan, Malawi) deployed to compare individual samples of the AGP participants are extremely confusing: to what extent is the Venezuelan or the Malawi population ‘traditional’? Does the ‘Western’ category include North American residents or just North American citizens? Many different populations with different lifestyles (that do not fit under the ‘Western’ label) live in the US; how do

these categorisations reflect the heterogeneous social (and economic) reality of the US? The AGP does not address any of these questions, nor does it provide any criteria detailing how these categories were established.

A closer look at the data and the AGP website reveals that these three (racial) categories of difference based on nationality/residency—‘Venezuelans’, ‘Malawians’, and ‘Westerners’—are taken from a single human microbiome study conducted by Yatsunenکو et al. (in which Dominguez-Bello and Rob Knight are co-authors) in 2012. As I have discussed earlier in the chapter, Yatsunenکو et al.’s ‘Human gut microbiome viewed across age and geography’ is a landmark publication in the field. This cross-cultural and cross-national study is a model for microbiome studies because of the diversity of the variables studied (Fortenberry, 2013). It included mono- and dizygotic twins, children and adults, assessments of residency, kinship, diet, and cultural and social practices and habits. Regarding sample collection, the authors only mention that ‘(s)ubjects were recruited for the present study using procedures approved by Human Studies Committees’ of each of the participating institutions (Yatsunenکو et al., 2012, p. 9).

Furthermore, there clearly is a remarkable difference between the AGP and the MHC research regarding how the embodied form of the microbial samples is produced in the scientific discourse of microbiome science: the participants of the AGP are ‘citizen scientists’, while the Malawians, Amerindians Venezuelans, and the blurry category of ‘Westerners’ are ‘research subjects’. Clearly, the former have a proactive role: they hold a ‘biological citizenship’ (Petryna, 2002), while the latter are purely passive, devoid of citizenship, ‘illegal’, as it were. While the AGP is an open-access scientific project exploring population-level patterns and trends, and therefore does not provide any clinical or commercial information, those who can relate to the sequenced microbial DNA are predominantly, if not all, Western (white) individuals. From a conceptual perspective, this is because biomedicine’s general assumption is that bodies are the same and they can be normalised through biomedical technologies, a thought that has its roots in the European colonial empires (Lock & Nguyen, 2010). But the fact that knowledge of the microbiome is articulated using biomedical propositions about health and disease is not the main reason that microbiome science is reinstating the old immunological precept of inclusion and exclusion (through the inclusion of certain bodies [Western] and the exclusion of others [non-Western]). This is since human microbiome research is focused

on ‘modern diseases’ or ‘lifestyle diseases’ such as diabetes, asthma, and obesity; diseases that affect those populations living in the West or adopting a ‘Western’ lifestyle.

Despite the initiative having been publicised as ‘open to all’ (North Americans), filling the gap of the NIH HMP (Knight, 2014), I suggest that participants of the AGP belong to a very selective population within the US, with substantial socio-economic and cultural capital. Not everyone has \$100 to spend on this kind of personalised medicine initiative, and not everyone has the educational and cultural conditions to access information on personalised medicine initiatives such as the AGP. Likewise, I suggest that the participants of the AGP fall into one or more of the following categories:

- 1) Health concern: due to a health issue such as a disease or a family history of a disease.
- 2) ‘Healthism’ (Shilling, 2012; Rose, 2007): to enhance their actual physical condition.
- 3) Curiosity/fashion: the marketing behind individualised microbial profiling concentrates on making medical terms and concepts of the human microbiome familiar, using casual language and anecdotes and the design of packages including ‘your loved ones’ (i.e. dog, baby, partner).

Sociologist Amy Hinterberger (2012a) has pointed out that the ‘question of population needs to be reactivated as human genome science is increasingly linked to promises of individualized and personalized medicine’ (p. 87). As Hinterberger also argues, historian of science Evelyn Fox-Keller has elaborated on the contradictory use of individual and population categories in contemporary life sciences, a confusion, she argues, that is rooted in language, particularly in the terms heritable and heritability (2010, pp. 55–57):

The difficulty in maintaining the essential distinction between individual and population persists, and it may even have been compounded. When authors write about sorting genetic from environmental contributions to the development of traits, it is not only the distinction between trait and trait difference that has been tacitly erased, but also the distinction between individual and population. ... Our difficulty in maintaining this conceptual distinction is sustained, if not caused, by the words we use (Fox-Keller, 2010, p. 55).

In this light, coming from Foucault’s idea of population as a question of power and politics, Hinterberger (2012a) argues that social and humanities studies of large-scale human genome science should tackle the concept of populations in all its ambiguity, as Fox-Keller shows.

I concur with Hinterberger that, while Euro-American science policy discourse focuses on the construction of the ‘responsible and self-policing individual’, life science research is concerned with populations (Hinterberger, 2012a, p. 87), as the chapter has

demonstrated. However, Hinterberger misses an important element of contemporary population genomics research. A closer analysis of human microbiome research through Dominguez-Bello's MHC project research have revealed that online initiatives such as the AGP or the BG use open-access population genomic data (particularly data from non-Western populations) to provide contextual information for certain (privileged) Western individuals. While the Foucauldian concept of population in relation to power and politics might be a useful framework through which to analyse large-scale postgenomic projects like human microbiome science, as Hinterberger suggests, I instead associate this trend of the process of microbiomisation—by which microbiome science takes social groups as pre-existing, 'natural' phenomena and biologises them by attributing microbes and microbial profiles to them—with what medical anthropologist Didier Fassin (2009) calls 'bioinequalities'.

To conclude, I maintain that the process of microbiomisation not only rests upon (1) the bioprospection of DNA from human and non-human populations (see Section 3.3), but also, and equally importantly, on (2) the economic, social, and cultural capital of consumers (mostly from Northern richer nations) of microbiome profiling online platforms such as the AGP, an aspect that I link with Fassin's concept of bioinequalities.

3.6 Conclusion

This chapter has developed the concept of the 'microbiomisation of race' and has also provided an empirical and conceptual framework for what I refer to as the 'microbiomisation of social categories of difference'.

Drawing on ethnographic fieldwork with microbial ecologist Maria Gloria Dominguez-Bello and her research team in San Juan (Puerto Rico) and New York (US), interviews with influential microbiome scientists in London (UK), my attendance of microbiome conferences, and an analysis of scientific publications and the microbiome online community, I have theorised the 'microbiomisation of race' as the process by which microbiome science takes social groups and socio-cultural practices as pre-existing 'natural' phenomena and biologises them by creating and attributing microbes and microbial profiles to them. By correlating certain microbial species and diversity and hunter-gatherers, ideas of race, nation, and ethnicity become microbiomised. Unlike other biological-social interplays—such as the personification of cells, by which biomedicine writes and speaks about cells as if they were interchangeable with persons (Martin, 2006)—in the process of microbiomisation, the 'social' (i.e. lifestyle, cultural habits,

ritual, traditions, local milieus) is the main element that animates scientific research on microbes. The microbiome study I have documented and examined, the MHC project, started from a non-scientific assumption about social differences: what are the differences between Western and indigenous (microbial) populations?

Among the principal aims of MHC was the search for ‘ancient microbes’ as potential solutions for restoring the microbiome of Western and westernised societies. The bioprospection of microbial ‘populations’ from human and non-human populations is a key element of the process of microbiomisation, I have demonstrated. Yet, human microbiome science, as part of postgenomics, does not only operate at the level of populations, as some authors have suggested (Fox-Keller, 2010; Hinterberger, 2012a), nor does it only operate on the individual via personalised medicine projects, as others have claimed (El-Haj, 2007; Wade et al., 2014). By contrast, I have contended that the individual dimension of human microbiome science is sustained by microbial DNA data from human populations, and gains meaning through informal online networks of pseudoscientific microbial-related evidence.

It is in this sense that the principal contribution of the chapter to the social and humanities scholarship of biomedicine, particularly to the cultural and social study of microbiome science, is to show that the ‘microbiomisation of race’ is constituted within a nexus between bioprospection (i.e. population genomic research) and bioinequalities (i.e. personalised medicine projects). In other words, I have argued that biomedical interventions (including initiatives such as the AGP) aimed at defining a ‘healthy’ microbiome and improving health through the human microbiome are articulated upon (1) the microbial genetic makeup of non-Western(ised) communities, societies, and locales; and (2) individual economic, social, and cultural capital in neoliberal societies. Human microbiome science re-enacts an immunitarian model of inclusion and exclusion, self and other, by racialising human and microbial populations.

CHAPTER 4 The microbiomisation of class: Antimicrobial resistance and the ‘biology of capital’

4.1 Introduction

Antimicrobial resistance (AMR), microbiome scientists insist, is the main cause of the loss of microbial diversity in high-income countries. Biomedical, public health, and science policy epistemologies describe AMR as a phenomenon of global proportions, horizontally distributed, affecting all in the same way, rich and poor. I sustain the opposite. AMR is not global. It does not affect everyone in the same way.

This chapter proposes what I call the ‘microbiomisation of class’ as a speculative ‘proposition’—what philosopher of science Isabelle Stengers calls ‘innovative fiction’⁸³ (1997)—*informing* about the relevance of ‘questions or possibilities that were not taken into account’ (Stengers, 2018, p. 9) in the scientific production of the human microbiome but that have become important. These ‘questions or possibilities’ that have become important involve, I will argue, microbiome science as the re-enactment of an immunologic of inclusion and exclusion. I focus on the links between microbiome science and AMR, an understudied theme in the social and cultural studies of postgenomic science. My argument is that a diverse microbiota, as crucial as it is for overall health and immunity as microbiome science indicates, is not accessible to everyone. Microbial diversity is conditioned by socio-economic status. The more affluent, the more microbial diversity, the less susceptibility to AMR, and vice versa. This social stratification of microbes and immunities, in turn, reflects the ways in which entanglements between neoliberal capitalism and the life sciences are lived and experienced differently in and by different bodies.

As occurs with the microbiomisation of other social categories of difference, such as race (Chapter 3) and gender (Chapter 5), what I call the ‘microbiomisation of class’ relates to the biologisation and naturalisation of socio-economic conditions and cultural values into microbial profiles. Unlike the microbiomisation of race and gender, however, the microbiomisation of class is less substantiated in microbiome science publications, a fact that reflects, I claim, a lack of political willingness to tackle health disparities

⁸³ Stengers (1997) defines an ‘innovative fiction’ as a proposition that ‘makes a new phenomenon, or a phenomenon in a new mode, intervene in discussions’ (p. 140). I will develop this concept in relation to the ‘microbiomisation of class’ in the fourth and last section of the chapter.

resulting from neoliberal politics and policies in rich nations. However, the fact that there is less published scientific research on the topic does not invalidate the association between class and human microbiome research. On the contrary, it is imperative for social and cultural studies of science to provide alternative ways of evidencing this link. I do so by combining insights from my ethnographic fieldwork on microbiome science and science policy analysis with embodied experiences and analytical perspectives from the work of feminist science studies scholars Hannah Landecker (2016), Melinda Cooper (2008), and Isabelle Stengers (2018).

I divide the chapter into four sections. In the first section, I read microbiome scientific discourse of AMR through the lens of Priscilla Wald's concept of the 'outbreak narrative' (2008). My argument here is that neither antibiotics/substances such as probiotics nor policing individuals' and communities' attitudes towards and relations with microbes solve the problems associated with AMR. This is simply because these are the same approaches (or 'solutions') that have been deployed to address AMR for over decades, unsuccessfully. In the second section of the chapter, I engage with feminist science studies scholar Hannah Landecker's concept of the 'biology of history' (2016). This notion refers to the materialisation of historical events in biological bodies, processes and ecologies. Contrary to individualist, mainstream analysis of resistance based on rationality and behavioural changes, Landecker's work offers an insightful perspective on AMR by highlighting the materiality and the interconnection of ecosystem and species. However, despite the possibilities that 'biology of history' offers in terms of situating AMR away from 'deliberate human action' (Lee & Motzkau, 2013), this concept has two limitations that I would like to overcome. On the one hand, it is somehow framed within an Anthropocene discourse of globality; on the other, it excludes political economy from the history of antibiotic use.

In overcoming these limitations, the third section of the chapter complements and reformulates Landecker's 'biology of history' as the 'biology of capital'. Drawing on Cooper's 'capitalism delirium' (2008) and Stengers's 'intrusion of Gaia' (2015), I analyse the 'National bioeconomy blueprint' (NBB), an US science policy document published by the White House in 2012. While in the third section I propose 'biology of capital' as a concept reflecting the co-production (Jasanoff, 2004) between science policy and biomedicine, the fourth and last section of the chapter focuses on how the entanglement between neoliberal capitalism and the life sciences is embodied and experienced differently in and by different bodies (Lock & Nguyen, 2010). Through three speculative

examples of bioinequalities (Fassin, 2009) in human microbiome science (breastfeeding, eating, and inhabiting), I maintain that socio-economic deprivations and marginalisation translate into a poor microbial diversity, and thereby into a higher susceptibility to AMR. The ‘biology of capital’ figures as a necessary precondition for the ‘microbiomisation of class’, I argue.

Ultimately, the relevance of my speculative proposition of the ‘microbiomisation of class’ lies in its potential to *inform* microbiome science about the ‘questions or possibilities that were not taken into account’ (Stengers, 2018, p. 9) in the scientific production of the human microbiome, but that have become important. That is, in neoliberal capitalism, the biology of health and well-being has become a privilege instead of a right. My proposition of the ‘microbiomisation of class’ is a way for the sciences to engage with critical science studies and move away from positivism.

4.2 AMR as an outbreak narrative

4.2.1 *Staphylococcus aureus* and the *pharmakon*

At the 3rd Wellcome Trust conference on microbiome research, ‘Exploring Human Host–Microbiome Interactions in Health and Disease’, held at the Genome Campus in Cambridge, UK, between 14 and 15 April 2014, Dr. Joaquim Madrenas, also known as Quim Madrenas, opened his talk with the following sentence: ‘When I studied [microbiology and immunology, ANC], you shouldn’t have microbes in your body. Nowadays we know a different story’.

Madrenas is a leading researcher in the fields of microbiology and immunology who, in addition to his academic appointment at McGill University, Canada, is a passionate about public engagement and science communications. Madrenas’s presentation, entitled ‘Functional microbiomics and human disease tolerance: The *S. aureus* story’ and presented in the panel ‘the anti-infective potential of the microbiome’, was an entertaining and accessible lecture on the duality of (human) host–microbiome interactions. At the beginning of the lecture, he explained that ‘there are only 1,415 microbes known to be human pathogens, which is a very small number compared to the 10^{13} - 10^{14} commensal⁸⁴ [microorganisms, ANC]’ that live on and in the human body.

⁸⁴ Coming from ecology, the term ‘commensal’ refers to the relation between two organisms, in which one benefits and the other is neither benefited nor harmed. Commensalism is a type of symbiotic relationship. Symbiosis in biology refers to the close interaction between two different biological species. The most

He then borrowed historian and philosopher of science Thomas Kuhn's term 'paradigm shift' (1962) to interpret this data.

He described 'functional microbiomics' as a research subfield of microbiome studies which combines the systems biology⁸⁵ apparatus, immune versus non-immune mechanisms, and a focus on health states rather than on disease. During his intervention, he introduced the term 'disease tolerance', which refers to host–microbiome interactions by which 'microbes "tell" the host [human, in this case, ANC] to be not so aggressive towards them and so they both benefit from the relationship'. This type of relationship is called mutualism in ecology. He illustrated his concept of disease tolerance using the case of the bacterium *Staphylococcus aureus*. *S. aureus* is a type of bacterium frequently found in humans, in the respiratory tract as well as on the skin. However, *S. aureus* can also cause harm. The (in)famous MRSA (methicillin-resistant *Staphylococcus aureus*) is a pathogenic strain of *S. aureus* that has developed resistance to antibiotics. MRSA began as a nosocomial (i.e. hospital-acquired) infection.

Madrenas insists, however, on the twofold property of *S. aureus*: it has pro-inflammatory and immune-modulator properties. The first means that it facilitates inflammation, acting as a 'pathobiont' or pathogen, and the second that it triggers a human immune response promoting commensalism and disease tolerance. But, mostly, he explained, *S. aureus* is 'balancing and preventing infection'. Given its duality then, what kind of mechanisms or conditions lie behind both antithetical functions? Or in other words, what are the factors that determine that in some cases, *S. aureus* acts to promote health while in others, it acts as a disease agent? I wondered.

Madrenas's pleasant and accessible talk brought to mind Derrida's 'Plato's pharmacy' (1981), in which he traces the genealogy of writing of Plato's *Phaedrus* and deconstructs 'the dialectic of the opposites' between remedy and poison (p. 101). In *Phaedrus*, the god Theuth offers the king Thamus the gift of writing, a truth-revealing practice of medical qualities that improves memory. Thamus, however, rejects the gift. He associates writing with its opposite: forgetting. Derrida purports that these conflicting views are inscribed in the meaning of the word *pharmakon*. The *pharmakon* is a *technē*

common types of symbiosis are commensalism, mutualism (both organisms take advantage of each other), and parasitism (one benefits at the expense of the other).

⁸⁵ Systems biology can be defined as 'an integrative research strategy designed to tackle the complexity of biological systems and their behavior at all levels of organization (from molecules, cells and organs to organisms and ecosystems)' (Auffray et al., 2009, p. 1, as cited in Calvert, 2013, p. 467).

through which to deal with finitude (pp. 103–104). The ambiguity in the translation of the word is manifested in the fact that it surpasses its positive signification as remedy. Thus, the aid conferred by the *pharmakon* is at the same time subverted. In this case, its effects become ‘hard to master, a dynamics that constantly surprises the one who tries to manipulate it as master and as subject’ (p. 99). Interestingly, as occurs with AMR, Derrida links the *pharmakon* with the production and dissemination of resistance:

Disease demonstrates its autarky by confronting the pharmaceutical aggression with metastatic reactions which displace the site of disease, with the eventual result that the points of resistance are reinforced and multiplied (Derrida, 1981, p. 104).

Derrida’s insight about resistance as a consequence of pharmacological aggression is relevant because it correlates with the argument I develop in the chapter: Antibiotic excess causing AMR articulates a capitalist surplus value, in other words, is part of what I call the ‘biology of capital’ (Sections 4.4 and 4.5). What Derrida calls ‘pharmacological aggression’ can be read in terms of AMR as a consequence of antibiotic excess. This is indeed sustained by the logics of the pharma industry, an indispensable sector in neoliberal capitalism. This view, as I show in what follows, contrasts with the public and global health discourse on tackling AMR. The mainstream official epistemology around AMR points to two main reasons that AMR is spreading: a dry antibiotic pipeline (i.e. lack of discoveries of new antibiotic substances) and individual and collective non-compliant antibiotic use.

4.2.2 Microbiome scientists and the discourse of resistance: The ‘dry pipeline’

AMR refers to the ability of microbes to grow in the presence of a drug or chemical that would normally limit their growth (Antimicrobial (drug) resistance, 2016). As part of a new generation of biologists concerned with relational and ecological ontologies of life, Dominguez-Bello and her collaborators are dealing with the outcomes of the ‘biology of history’ (Landecker, 2016) in microbial life, specifically in relation to the disappearance of microbes and the resulting disrupted balance of the ‘holobiont’.⁸⁶ Landecker’s (2016) concept of the ‘biology of history’ refers to ‘how human historical events and processes have materialized as biological events and processes and ecologies’ (p. 3). As I will elaborate further later in the thesis, Martin J. Blaser, one of the closest collaborators of

⁸⁶ Coming from Margulis’s symbiogenesis, the term ‘holobiont’ refers to different species that form an ecological unit. In human microbiome science it is widely used to denote human–microbe entanglements.

Dominguez-Bello and the current director of the Human Microbiome Program at NYU, develops the thesis of the ‘disappearing microbiota’ in his most recent popular science book *Missing microbes: How killing bacteria creates modern plagues* (2014a). Embodying the Derridean *pharmakon* of the remedy turned into poison, Blaser claims: ‘I’m not against antibiotics any more than I’m against ice cream—both great at serving their purpose—but sometimes there can be too much of a good thing’ (p. 199). Using a dystopian rhetoric, Blaser argues that killing bacteria creates what he calls ‘modern plagues’, namely a meteoric increase in autoimmune, metabolic, and inflammatory diseases in Western and westernised countries. He also alerts us to the toxic impact of antibiotics on ecosystems:

We talk about a pre-antibiotic era and an antibiotic era; if we’re not careful, we’ll soon be in a post-antibiotic era. I am thinking about not only the failure of antibiotics because of resistance but also the increased susceptibility of millions because of a degraded ecosystem. The two go hand in hand, but in a smaller interconnected world the second is a deluge waiting to happen and growing each day (p. 198).

Ecosystems, however, have always harboured antibiotics. AMR is an ancient, naturally occurring phenomenon in the biosphere (D’Costa et al., 2011). In the origins of life, as Lynn Margulis and Dorian Sagan explain in *What is life* (1995), bacteria were the vital organisms in charge of keeping environmental toxins at bay:

Gene exchanges were indispensable to those that would rid themselves of environmental toxins. ... Replicating gene-carrying plasmids owned by the biosphere at large, when borrowed and returned by bacterial metabolic geniuses, alleviated most local environmental dangers, provided said plasmids could temporarily be incorporated into the cells of the threatened bacteria (pp. 110–111).

The antibiotic-resistant genes or resistome (Wright, 2007) that Blaser and Dominguez-Bello and colleagues are characterising do not include the ancient mechanism of genes encoding resistance to antibiotics (r genes) as an evolutionary process. They are rather examining antibiotics as *pharmakons*, which pertain to the modern ecological distribution of r genes as a selective pressure resulting from the use, overuse, and misuse of antibiotics since they became publicly available and commercialised in the late 1930s (Davies & Davies, 2010, pp. 418–419).

The environmental spread of AMR is not a cause in itself but a toxic by-product of antimicrobial practices in human medicine and non-human animal health and husbandry. As the Center for Disease Control and Prevention (CDC) states, ‘simply using antibiotics creates resistance’ (‘Antibiotic/antimicrobial resistance’, 2015). Irresponsible

antibiotic disposal by the pharmaceutical industry and antibiotic use in agriculture and aquaculture ‘create major environmental reserves of resistance’ (Davies & Davies, 2010, p. 424). In the light of the global distribution of *r* genes across the entire biosphere, it is not surprising then that estimates of annual deaths attributable to AMR, compared to other major causes of death, predict 10 million globally in 2050, surpassing cancer by two million (WHO, 2014, p. 5).

Public health and scientific narratives describe the discovery void in new classes of antibacterial drugs since the late 1980s as one of the principal causes, next to antibiotic overuse, of AMR. The ‘dry antibiotic pipeline’ discourse supposes a major problem in the clinical containment of AMR, according to the WHO (2014). At the same time, microbiome scientists associate reduced microbial diversity with three main elements of the ‘modern lifestyle’: processed food, C-sections, and antibiotic overuse (Blaser, 2014a, 2014b; Blaser & Dominguez-Bello, 2014; Dominguez-Bello et al., 2010a; Dominguez-Bello, 2013, 2012; Ruiz-Calderon et al., 2016). In this sense, the research of Dominguez-Bello and her team, as I examine in the previous chapter, identifies the microbiome of non-Western indigenous communities and environments of the Peruvian and Brazilian Amazon basin as a model for probiotic development. Tentatively, these probiotics would be able to replenish the loss of microbial diversity in the West, microbiome scientists sustain. However, as I elaborate in the chapter, those who would benefit from the microbiome of indigenous communities are not ‘westerners’ or, generally, citizens of rich (Western) countries. They are, I claim, very specific sectors of Western societies: the privileged, those from higher socio-economic backgrounds, not just because they hold cultural and economic capital to participate in personalised microbiome initiatives (Chapter 3) for example, but because, overall, they are socio-economically able to sustain healthy lifestyle choices. Those healthy lifestyle choices necessary to ‘cultivate’ microbial diversity (and therefore overall health) are not innocent, everyday decisions, actions, or embodiments. On the contrary, my argument is that, in neoliberal capitalism, attaining microbial diversity reproduces health disparities. Put differently, it produces and reproduces what we might call ‘immunitary privileges’.

4.2.3 AMR as a behavioural problem

In 2014, the WHO warned that AMR poses a ‘major global threat’ that endangers ‘the achievements of modern medicine’, inaugurating a ‘post-antibiotic era’ in which common

infections and minor injuries that have been treatable for decades can now kill (WHO, 2014). As the authors of the WHO report on AMR write:

Antimicrobial resistance (AMR) within a wide range of infectious agents is a growing public health threat of broad concern to countries and multiple sectors. Increasingly, governments around the world are beginning to pay attention to a problem so serious that it threatens the achievements of modern medicine. A post-antibiotic era—in which common infections and minor injuries can kill—far from being an apocalyptic fantasy, is instead a very real possibility for the 21st century (WHO, 2014).

The apocalyptic scenario portrayed in the above statement has become a commonplace narrative employed well beyond public health agencies. Most notably, the figure of the dreaded ‘superbug’ (i.e. antibiotic-resistant bacteria) has an increasing presence in the headlines of newspapers, specialist magazines, and other media such as television news and documentaries (Morris, Helliwell, & Raman, 2016; Nerlich, 2009). The level of fear and neurosis around the rapid emergence of ‘superbugs’ alongside its association with the end of modern medicine—or at least with the end of biomedicine as we know it—is encapsulated in a statement made by Dr. Dame Sally Davis, the Chief Medical Officer for England since 2010. In 2013, Davis went as far as to suggest that the threat of AMR ‘should be ranked along with terrorism in a list of threats to the nation’ (Walsh, 2013). Thus, AMR is not ‘only’ a question concerning public and (global) health but also (global) biosecurity (Brown & Nettleton, 2017).

The post-antibiotic apocalypse associated with the emergence and spread of ‘superbugs’, what Nerlich (2009) frames as the ‘catastrophe discourse’ in microbiology, is similar to the climate change discourse: it also brings funding, policy attention, and new lines of scientific research. Yet, on the other hand, ‘it might also induce fears which could stifle behavioural change’ (p. 584). The focus on behaviour here is important because science, science policy, and public and global health discourses usually frame AMR in relation to human behaviour and patients’ compliance (along with a dry pipeline). For Blaser (2014a), for example, changing behaviour is crucial to prevent common infections from becoming life-threatening events:

The loss of microbial diversity on and within our bodies is exacting a terrible price. I predict it will be worse in the future. Just as the internal combustion engine, the splitting of the atom, and pesticides all have had unanticipated effects, so too does the abuse of antibiotics and other medical or quasi-medical practices (e.g., sanitiser use). An even worse scenario is headed our way if we don’t change our behaviour. It is one so bleak, like a blizzard roaring over a frozen landscape, that I call it ‘antibiotic winter’. I don’t want the babies of the future to end up like my poor aunts. This is why I am sounding an alarm (p. 6).

Here, Priscilla Wald's concept of the 'outbreak narrative' in her book *Contagious* (2008) is insightful.

4.2.3.1 *AMR and the 'outbreak narrative': Immunitary othering*

The 'outbreak narrative' refers to stories about tenacious microbes and infections amplified by popular and media news and information. The difference, however, lies in that in the discourse of AMR, the fear and anxiety is not directed at infection and contagion but at the opposite: at what we might call a 'microbial desert' or what Martin Blaser refers to as 'missing microbes' and the process of the 'disappearing microbiota'. This process is, according to scientific evidence in microbiome research (Blaser, 2014a; Shin et al., 2015), the perfect breeding ground for recalcitrant microbes (read antibiotic-resistant) to emerge. The outbreak narrative can compromise the diagnosis of infectious diseases and affect survival rates and the economy, as Wald demonstrates. Importantly, she warns of the dangers of the outbreak narrative in terms of the stigmatisation of certain social groups (i.e. in the case of homosexuals and HIV in the 1980s in North America and Europe).

As occurs with the 'outbreak narrative' (Wald, 2008) in relation to 'patient zero' as the primary source of infection, the popular discourse on AMR reinforces the racist idea that multidrug-resistant strains originate in non-Western, (often poor) overpopulated nations, predominantly India and China (Raman, 2016). Interestingly, public health and scientific discourse situate both the solution and the cause of AMR *outside* their own *borders* and *bodies*, in the non-Western world. In 2014, former UK Prime Minister David Cameron commissioned a report on the topic, chaired by former Goldman Sachs's chief economist Jim O'Neill (2014). The report warned of a very high estimated death toll of ten million in a relatively short time frame, namely by 2050 and its stratospheric economic cost (£64 trillion). 'We cannot allow these projections to materialise for any of us, especially our fellow citizens in the BRIC (Brazil, Russia, India, China) and MINT (Mexico, Indonesia, Nigeria, Turkey) world, and our ambition is such that we will search for bold, clear and practical long-term solutions', he claimed (O'Neill in Siddique, 2014). It goes without saying that one of the points of this statement is AMR 'contagion'. In other words, resistant strains that spread globally (read 'come here', to rich nations) via international travel (read globalisation) and migration (read mostly illegal).

The high rate of AMR in these countries is attributed to over-the-counter access to antibiotics and, more generally, to lax regulation of antimicrobials, as popular science

literature and media news alike often report (O'Neill, 2014). Fundamentally, what the O'Neill report highlights is that AMR springs from contexts in which non-compliant behaviours mix with 'ineffective' institutional settings. While the report recognises that AMR affects countries differently (p. 9), it states that resistance to antibiotics is 'a crisis of global scale' (p. 9). Although I will return to the issue of globality and universality ascribed to AMR later in the chapter, in relation to the debates around the Anthropocene (see Section 4.3), it is important to highlight that the idea of 'BRIC' and 'MINT' as exporters of AMR has recently been disputed.

In a recently published study on global antibiotic consumption, Klein et al. (2018) found that poorer nations use antibiotics far less intensively than rich nations. 'In low and middle-income nations, the number of "defined daily doses" handed out per 1,000 people rose 77% from 7.6 to 13.5 over the 16 years studied. But richer nations consume antibiotics at nearly twice that rate', *The Guardian* reports. For the authors, the main issue arising from their research is that 'inequities in drug access persist, as many (LMICs) [low- and middle-income countries, ANC] continue to be burdened with high rates of infectious disease-related mortality and low rates of antibiotic consumption' (Klein et al., 2018, p. E3463).

In this line, a recent study conducted by social scientists Ismael Ràfols and Jack Stilgoe (2018) demonstrates that mainly rich nations benefit from global biomedical research. 'Big pharma R&D [research and development, ANC] and public research both', the authors explain in an article for *The Guardian*, 'appear to focus on some diseases that are prevalent in high-income countries, such as cancer or skin diseases, leaving other areas relatively under-invested'. These 'other areas' are parasitic and infectious diseases such as malaria and tuberculosis. For Ràfols and Stilgoe, the fact that 'the vast majority of global science is conducted in rich countries seems to be causing neglect of global health problems'. The authors argue that 'public R&D is following rather than counterbalancing pharmaceutical research agendas' and they point out three possible reasons for that:

First, researchers in public labs may also receive private funding that is related to market for a disease and the likelihood that the disease can be treated using a conventional biomedical business model. Second, notions of healthcare are still dominated by drug-centred therapeutic approaches rather than improving lifestyle and promoting healthier environments. And, third, in many countries the narrative of 21st century science is increasingly tied to economic needs (often seen as national priorities) rather than fostering wellbeing. The problem is not just in how problems are chosen but also with how solutions are designed. Market

forces cause an over-emphasis on certain diseases and on pharmaceutical solutions rather than preventative public health approaches.

While the first point they make exceeds the scope of this thesis, in the following two sections of the chapter I address the second and third aspects that Ràfols and Stilgoe identify. I do so by reformulating sociologist of science Hannah Landecker's notion of 'biology of history' as the 'biology of capital' through a science policy analysis of the US and European bioeconomy.

To summarise the main points, in this section of the chapter I have argued that public and global health and scientific discourse around AMR are mainly articulated around two issues. First, a dry antibiotic pipeline (i.e. blaming bacteria for the technoscientific inability of finding or creating new antimicrobial substances). Here the research of Dominguez-Bello has the potential of transforming 'indigenous' microbiomes into probiotics as an alternative to antibiotics (Chapter 3). Beyond the 'dry antibiotic pipeline', the official epistemology around AMR in public health also focuses on individual and collective attitudes and behaviours around antibiotics (de Lima Hutchison, Knight, Stabler, & Chandler, 2018), especially in the non-Western world. Despite recent studies showing that poorer nations use antibiotics far less intensively than rich nations (Klein et al., 2018), this Grand narrative conceals a very different reality: AMR is principally produced by current practices of husbandry (i.e. mass production of meat) (Bud, 2007; Kirchhelle, 2018) and the multinational pharmaceutical industry (Davies & Davies, 2010; Kamat & Nichter, 1998; Klein et al., 2018).

Clearly, both causes of (i.e. behaviours in the non-Western world) and solutions to (e.g. indigenous microbiomes) AMR evade responsibility by blaming and stigmatising the 'Other' (mostly non-Western, mostly poor) (Biehl, 2007; Ecks, 2005). In order to bring political economy into the spotlight of the AMR problem, away from non-human (bacteria) and human responsabilisation, and especially away from stigmatising the (non-Western) poor, I argue that Hannah Landecker's notion of the 'biology of history' offers an insightful alternative to the mainstream discourse of AMR.

4.3 The biology of history

In science studies, there is an important lacuna in the study of antimicrobial resistance. In recent years, however, social sciences and humanities scholars have turned their attention to the social, historical, and political configurations of AMR, albeit from varied perspectives (Farmer, 2005; Landecker, 2016; Lee & Motzkau, 2013). The growing

concerns of the social science literature with AMR come at a time when microbes have also become objects of critical inquiry (Benezra et al., 2012; Helmreich, 2009; Hinchliffe, 2015; Hinchliffe & Ward, 2014; Nading, 2014) and even fields of study in themselves (c.f. Kirksey & Helmreich, 2010, on multispecies ethnography). Landecker's (2016) recent and inspiring research on AMR demonstrates 'how human historical events and processes have materialized as biological events and processes and ecologies', a phenomenon that she describes as 'the biology of history' (p. 21).

I argue that Landecker's concept of the 'biology of history' offers an insightful analytical approach to AMR beyond human intentionality and behavioural management. By combining archival research on the mass production and introduction of antibiotics as medical treatments in the early 1940s with contemporary scientific insights on AMR, Landecker situates AMR away from individual behaviour and rationality. She argues that 'the physical registration of human history in bacterial life' is not confined to singular bodies, because an 'antibiotic meant as an individual intervention is an environmental event, with effects spilling out beyond the target body (or hive)' (pp. 19, 34). This is illustrated, as Landecker explains, by research that demonstrates that when one member of a household takes a prolonged antibiotic course, the density of antibiotic-resistant bacteria on the skin increases for everyone in the household (p. 33, citing Levy, 1998).

The accelerated ecological distribution of AMR is understood by modern biology in terms of lateral gene transfer (LGT), that is, horizontal modes of sharing and exchanging genes at an intra- and interspecies level. LGT, as anthropologist of science Stephan Helmreich (2009) argues, entails a shift in biological kinship from the Mendelian vertical inheritance as the classical dogma of genetics to a horizontal and more fluid traffic of genetic material across kingdom bacteria. This new type of bacterial relatedness allows *r* genes to evolve, assemble, and adapt to changing environments rapidly (e.g. to antibiotic substances). For Landecker, bacterial reproduction through the phenomenon of LGT figures as a biological mechanism through which to explain how history gets into biological matter (i.e. the biology of history). This is a remarkable approach to the topic because it moves away from deliberate human action and behavioural approaches to AMR. As she argues:

Antibiotic resistance was recognized as a problem and yet seemed not to be an urgent one. Complacency prevailed: another drug could always be found, existing drugs could be further altered, and it was assumed to be an infrequent problem affecting non-compliant patients (Landecker, 2016, p. 29).

Importantly, Landecker is the first social scientist to devise links between AMR and the human microbiome, particularly in relation to the unintended consequences of antibiotic resistance for commensal bacteria. Antibiotic-resistant genes are not per se pathogenic, as Margulis and Sagan (1995) demonstrate (see Section 4.2.2), they are ‘usually harmless and go undetected’ (2016, p. 35):

Organisms today carry high loads of antibiotic resistance determinants in their microbiota—this is not illness, but an evolved condition of bacterial populations exposed to antibiotics in increasing amounts since 1950 (Sommer et al., 2009). ... In human population-scale studies of commensal bacterial populations (populations of populations), the kind and frequency of antibiotic resistance found in the human microbiome correlates with antibiotic usage in medicine and agriculture in given countries (Landecker, 2016, p. 35).

Landecker refers here to the relationality of micro(be) and macro (ecosystems) environments without invoking a post-antibiotic apocalypse, a ‘dry’ biomedical pipeline in research, or individual and collective compliance as causes of resistance.

The relevance of her concept of the ‘biology of history’ lies in its material relationality in terms of a double movement of history and biology, or, as she puts it, the ‘materiality of history and the historicity of matter’ (p. 19). Here, the ‘scale of production [of antibiotics, ANC] is also the scale of resistance [read resistance in human microbiomes, ANC]’ (p. 20). It is in this sense that Landecker’s ‘biology of history’ echoes, as she recognises, contemporary debates on the Anthropocene (2016, pp. 23).

4.3.1 The biology of history as an anthropogenic force

Since Nobel laureate Paul Crutzen proposed the neologism of the ‘Anthropocene’⁸⁷ in 2002, the meteoric career of the concept led to it also being applied to biology, specifically to the pharmacological character of AMR as a human-induced phenomenon. Although the theme of the Anthropocene exceeds my scope and interest in this thesis, it is important to outline some of the debates around the topic. This is because popular discourses on the Anthropocene are, at many levels, interchangeable with public and global health and media news discourses about AMR. They are both framed in terms of an apocalyptic scenario (see Sections 4.2.2 and 4.2.3). In such a worst-to-come (near) future (Brown & Nettleton, 2016), recalcitrant bacteria along with past human action are the culprits. Human action is here individualised, as part of the rational, autonomous, and self-managerial individual (Martin, 1994; Lee & Motzkau, 2013). In fact, the ‘human’ is

⁸⁷ I also discuss the concept of the ‘Anthropocene’ in the context of multispecies ethnographies in Chapter 2 (section 2.2.2).

also responsible for the mass extinctions and degradation of nature, including the lack of microbial diversity, which contributes to the spread of antibiotic-resistant bacterial strains. In this sense, AMR is an ‘anthropogenic’ phenomenon. It results from human impact on microbes, due to antimicrobial overuse in healthcare and agriculture.

In this line, concurring with the materialism of Landecker’s ‘biology of history’ and its ramifications in relation to discourses of the Anthropocene, cultural theorist Adrian Mackenzie (2014) has recently argued that industrialisation via fossil fuels makes up and transforms bodies. Exploring the implications of fossil fuels and microbial metabolism, what he refers to as ‘anthropocene bodies’ troubles possessive ways and understandings of ‘having a body’. As I will expand below, Mackenzie’s take on the Anthropocene is relevant as an example of Landecker’s ‘biology of history’ (i.e. how industrialisation, through the lens of fossil fuels, embeds itself in [human] bodies). Furthermore, it also links to the ecological rhetoric of microbiome science (i.e. human–microbial entanglements as redefining the human body).

4.3.1.1 *Having an ‘anthropocene body’?*

Fossil fuels such as coal, natural gas, or crude oil are omnipresent elements in several spheres of life, especially in politics, economy, and geology (Mackenzie, 2014; Mitchell, 2011). However, according to Mackenzie, there is an important lacuna in relation to bodies and fossil fuels. After all, bodies are hydrocarbon derivatives and ‘hydrocarbon derivatives can fuel engines or they can become metabolic processes’ (p. 4). This fact sketches hydrocarbons as both living and non-living, as ‘simultaneously biological and technical’ (p. 7). In the light of the above, Mackenzie develops the notion of ‘anthropocene bodies’. This notion reflects on the intimate entwining of the infrastructure of oil extraction, production, and consumption and bodies (human or otherwise). If political theorist and historian Timothy Mitchell (2011) has cogently demonstrated another dimension of democracy and energy, that of ‘democracy *as oil*’ (p. 5), Mackenzie shows that fossil fuels are *always already* in bodies. They constitute bodies. Crucially, for Mackenzie, this fact captures another important question in relation to forms of possession or to ways of *having* bodies.

Resisting the reductionism that equates bodies to hydrocarbons, Mackenzie suggests that the biotechnological engineering of microbial metabolism, employed by synthetic biologists to produce next-generation biofuels that progressively replace fossil fuels, illuminates conceptual alternatives to the possessive understanding of the body.

Similarly, the body as a form of possession has been extensively explored by cultural theorist Ed Cohen (2009) in relation to the legal, historical, and biopolitical origins of immunity. Next-generation biofuels, Mackenzie writes,

negotiate various relations of possession, ranging from the capture of sunlight through to the volatile embodied energies of market attention to microbial life. ... [they] stand at the intersection of biotechnology, agriculture, the oil industry and the global supply chains of commodities such as oil, chemicals and food (pp. 22–23).

Hence, the idea behind next-generation biofuels is to engineer microbial metabolism of biomass (plant-based materials) to produce energy; a process in which microbes, plants, oxygen, and carbon, among other compounds, are implicated. This eco-circle of production and reproduction at different levels of entanglement between industrial, biological, and technical systems shows the immense possibilities of nature through the lens of modern biotechnologies and disciplines such as synthetic biology or complex systems biology. Mackenzie's approach attends to the promises of biotechnologies, leaving the intricacies of capitalist modes of production, reproduction, and exploitation of these bodies underexplored. On the other hand, he goes further to argue that recent scientific evidence from the HMP indicates 'a growing sense that we have a body less than we thought' (p. 22).

What this body-less or disembodied vision suggests is that postgenomic science is *replacing* older ideas and practices associated with biological identity and organismal individuality (see also Cohen, 2009; Hird, 2009).⁸⁸ This thesis, however, does not subscribe to this interpretation. It rather holds the contrary: the human microbiome, in its actual conceptualisation and practice, is indissociable from the idea of possession and belonging, of 'having a body'. As I have shown in previous chapters, in scientific epistemology the human microbiome is defined as the 'forgotten organ' or the 'second genome' (Chapter 3). In other words, microbes *belong to* the human. Consequently, the microbes that live in the surrounding physical environment of humans are not conceived of as part of the organism. Contradicting Mackenzie's take on the human microbiome and its potential to foster a non-possessive understanding of bodies, I contend that the ontological and epistemic basis of the human microbiome is still imbued with modes of 'having' an individuality. The human is deeply ingrained in *human* microbiome science.

⁸⁸ I review this literature in Chapters 1 and 3.

4.3.2 The problem of ‘globality’

The dystopian future that the Anthropocene and AMR discourses (as one of the ramifications of the former) (Lee & Motzkau, 2013) generate is articulated within an all-encompassing and homogenising global rhetoric. These narratives assume that the effects of ‘anthropogenic forces’ (such as fuels, diet, or pollution) on bodies (microbial and human) are the same everywhere, that is, the same proportions, same distribution, and same effects across bodies and the world, constituting its ‘globality’. What Mackenzie theorises as ‘anthropocene body’ (2014) cannot be framed as if it were a homogeneous and equally distributed universal reality (i.e. ‘all bodies are anthropogenic’). Similar to Mackenzie, and despite offering a situated account of AMR by drawing on the history of antibiotic use and consumption in the US, Landecker (2016) also focuses on the phenomenon of LGT as the cause of the ‘globality’ of antimicrobial resistant bacteria. Antibiotics, she claims, ‘have global effects far beyond their intended targets in part because resistance genes move around together in clusters’ (p. 33). However, this claim does not reflect that, for instance, London inner-city children have less environmental microbial exposure than children from Derbyshire county due to less green and open-air spaces; those living on busy inner-city roads are at higher risk of pollution than those who live in quieter areas, closer to green environments and spaces, and so forth.

Although they are unintentional, I suggest that these claims of globality fall into the official discourses of AMR and climate change as a worldwide problematic that requires the response and involvement of everyone. This is a misleading message. Its implications relate to a discourse of individual responsabilisation and stigmatisation (see previous section). Surely, the oil, the food, or the pharma industries, to name a few, alongside governments, hold more responsibility than individuals. In addition, this discourse of globality often confuses the ubiquity and recalcitrance of AMR, or for the same matter of air pollution, with a worldwide, homogeneous distribution. I associate this rationale that correlates globality with homogenisation (i.e. ‘AMR affects everyone the same’, ‘we are all in the same boat’) with the public health and scientific discourse’s focus on behavioural change and new substance discoveries as the ways to tackle AMR (see Section 4.2).

It is important to insist on the ‘situatedness’ (Haraway, 1988) or ‘local biologies’ of AMR (Lock & Nguyen, 2010) because claims of globality risk obscuring bioinequalities at play in health and disease. In the case of human–microbe entanglements, what I want to show through what I call the ‘microbiomisation of class’

(see Section 4.5) is that AMR is not global because it more strongly affects those humans with lower socio-economic, cultural, and educational capital; the poorer, in a word. And crucial to this is the fact that these claims of globality around issues of climate change or AMR are inseparable, I suggest, from a capitalist logic of establishing new opportunities out of its own processes of degradation and precarisation (Cooper, 2008; see also Haraway, 2016; Tsing, 2015). This is a focus that Landecker's and Mackenzie's analyses of biome depletion and biological-industrial entanglements miss. In the next part of the chapter, I address this limitation by elaborating a political economy dimension under which the 'biology of history' articulates, expands, and reproduces. I refer to these processes as the 'biology of capital'.

4.4 The biology of capital: The political economy dimension of the 'biology of history'

In her latest book, *Staying with the trouble: Making kin in the Chthulucene* (2016), Donna Haraway challenges contemporary discourses about the homogeneous impact of anthropogenic forces across bodies and ecologies. For Haraway, the concept of the Anthropocene is a patriarchal 'Grand theory' devoid of any critical standpoint. As she writes:

Species Man did not shape the conditions for the Third Carbon Age or the Nuclear Age. The story of Species Man as the agent of the Anthropocene is an almost laughable rerun of the great phallic humanizing and modernizing Adventure, where man, made in the image of a vanished god, takes on superpowers in his secular-sacred ascent, only to end in tragic detumescence, once again (p. 47).

In addition, Haraway points out that the concept is a heuristic device at the service of the privileged ('intellectuals in wealthy classes and regions') rather than 'an idiomatic term for climate, weather, land, care of country, or much else in great swathes of the world, especially but not only among indigenous peoples' (p. 49). The Anthropocene, she insists, 'teeters constantly on the brink of becoming too much Too Big' (p. 50). The same applies, she argues, to the emergent notion of the Capitalocene (Moore, 2017).

Environmental historian Jason W. Moore has recently coined the term 'Capitalocene' (2017) to refer to 'a system of power, profit and re/production in the web of life' (p. 594). Moore argues that, against the binary character of the Anthropocene that demarcates human from nature and vice versa, the concept of the Capitalocene considers human organisations like capital part of nature (p. 594; see also Sullivan, 2018).

Likewise, it highlights capitalism as a history in which ‘islands of commodity production and exchange operate within oceans of Cheap [food, labour, energy and raw materials, ANC]—or potentially Cheap—Natures’ (p. 606). The Capitalocene, therefore, makes capital and its consequences part of nature in terms of damaged micro- and macroecologies. The Capitalocene is relevant for critical analyses of AMR. In particular, it is a useful complement to Landecker’s ‘biology of history’, as a supplement to the entanglement between biology and political economy. However, as occurs with Anthropocene narratives, I concur with Donna Haraway in that Moore’s notion lacks specificity. Its main weakness is its bigness. But it is also important to remark that the significance of the Capitalocene is not new.

Sociologist Melinda Cooper’s concept of ‘capitalism delirium’ in the book *Life as surplus* (2008) already ties ‘nature’ and the life sciences to capitalist modes of production and reproduction. She is inspired by the thought of two of the most influential (white male) figures of European thought, namely Freud and Marx. ‘Capitalism delirium’, Cooper suggests, ‘is intimately and essentially concerned with the limits of life on earth and the regeneration of living futures—beyond the limits’ (p. 20). Cooper consistently exposes and examines the existing tensions between the promise of a *surplus of life* and the depletion and devaluation of the latter by engaging with an eclectic source of case studies of biotechnologies (e.g. such as those implicated in tissue engineering and regenerative medicine) and what lies behind them: the neoliberal strategies of debt servitude fostered by the US bioeconomy. The core feature of the (contradictory nature of the) delirium of capitalism lies in its ‘drive to push beyond limits and the need to reimpose them, in the form of scarcity’ (p. 49). Unlike the anthropocentric universality of the Anthropocene and the Capitalocene (Moore, 2017) narratives, Cooper’s ‘capitalism delirium’ is a situated account of contemporary biotechnologies in the service of capital.

The perverse operational logic of capitalism encapsulated in Cooper’s ‘capitalism delirium’ has also been analysed by philosopher of science Isabelle Stengers (2018). As she suggests, the ‘logic of capitalist functioning cannot do anything other than identify the intrusion of Gaia with the appearance of a new field of opportunity’ (p. 54). In other words, environmental collapse and biome depletion can also be profitable. Stengers’s contribution to debates on biome depletion is remarkable because, as Cooper does, she frames the latter as part of capitalist political economy. In addition, instead of using buzzwords (i.e. Anthropocene, Capitalocene) or ‘turn’, Stengers proposes the term the ‘intrusion of Gaia’ as a way of ‘staying with the trouble’ (Haraway, 2016):

Naming Gaia, she who intrudes, signifies that there is no afterwards. It is a matter of learning to respond now, and notably of creating cooperative practices and relays with those who Gaia's intrusion has already made think, imagine, and act (Stengers, 2015, p. 57).

Similarly, in her most recent book *Another science is possible: A manifesto for slow science* (2018), she proposes her concept of 'cosmopolitics' as the 'intrusion of Gaia', 'not as a solution to the problem', she writes, 'but as a way of "staying with the trouble"' (p. 151).⁸⁹

Cooper's 'capitalism delirium' (2008) and Stengers's 'intrusion of Gaia' (2015) offer an insightful framework of analysis and interpretation of AMR as a consequence of capitalist surplus value, of antibiotic excess. Drawing on both notions, I would like to examine the 'National bioeconomy blueprint' (NBB), an US science policy document published by the White House in 2012. This document, I suggest, is important because it reveals that the prominent role that microbes and the environment play in postgenomic science cannot be dissociated from postgenomics' (capitalist) economic potential. The steady depletion of social welfare, particularly in Europe and especially in terms of the privatisation of healthcare and education, affects everyone, but those who suffer the most serious consequences are the most vulnerable (socially, economically). The US' (and European Union's) bioeconomy as pushing 'beyond limits' and reimposing them through scarcity measurements (Cooper, 2008) means that history is biology, as Landecker has insightfully demonstrated, but, crucially, that real-time politics is biologically embodied as well. The 'biology of capital' has very specific effects on human-microbe entanglements: social and economic deprivations translate into a poor microbial diversity and a higher susceptibility to AMR. I frame this in terms of the 'microbiomisation of class' (see Section 4.5).

4.4.1 The 'National bioeconomy blueprint' as 'capitalism delirium'

The NBB was published by The White House in April 2012. The NBB is the (bio) economic strategic plan of 'A new biology for the 21st century: Ensuring the United States leads the coming biology revolution' (NRC, 2009), published by the US' National Research Council (NRC). Therefore, before detailing the NBB, it is important to provide a brief background of the 2009 New Biology (NB) report.

⁸⁹ I will come back to Stengers's slow science proposition in Chapter 5 in relation to feminist para-ethnographies as a social justice intervention.

4.4.1.1 *The New Biology*

Imagine a world:
where there is abundant, healthful food for everyone;
where the environment is resilient and flourishing;
where there is sustainable, clean energy;
where good health is the norm (NRC, 2009, p. 9).

The concept of ‘New Biology’ is a ‘policy category’ (Calvert, 2013) introduced by the US’ NRC in the report ‘A new biology for the 21st century: Ensuring the United States leads the coming biology revolution’ (NRC, 2009). Written by a panel of sixteen biologists at the National Academy of the Sciences, the report’s principal objective is to find solutions to ‘societal needs’ through the development of the latest knowledge and tools of biology. As summarised in the above quotation, the focus of the NB is directed at four areas of intervention: food, energy, the environment, and health. The report defines ‘New Biology’ as the ‘integration—re-integration of the many subdisciplines of biology, and the integration into biology of physicists, chemists, computer scientists, engineers, and mathematicians to create a research community with the capacity to tackle a broad range of scientific and societal problems’ (NRC, 2009, pp. vii, 3). Such integration and reintegration of interdisciplinary, collaborative, large- and small-scale projects at all levels of biological complexity—that is, from the micro to the macro or from molecules to ecosystems—is meant to address the four principal ‘societal challenges’: a) sustainable and efficient food plants production to counteract the uncertainty of changing environments (area of food); b) damage to ecosystems and decrease in biodiversity (area of environment); c) fossil fuels’ environmental impact and the search for sustainable alternatives (area of energy); d) understanding individual health through a tailor-made approach (area of health) (pp. 4–5).

The New Biology as a policy category, as sociologist Jane Calvert suggests (2013), is the new language of contemporary biology also adopted by science-policymakers. This also involves a rhetoric based on the entanglement and co-dependency of life processes and organisms, of bodies and environments (Nading, 2014). Interestingly, the narrative of the report revolves around depletion of natural resources. The solution, the report suggests, consists of sustainable alternatives for plant growth and the restoration of the environment. ‘Ecological restoration has a role to play in improving crop productivity, reducing energy needs and slowing the loss of biodiversity’ (NRC, 2009, p. 28).

While food, the environment, and energy are approached as global and impersonal areas of intervention of the NB report, the report shifts in its strategy on health. Health in the twenty-first century requires a tailor-made approach in order to fulfil individual needs (NRC, 2009. p. 31). Likewise, the NB report insists that the future characteristics of biomedicine will be based on prediction and individualisation. For ‘predict[ing] the behaviour of complex biological systems’ (p. 11), it is not sufficient to look at genetic (i.e. genome sequencing) or molecular data (e.g. blood test) because ‘feedback from the environment affects how the genetic blueprint is executed’ (p. 33). Therefore, unravelling entanglements between the non-genetic macro-environment and the genetic micro-environment of the human microbiota will not only require a complex-systems approach to health and disease but also the personalisation of preventive medicine (pp. 36–38).

If healthcare is to move from treatment based on statistical likelihood to treatment based on each individual’s specific circumstances—in other words, truly personalized medicine—the chasm between genotype and phenotype will have to be bridged. This is a challenge that is beyond the scope of any single Institute at the NIH. Indeed, it is a challenge that will demand a New Biology–driven research community empowered by scientific and technical resources from across the federal government, the broad community of scientists, and the private sector (p. 34).

This new medical model based on individualised preventive medicine articulates, as the above quote suggests, the linkage between public health and the private sector.⁹⁰ Clearly, the NB report establishes the foundations for bio-based, integrative research that goes further than biology and medicine themselves, ramifying throughout other areas—energy, the environment, and food. It is in this sense, as I will demonstrate in what follows, that the NBB makes economically feasible the main premise articulated in the NB, namely to provide ‘bio-based solutions’ to ‘societal needs’. Put differently, the NBB is the (bio) economic strategic plan of the 2009 NB report, I suggest.

4.4.1.2 *The ‘National bioeconomy blueprint’*

As explained above, the NBB was published by The White House in April 2012. It revolves around five ‘bioeconomy trends’: Health, energy, agriculture, environment, and sharing. These five ‘trends’ are the same ‘areas of bio-based solutions’ that the NB report develops. In health, the report refers to the HGP as a model for a ‘new era of personalized medicine’ and ‘customized healthcare’ (p. 9). In the area of energy, it signals the pitfalls

⁹⁰ I will be discussing public-private initiatives in biomedicine in terms of what I call the ‘biology of capital’ in the following section of the chapter.

of oil, coal, and natural gas and therefore ‘the need to make ourselves more secure and control our energy future’(p. 10). ‘The potential of microorganisms and plants to produce fuels’ are not the only alternatives; ‘synthetic biology and other genetic-manipulation techniques will enable rational design of organisms to produce conventional products more efficiently as well as novel products’ (p. 10). In agriculture, the focus is on the production of crops with ‘higher nutritional value [and] enhanced disease resistance’ (p. 11). In the area of the environment, the aim is to cease the effects of climate change and loss of biodiversity and ‘to monitor and mitigate human impact’, as well as at the same time restoring the environment through biotechnologies such as synthetic biology (p. 11). Finally, ‘sharing’ involves ‘precompetitive collaborations’, ‘where “competitors” partner and pool resources’ (p. 12).

Similarly, the European Commission (EC) published, also in 2012, the policy document ‘Innovating⁹¹ for sustainable growth: A bioeconomy for Europe’, a bioeconomy strategy under the EC framework Horizon 2020.⁹² Considerably shorter than the NBB, ‘A bioeconomy for Europe’ has precisely the same concern as the former: tackle ‘societal challenges’ (pp. 3–5). This policy document, however, deploys a different lexicon to refer to the selected areas of bioeconomic intervention and implementation: food security (‘food’ in the NBB); natural resources sustainability (‘environment’ in the NBB); ‘reducing dependence on non-renewable resources’ and ‘mitigating and adapting to climate change’ (p. 4) (‘energy’ in the NBB); and ‘creating jobs and maintaining European competitiveness’. Although the last is a new category responding to the 2008 financial crash, it is comparable to ‘sharing’ in the NBB.

While the EC bioeconomy strategy does not discuss implementation, the NBB document (White House, 2012) lays out five ‘strategic objectives’ to tackle the five areas of bioeconomical intervention (i.e. health, energy, agriculture, environment, and sharing). This includes: ‘support R& D investments’ through the development of ‘essential bioeconomy technologies’ such as ‘synthetic biology, biology-related information

⁹¹ There is a growing body of work in science and technology studies (STS) which incorporates innovation studies. See, for instance, the work of sociologists of science Jane Calvert (2013) and Niki Vermeulen (2016). Moreover, ‘innovation’ has also become in recent years a policy strategy for national and international programmes on research and development. In Spain, for example, the concept of ‘research, development and innovation’, otherwise known as ‘I+D+i’, replaced the previous concept of research and development (I+D).

⁹² Horizon 2020 is a seven-year (2014–2020), €80 billion EU Research and Innovation programme. Its main objective is to generate ‘breakthroughs, discoveries and world-firsts by taking great ideas from the lab to the market’ (European Commission, 2018).

technologies, proteomics’ (p. 3); foster translational research, especially focusing on the ‘transition of bioinvention from research lab to market’, integrating as well ‘entrepreneurship and industry involvement into the university research experience’ (pp. 3, 4); ‘reform regulations to reduce barriers ... and reduce costs while protecting human and environmental health’ (p. 4); and ‘align academic institution incentives with student training for national workforce needs’, particularly in what is known as STEM, an abbreviation for science, technology, engineering, and mathematics (p. 5).

Marketisation of health and education

These ‘strategic objectives’ for the implementation of the ‘bioeconomic trends’ (health, food, energy, agriculture, and ‘sharing’) outlined in the NBB—and, to a certain extent, in the EC’s ‘A bioeconomy for Europe’—are relevant because they evidence a neoliberal logic and practice of free-market deregulation. Despite the fact that the human microbiome is not mentioned in the NBB, the report refers to a ‘new era of personalized medicine’ and ‘customized healthcare’ (White House, 2012, p. 9) following the deciphering of the human genome. This is an individualised approach to health, using as raw materials genetics and environmental history of individual as an important aspect of biomedicine in contemporary Euro-American science policy (NRC, 2009; NBB, 2012, pp. 11–12). Crucially, the ‘personalisation’ of healthcare approaches rests on another bioeconomic strategy, namely *sharing*. Sharing through ‘pre-competitive collaborations’, ‘where “competitors” partner and pool resources’ (p. 12) mainly involves the private (mainly biopharma) and public sector (mainly universities and biomedical institutes).

The NBB report attributes this new way of organising scientific labour to ‘changing economic and technological conditions’, stating that it was developed in order to ‘leverage constrained resources and surmount shared problems’ (p. 12). This reason, I suggest, appears as a justification for public-private partnerships which, to be sure, entail the commodification of health and education as marketable ‘services’ in Europe and elsewhere. Following the research by sociologists Ràfols and Stilgoe (2018), it is important to highlight what the (rather obscure) label of ‘public-private partnership’ really involves: public money (and institutions) being used to follow and support (financially and infrastructurally) the (private) research interests and agenda of biopharmaceuticals.

Medicine-as-commerce ... is at heart of some good trends and most of the bad ones. It is clear enough that biotech and pharmaceutical firms can work miracles. But it is also true that they lean heavily on public funding and end up making a great deal of private profit. Even more troublesome are the rapidly growing

investor-owned health plans. They go under many names, including health-maintenance organisations. Although some of these are not-for-profit, many have in common a basic strategy: selling ‘products’ to ‘consumers’ rather than providing care to patients (Farmer, 2005, p. 162).

What Paul Farmer calls ‘medicine-as-commerce’ has real consequences for the lives of people, especially the unprivileged. While cancer, diabetes, or, in this case, microbiome science get substantial funding, basic research and clinical trials on tuberculosis and other infectious and parasitic diseases affecting the poor are underbudgeted (Farmer, 2005). Similarly, STS scholars Javier Lezaun and Catherine Montgomery (2015) have recently demonstrated, in relation to global health R&D, that the policy-centred discourses on ‘sharing’ and ‘private-public partnerships’ carry ‘multiple forms of exclusions’: ‘exclusion in the present by not being the bearer of property (having nothing to share) and exclusion in the future by not having shared in the past and therefore having no claims to the fruits of collaboration’ (p. 22). For the authors, these exclusions affect the poor as well as researchers in limited-resources countries the most, ‘throwing into doubt the assumption that sharing and partnering will, by themselves, create a qualitatively different distribution of power in global health R&D’ (p. 22).

In spite of this, ‘sharing’ and ‘public-private partnerships’ is the mode and model of organisation and operation of contemporary biomedicine today, of innovation and frameworks of ‘excellence’, as Stengers (2018) points out:

Today, publicly financed research is in the process of losing its autonomy. Researchers feel that they have been ‘betrayed’ by the political authorities, who, instead of respecting a consensually recognised right, have given corporations the power to select who among them will benefit from public sponsorship in every field where economic competition is in play. And where this isn’t the case, where neither patent, nor partnership, nor ‘spin off’ are likely, a governing pseudo-market law has been put in place that is supposed to guarantee that public money will be used in the same kind of optimal fashion that the market, they say, would provide. The definition of the mechanisms of evaluation that are presented as ‘objective’, because they are blind to what counts for the researchers themselves, is an integral part of this enterprise (p. 48).

For example, the new £650 Million, 93,000 square meter Francis Crick Institute in London (now the biggest biomedical institute/lab in Europe) uses public-private partnerships as its core strategy (Vermeulen & Nunez Casal, 2017). It adopted this form of governance following other successful biomedical research institutes, particularly the North American Rockefeller Institute previously presided by Sir Paul Nurse (2003–2011), the current director and ‘chief executive’ of the Francis Crick Institute (Vermeulen & Nunez Casal, 2017). These types of institutions are both centres of biomedical research

and education and training, often offering doctorates as well as short outreach and educational programmes such as summer courses (Vermeulen & Nunez Casal, 2017).⁹³

Green capitalism

You will have understood that to trust in capitalism as it presents itself today, as the ‘best friend of the earth’, as ‘green’, concerned about protection and sustainability would be to commit the same kind of error as the frog in the fable, who agrees to carry a scorpion on his back across the river. If the scorpion stung him, wouldn’t they both drown? And yet the scorpion stings him, right in the middle of the river. With his last breath the frog murmured ‘why?’ to which the scorpion, just before sinking, responded ‘it’s in my nature, I couldn’t help doing it’. It is in the nature of capitalism to exploit opportunities: It cannot help doing it (Stengers, 2015, pp. 53–54).

Along with the commodification of health and education, the NBB belongs to what Isabelle Stengers (2015) refers to as ‘green capitalism’ and Melinda Cooper (2008) calls ‘capitalism delirium’, that is, ‘the drive to push beyond limits and the need to reimpose them, in the form of scarcity’ (p. 49). Here, the ‘logic of capitalist functioning cannot do anything other than identify the intrusion of Gaia with the appearance of a new field of opportunity’ (Stengers, 2015, p. 52). This dimension of the NBB is particularly evident in the role it ascribes to microbes and the ‘environment’ as potential areas of sustainable and responsible bioeconomic development.

Like in the 2009 NB report, microbes and the environment elicit an equally prominent place in the 2012 NBB report. In genetically modified plants and microorganisms alone, the NBB (White House, 2012) reports a revenue of roughly \$300 billion:

In 2010 revenues from genetically modified plants and microbes, a single economic indicator of the U.S. bioeconomy, were estimated in one assessment to account for approximately \$300 billion in U.S. revenues, equivalent to more than 2% of gross domestic product. According to the USDA [United States Department of Agriculture, ANC], U.S. revenues from genetically modified crops were roughly \$76 billion. Based on the best available data, U.S. revenues from industrial biotechnology were estimated to be \$115 billion (p. 14).

The NBB gets more specific and attuned to the current ‘trends’ in the life sciences by underpinning the ‘transformative potential’ of ‘biological data’, big data, and bio-based material (e.g. plastic, therapeutic products such as probiotics) (pp. 8, 16). The potential

⁹³ See, for example https://www.crick.ac.uk/news/2018-07-22_bringing-academia-and-industry-closer-together. GSK and AstraZeneca are pharmaceutical companies with offices at the Francis Crick Institute. Their presence is celebrated by scientists and students: biopharma is now indispensable. Contemporary science cannot be done without these partnerships, as the only way to turn ‘biology into drugs’ (Miller, 2018).

of microbes to execute the requirements in each of the four areas of intervention is greater than ever expected. For instance, biodegradable plastics from biomass, biosensor pollution monitoring, or allergen-free peanuts are some of the marketable examples derived from the biotechnological industry (pp. 10–12). Microorganisms and their constituents are also ‘being used to detoxify industrial waste and clean up ecosystems contaminated by environmentally hostile practices’ (p. 15), a clear example of ‘capitalism delirium’. As Stengers (2015) points out in relation to biofuels, ‘green capitalism’ is based on a perverse logic of choice between the worst or the ‘less bad’: ‘either a major energy crisis or the forfeiting of a considerable share of productive land’ (p. 56). In other words, bioeconomy serves here as a justification for neocolonial practices of land appropriation. As I have argued in Chapter 3, this also applies to microbiome science and its practices of biopiracy and bioprospection.

Inseparable from the logic of capitalism and its (fake) ‘environmentalism’ is the immunitary rhetoric of security. In the NBB, self-protection and self-preservation is theorised through a ‘microbial forensic analytic approach’ (p. 18) involving ‘homeland security’ (p. 18). This is based on the ‘identification and characterization of any microbial organism, including “unknown” organisms such as emerging, engineered, chimeric, or purely synthetic organisms’ (pp. 18–19).

Apart from being a resource for homeland security, ‘microbial forensic analysis’, the document predicts, would tentatively have medical applications in public health, diagnosis research, and food safety (p. 18). Biosensors, to monitor polluted ecosystems in marine environments, are another industrial application of microbial biotechnology (p. 12). Furthermore, the USDA predicts that biorefineries that ‘use microbial catalysts to directly convert feedstock (sugar or lipid) into a vast array of commercially valuable product’ will soon emerge (p. 11). These industrial applications of microbes outlined in the NBB fulfil an immuno-logic of national security, self-preservation, and economic growth.

The promises and expectations of bioeconomy (Borup, Brown, Konrad, & van Lente, 2006) assume that pressing societal needs in health, energy, the environment, and food will be met by adopting a sustainable or an ‘environmentally conscious’ approach in each of them. Economic growth and scientific ‘innovation’, a vocabulary that is to the twenty-first century what the notion of progress was to the Enlightenment (Stengers, 2018), cannot be achieved without a strong compromise on the environment. The ‘environmentalism’ or ‘green capitalism’ that is informing contemporary science policy

is in fact influenced by the post-war expansion of environmental social movements that, during the second half of the twentieth century, irrupted mainly in the US and the UK. Moreover, as historian Dipesh Chakrabarty has recently argued (2009), since approximately the late 1980s the public discussion on environmental protection, particularly regarding the issue of global warming and climate change, has run parallel to discussions on globalisation by social sciences and humanities scholars (pp. 198–199).

By adopting ‘environmental consciousness’ as an institutionalised political discourse and economic practice, Western nations respond to critical aspects of their governance, especially in relation to environmental damage and resource depletion. The NBB (along with the NB report, 2009), is articulated around a twofold attribute of the environment and microbes: they act as potential economic or ‘bioeconomic’ agents as well as ‘sustainable’ resources (i.e. ‘capitalism delirium’, see Cooper, 2008; ‘green capitalism’, Stengers, 2015). This demonstrates, I argue, the importance of science policy for critical science studies. The emergence of microbiomes and the environment as epistemic and experimental objects (Rheinberger, 2010) in postgenomics cannot be analysed without its political and economic magnitude. Science policy analysis proves that the ‘biology of history’ is also the biology of capital.

The fact that science and politics (read also political economy) are entangled has already been the subject of substantial critical scholarship on the topic (Jasanoff, 2005; Latour, 2004; Stengers, 2010, 2015, 2018). Unlike the cited authors’ focus on how to make science more democratic, my interest lies more in science and politics as producers of inequalities in health and disease and how to tackle this from a social sciences and humanities standpoint (Chapter 5). This is not to say that the question of science and democracy is left aside, because exposing, condemning, and tackling inequalities should be an indissociable aspect of democratic knowledge practices.

While in this third part of the chapter I have examined how what I call the ‘biology of capital’ (i.e. biology and capitalism; science and politics)—as a concept complementing Hannah Landecker’s ‘biology of history’ (2016)—is co-produced between science policy and science, the next section revolves around how the entanglement between neoliberal capitalism and the life sciences is lived and experienced in and by different bodies differently by drawing on microbiome science. Some bodies have more microbial diversity, others less. This ‘biological differentiation’ (Lock & Nguyen, 2010) in turn has an effect on AMR: the more microbial diversity and therefore

immunity, the less susceptibility to AMR, I speculate. The biology of capital is a necessary precondition for the microbiomisation of class.

4.5 The microbiomisation of class

I would now like to turn to a situated account of the political economy dimension of AMR, or what I have reformulated in the previous section as the ‘biology of capital’. Exploring how neoliberal capitalism gets under the skin (Mansfield, 2012; Meloni, 2014b) and impacts microbiomes, I have selected three examples of ‘intra-species inequalities’ (Malm & Hornborg, 2014) or bioinequalities (Fassin, 2009): breastfeeding, eating, and inhabiting. These examples emerged from data from my empirical fieldwork, mainly from interview material with immunologists and microbiologists (categories of ‘eating’ and ‘inhabiting’) and embodied experiences (category of ‘breastfeeding’).



Figure 17. Selling immunity: The microbiomisation of class. Photo by the author.

4.5.1 Three examples of bioinequalities in microbiome science: Breastfeeding, eating, inhabiting

4.5.1.1 Breastfeeding

I am no longer worried about the microbial diversity of my child. Breastfeeding was and still is key for me. Breast milk and breastfeeding is a sociologically interesting practice. It acts as a social equaliser: Every woman produces milk after birth. It is free. And breast milk composition varies little.

Only in conditions of severe malnourishment does the milk supply dry out. Breastfeeding, along with delivery mode, is one of the main mechanisms of transmission of microbes, of microbial inheritance. Breast milk is very rich in oligosaccharides, molecules that 'feed' microbes, producing, in turn, microbial diversity. In addition, maternal skin microbes (arms, nipple, face, chest) are also transmitted when breastfeeding.

For me, breastfeeding led to the development of a strong(er) class consciousness, or, in Paolo Freire's terms, 'conscientisation' (1970). I have learnt that breastfeeding in neoliberal capitalist societies is challenging, many times impossible, especially in the case of long-term breastfeeding (i.e. beyond the first year of life). Beyond the social pressure and stigma associated with breastfeeding a baby who is over six months, the impossibility of breastfeeding rests on the severe inequality women and mothers experience at all levels, and at the workplace in particular. The long hours I have spent in the playgrounds of London were, and still are sites of reflection and revelations. There, I have met many women who decided to quit their jobs to become full-time carers. I have also met many precarious, overworked and racialised carers, particularly in affluent areas, who can barely communicate in English. In the UK, the stratospheric price of childcare forces women to renounce their careers in order to become economically dependent on others (mostly male partners). The cheapest alternative to this, it seems, is to outsource childcare by semi-enslaving non-Western poor migrant women.

Maternity leave in the UK and many other European countries is usually between four months and one year, meaning that breastfeeding will end at the same time waged labour starts. Unsurprisingly, several studies have pointed out a 'motherhood penalty', which means that having a child slows down careers and decreases the chances of promotions. The impact extends as much as twelve years after the birth. The only good thing about being a precarious doctoral researcher at this point in my life is that I could and can be with my child and have the choice of breastfeeding. Breastfeeding brought me closer to feminism and to feminist activism. Motherhood, for me, has been a site of political and existential empowerment and resistance (see Rose, 2018).

In neoliberal capitalism, you need a series of (privileged and/or precarious, as in my case) conditions to be able to breastfeed. From a biological standpoint, we heard that breast milk is, without any doubt, nutritionally superior to formula feeding. Breast milk not only provides oligosaccharides, a kind of 'microbial fermenter' for babies, but it also reverberates positively in psychological health in adulthood. In my case, the 'natural' approach towards childbirth and childcare became entangled with my cultural capital on the latest microbiome and antimicrobial resistance information in biomedical research. In microbiome science, debates around the natural or traditional versus the artificial or modern are part of the (para-ethnographic) basis of the field. In the case of breastfeeding, this translates to the old

Cartesian nature (breast) as opposed to culture (formula milk). 'Breast is best', yet, not unproblematically. Is breast milk really a social equaliser, a classless liquid?

Popular science writer Ed Yong (2016) explains the significance of breastfeeding merely in microbial terms:

Every mammal mother produces complex sugars called oligosaccharides, but human mothers, for some reason, churn out an exceptional variety: so far, scientists have identified more than two hundred human milk oligosaccharides, or H.M.O.s. They are the third-most plentiful ingredient in human milk, after lactose and fats, and their structure ought to make them a rich source of energy for growing babies—but babies cannot digest them. When German first learned this, he was gobsmacked. Why would a mother expend so much energy manufacturing these complicated chemicals if they were apparently useless to her child? Why hasn't natural selection put its foot down on such a wasteful practice? Here's a clue: H.M.O.s pass through the stomach and the small intestine unharmed, landing in the large intestine, where most of our bacteria live. What if they aren't food for babies at all? (pp. 93-94).

Breast milk is not for babies ('at all'!) but for microbes, Yong claims. Such disembodied accounts of (microbiome) science are rampant. Similarly, the healthcare message that permeates through to new mothers and families is the 'breast is best' slogan. The 'breast is best' message is based on the numerous health benefits of exclusive breastfeeding for the first six months of life and beyond for both the baby and the mother. These include a reduced risk of infections, diarrhoea, childhood leukaemia, type 2 diabetes, obesity, and cardiovascular diseases in adulthood for babies. And a reduced risk of breast and ovarian cancer, osteoporosis, obesity, and cardiovascular diseases for mothers (Benefits of breastfeeding, 2017). The slogan originated in the 1978 book *Breast is best* by Penny Stanway, Andrew Stanway and Hugh Jolly. In the book, the authors outline the health benefits and offer a practical guide to breastfeeding.

Despite the prominence of 'Breast is best' in healthcare systems and other influential institutions such as the National Childbirth Trust (NCT), the largest childbirth charity in Europe, breastfeeding rates in Western countries are extremely slim. For example, in the UK, exclusive breastfeeding at six months remains at around 1 per cent (Unicef, 2018). This fact contrasts with the general recommendation by the WHO (Breastfeeding, 2018) of breastfeeding for up to the first two years of life or longer. Part of the problem, as several feminist and women's studies scholars have pointed out (Gimeno, 2018; Wolf, 2011), has to do with the exclusive focus on the chemical properties of breast milk and the (individual) responsabilisation of mothers.

Contrarily, breastfeeding is a collective, complex, and contested biosocial and cultural practice and process (Cassidy & El Tom, 2015). It is, in fact, a ‘polarising social issue in high-income countries’, as editor of *The Lancet Global Health* Zoe Mullan argues (2015):

Some health-related topics are guaranteed to stir up heated debate in the general public whenever they crop up in the news. Publishing a research paper on chronic fatigue syndrome, homoeopathy, or mode of childbirth is a recipe for a media field day, a lively letters section, and a jammed inbox. *The Lancet Global Health* experienced its first taste of such events when we published Cesar Victora and colleagues’ birth cohort study on breastfeeding and adult intelligence in March this year. Newspaper headlines proclaimed the ‘good news’, but many readers (notably in high-income countries) weren’t so sure. ‘As if mothers don’t feel enough pressure’, tweeted one. ‘What a load of rubbish ... There may be health benefits in third world countries but this does not apply to the western world’, pronounced another by email. ‘Propaganda!’ accused a Facebook follower.

To the links between breastfeeding and intelligence that Mullan refers to must be added one of the benefits of breastfeeding most repeated by health authorities such as the WHO and the UK’s National Health Service (NHS): breastfeeding is free. Until recently, this message was ubiquitous. In addition, the ‘free’ cost of breastmilk was usually accompanied by a social justice message: because breast milk is free and its chemical composition barely varies across human species (only in severe cases of malnourishment) breastfeeding is a social equaliser. This is why in the above quote, for example, Mullen refers to a social media user who associates the benefits of breastfeeding with low-income countries.

This belief of breastfeeding as free has been questioned lately. Breastfeeding is not free because of the infrastructure women need to make it possible. It actually costs money. Women need to be out of work in order to meet the WHO recommendation of six months exclusive breastfeeding on demand. Yet public health recommendations are not in tune with the working conditions and social realities of women in many (Western) societies. In Spain, maternity leave lasts four months, the same as in the Netherlands, for example. In the UK, maternity leave varies widely. As a precarious PhD student and early career researcher, I can ‘enjoy’ flexible working hours. I am able and I ‘chose’ to breastfeed, obviously influenced by my own situatedness and embodied experience as mother and my doctoral work on the human microbiome: according to microbiome science, breastfeeding is vital for the long-term immunity of babies. Breastfeeding for me has meant organising my life around my baby’s needs. My ‘choice’ is also conditioned by the exorbitant childcare cost in the UK, the highest in the world. Because I cannot

afford childcare, I spend most of the time with my child, a fact that enables and contributes to ‘extended breastfeeding’ (i.e. over one year old). But my reality and conditions are transitory and very specific. I wondered: how many mothers share my circumstances? Not many, I believe. In the US, for example, there is no such thing as ‘maternity’ leave. Only Sweden offers 480 days (around sixteen months) of maternity and paternity leave. This is to say that in the vast majority of Western countries, breastfeeding is not for the working mother. It is not for everyone.

The point I want to make is that breastfeeding has indeed become a luxury good in capitalism. This is to say that breastfeeding and class are indissociable. Class determines whether you breastfeed (Glaser, 2014). Only upper classes have the infrastructure that supports breastfeeding: ‘Longer maternity leaves, jobs that allow for pumping breaks, the ability to hire outside help to support a new mother, and—perhaps most importantly—immersion in a culture that unconsciously views breastfeeding as a desirable status symbol and pressures them to continue to that hallowed six-month mark and well beyond’ (Purtill & Kopf, 2017). It also implies a heteronormative and anachronic family structure composed of a ‘stay-at-home mum’ and a ‘working’ dad (see McRobbie, 2013).⁹⁴

For feminist activist Beatriz Gimeno, lactivist groups somehow resemble the patriarchal and sexist idea of women (or better mothers) as the only childcare ‘providers’ (Gimeno, 2018). The pressure in terms of the health benefits of breastfeeding combines with its overstated psychological importance in terms of bonding and attachment in order to avoid psychological issues in later life. This contentious idea, according to Gimeno, is a form of over-responsibilisation and control of women, and this is why feminism should tackle the question of breastfeeding as a ‘choice’ rather than as a ‘must’. Similarly, Joan Wolf has argued in her controversial book *Is breast best?* (2011) that the science behind breastfeeding is highly contentious. This is because, she argues, there cannot be randomised control trials to study the benefits of breastfeeding. Consequently, it is very

⁹⁴ In ‘Feminism and the new “mediated” maternalism: Human capital at home’ (2013), McRobbie argues that the ‘new moral economy of the family’, and motherhood in particular, ‘re-assures the social structures of domination by constraining young mothers in a field of anxieties brought about by the promise of “complete perfection”’ (p. 142). Class, here, is key. As she writes: ‘Therefore the *dispositif* of new maternal-familialism is inextricably tied up with expansive norms of respectable middle-class life, which in turn entails careful financial planning, good self-governance to insure against family breakdown, along with the increasing professionalization of motherhood which sets new horizons for middle-class status on the basis of aspirational lifestyle, non-reliance on the state or on benefits and a female head of household who can “do it all” even if she cannot quite “have it all”’ (p. 142).

difficult to separate a positive and caring home environment from the benefits of breastfeeding. Women who breastfeed exclusively tend to have higher levels of education, higher income, better access to healthcare, and are more likely to engage in healthy prenatal behaviours.

In microbiome science, however, the health benefits of breast milk are indisputable: the bacterial communities of the breast milk establish and develop the infant's gut microbiome (Pannaraj et al., 2017). In these heated debates on breastfeeding, one thing is certain: breastfeeding, along with its microbial benefits in terms of HMOs, is predominantly experienced by upper and middle classes.

4.5.1.2 *Eating*

According to the scientific discourse on the human microbiome, the first food we eat, either breast or formula milk, is determinant for the microbiome, but the food we consume in childhood and as adults also shapes bacterial communities in the gut, where the largest part of microbes in mammals reside. This is why, for these scientists, diet is the simplest way through which the human microbiome can be modified.

Professor of Genetic Epidemiology and consultant physician Tim Spector became interested in the human microbiome soon after publishing his 2012 book *Identically different*. Spector suggests that scientists do not have the tools and technological devices to go far with epigenetics (processes of methylation, demethylation of DNA, chromatin remodelling) yet. Epigenetics is currently more advanced with respect to cancer. However, in other areas of contemporary biomedicine such as inheritance, he expresses, epigenetics 'is disappointing' (T. Spector, personal communication, June 29, 2017). A key point is that the 'epigenome' is not as easily accessible and manipulable as the microbiome (i.e. through accessing faecal samples). Spector is much more interested in microbiome research because of all the interventions and outcomes that can be derived from this field.

In 2015, he published *The diet myth: The real science behind what we eat*, a popular science account on the human microbiome in relation to nutrition. In the book, he debunks ingrained beliefs such as that fat is bad or that eating fat translates into body fat. He is also critical of labelling and quantifying food in terms of 'nutritional value' charts based on calories, carbohydrates, fats, proteins, and, salt. For Spector, this information is misleading because it overlooks the entanglement between the food we consume and the microbes we 'harbour'. In other words, microbial metabolism affects

our metabolism. This, in turn, translates into a higher or lower body mass, different health outcomes, etc. (T. Spector, personal communication, June 29, 2017).

In the *Diet myth*, Spector mentions AMR and the necessity to reduce the use of antibiotics. In the formal interview I conducted with him in June 2017, he specified that one of the actions to achieve in fighting AMR is a greater transparency in the food industry. ‘Having basically supermarkets and shops saying which meat products may contain antibiotics would be a pretty good start, and I think people would stop buying it if they saw that’, he expressed. In addition, he pointed out that the (cheap) price of food⁹⁵ is a fundamental problem in the control of AMR:

Well, it can be regulated, it’s a question of the food companies resisting it, that’s all; and the pressure, you know, food is getting cheaper every year and at some point people have got to say, well, okay, there’s a limit, this is cheap food, but if you want cheap food you’re going to have all kinds of crap in it; do you really want a chicken that costs less than one pound, or do you want to pay a bit more and eat less and have something you know is free of chemicals? (T. Spector, personal communication, June 29, 2017).

Organic, hormone-free food is significantly more expensive than its non-organic counterpart. Following the neoliberal logic of ‘choice’ (i.e. individual responsibility), Spector overlooks the fact that organic food is *only* an option for those with certain economic and socio-cultural capital (i.e. middle and upper classes). Diet and economic poverty are strongly related, which in turn affects microbial diversity and disease susceptibility. As Harrison and Taren (2018) have recently demonstrated, ‘income inequality is an underlying factor for the maladaptive changes seen in the microbiota in certain populations [lower-income, ANC]’ (p. 279).

Diet and breastfeeding are two examples of (human) species intra-inequalities in contemporary neoliberal capitalism; of how capitalism is embodied, how it gets into the skin (Mansfield, 2012), into microbiomes. But where we reside, including the architecture of our housing (see Chapter 3), also affects microbial abundance and scarcity, as I outline below.

4.5.1.3 *Inhabiting*

Emeritus Professor of Medical Microbiology Graham Rook’s work at the intersections of immunity, microbiology, mental health, and inequalities is remarkable. Back in 2003,

⁹⁵ According to Moore, food is one of the ‘Four Cheaps’ of Cheap Nature in the Capitalocene, along with labour power, energy, and raw materials (Moore, 2016).

Rook reformulated David Strachan's hygiene hypothesis⁹⁶ (1989) as the 'old friends mechanism'. For Rook, the term 'old friends' is broader than 'hygiene'. It involves exposure to microbes and other organisms during critical phases of human development. 'Because the western lifestyle and medical practice [read antibiotics, ANC] deplete the "old" infections (for example helminths), immuno-regulatory disorders have increased, and the immune system has become more dependent upon microbiotas and the natural environment', Rook and colleagues explain (Rook, Raison, & Lowry, 2014).

Similar to Dominguez-Bello (2013), Rook argues that antibiotics, diet, and C-sections are the three principal causes of the loss of 'old friends' (the 'missing microbes' in Blaser's terms), particularly in Western urban environments. The novelty of Rook's approach and theory lies in its focus on the natural environment and urban green spaces. When I interviewed him in April 2017 at his North London home, he passionately explained to me why the health benefits of living close to green environments (i.e. a more diverse and populous microbiome) are especially visible 'towards the bottom end of the socio-economic scale' (G. Rook, personal communication, April 21, 2017). Following large epidemiological studies correlating green spaces with positive short-term psychological effects, Rook is interested in the long-term effect of the natural environment and green spaces in terms of microbiota. In order to shed light on this question, he argues, microbiome science needs to overcome its major weakness, which has to do with a lack of studies examining the role of spores in health and disease:

Spores can last in the environment for thousands, maybe ten thousand, maybe hundreds of thousands of years. So the way I like to put it is that whenever humans have been on this planet, there will be human gut-adapted strains in the environment. And that may be incredibly important because say you've been living on Coca Cola and MacDonald's and taking antibiotics, in other words, you're a typical American, you will lose quite a lot of organisms from your gut microbiota, which is going to make you very sick. But, of course, the natural environment can provide spores for all these guys. And that can be fantastically important (G. Rook, personal communication, April 21, 2017).

What Rook is suggesting in the above quote is that green environments, via spore-forming microorganisms, can compensate for the effects of an unhealthy processed diet and antibiotic consumption (sub-therapeutically via food or therapeutically). The important point here for me is the repercussions of this in terms of inequalities, particularly with class differences. Low-income families tend to consume less healthy food than wealthy

⁹⁶ The 'hygiene hypothesis' refers to the decreasing incidence of infections as the origin of the increasing incidence of allergic and autoimmune diseases.

families (see previous example about eating). In addition, as Rook et al. (2014) explain, urban individuals from lower socio-economic status experience less contact with green environments, usually because of the area in the inner city they live in and the ‘lack of rural second homes and rural holidays’:

Urbanization maintains exposure to the crowd infections that lack immunoregulatory roles while accelerating loss of exposure to the natural environment. This effect is most pronounced in individuals of low socioeconomic status (SES) who lack rural second homes and rural holidays. Interestingly, large epidemiological studies indicate that the health benefits of living close to green spaces are most pronounced for individuals of low SES (p. 1).

Similarly, Mitchell and Popham (2008) have demonstrated in an earlier observational study that income-related inequality in health is ‘less pronounced in populations with greater exposure to green space’ and, therefore, ‘physical environments that promote good health might be important to reduce socioeconomic health inequalities’ (p. 1655).

4.5.2 The microbiomisation of class as an inventive fiction

Through the above three examples I have showed and argued that, despite the fact that a diverse microbiota is crucial for health, as microbiome scientists insists, microbial diversity is not accessible to everyone. Neoliberal capitalism generates sharp socio-economic inequalities. Inequalities are embodied (Mansfield, 2012; Meloni, 2015). This is what authors like Malm and Hornborg define as ‘intra-species inequalities’⁹⁷ (2014) and Didier Fassin calls ‘bioinequalities’ (2009). My interest in the embodiment or physical registration of health disparities relates to the ways in which it evidences what I call the ‘microbiomisation of class’.

The microbiomisation of class relates to the biologisation and naturalisation of socio-economic conditions and cultural values into microbial profiles. In contrast to the microbiomisation of race (Chapter 3) and the microbiomisation of gender (Chapter 5), the microbiomisation of class is much less substantiated in microbiome science publications. My own conjecture is that this is simply the result of insufficient funding for establishing correlations between socio-economic status and microbial diversity. This, in turn, reflects the lack of political willingness to tackle health disparities resulting from neoliberal capitalism policies (in rich nations).

⁹⁷ Malm and Hornborg (2014) define ‘intra-species inequalities’ as ‘part and parcel of the current ecological crisis’ which ‘cannot be ignored in attempts to understand it’ (p. 62).

Instead of seeing the lack of published scientific research on the topic as a weakness, I argue that it offers an opportunity for social sciences and humanities scholars to critically discuss the association between the human microbiome and class. I have demonstrated an alternative way (less formal than scientific papers) of evidencing that link through the examples of breastfeeding, eating, and inhabiting. The link between microbiomes and class means that socio-economic deprivations and marginalisation translate into poor microbial diversity, and thereby, I claim, into a higher susceptibility to AMR. Or, put differently, the more microbial diversity and therefore immunity, the less prone you become to AMR.

The ‘biology of capital’ is a necessary precondition for the ‘microbiomisation of class’. The ‘microbiomisation of class’ is a speculative proposition or what philosopher Isabelle Stengers (1997) calls an ‘innovative fiction’. An ‘innovative fiction’ is a type of proposition that

makes a new phenomenon, or a phenomenon in a new mode, intervene in discussions. As such, it proposes the testimony of a phenomenon that will modify the degrees of freedom of all the works that must, or will be able in the future to, take this testimony into consideration, suppressing some and creating others (p. 140).

I want to emphasise the fact that what I call the ‘microbiomisation of class’ is not a theory. Whereas a proposition ‘can drastically change and subvert the conceptual landscape, connect regions and disconnect others’, a theory ‘requires that the hierarchization of the conceptual landscape that it proposes be socially ratified’ (p. 144).

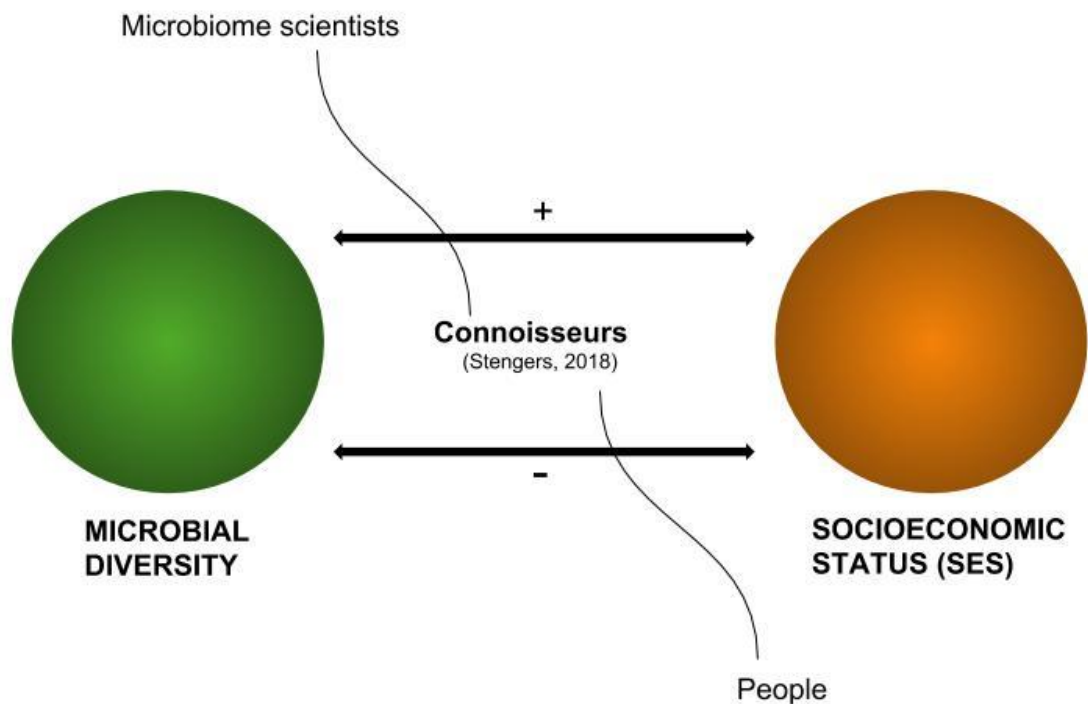


Figure 18. The microbiomisation of class as an ‘inventive fiction’ (Stengers, 1997), by the author.

Likewise, the ‘microbiomisation of class’ proposes a ‘conceptual landscape’ that is not socially ratified (yet). It makes the phenomenon of ‘microbial diversity’ and ‘antimicrobial resistance’ ‘in a new mode, intervene in discussions’ (p. 140). This is important because my principal aim in proposing the ‘microbiomisation of class’ is to *inform* microbiome science as a way to engage with critical science studies and move away from positivism. In fact, informing biomedicine about the microbiomisation of class is part of the role that social sciences and humanities scholars have as ‘connoisseurs’ (Stengers, 2018).

We as connoisseurs ‘are agents of resistance against a scientific knowledge that pretends it has general authority’ (p. 9). In this sense, my speculative proposition of the ‘microbiomisation of class’ is informing the sciences about the relevance of ‘questions or possibilities that were not taken into account’ (p. 9) in the scientific production of the human microbiome but that have become important in neoliberal capitalist societies, in which the biology of health and well-being has become a privilege instead of a right (see Figure 18). In this way, the social scientists or—in Stengers’s lexicon—connoisseurs, are

mediums or ‘translators’ between scientists and patients. This is an argument I develop in the following chapter in relation to ‘feminist para-ethnographies’, a care and decolonial *intervention* in microbiome science with the potentiality, I suggest, of assisting the tackling of antibiotic overuse, AMR, and biome depletion.

4.6 Conclusion

Drawing on ethnographic material, science policy documents, and embodied experiences, in this chapter I have argued that AMR is embodied differently according to what we might call ‘immunitary privileges’. This means that socio-economic deprivations and marginalisation translate into a poor microbial diversity, and thereby into a higher susceptibility to AMR. Differently put: the more microbial diversity and therefore immunity, the less prone you become to AMR.

In the first section of the chapter, I have argued that public health and scientific discourse around AMR are mainly articulated around two issues: (1) a dry antibiotic pipeline resulting from recalcitrant bacteria. Here, the research of Dominguez-Bello has the potential of transforming ‘indigenous’ microbiomes into probiotics as an alternative to antibiotics (Chapter 3). And (2), individual and collective attitudes and behaviours around antibiotics, especially in the non-Western world. Clearly, both causes of (i.e. behaviours in the non-Western world) and solutions to (e.g. indigenous microbiomes) AMR are directed at the ‘Other’. Despite recent studies showing that poorer nations use antibiotics far less intensively than rich nations (Klein et al., 2018), this Grand narrative obscures the fact that AMR is principally produced by current practices of husbandry (i.e. mass production of meat) and, to a lesser extent, the pharma industry in the West.

I have then suggested that Hannah Landecker’s notion of the ‘biology of history’ figures as an insightful alternative to the mainstream and apocalyptic discourse around AMR. I have also pointed out, however, two main and interlocking limitations of the concept in relation to its ‘global’ scope and the absence of political economy perspectives on historical processes of industrialisation and commercialisation of antibiotics. Reformulating Hannah Landecker’s notion of the ‘biology of history’ (2016), I have proposed the concept of the ‘biology of capital’, suggesting that it is a necessary precondition for what I call the ‘microbiomisation of class’. As an ‘innovative fiction’ (Stengers, 1997), the ‘microbiomisation of class’ aims at *informing* microbiome science as a way to engage with critical science studies and move away from positivism. Furthermore, informing biomedicine about the microbiomisation of class is part of the

role that social sciences and humanities scholars have as ‘connoisseurs’ (Stengers, 2018), an aspect I will develop further in the context of feminist para-ethnographies (Chapter 5).

CHAPTER 5 Feminist para-ethnographies as an ‘engaged’ intervention in human microbiome science: The case of the microbiomisation of gender

5.1 Introduction

Drawing on my embodied experiences of childbirth, ethnographic fieldwork on microbial ecologist Dominguez-Bello and her team’s research about the vertical transmission of microbes, and (mostly) feminist literature on scientific knowledge production (Despret, 2004; Latour, 2004; Stengers, 2000, 2018), in this chapter I propose and develop feminist para-ethnographies as a caring, ‘slow science’ (Stengers, 2018) and ‘engaged’ (Hinchliffe et al., 2018) *intervention* in human microbiome science.

‘All matters of fact require in order to exist’, Bruno Latour (2004) argues, ‘a bewildering variety of matters of concern’ (p. 247). ‘Matters of fact’ refers to scientific hypotheses, theories, and experiments posed as ‘objective’ and represented by the ‘hard sciences’. ‘Matters of concern’, on the other hand, refers to interpretations, beliefs, opinions, and speculations regarded as subjective and represented by the humanities and social sciences. In this chapter, I ask: how to reconcile both (i.e. matters of fact and matters of concern, ultimately science and people); how to enable an ‘engaged research’⁹⁸ in order to co-generate and co-produce a ‘critical friendship’ (Rose, 2013)—that is, a friendship able to generate assemblages between the sciences and the social sciences and humanities, between scientists and people, and overall, between ‘matters of concern’ and ‘matters of fact’ (Despret, 2004; Latour, 2004; Stengers, 2018)?

To answer this question, the first two parts of the chapter draw on ethnographic fieldwork on a team of microbiome scientists working on the microbiology associated with the mode of delivery at birth (Dominguez-Bello et al., 2010a). The microbiology of reproduction is a controversial field in human microbiome science research. I illustrate these controversies through the lens of my embodied experiences as a woman in labour and GBS ‘carrier’ in pregnancy. These experiences offer a ‘lived’ and ‘socialised biology’

⁹⁸ As I will explain in the chapter, geographer Steve Hinchliffe and colleagues (2018) refer to the concept of ‘engaged research’ as research which ‘facilitates the emergence of healthy publics—“dynamic collectives of people, ideas and environments that can enable health and well-being” (p. 2) through sharing experiences and information, provides opportunities to change dominant systems of knowledge, and creates possibilities for new practices and care pathways’ (p. 7). As the authors specify, ‘engaged research’ is aimed at benefiting those who are being marginalised from healthcare decision-making—including non-academic partners—ecosystems, and trans-species health.

(Riley, 1983); an example of the ‘microbiomisation of gender’ and of how the latter is entangled with existing gaps and contradictions between two competing theories in the microbiology of reproduction: the ‘sterile womb’ and the ‘in utero colonisation’ hypotheses. Particularly, I show how my embodied experiences evidence a mismatch between (post-Pasteurian) biomedical research and (Pasteurian) clinical practice. These inconsistencies, in turn, frequently result in clinical advice and procedures that increase the likelihood of (often unnecessary) administration of intra-labour and postnatal antibiotics.

I begin the third part of the chapter with a vignette of my post-partum experience in relation to ‘Birth Reflection’, a public health service offered by the NHS to discuss (mostly difficult and/or traumatic) childbirth experiences together with a team of midwives. My experience resonates with a vast body of feminist literature suggesting that women lose their political agency during medical interventions in labour, becoming a medium or receptacle who (or better ‘which’) facilitates new life (Franklin & McKinnon, 2002; Martin, 2001; Rapp, 1999). Although this type of analysis offers valuable critical reflection, I argue that it has an important limitation: this kind of critique does not build alliances that assemblage and gather (Latour, 2004).

Bringing together these empirical materials around ‘matters of fact’ (Sections 5.2 and 5.3) and ‘matters of concern’ (Section 5.4) with Hinchliffe et al.’s notion of ‘healthy publics’ (2018)—‘dynamic collectives of people, ideas and environments that can enable health and wellbeing’ (p. 2)—and (mostly) feminist literature on scientific knowledge production (Despret, 2004; Latour, 2004; Stengers, 2000, 2018), in the fourth part of the chapter (Section 5.5) I propose and develop the concept of ‘feminist para-ethnographies.’ I theorise feminist para-ethnographies as an ‘engaged research’ intervention of biome restoration across socio-economic classes to alleviate health disparities, derived from microbiome science. Feminist para-ethnographies is a (relational) material-semiotic device of registration, documentation, and interpretation of embodied experiences of health and disease as part of medical diagnostic and therapeutic data. Likewise, it allows the emergence of ‘healthy publics’ by making ‘available’ (Despret, 2004) new relationships and alliances between humans and microbes, clinicians/medical staff and patients/people, and, fundamentally, between medical ‘facts’ and embodied experiences. Ultimately, feminist para-ethnographies aim at the socialisation of care and the delivery of health justice through the transformation of silenced and private embodied experiences into shared and collective experiences.

5.2 The microbiology of reproduction: Matters of fact and concern around antibiotic use and microbiomisation processes

5.2.1 The microbiology of the mode of delivery at birth as a ‘matter of fact’

I am at the Biology Department at the UPR, San Juan, chatting with Kassandra M. de Jesus, one of Dominguez-Bello’s undergraduate students. Kassandra is heavily pregnant. Her due date approaches soon, in just ten days. At the beginning of our conversation, she mentions that she wants to leave the benches and academia to open a bakery. Her ambition surprises me. It brings me back to when I was an undergraduate student. While memorising complex names of molecules, often involving the combination of letters and numbers (i.e. p53, mdm2, RB1), thus making the mental process of retention more challenging, I used to fantasise about becoming a writer.

De Jesus is holding a notebook in which she has previously annotated key points of the investigation she is currently working on, entitled ‘Developmental Ecology of the Human Microbiome’. The aim of the study, she explains, is to determine the natural pattern of development of the bacterial communities during the first year of life together with the effect of perturbations on the development of the microbiome. In doing so, the team led by Dominguez-Bello have analysed the differential microbial patterns in the microbiome of newborns in relation to the mode of delivery at birth: vaginal tract versus caesarean section. The team collected oral, skin, and vaginal samples from mothers one hour before delivery, and oral, skin, and nasopharyngeal samples from neonates in the first five minutes after birth. Before selecting the research participants—using a ‘gatekeeper’ at the University Pediatric Hospital Dr. Antonio Ortiz, in San Juan—scientists constructed a criterion for ‘healthy’ pregnant women participants based on several health-related factors. Those included the absence of sexually transmitted diseases (STDs) and allergies and a ‘normal’ BMI.



Figure 19. Left, main entrance of the Paediatric University Hospital Dr. Antonio Ortiz in San Juan, Puerto Rico. Right, architect Humberto Cavallin and research assistant Kassandra de Jesus, preparing to enter in the operating theatre. Photos by the author.

De Jesus expresses the difficulties involved in the recruitment of participants due to the high rate of obesity in Puerto Rico, which affects 28.3 per cent of Puerto Ricans ('Prevalence of self-reported obesity among U.S. adults by state and territory', 2014). However, taking into consideration the prevalence of overweight adults, which affects more than half of the population, the previous percentage triples (71.2 per cent of men and 62.4 per cent of women) (Henry J. Kaiser Family Foundation, 2015). The high number of C-sections in Puerto Rico is a complex problem as well. C-sections are a common medical practice on the island, particularly since the late 1980s, among high-income women delivering in private hospitals ('Rates of cesarean delivery among Puerto Rican women', 2006). In 2002, as much as 45 per cent of the deliveries were C-sections ('Rates of cesarean delivery among Puerto Rican women', 2006), the world's highest caesarean section rate.

Dominguez-Bello regrets that her only daughter, Valeria, was born by C-section in her native Caracas in the late 1990s. At that time, C-sections were the norm in Venezuela (especially among the privileged). C-sections were also associated with a faster postpartum recovery, Dominguez-Bello recalls, fulfilling the pervasive ideal of 'coming back' to a pre-pregnancy body. This means getting rid of the 'baby weight' by dieting and exercising. Breastfeeding and vaginal birth were conceived, particularly among the affluent 'consumers' of private healthcare, as ruining women's body shapes. Breastfeeding causes the breasts to 'fall down' and a 'natural' birth often leads to vaginal enlargement, Dominguez-Bello explains, laughing. Within this particular context of privileged Venezuelan women and families like Dominguez-Bello herself, C-section

often went hand in hand with bottle-feeding and, therefore, against the golden trio of a healthy microbiome in infants: vaginal birth, breastfeeding, and skin-to-skin contact.

The microbial ecology of reproductive practices, particularly the microbiological dimension of C-section and delivery mode at birth, is the theme that established Dominguez-Bello as a world-leading microbiome scientist. In 2010, Dominguez-Bello et al. published the first article on the topic, entitled ‘Delivery mode shapes the acquisition and structure of the initial microbiota across multiple body habitats in newborns’ (2010a). The article established the basis of the vertical acquisition (mother to infant) of microbiota in humans, becoming a reference in the field and in microbiome research more broadly. The research was conducted in a hospital in Puerto Ayacucho, in the Amazonas State in Venezuela, one of the main locations of data collection for Dominguez-Bello and her team and collaborators (see Chapter 3). There, the team sampled nine women’s oral, skin, and vaginal microbiota one hour before delivery and their newborns’ skin, oral, and rectal microbiome within seconds of delivery (p. 11973).

In the study, this team of microbiome scientists found that vaginally delivered infant are ‘colonised’ by microbial communities that resemble the vaginal microbiome of their mothers, while C-section-born infants acquire bacterial communities that resemble the maternal skin microbiome as well as the non-maternal skin microbiome associated with medical staff during the delivery. As the authors explain:

Vaginally delivered infants acquired bacterial communities resembling their own mother’s vaginal microbiota, dominated by *Lactobacillus*, *Prevotella*, or *Sneathia* spp., and C-section infants harbored bacterial communities similar to those found on the skin surface, dominated by *Staphylococcus*, *Corynebacterium*, and *Propionibacterium* spp (p. 11971).

This bacteria taxon does not mean much in itself. The bottom line is that vaginal microbiota seems to provide protection against infection in newborns. For example, as the authors note, C-section babies, whose first microbial communities are abundant in *Staphylococcus* spp., are more susceptible to MRSA skin infection. The key finding of the study is that ‘the mother’s vaginal microbiota provides a natural first microbial exposure to newborn body habitats’ (Dominguez-Bello, Costello, & Knight, 2010b, p. E160). What they call ‘natural first microbial exposure’, also known as the ‘first inoculum’, they suggest, plays a crucial role in the co-maturation of the immune system and the microbiome in humans.

Two years after my ethnographic encounter with this field of microbiome research, I experienced another (extra-academic) dimension of the microbiology of reproduction: embodied, during childbirth.

5.2.2 The microbiology of reproduction as (my) ‘matter of concern’

It is 3 September 2016. I am in labour. My partner and I arrived at the University College London Hospital (UCLH) maternity department in the afternoon, after waiting at home with mild contractions for several hours. It is Sunday and the maternity unit seems very quiet, with very few staff and patients. We are quickly moved to the birth centre, which is located at the fifth floor of the hospital. I can barely walk. The warm voice and hands of the midwife on rota comforted me while in the elevator. We enter in the birth centre. Our room looks like a spartan hotel room, although the big bathtub (for a waterbirth) makes a difference. A midwife comes every fifteen minutes for fetal heart rate monitoring. She uses a special stethoscope called ‘doppler transducer’. The transducer is placed against my abdomen to hear the fetus’s heartbeat. This is the third time the midwife comes to perform the auscultation. Complications started. I realise that I am bleeding heavily. Most worrying, she cannot detect the fetus’s heartbeat. Although I am extremely worried, what worries me the most is the anxious look of my midwife. We are rushed to the labour ward.

At the ward, my midwife nervously asks me to wear a belt which monitors and records contractions and fetal heartbeat electronically. Because of the anxiety and fear that being in an environment like a labour ward generates, I am aware of the fact that the chances of medicalisation as well as of an assisted delivery (i.e. via forceps or ventoses) and caesarean section increase dramatically here. I am monitored, in indescribable pain, at a hospital. But I am not a patient because I am not sick. I am in labour, which is not a medical condition. I want to have a say in where and how my baby is born. But my wish is not translatable to what Annemarie Mol (2008) describes as the ‘logic of choice’, the dominant healthcare approach in richer nations based on (Enlightened) rationalism and neoliberal individualism (i.e. patients as consumers), simply because I am not a patient. Yet, I am at a hospital. And things are starting to go wrong. Unwillingly, I am becoming a patient. It is not only becoming a patient that worries me. I wonder if I would become subject to ‘obstetric violence’, a term that refers to a ‘dehumanizing care, over-medicalization, and the conversion of biological processes into pathological ones’ (Vacaflor, 2015).

I am in tremendous pain. The midwife offers me an epidural. I reject it. I do not have masochistic tendencies, but I have not taken any medications during all the pregnancy. I have been very careful and done lots of research on how to prevent UTI and other common illness in pregnancy. I am not going to ‘surrender’ to medicines now, just at the end. ‘I am almost there!’, ‘almost done’, I tell to myself. I am trying to overcome the pain with gas and air (Entonox), although I am incapable of feeling its effect. Minutes later, the midwife suggests me to start with intravenous penicillin. She has just read in my pregnancy notes that I am Group B Streptococcus (GBS) positive.

I studied the bacterium during my bachelors and I updated my knowledge on it during my pregnancy. GBS is a common bacteria in humans. It is part of a healthy microbiome. The presence of the bacterium is intermittent. It ‘comes

and goes.’ The cycles often last for five weeks. Testing positive once does not mean you would a second time. This is because diet among other environmental factors affect the Streptococcus presence in fecal samples. GBS can cause infection in newborns, especially in premature babies. GBS can cause infection in newborns, especially in premature babies. The midwife in room is obviously concerned about this. She is urging me to start the intravenous antibiotics. I declined. My baby is not premature (I am in my 41 week plus 1 day of pregnancy) and the likelihood of an infection is extremely low, scientific evidence suggests. She insists. My partner insists as well. I continue bleeding. The pain is unbearable. I ask for an epidural. It is Sunday and there is not any anaesthetist available. I need to wait.

While waiting for pain relief, I am feeling a hot liquid dripping along my knees. It is the amniotic fluid. This is colloquially known as ‘water breaking’. The amniotic fluid is the liquid that surrounds the fetus. It is contained in the amniotic sac. I soon realise that the fluid is not transparent or yellowish (as it ‘should be’). It is dark, brownish, with small brown and green floating particles and lumps. This is the meconium: the baby’s first faeces. Meconium in labour indicates fetal distress. In the antenatal classes I attended as well as in the numerous online information on labour I have been consulting over the last few weeks, I learnt that the presence of meconium during water breaking can be dangerous, a source of neonatal infection. This is especially worrying if the baby swallows the amniotic fluid. But there is no way to know whether the fetus will or will not swallow it. To be on the safe side, the current medical recommendation under this circumstance is to provide intravenous antibiotics. However, I have also learnt that the presence of meconium in the process of ‘water breaking’ is a relatively frequent occurrence. The possibility of an infection deriving from meconium mostly affects premature babies, due to the severe immaturity of their immune systems and lungs.

The two midwives and the doctor in the room are urging me to take antibiotics. They enumerate all the risks for my baby if I do not comply. They do not mention, however, the positive side. The favourable and crucial (I believe) condition that makes my situation and case less likely to result in a neonatal infection: I am over the forty weeks of pregnancy. My baby has fully mature lungs and, supposedly, more developed immunity to cope with adversity. In a curious twist, my ‘choice’ (i.e. rejection of antibiotics) appears to be the wrong choice. It looks like I am no longer entitled to be an autonomous and responsible individual who has the ability to choose—although arguably this is a fiction of autonomous selfhood (Mol, 2008)? Medical staff approach me with the gendered stereotype of the ‘stubborn type’ of woman. The paranoid. The hysterical?

In all my fear and pain, I feel that I have been coherent all the way up to now. The risk of infection for the baby is now higher, not just due to GBS but because of the presence of meconium. I decline antibiotics once again. But this time it is different. I arrived at the hospital almost twelve hours ago. Every hour is getting worse. I am tired and in pain. I am vulnerable. No one agrees with my decisions. I am fearing I am putting at risk the life of my unborn child. I am considering antibiotics. My body recedes to the background. When did I transform into a receptacle? I wonder.

My embodied experiences of childbirth, my ‘concerns’ during and after the events I have narrated above, made me re-evaluate my ethnographic insights from the microbiome

study on the mode of delivery at birth led by Dominguez-Bello (2010). As I have explained earlier in the chapter, Dominguez-Bello was the first microbiome scientist to demonstrate that newborns acquired a different inoculum (i.e. first microbiome) depending on the mode of delivery at birth (vaginal or C-section delivery). Furthermore, her research also suggested that, unlike C-sections, a vaginal delivery produces better health outcomes in later life—both in childhood and adulthood and especially in terms of a lower prevalence of autoimmune, metabolic, and inflammatory diseases—due to the protective role of the vaginal microbiota of the mother.

I had an (assisted through forceps) vaginal birth, yet I found hard to believe that the intra-labour and postpartum antibiotics I was urged (not to say obliged) to take have not impacted the vertical transmission of microbes (from me to my newborn).



Figure 20. Mother and newborn. Photo by Maria Elena Casal Mera.

My postpartum recovery passed slowly. I needed two more operations to repair my severe perineal tear. In the meantime, I became more interested in the links between what I lived through my body (i.e. matters of [embodied] concerns) and what I read and observed while researching microbiome studies on reproduction (i.e. matters of fact). I discovered

that my ‘concerns’ and doubts about Dominguez-Bello’s study (2010a) also generated a scientific controversy, particularly around the very same issues I embodied in childbirth: antibiotic use in labour (i.e. intra-labour antibiotics) and the correlation between certain bacteria and states of health and disease in women, which in my case was encapsulated by being a ‘carrier’ of the GBS in pregnancy.

5.2.3 Controversies: Antibiotics and microbiomisation

In a letter published in the journal *Proceedings of the National Academy of Sciences*, Putignani, Carsetti, Signore, and Manco (2010) argue that Dominguez-Bello’s study needs to be more rigorous and methodologically precise, especially in relation to the sampling and antibiotic administration and record. Dominguez-Bello and colleagues explain that women who delivered via C-section ‘were administered cephalosporin several hours before the C-section’ (2010a, pp. 11971–11972). Putignani et al. (2010), however, remark that this procedure goes against international guidelines, which ‘recommend [antibiotic, ANC] administration during C-section, at skin incision, or after umbilical cord clamping’ (p. E159). The authors criticise Dominguez-Bello et al.’s claim about the lack of effect of antibiotics on the bacterial community structure (2010a).

In addition, Putignani et al. (2010) also criticise the lack of evidence regarding the underlying medical conditions justifying some of the participants’ caesarean sections as well as the omission of the mother’s gut microbiome (i.e. no rectal swabs) (p. E159). The time frame of microbial collection from newborns is also problematic according to Putignani et al., who argue that it is impossible to register microbial colonisation from non-maternal sources and hospital environments within seconds (p. E159). To these issues surrounding the validity and reliability of methods and protocols (e.g. record on antibiotic administration) another is added: the correlation that Dominguez-Bello’s study establishes between bacteria and certain populations and states of health and disease (e.g. vaginal microbiome of African American and Hispanic women and lack of *Lactobacillus*).

In nonpregnant United States women, lack of lactobacilli dominance has been related to bacterial vaginosis (25), which was not evident in any of the women in this study, although the possibility of under-diagnosis cannot be ruled out (Dominguez-Bello et al., 2010, p. 11972).

This claim was later reviewed and corrected based on a scientific study evidencing that a low abundance of *Lactobacillus* species is not related to disease but, rather, to racial differences (Ravel et al., 2010):

Vaginal bacterial communities dominated by species of *Lactobacillus* (groups I, II, III, and V) were found in 80.2% and 89.7% of Asian and white women, respectively, but in only 59.6% and 61.9% of Hispanic and black women, respectively. The higher median pH values in Hispanic (pH 5.0 ± 0.59) and black (pH 4.7 ± 1.04) women reflects the higher prevalence of communities not dominated by *Lactobacillus* sp. (cluster IV) in these two ethnic groups when compared with Asian (pH 4.4 ± 0.59) and white (pH 4.2 ± 0.3) women (Table 1) (p. 4683).

These scientists argue that a low presence of lactic acid-producing bacteria is not pathological because, despite that it is not common among healthy Asian and white women, a low prevalence of *Lactobacillus* is common in healthy black and Hispanic women. This study debunks that a low pH and high numbers of *Lactobacillus* sp. are synonymous with being ‘healthy’, begging the question of ‘what kinds of bacterial communities should be considered “normal” in Hispanic and black women’ (p 4683). This point is very relevant considering that, in the context of the US, where the study was conducted, many Hispanic and black women belong to vulnerable and unprivileged communities (as both non-white and as women).

Yet, this issue complicates itself once again when, contradicting Ravel et al.’s research about a more diverse biomedical conception of what a ‘healthy’ vaginal microbiome means in terms of microbial composition, Funkhouser and Bordenstein (2013) claim that the microbiome of African American and Hispanic women relates to microbial ecologies associated with bacterial vaginosis (i.e. dysbiosis and pathogenesis):

Interestingly, the vaginal microbial community varies significantly among American women of different ethnicities (Caucasian, African-American, Asian, or Hispanic), with African American and Hispanic women more likely to have a microbiota traditionally associated with bacterial vaginosis (predominance of anaerobic bacteria over *Lactobacillus* species) [33] and a higher rate of spontaneous preterm deliveries (reviewed in [34]) (p. 1).

Clearly, the aforementioned microbiome studies are based on statistical norms that homogenise communities and have their own issues in terms of validity and reliability. As I have been arguing throughout the thesis, I encapsulate this form of reductionism and essentialism in microbiome science with the term ‘microbiomisation’ (see Chapters 3 and 4). By correlating certain microbial species and diversity with women and/or with African American, Hispanic, or Caucasian (as in the quotes above), social categories of difference become microbiomised. In the process of microbiomisation, socio-cultural practices such as mode of delivery at birth (along with cleaning frequency, family size, diet, kinship, etc.) are biologised, that is, essentialised, into racial (Chapter 3), class (Chapter 4), and gender (Chapter 5) categories when microbial species are used as markers of population

differences. What, in the previous chapter, I framed as the microbiomisation of race and class, here entangles with the microbiomisation of gender, as I will further develop in what follows, particularly in connection to antibiotic use in labour.

5.2.3.1 *The intersectionality of microbiomisation in intra-labour antibiotics administration*

The limitation of Dominguez-Bello et al.'s study (2010a) in relation to how intra-labour antibiotics affect the vertical transmission of microbes has recently become an emerging theme of scientific research. Microbiome scientists have started to gather evidence about the impact of antibiotics on pregnant women and infants. As Gomez-Arango et al. (2017) report:

Emerging evidence shows that antibiotic administration to mothers during labour significantly affects the development of the intestinal microbiota in preterm neonates, reduces intestinal host defences, and leads to alterations in the vaginal microbiota prior to birth (p. 4).

Interestingly, several influential scientific papers on the theme were published right after my son was born in early September 2016, particularly during the period 2016–2018. For example, mingling studies on the gut–brain axis and antibiotics, Yang and colleagues (2016) claim that the prenatal and postnatal administration of antibiotics has implications for neurocognitive development. Another study suggests that intra-partum antibiotics alter the oral microbiome of newborns (Gomez-Arango et al., 2017). In this line, in 2017, a scientific team from McMaster University in Hamilton, Canada, argued that ‘intra-partum’ antibiotics for GBS prophylaxis, the bacterium I tested positive for five weeks before delivery, alter the vertical transmission of the human microbiome. In the study, Jennifer Stearns et al. (2017) show that infants exposed to antibiotics in labour have a significantly lower microbial diversity and an abnormal development of the gut microbiome:

The fecal microbiota of IAP [Intrapartum Antibiotic Prophylaxis, ANC] exposed infants had significantly lower alpha diversity and there was a delay in the colonization patterns in these infants compared with unexposed infants. Bacterial genera most impacted by IAP for GBS during vaginal birth included *Bifidobacterium*, *Escherichia* and *Parabacteroides*. By 12 weeks of age, community diversity and structure of the bacterial communities of vaginally born infants exposed to IAP for GBS was similar to that of unexposed infants. However, for every hour of IAP administration, there was a decrease of 7% in the abundance of *Bifidobacterium* at 12 weeks suggesting that infants with longer IAP exposures experienced a more persistent impact (p. 4).

While the authors point out that the effect of antibiotics on the infant microbiome is reversed by twelve weeks of age, the duration of the antimicrobial treatment has an

important impact on the infant microbiome. Interestingly, they also found that, over the first twelve weeks, the exposure to antibiotics ‘acts independently of mode of delivery in influencing the gut microbiota’ (p. 5). This adds an important aspect to Dominguez-Bello and colleagues’ study on the difference between the microbiome of infants born vaginally and infants born via C-section (2010a).

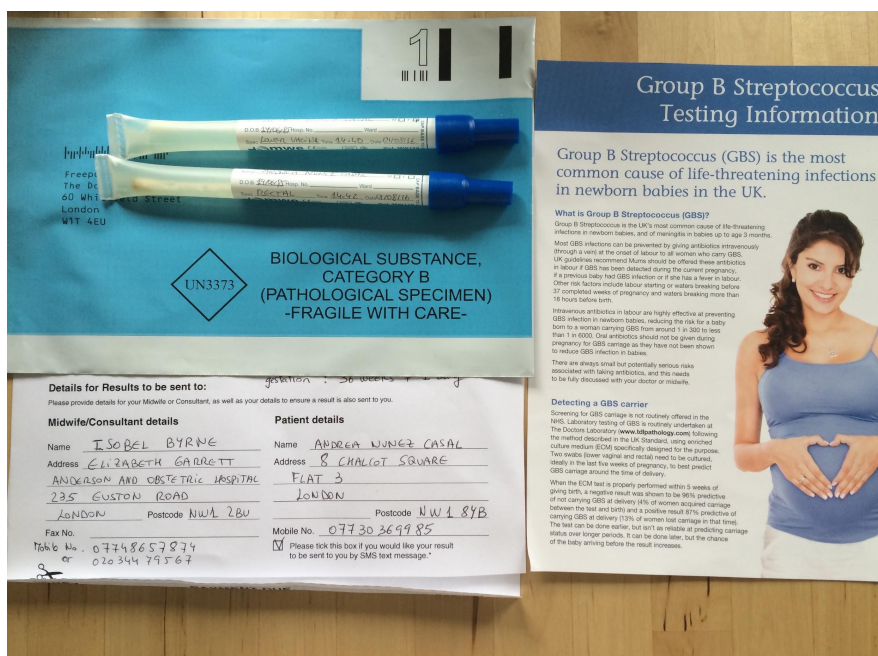


Figure 21. Testing for GBS. Photo by the author.

This is a relevant scientific ‘fact’, considering that testing positive for Group B *Streptococcus* (GBS) is one of the most common causes of antibiotic administration during labour. For example, in the US alone, 50 per cent of low-risk, full-term infants receive antibiotics (p. 1). The (biomedical) motto behind the unnecessary antibiotics I received was ‘better safe than sorry’, as several medical staff repeated to me while I was labouring. I received intra-partum antibiotics as a preventive measure, despite the chances of my child developing a GBS infection being very slim. I ‘knew’ that before Stearns et al.’s study was published. Infection would only occur in cases of severe prematurity, when the lungs and other vital organs are still forming. My child, as the infants of the study (Stearns et al., 2017), was classified as ‘low risk’ as full-term infant. I had, as the women recruited in the study, a low-risk pregnancy, free of medical complication, yet I was urged to take antibiotics.

In the light of recent microbiome studies on the topic, however, public health entities have also started questioning the preventive administration of intravenous intra-labour antibiotics. An example of this is the current public health recommendation in the

UK. Unlike other European countries such as Spain, Germany, or Belgium, in the UK, the NHS does not currently offer GBS tests to pregnant women. In March 2017, Public Health England (PHE) released a statement which did not recommend GBS screening in pregnancy. The advice was based on evidence from the National Screening Committee UK (NSC UK). Among the strongest reasons behind the advice, the Director of Programmes for the UK NSC, Anne Mackie, pointed out that:

At the moment there is no test that can distinguish between women whose babies would be affected by GBS at birth and those who would not. This means that screening for GBS in pregnancy would lead to many thousands of women receiving antibiotics in labour when there is no benefit for them or their babies and the harms this may cause are unknown ... This approach also cuts against the grain of ongoing efforts to reduce the number of people receiving unnecessary antibiotics. Much better evidence is needed on such widespread antibiotic use among pregnant women and whether it is possible to find a more accurate test (PHE, 2017).

Unfortunately, this public health advice came too late for me. When I gave birth, this ‘evidence’ was not updated. Apart from the GBS test I had in pregnancy and the intravenous penicillium in labour, I was also prescribed amoxicillin with clavulanic acid during my postpartum as a prophylactic measure for my severe perineal tear. My son developed a severe form of atopic dermatitis (severe eczema) a few weeks after birth. He was ‘delivered’ vaginally, yet I believe that the antibiotics I received decimated my vaginal microbiome, altering, in turn, our ‘microbial generosity’ (Hird, 2009), that is to say, the vertical transmission of microbes. My son’s skin condition, an autoimmune disease, is correlated in scientific literature with the predominance of the bacterium *Staphylococcus aureus* in his skin microbiome (Kobayashi et al., 2015), which, in turn, is a result of my intrapartum antibiotics (I believe).

Interestingly, there is a growing body of scientific literature on the microbiology of reproduction, suggesting that the microbiome transmitted from mother to child at birth (vertically) already harbours resistant bacterial genes resulting from horizontal reproduction (i.e. which is the main biological mechanism of AMR) (Chapter 4). In particular, these studies emphasise and insist on the risk of AMR and antibiotic resistance genes (AR) for newborns and children. Yassour et al. (2016), for example, reported an increase in AR following intra-partum antibiotics:

Our longitudinal sampling, coupled with whole-genome shotgun sequencing, allowed us to detect strain-level variation as well as the abundance of antibiotic resistance (AR) genes. The microbiota of antibiotic-treated children was less diverse at the level of both species and strains, with some species often dominated by single strains. In addition, we observed short-term composition changes between consecutive samples from children treated with antibiotics (pp. 1–2).

This study also reports that the abundance of AR in children exposed to antibiotics declines once the treatment ends, yet ‘some genes on mobile elements persisted longer after the end of antibiotic therapy’ (p. 2). Another recent study confirms this observation:

Animal studies have shown that even after termination of low-dose penicillin, mice displayed altered microbial phenotypes and higher ratios of fat mass, with a decrease in fat mass attributed to later exposure to the antibiotic (Cox et al., 2014). Further, both pathogenic and normal microbial profiles have been linked to altered physical, behavioral, and memory functioning in recent animal models (Yang et al., 2016, p. 7).

Although the long-term health effects of intra-labour and postnatal antibiotics for the offspring are still unknown, scientists are beginning to highlight the importance of longitudinal studies on the topic (Yang et al., 2016), especially in relation to the growing evidence on the ubiquity of AR genes and the risk that this entails for the spread of AMR.

This literature on the influence of antibiotics on the microbial transmission in humans is very interesting from a framework of ‘microbiomisation’. In particular, the relevance of this resides on how antibiotic use and biome depletion are socially mediated through processes of microbiomisation. I suggest that the vertical transmission of microbes (mother to child) involves the microbiomisation of gender, while the horizontal transmission of microbes (or LGT) in bacteria, the principal process of AMR, relates to the microbiomisation of class (Chapter 4). Yet, both types of reproduction intersect, they are entangled, as Hannah Landecker (2016) argues: ‘horizontal gene transfer and the vertical mode of reproduction within a species are not opposed but are intersecting modes of proliferation over space and time’ (p. 32). In other words, in humans, the microbiome transmitted from mother to child at birth (vertically) already harbours resistance bacterial genes resulting from horizontal reproduction. In terms of processes of microbiomisation, this means that the microbiomisation of class and gender intersects.

The relevance of this argument is paramount. Individuals and communities of lower socio-economic status are more vulnerable to AMR. This is because their limited access to healthier lifestyles translates into a lack of microbial diversity and therefore into a(n) (immunitary) predisposition to AMR (Chapter 4). This reasoning extends to the vertical transmission of microbes because babies born to mothers from low SES would have less diverse microbiomes. Class, therefore, is always already social and biological. Class within this context potentially becomes part of a bioinequality. This is to say that privilege can be socialised as a form of bioinequality.

To summarise the main points of this first section of the chapter, my embodied experience as GBS ‘carrier’ in pregnancy and labour offered a ‘lived’ and ‘socialised biology’ example of the ‘microbiomisation of gender’ and of how the latter intersects with the microbiomisation of class (Chapter 4). Through the lens of my embodied experiences, I have sustained that:

- 1) Conflicting scientific information and clinical advice surrounding microbes and pregnancy lead to the administration of unnecessary antibiotic courses during labour as well as pre- and postnatally and during the first years of life.
- 2) There are important tensions between a ‘logic of choice’ (Mol, 2008) and processes of microbiomisation by which certain bacteria (such as GBS) are associated with women and states of health and disease.
- 3) The vertical transmission of microbes is not only about microbes but about the (re)production of structural differences in society in terms of health and disease.

These points (the first two in particular) are part of a broader controversy and conflicting views in the microbiology of reproduction: Pasteurianism versus post-Pasteurianism. Doctors often prescribe antibiotics to women during prenatal and postnatal periods. Also urine cultures and other microbial tests are more common during pregnancy. This is to reduce the chances of bacterial infections which are thought to pose a serious risk to the fetus and, in some occasions, the mother. I argue that this fear springs from Pasteurian⁹⁹ understandings of pregnancy, by which reproductive organs are microbial free. However, the *clinical* prescription of antibiotics and the fear of infection (fear of the microbe) in pregnancy enters in conflict with the post-Pasteurian¹⁰⁰ *research* ethos of microbiome science, which proposes new practices and therapies to counteract the dominant Pasteurian practices of the clinic. As I will argue in the next section of the chapter, these two competing views in the microbiology of reproduction translate into and evidence a tension between science and people, between matters of fact (i.e. reproductive science) and matters of concern (i.e. embodied experiences, concerns, and beliefs of women).

⁹⁹ In Chapter 1 I discuss ‘Pasteurianism’, drawing on the work of Bruno Latour (1988).

¹⁰⁰ For further details on ‘Post-Pasteurianism’, see Chapter 2 (Section 2.2).

5.3 Pasteurianism versus post-Pasteurianism: Science versus people

5.3.1 Pasteurianism: The uterus as a sterile milieu

The placenta is a transient organ attached to the womb and formed during pregnancy. Pregnancy tests (both urine dipsticks and blood tests) detect the human chorionic gonadotropin (hCG), a hormone produced by the placenta after implantation. Without a placenta, there is no pregnancy. The placenta links mother and fetus. Belly buttons are universal traces of that primordial linkage. The placenta has its very own physicality, despite often being erased from the collective imaginary of pregnancy. At birth, it usually weighs around 0.7 kilogrammes. The biological role of the placenta is impressive: it absorbs nutrients, produces hormones, exchanges gases, eliminates waste, thermo-regulates, and fights infection, the literature emphasises (Simister & Story, 1997; Kiserud & Acharya, 2004).

The immunitary role and antimicrobial quality of the placenta have been a central dogma in gynaecology and obstetrics. The ‘sterile womb paradigm’ or, in other words, the placenta as the physical-reproductive barrier impeding contact between the fetus and microbes, has been debated for about 150 years, reaching scientific consensus in the second half of the twentieth century (Perez-Munoz, Arrieta, Ramer-Tait, & Walter, 2017, p. 2). From this perspective, the immune system weakens in pregnancy to ‘tolerate’ the fetus, making pregnant women more vulnerable to infections. This discourse has dictated much of the public health campaigns and advice targeted at pregnant women. For example, contact with cat faeces during pregnancy might be dangerous because of the *Toxoplasma gondii* parasite. This parasite is able to cross the placenta and infect the fetus. The consequences can be lasting and include mental and physical developmental ‘delays’. Pregnant women are also advised to avoid unpasteurised dairy products, soft cheeses and pates, and any undercooked food to prevent listeriosis. Listeriosis is an infection caused by the bacterium *Listeria monocytogenes*, which ‘lives’ in vegetables, butter, and meat. The exposure to the bacterium in uterus can lead to miscarriage, premature birth, or stillbirth. While these two examples are some of the more serious and dramatic cases of infection in pregnancy, the biomedical discourse that permeates public opinion (via public health campaigns) is that microbes, more generally, are particularly dangerous in pregnancy. Even in cases in which there is little or no evidence on the effect of viruses and bacteria on pregnancy and fetuses, like the case of influenza, for example, the recommendations are to get the flu jab or to avoid close contact with sick people.

Although this advice might seem counterintuitive, they reveal that the generalised fear of infection in pregnancy is indissociable from the ‘sterile womb paradigm’.

New evidence in human microbiome research using molecular techniques, however, suggests that the womb, the placenta, and the umbilical cord are not microbial free (Funkhouser & Bordenstein, 2013; Perez-Munoz et al., 2017). This new theory, known as the ‘in utero colonisation’ hypothesis (Perez-Munoz et al., 2017), proposes that the placenta harbours its microbiome. Likewise, fetuses acquire microbial communities not at birth during the passage from the birth canal to ‘world’ but rather, microbial acquisition and exposure occurs prenatally, in utero.

5.3.2 Post-Pasteurianism: ‘In utero colonisation’ hypothesis

In a journal article entitled ‘Mom knows best: The universality of maternal microbial transmission’ (2013), biologists Lisa Funkhouser and Seth Bordenstein argue that the internal transmission of microbes, that is, ‘in utero colonisation’ (Perez-Munoz et al., 2017), is ‘a universal phenomenon in the animal kingdom’ (p. 1). Similarly, Younes et al. (2018) argue that the vaginal microbiome plays an essential role in fertilisation and healthy pregnancies:

Microbial communities have been isolated from formerly forbidden sterile niches such as the placenta, breast, uterus, and Fallopian tubes, strongly suggesting an additional microbial role in women’s health. A combination of maternally linked prenatal, birth, and postnatal factors, together with environmental and medical interventions, influence early and later life through the microbiome (p. 16).

Microbes are vital for women’s health and the mother–child transfer is ‘a key determinant in infant health, and thus the next generation’ (p. 16). A recent review conducted by some of Dominguez-Bello’s collaborators went a step beyond the existing literature on the topic by referring to the ‘prenatal gut microbiome’ (Walker, Clemente, Peter, & Loos, 2017). According to the authors, prenatal studies in animals (mostly mice) evidence in utero transfer of microbes between mother and fetus. It is still unclear whether this mechanism applies to humans, although many scientists believe that it might be ‘a universally shared phenomenon and colonization of the infant gut in utero could be the result of a beneficial evolutionary process, even in humans’ (p. 7). In the article, Walker et al. propose a model for the mechanism of prenatal acquisition of microbiome in humans:

Translocation of bacteria from the oral and gut microbiomes of mothers during pregnancy, in addition to ascension of bacteria from the vaginal microbiome, may explain the presence of non-pathogenic bacteria in intrauterine locations. Maternal-derived bacteria detected in neonatal meconium, a proxy for the in

utero gut microbiome, is suggestive of the prenatal transfer of bacteria from mother to infant (p. 9).

If we adopt the view that there exists microbial traffic between the oral, gut, and vaginal maternal microbiomes and the fetus, as these studies propose, then my experiences as a carrier of GBS acquire a different meaning, and, what is more important, would have led to more favourable clinical consequences for my child and me. Consequently, GBS is no longer pathogenic in pregnancy and labour but part of a healthy microbiome. In addition, the viability of the fetus would be understood in microbial terms as well. GBS and fetal contact with meconium are part of a healthy and normal delivery process.

Yet, up to date, the scientific community does not fully support the ‘in utero colonisation’ hypothesis. Rather, it is the ‘sterile womb paradigm’ which holds scientific consensus. For example, in 2015, Dominguez-Bello et al. updated their original and influential research on the microbiology of mode of delivery at birth by including the new hypothesis. As they write:

The intrauterine environment during healthy pregnancy has been presumed to be free of bacteria (see [36] for a review and critique of this perspective), although recent evidence of microbes present in the amniotic fluid [37–40], umbilical contamination of bacteria-free samples is high and strict controls are needed to exclude contamination (Mueller, Bakacs, Combellick, Grigoryan, & Dominguez-Bello, 2015, p. 4).

It is interesting to note that while the authors acknowledge the ‘in utero colonisation’ paradigm, they do not subscribe entirely to it. Instead, they call for caution in the interpretation of results, alluding to the possibility of cross-contamination in the data supporting the ‘in utero colonisation’ hypothesis. In a more recent interview given to the scientific journal *Nature*, Dominguez-Bello claims that research on bacteria in meconium is not convincing. Taking sides in favour of the ‘sterile womb paradigm’, she insists that the only way in which sterility of the maternal environment is broken is when the amniotic sack breaks (i.e. ‘water breaking’). This leaves time for bacteria to reach the fetus, placenta, umbilical cord, etc. (Dominguez-Bello in Willyard, 2018). Here, Dominguez-Bello, as the medical staff who attended my labour, clearly adheres to the guidelines and protocols of the ‘sterile womb paradigm’. The practical application of this theory entails the administration of antibiotics within a time frame of twelve hours since the breaking of the amniotic sac. If, as happened to me, the waters are tinted in meconium and blood, intravenous antibiotics are immediately administered.

Proponents of the ‘in utero colonisation’ hypothesis, like biologists Funkhouser and Bordenstein (2013), justify the weakness of the evidence for the internal transmission of microbes due to ‘the ethical and technical difficulties of collecting samples from healthy pregnancies before birth’ (p. 2). Yet, in the most complete scientific review on both hypotheses (the ‘sterile womb paradigm’ and the ‘in utero colonisation’) to date, biologist Perez-Munoz and her colleagues (2017) sustain that the ‘in utero colonisation’ theory is empirically unsustainable. Drawing on various bodies of evidence, Perez-Munoz et al. (2017) reject the idea that microbiome acquisition begins in utero. The use of molecular techniques such as PCR and NGS, which have an ‘insufficient detection limit to study “low-biomass” microbial populations’ (p. 14), along with a lack of controls for contamination, the authors claim, make this hypothesis questionable. For this team of microbiome scientists, however, the strongest evidence against a ‘commensal placental microbiome’ comes from ‘the successful generation of germ-free animals via aseptic transfer of the entire uterus (containing the placenta)’ (pp. 14–15).

5.3.3 Science versus people

Importantly, Perez-Munoz et al.’s article (2017) also includes a discussion about the public impact of the controversy. For the authors, the ‘scientific self-correction process is slower than the transfer of information’ (p. 15). Here, they are referring to the movement of scientific information from the benches to the social realm, particularly through social media, ‘before the scientific community has thoroughly discussed and vetted the evidence’ (p. 15). This effect not only compromises health, they claim, it also erodes the public trust in science. In other words, what these scientists suggest is that the ‘public’ is not capable of critical analysis and interpretation of scientific hypotheses.

The frustration expressed by the authors about the circulation of scientific information in social media is conditioned by the fact that, despite the fact that current scientific consensus on the microbiology of human reproduction subscribes to the ‘sterile womb paradigm’, the ‘in utero colonisation’ hypothesis has permeated through non-specialised publications and lay public deeper, gaining wider attraction. For example, an article on the news website Time reports:

In recent years, scientists have been able to detect small amounts of bacteria in the amniotic fluid and in the placenta, and even in the fetus’ intestines, supporting the idea that the baby’s microbiome actually gets established far earlier than thought, in the womb (Park, 2015).

The website news ScienceNews reports similar information:

Bacteria breaks into the fetus long before the big squeeze into life on the outside. Scientists have spotted bacteria in amniotic fluid, blood in the umbilical cord, the membrane that surrounds the fetus and even babies' first poop. All of those tissues should be sterile if everything else in there is. Babies in these studies were all healthy, suggesting that these bugs aren't harmful. Instead, they're just a part of normal human development (Sanders, 2014).

The wish for the control of and monopoly on scientific information these scientists express in the article (Perez-Munoz et al., 2017) is also misplaced and non-plausible. To be sure, the controversies surrounding the intra- and intergenerational transmission of microbes spring from scientific circles, particularly from the proponents of the two competing theories (i.e. sterile womb environment and the in utero colonisation), rather than from the circulation of scientific information through informal and non-specialist networks of communication (mainly social media), as the article suggests (Perez-Munoz et al., 2017). After all, microbiome scientists and other experts in the field have been 'translating' the complexity of their field of research in terms of 'microbial coexistence', 'microbial gardens', stating repeatedly that we, humans, are outnumbered by microbes and therefore, at least biologically speaking, we are 'more microbial than human' (Blaser, 2006, 2014a; Knight, 2014; Knight & Buhler, 2015).

With these messages populating and dominating media news and popular books about the human microbiome it is logical that the public understanding of fetuses, placentas, uteruses, etc. rests on a post-Pasteurian view. In other words, the fact that the 'in utero colonisation' hypothesis has gained traction across the public domain is, I suggest, a logical consequence of the (popular) 'translations' microbiome scientists and related stakeholders make. They are responsible, to a great extent at least, for the public understanding of the human microbiome. This reflects a significant inconsistency at the heart of microbiome science. I argue that this is an inconsistency between its post-Pasteurian epistemology, based on harmonious microbial entanglements, and its Pasteurian clinical practice, based on the biomedical application of the 'sterile womb paradigm' during labour.

As my embodied experience as a GBS carrier attests (Section 5.2.2), the divorce between matters of concern or 'people' and matters of fact or 'science', particularly around the post-Pasteurian (i.e. 'in utero colonisation') and Pasteurian (i.e. 'sterile womb paradigm') views respectively, often leads to clinical advice and procedures that increase the likelihood of unnecessary antibiotics administration during labour, prenatal, and postnatal periods as well as in infancy. Simultaneously, however, there is a growing body

of microbiome research focused on experimental solutions to biome depletion under an ‘interdisciplinary’ framework. Adding another layer of complication to the Pasteurian versus post-Pasteurian debates around microbial reproduction, the essence of these interdisciplinary microbiome solutions to biome depletion is a post-Pasteurian understanding of health, in which microbes are not only ubiquitous life forms but, fundamentally, granters of immunity and overall health.

5.3.4 Interdisciplinary’ solutions to biome depletion

One of the aspects that attracted me to documenting and following Dominguez-Bello’s studies of the human microbiome was its marked interdisciplinary ethos. The MHC project (Chapter 3) and the microbiology of modes of delivery at birth (Section 5.2) are both formed of interdisciplinary teams of physicians, microbial ecologists, architects, and bioinformaticians. Similarly, another of my epistemic partners (Holmes & Marcus, 2008), renowned immunologist and microbiologist Graham Rook, also calls for interdisciplinary collaborations among ‘scientists, urban planners, local authorities’, psychologists, and psychiatrists (G. Rook, personal communication, April 21, 2017) (see also Chapter 4) in his proposal on public green spaces design. Interdisciplinary concerns, especially in relation to the microbiology of built environments, is becoming a widespread framework in microbiome science and AMR research.

As part of his ongoing research on the role of biodiversity from the natural environment in the regulation of the immune system (2013), Graham Rook is a firm advocate of ‘re-engaging with green spaces’ (G. Rook, personal communication, April 21, 2017). In doing so, he and his colleagues argue, the focus should be on ‘the need for increased hygiene, coupled with innovative design for homes and sustainable cities that promote appropriate microbial exposures’ (Rook et al., 2014, p. 8). Remarkably, Rook suggests that future solutions to (micro)biome depletion (or loss of contact with ‘old friends’) in high-income countries should involve ‘design [meant] to contain and release to the environment the right microorganism’ (G. Rook, personal communication, April 21, 2017). This type of ‘intelligent social medicine’ that Rook proposes would benefit those most vulnerable to ‘microbial disadvantage’ (i.e. low SES inner-city children).¹⁰¹

In a similar line, Dominguez-Bello has also proposed and designed a method to compensate for the lack of microbial exposure in babies born via caesarean section known

¹⁰¹ ‘See also Chapter 4, Section 4.5.1.

as ‘vaginal seeding’. This technique consists of the relatively simple practice of inoculating neonates with maternal vaginal flora immediately following a caesarean-section delivery. Gauze swabs are placed in the mother’s vagina. After the caesarean birth, the gauze is rubbed onto the baby’s skin. The idea is to mimic the vertical transmission of microbes in babies born by vaginal delivery. In this way, Dominguez-Bello and her colleagues believe that immunity response to inflammatory diseases, asthma and allergies is boosted (M. G. Dominguez-Bello, personal communication, January 28, 2014).

Vaginal seeding as a microbial restoration technique has gained widespread media attention soon after the clinical trials started. For example, in 2015, *The Guardian* reported on Dominguez-Bello’s technique, claiming ‘a positive impact on the diversity of a newborn’s microbiome’ (Molloy, 2015). Similarly, BBC News (Collen, 2015) echoes the autobiographical experience of Dr. Rob Knight, one of the principal collaborators of Dominguez-Bello (see Chapter 3):

Shortly after his wife gave birth by emergency Caesarean section in 2012, US scientist Rob Knight waited for the midwives and doctors to leave the room, then rubbed his new baby daughter’s little body with a swab coated in his wife’s vaginal fluids ... Prof Knight and Dr Dominguez-Bello are now working on a larger trial, and are planning to follow the babies as they grow to see if vaginal swabbing reduces rates of allergies and autoimmunity. Just as with a vaginal birth, there are concerns about transferring harmful microbes alongside the beneficial ones that must be considered. But if these and other trials prove a success, we could see vaginal swabbing rolled out as a standard procedure to ensure future generations continue to receive the beneficial microbes that have accompanied humans throughout our history.

In spite of the optimism, the open post-Pasteurianism of vaginal seeding makes it a controversial method of microbial restoration. There is no scientific consensus yet, mainly because of the lack of clinical trials. A Danish research group on the issue reported that the main risk are serious infections in newborns. ‘Early onset neonatal sepsis—a serious infection more common in preterm babies—can be caused by transfer of bacteria including *E. coli* and *Group B streptococcus* from the mother during vaginal birth’ (PubMed Health, 2017). Overall, the current medical recommendation advises against it (Haahr et al., 2017).

What these two examples of interdisciplinary solutions to biome restoration show is that, once again, the immunitary logic of Pasteurianism (i.e. fear of microbes, fear of infection) dominates not only clinical practice but the possibilities of research innovation through, for instance, more clinical trials on a (post-Pasteurian) technique such as

Dominguez-Bello's 'vaginal seeding'. But Rook's green environment design and Dominguez-Bello's vaginal seeding are also interesting for this thesis because they connect to care (Chapter 1) as sustainable methods of biome restoration in healthcare (Dietert & Dietert, 2015), of 'staying with the trouble' (Haraway, 2016) (Chapter 2). In contrast with personalised microbiome science initiatives such as BG or the AGP (see Chapter 3), these two examples can be framed as 'social medicine'; as universal and public microbiome initiatives. Yet, as I have demonstrated in Chapter 3, it is important to not lose sight of how microbiome science operates: its basis is sustained through the microbial genetic makeup of non-Western(ised) communities, societies, and locales. Its therapeutics (including the aforementioned methods or 'solutions') are only applicable to medical conditions affecting rich nations (i.e. inflammatory, autoimmune, and metabolic diseases). With this in mind, however, it is also important to remark that both Rook's and Dominguez-Bello's microbial solutions to the loss of microbiota in Western and westernised countries would help to reduce health disparities in rich nations. My concern is: how to secure the social contract (especially for the disadvantaged) of this kind of microbiome initiatives? Where is, or what is the role of, the social? Who would bring the social agenda, particularly in the sense of inequalities in health and disease, to the forefront of these microbiome initiatives?

My argument here is unambiguous: without social sciences and humanities' expertise around issues of embodiment, race, gender, class, and inequalities, these types of microbiome initiatives are short-sighted. As Ràfols and Stilgoe's research has recently demonstrated (2018), public research (i.e. financed by citizens) often meets and mimics the research agenda of big pharma companies (instead of being at the service of the public good) (Chapter 4). Without the 'social' of the social sciences and humanities, microbiome science is at risk of favouring frameworks of 'research excellence', publication demands, and venture capitalist goals (Stengers, 2018) rather than being at the service of a universal and public healthcare.

Although there is literature on the social and ethical aspects of the human microbiome (see Rhodes et al., 2013), the framework of reference is ELSI (Ethical, Legal, and Social Implications). I concur here with sociologist Ana Viseu (2015), who, in relation to nanotechnology, highlights the duality of ELSI frameworks. On the one hand, ELSI brings the social sciences to 'care' for the science, Viseu claims. On the other, however, as the only social approach to postgenomics, ELSI reifies old divides and

imposes control through policy documents detailing how care should be executed (Martin et al., 2015, p. 632). As Viseu argues:

Despite integration's potential for creating new forms of collaboration between the social and natural sciences, its discourses and socio-material orderings are based on traditional and prescriptive arrangements, where disciplinary boundaries, funding arrangements and power asymmetries are not challenged but reified such that there is little to no room to re-imagine existing practices. Integration in its current format is problematic and must be reassessed (Viseu, 2015, p. 657).

Beyond ELSI frameworks, the social can no longer be elicited from the biological in so-called 'interdisciplinarity' microbiome research. The main question I ask in this chapter is: how to reconcile both views (Pasteurianism and post-Pasteurianism, 'Science' and people), how to foster a 'critical friendship' (Rose, 2013), but a 'critical friendship' able to generate assemblages between the sciences and the social sciences and humanities, between (microbiome) scientists ('Pasteurians') and people or public opinion ('post-Pasteurians'), and overall, between 'matters of fact' and 'matters of concern' (Despret, 2004; Latour, 2004; Stengers, 2018)? What is important are alliances between the sciences and the social sciences and humanities in which the social is, first of all, included; second, re-valued; third, listened to. My own proposition towards this inclusive 'biosociality' (Rabinow, 1996b) is 'feminist para-ethnographies', as I will elaborate later in the chapter (see Section 5.5).

I would like to turn to how the social sciences approach the 'factualities' around the microbiology of reproduction. In doing so, I examine my postpartum experience as a 'matter of concern' through the lens of feminist literature on reproduction, mainly drawing on the work of feminist anthropologist Emily Martin (2001).

5.4 Birth reflection as matter of concern

The postpartum recovery was slow. I was unable to walk for three weeks. It took me half a year to feel comfortable when sitting. Four months after giving birth, I had a surgery to repair my perineum. This physicality of the birth had also a traumatic dimension. My childbirth experience haunted me for a while. All my efforts in transmitting a rich and diverse microbiome to my child were jeopardised at birth, which according to microbiome science is the most crucial moment in the intergenerational transmission of microbes. How and why did the succession of events during labour go so wrong, I wondered? Did my choices, my determination of being drug free, sabotage my ultimate goal for a non-medicalised childbirth?

My midwife, who was a great support, referred me to an NHS maternity service at UCLH called 'Birth Reflections'. Birth Reflections is a public health service to discuss the birth experience with a team of midwives. The

idea is to narrate and express the experiences and feelings of childbirth as a way to decrease the possibility of psychological stress and increase confidence in going in future pregnancies. I was seduced by the idea.

My session lasted for forty-five minutes. It was held at the maternity wing, in a tiny room without windows. When I entered the room, the head of the UCLH midwifery and another midwife were waiting for me. They had my maternity and labour notes with them. I recognised the book. I explained to them the reason for my visit: the traumatic birth experience I endured half a year ago.

My flashbacks and fears. My disappointment about how things evolved. We went through all the notes, from the moment I arrived in the hospital until the birth of my baby. I was surprised by the detailed time frames. In these books, midwives, nurses, and doctors keep a real-time record of the events, administered medications, and physical state of the woman in labour and the fetus. I had many questions. I asked them whether my transfer from the birth centre to the labour ward was appropriate; whether my initial reticence and the final decision of having epidural could have complicated labour; whether intravenous penicillin and the subsequent postpartum antibiotics were avoidable. Unsurprisingly, both midwives qualified everything as the right decisions. The administration of antibiotics was very advisable, they insisted. My disappointment normal, even sane, they expressed affectionately.

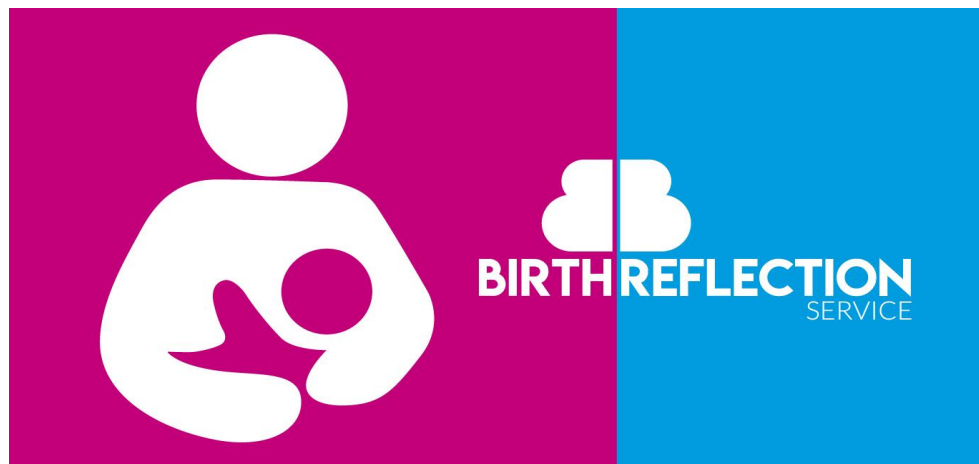


Figure 22. NHS Birth Reflection service. Source: www.nhs.co.uk.

Despite the potentialities of the service regarding a distributed care practice between medical staff and patients, my experience of ‘Birth Reflections’ was lived as an exculpatory device. Unsurprisingly (and understandably), health workers are trained to be careful of contestations alleging legal responsibility and accountability for possible health effects. My experience resonates with a vast body of feminist literature suggesting that women lose their political agency during medical interventions in labour, becoming a medium or receptacle who (or better ‘which’) facilitates new life (Franklin & McKinnon, 2002; Martin, 2001; Rapp, 1999).

5.4.1 'Producing' humans

This idea of the pregnant woman as being untrustworthy in her decisions or feelings during labour links with what feminist anthropologist Emily Martin argues in *The Woman in the Body* (2001). In the book, Martin examines how North American culture sees processes of reproduction, drawing on ethnographic fieldwork (interviews and participant observation). In doing so, she refines the association between Western thought and medicine and the 'body as a machine'. For her, there are more metaphors at play, particularly economic metaphors affecting the 'entire process of work' by which 'production in factories [is] being applied to birth' (p. 57). Focusing on the three reproductive processes and stages of women's bodies (menstruation, birth, and menopause), Martin shows how the metaphor of production, rather than mechanistic metaphors, populates scientific North American culture, particularly the field of obstetrics. The production metaphor, Martin suggests, 'allows us to ask, for example, whether the doctor *is* only a mechanic or perhaps more like a factory supervisor or even an owner. If the doctor is a supervisor, the woman might be a "labourer" whose "machine" (uterus) produces the "product", babies' (p. 57).¹⁰²

Martin's production metaphor applied to reproduction links with feminist theorist Silvia Federici's *Caliban and the witch: Women, the body and primitive accumulation* (2004). In the book, Federici situates reproduction at the centre stage of capitalist production. Reproduction is a 'source of value-creation and exploitation' (p. 8), she argues. This is an important point because the relationship between women, their bodies, and capital is a ubiquitous (yet unacceptable) absence in the work of Marx (capitalist production) and Foucault (biopolitics and biopower) (p. 8). Drawing on Leopoldina Fortunati's work on housework and reproduction (1996), Federici shows that the transition from feudalism to capitalism is characterised by the scission of reproduction from production. This serves capitalism—a counter-revolution orchestrated by the feudal lords, merchants, bishops, and popes against the communal possibilities of anti-feudal struggles, rather than a 'product of evolutionary development' from feudalism (pp. 21–22)—the use of waged labour (men) to command unwaged labour (women) and 'capture gender through binary oppositions' (p. 8). Here, in another turn of the history of ideas, Federici is suggesting that binary oppositions are not purely Cartesian. They originate in

¹⁰² Martin already explored the recalcitrant entanglement between patriarchy and capital (Federici, 2004) in relation to reproduction in the influential article 'The egg and the sperm' (1991).

the transition from feudalism to capitalism in late sixteenth- and seventeenth-century Europe.

In the context of British developmental psychology, Denise Riley (1983) argues that there was a clear separation between the ‘class of women workers’ and the ‘class of mothers’ after the Second World War (p. 8). Motherhood during this period ‘rendered invisible the needs of those working women with children’ (p. 7). British psychology, Riley argues, relied on unemployed mothers. This has to do with the fact that developmental psychology understands ‘socialisation’ (through the mother) as a ‘linear process’ and the social self as a ‘cumulative progress’ (p. 33). This is sustained in the belief that babies are born closer to biology and then get ‘more and more social’ through time (p. 33). Riley refers to this idea as the ‘priority of the biological’, a precondition for the opposition between the biological and the social, the individual and society, nature and culture or, in Latourian terms, between ‘matters of fact’ and ‘matters of concern’. For Riley, instead, ‘the individual is always already social, always there’ (p. 33), and she proposes ‘socialised biology’ as a concept to undo binarist thinking.

Riley’s concept is key for my proposition of feminist para-ethnographies as material-semiotic devices to register ‘socialised biology’. While I will return to this later in the chapter, I would like to highlight now the interlinkages between Riley’s and Federici’s arguments. For Federici, the unwaged reproductive work done by women is indispensable for the success of capitalism. Likewise, reproduction, women, psychology, work, and capital are all entangled in Riley’s work (1983). Similarly, women, the body, class, and work (in capitalism) are also present in Martin’s *The woman in the body* (2001). But the importance of Martin’s work for this thesis relates to the scissions between feminine and masculine, reproduction and production; to the binarisms that Federici (in relation to capital) and Riley (in relation to developmental psychology) point out.

5.4.2 Resisting binarism through embodiment

Martin (2001) insightfully shows that biomedicine does not capture (or erase, I would say) women’s embodied experience of menstruation, birth, and menopause. In doing so, science creates, recreates, and reproduces binarisms. As she writes:

The seemingly abstract code of medical science in fact tells a very concrete story, rooted in our particular form of social hierarchy and control. Usually we do not hear the story, we only hear the ‘facts’, and this is part of what makes science so powerful. *But women—whose bodily experience is denigrated and demolished by models implying failed production, waste, decay, and breakdown have it literally within them to confront the story science tells with another story, based*

in their own experience. ... When women derive their view of experience from their bodily processes as they occur in society, they are not saying 'back to nature' in any way. They are saying on to another kind of culture, one in which our current rigid separations and oppositions are not present (Martin, 2001, pp. 197, 200, my emphasis).

Women's embodied experiences are non-binary. They go against the reification of the ancestral (i.e. 'back to nature') (see Chapter 3). Embodied experiences advance other kinds of cultures. A culture that contrasts with the dominant ideology of evidence-based biomedicine, rooted in the confrontation between objectivity and subjectivity. In binarism. Embodied experiences are in fact a form of resistance against the medicalisation of reproduction, against the control and domination of women's bodies. Furthermore, Martin (2001) argues that 'the ways women are able to resist what they dislike about the medical treatment of birth is clearly affected by their class and their race' (p. 155). The less privileged (who, in North American society, are African American and Hispanic women) can identify more clearly the nature of oppression. In other words, the oppressed are not ignorant of their oppressors (pp. 202–203). If this 'were somehow reversed', Martin suggests, 'I would expect white males to gain relatively greater critical vision' (pp. 202–203). Here, class and gender intersect, an aspect which also links with Federici's argument about the false dichotomy between 'women's history' and 'class history'. For Federici (2004), 'if it is true that in capitalist society sexual identity became the carrier of specific work-functions, then gender should not be considered a purely cultural reality but should be treated as a specification of class relations' (p. 14).

Remarkably, this socially ingrained intersectionality of class and gender around social and cultural issues of reproduction applies to the microbiology of reproduction in terms of what I frame as 'microbiomisation', as I explained earlier in the chapter. The microbiomisation of class, which I have associated with horizontal modes of reproduction in bacteria (AMR) (see Chapter 4), entangles with vertical modes of reproduction in humans and thereby with the microbiomisation of gender. Since the human microbiome is vertically inherited (i.e. mother to child during birth), class embodied in microbial differences (i.e. more, less diversity and AMR) is (microbiologically) transmitted at birth as well. This is a very important point because it evidences Riley's 'socialised biology', debunking, in turn, what she calls the 'priority of the biological': the social (e.g. class differences) is always already biological, not just since we are born but even before, 'in

uterus'.¹⁰³ Clearly, if there is any doubt, the social and the biological are always already entangled.

Returning to Martin's work, the class differences she found in her ethnographic study of women's embodied experiences of reproductive processes not only translate into health disparities but in possibilities (e.g. resistance). For example, embodied experiences can be read through the lens of Federici's figures of Caliban and the witch. Caliban, the 'anti-colonial rebel', is a symbol of 'the proletarian body as a terrain and instrument of resistance to the logic of capitalism' (Federici, 2004, p. 11). The witch embodies 'a world of female subjects that capitalism had to destroy: the heretic, the healer, the disobedient wife, the women who dared to live alone, the obeah woman who poisoned the master's food and inspired the slaves to revolt' (p. 11).

Embodied experiences clearly are a form of resistance against the medicalisation of reproduction, against the control and domination of women's bodies. Yet my argument is that, although this type of analysis offers valuable critical reflection, it has an important limitation: this kind of critique does not build alliances that assemblage and gather (Latour, 2004). Similarly, Isabelle Stengers (2018) has recently expressed her concerns regarding the humanities' 'self-proclaimed privileged' critical standpoint (p.126). As she writes:

Indeed, I have heard it said a bit too often that what the golden-egg scientists lack is reflexivity, specifically that critical reflexivity cultivated by the humanities. I have even heard it said that if the humanities are today drastically underfunded it is because this critical reflexivity must be kept at bay, since it poses a threat to mobilisation. My claim, however, is that this reflexivity may also have to be reclaimed as part of the problem rather than the solution, at least in so far as it also defines itself as something that 'others' are lacking, thereby ensuring the humanities' self-proclaimed privileged standpoint: they believe, but we know better; and even better and better with each new theoretical turn (pp. 125–126).

In what follows, I show how and in what ways philosopher Vincianne Despret's notion of 'becoming available' (2004) is a helpful device for 'feminist para-ethnographies'. By opening up to embodied experiences (individual and collective), 'becoming available' is a notion that builds assemblages with the sciences while retaining the messiness of the world (Stengers, 2018), a dimension better captured by the social sciences and humanities. This approach, I will argue, gives a new experimental meaning to a public

¹⁰³ Here I am referring to the epigenetic field of Developmental Origins of Health and Disease (DOHD), which accounts for the 'environmental' influences during embryonic and fetal development on health and disease later in life.

health service such as ‘Birth Reflection’. Instead of being an exculpatory device, listening to and taking seriously women’s embodied experiences of childbirth (i.e. by recording them, documenting them, making sense of them) complement evidence-based biomedicine. Embodied experiences, I will suggest, need to be included as health(care) data and therapeutics (e.g. AMR, reduced intra-labour and postpartum antibiotics). Feminist para-ethnographies is the tool through which to make this possible (Section 5.5).

5.4.3 Becoming available

In building alliances and a ‘critical friendship’ (Rose, 2013) between the sciences and the humanities and the social sciences, feminist philosopher and animal studies scholar Vincianne Despret’s concept of ‘becoming available’ (2004) is an extremely insightful and valuable notion through which to explore how ‘human and non-human bodies become more sensitive to each other’ (p. 114). Drawing on the fields of animal and body studies and ethology, Despret proposes the term of ‘becoming available’ as a relational and epistemological alternative to the dominance of scientific knowledge production over their objects and subjects of study. For Despret, the definition of beliefs and expectations¹⁰⁴ in terms of ‘availability’ help to ‘overcome the great dividing-up that results from the “will to make science”’ (p. 125). By focusing on availability, both the subject and the world¹⁰⁵ are ‘active and both are transformed by the availability of the other. Both are articulated by what the other ‘makes him/her make’ (p. 125). Furthermore, Despret’s availability is fundamentally a caring practice. As she puts it:

The experimenter, far from keeping himself his body, he involves his knowledge, his responsibility and his future. The practice of knowing has become a practice of caring. And because he cares for his young goose, he learns what, in a world inhabited by humans and geese, may produce relations (p. 130).

I would like to illustrate Despret’s proposition of availability with a short vignette—I am reproducing here from the introduction of the thesis—of how *I became available* to new relations and new identities with microbes.

Months before I embarked on my PhD programme, I noticed a bodily pattern: A few days before suffering a UTI, a herpes simplex virus (HSV-1) physically manifested as a cold sore on either my upper or lower lip. I interpreted this biological occurrence not as an isolated fact without relation to other body parts (i.e. bladder, kidneys) but as a ‘message’ or ‘sign’ delivered by the

¹⁰⁴ Drawing on several experiments in psychology and ethology involving animals (e.g. rats, geese, and horses), Despret particularly refers to ‘beliefs’ and ‘expectations’ of the ‘experimenter’ or scientist.

¹⁰⁵ Here ‘world’ is interchangeable with ‘objects’ or ‘non-human subjects’.

virus. I wondered: Was there a relation between these two microbial communities (i.e. E. coli and herpes simplex) harboured within my body?

Herpes simplex virus is a life-long infection. Its persistent form is in a latent state in the neural ganglia, a group of nerve-cells bodies of the nervous system. Periods of reactivation or viral replication are characterised by periodic recurrence or outbreaks, which produce cold sores. I believed that the herpes virus in its activated form through the appearance of a cold sore had a meaning: the beginning of a UTI. I was also certain that both infections were closely related to my impaired immunity in periods of either emotional and/or physical stress.

The singularity of my experiences, I argue, allows experimentation and attunement in microbe–human relations beyond evidence-based biomedicine and the rigid precepts of scientific objectivity. My ‘becoming available’ to new (non-pathogenic) relations, to different ways of becoming-with microbes, is not just mediated by my decade-long embodied experiences as a ‘patient’ or ‘sufferer’ of UTIs (what belongs to ‘matters of concern’) but also by my knowledges-practices as an academic-to-be (what belongs to ‘matters of fact’). This is to say that both, my embodied experiences (concerns) and my academic practice (facts?), are indissociable (facts-concerns) parts of ‘becoming available’ to microbes. This, in turn, brings up issues related to the situatedness of social scientists, as to how researchers’ embodied experiences participate in knowledge production (Chapter 2).

Likewise, in devising how ‘human and non-human bodies become more sensitive to each other’ (Despret, 2004, p. 114), I supplement Despret’s notion of ‘availability’ with what philosopher of science Isabelle Stengers calls ‘connoisseurs’ (2018) (see also Chapter 4 and Figure 18). Connoisseurs are ‘agents of resistance against a scientific knowledge that pretends it has general authority; they partake in the production of what Donna Haraway calls ‘situated knowledges’ (p. 9). As she continues:

Connoisseurs are not advocates of ‘alternative’ knowledge, looking for professional recognition. But their interest in the knowledges produced by scientists is different from the interest of the producers of these knowledges. It is for this reason that they can appreciate the originality or the relevance of an idea but also pay attention to questions or possibilities that were not taken into account in its production, but that might become important in other circumstances (p. 9).

Bringing together Despret’s ‘availability’ and Stengers’s ‘connoisseurs’ demands to reconfigure the role of connoisseurs through the inclusion of embodied experiences. I suggest that embodied experiences as part of connoisseurs’ repertoire make ‘available’ (Despret, 2004) new identities, new ways of knowing and making knowledge, and crucially, new forms of intervention (e.g. medical diagnosis and therapeutic data).

Despret's notion of 'becoming available' to new modes of sensitivities (e.g. microbe–human entanglements), unlike other approaches exclusively focused on critique and reflexivity,¹⁰⁶ glues matters of fact together with matters of concern. Furthermore, as I will elaborate in the section that follows, becoming available is a necessary precondition of feminist para-ethnographies. Feminist para-ethnographies relies on 'connoisseurs' as 'mediums' or 'agents' through which to 'become available' and realise 'socialised biology', that is, biology '*lived out* by the individual in a social form ... lived within particular lives' (Riley, 1983, pp. 31, 40).

5.5 Feminist para-ethnographies

In this thesis, I have reformulated Holmes and Marcus's concept of the para-ethnographic (2008)—'a way of dealing with contradictions, exceptions, and facts that are fugitive' (p. 596)—as a feminist intersectional and situated practice that entangles the researcher's embodied experiences with 'fugitive' qualitative data in technoscientific claims and quantitative (microbiome) research. I have called this method 'feminist para-ethnographies' (Chapter 2). Feminist para-ethnographies as the realisation and materialisation of 'socialised biology' (Riley, 1983) is also a social justice proposition to restore biome depletion¹⁰⁷ across social classes and groups in order to alleviate health disparities resulting from microbiome science (see Chapter 4). This dimension of feminist para-ethnographies takes up Riley's 'socialised biology' ethos (1983) of accounting for how 'biology is lived out' in all its embodied and, crucially, political sense (p. 30). Its core is based on the socialisation of care and the delivery of health justice through the transformation of silenced and private embodied experiences into shared experiences. Although this dimension goes well beyond the scope of the thesis, I would like to use this last section of the chapter to establish its basis for future avenues of research. Here, I draw on recent scholarship on 'healthy publics', that is, 'dynamic collectives of people, ideas and environments that can enable health and wellbeing' (Hinchliffe et al., 2018, p. 2). In doing so, I elaborate 'feminist para-ethnographies' as a 'slow science' (Stengers, 2018)

¹⁰⁶ Here I am particularly referring to the Martin's critique of reproductive sciences (2001).

¹⁰⁷ I review literature on biome depletion in Chapter 2 (Haraway, 2016; Tsing, 2015). This emerging body of feminist literature concerned with ecology and biome degradation and restoration can be read as part of a wider engagement with a feminist conceptualisation of care as resistance to capitalism (Puig de la Bellacasa, 2011, 2015).

and ‘engaged research’ (Hinchliffe et al., 2018) intervention in human microbiome science.

5.5.1 De-medicalising interdisciplinarity

Feminist para-ethnographies is a method of registration, documentation, and interpretation of embodied experiences of health and disease as part of medical diagnostic and therapeutic data. It complements what evidence-based biomedicine fails to register and see, offering a de-medicalised approach. As Anderson and Mackay (2014) sustain in relation to autoimmunity, (embodied) biographies are an indispensable part of the efficacy of more conventional medical treatments. My proposition has very much to do with the ‘ethnographic turn’ Mol and Law (2004) call for as part of a ‘multi-voiced form of investigative story telling’ (p. 59). This requires the research design of tools in order to record, document, and provide situated accounts of embodied biological experience or ‘socialised biology’ (Riley, 1983). In doing so, the knowledge, practice, and experience of clinicians, microbiologists, immunologists, as well as psychologists, midwives, and other health workers is crucial.

For example, the work of feminist body studies scholar Lisa Blackman in the area of embodiment and voice hearing offers an innovative social science approach to the ‘psy’ disciplines (Rose, 1996) and mental health more broadly (Blackman, 2001, 2012, 2016a). In her work, Blackman brings together an eclectic and interdisciplinary body of research on voice hearing and embodiment with her long-standing collaboration with the psychiatric activist user movement *Hearing Voices Network*. Instead of forcing voice hearers to overcome or ignore the voices, Blackman shows how the processes of listening to, making sense of, and integrating the voices into their lives transform subjectivities. This non-pathologising approach towards the phenomenon of voice hearing underlines the importance of relationality, affectivity, and embodiment as alternatives to psychiatric medicalisation.

Similarly, as qualitative data evidence, feminist para-ethnographies aims at improving ‘the interpretation of statistical data’ (Hinchliffe et al., 2018, p. 3). In this line, the work of health psychologist and gender inequalities scholar Irina Todorova and colleagues (Todorova, Baban, Balabanova, Panayotova, & Bradley, 2006; Todorova, Baban, Alexandrova-Karamanova, & Bradley, 2009) helps to explain why cervical cancer is in sharp increase in Eastern European countries, against the general trend in Western European countries. Drawing on women’s experiences in Bulgaria and Romania with

cervical cancer prevention and diagnosis, Todorova et al. (2006) show that ‘the high level of mortality from this disease is related to how women’s sexual and reproductive health and well-being have been represented and politicised in media and state discourses’ (as cited in Hinchliffe et al., 2018, p. 3; see also Johnson, Horga, & Andronache, 1996; Rada, 2014; Todorova et al., 2009).

As I have previously argued in the chapter (see Section 5.3.4), biomedical solutions to biome depletion as restorative interdisciplinary practices (i.e. Dominguez-Bello’s vaginal seeding or Rook’s green spaces design) are based on very restrictive conceptions of interdisciplinarity (see Callard & Fitzgerald, 2015). An interdisciplinarity by which only certain areas of the life sciences (e.g. microbiology, biostatistics, ecology) and approaches within the social sciences (e.g. ELSI) are allowed. Furthermore, my embodied experiences of pregnancy and labour have provided me with a deeper awareness of the limitations of the evidence-based dogma in human–microbe relations. In this regard, despite the NHS’s ‘Birth Reflection’ being an interesting healthcare initiative allowing ‘reflection’ on the process of childbirth (see Section 5.4), it fails to bring together embodied experiences of labour with clinical aspects of the medical record. ‘Birth Reflections’, I have argued, focuses on clinical aspects of childbirth alone. It acts as an exculpatory device for medical malpractice(s) in maternity units. It is based on the rationality and objectivity of science as the only possible approaches and treatment in obstetrics and postnatal care. Moreover, it does not offer women the possibility of negotiating and discussing treatments and options during childbirth (e.g. administration of antibiotics, pain relief).

5.5.2 Building alliances through ‘slow science’ and ‘engaged research’ in microbiome research

Feminist para-ethnographies, instead, aims at changing perspectives and methodologies in human microbiome science through the re-evaluation of embodied experiences of health and disease. Rather than ‘start with individuals as targets for health messages, such as “eat well, exercise more”’, feminist para-ethnographies as ‘engaged research’ ‘generates recognition of, and has respect for, what people identify as barriers to their health, and these processes of engagement help to create the conditions for trusting and mutually respectful relations to form’ (Hinchliffe et al., 2018, p. 7). This requires different temporalities to those operating in biomedical research and clinical practice.

Puig de la Bellacasa (2015) argues that soil as a living multispecies community requires different temporalities to those based on innovation, productivism, and profitability. Likewise, feminist para-ethnographies as an *intervention* in microbiome science *calls for* a different way of making science. Here Isabelle Stengers's recent 'slow science' manifesto (2018) provides a helpful basis on which to build alternative knowledge practices of care and decoloniality based on alliances, therefore moving beyond the constraints of 'interdisciplinary' and 'objective' frameworks (Callard & Fitzgerald, 2015; Hinchliffe et al., 2018). As she writes:

What is messy from the point of view of fast science is nothing other than the irreducible and always embedded interplay of processes, practices, experiences, and ways of knowing and valuing that makes up our common world. This may be the challenge that slow science should answer, enabling scientists to accept that what is messy is not defective but simply that which we have to learn to live in and think with. The symbiosis of fast science and industry has privileged disembodied knowledge and disembodiment strategies abstracted from the messy complications of this world. But in ignoring messiness, and dreaming of its eradication, we discover that we have messed up our world. So I would characterise slow science as the demanding operation that would *reclaim* the art of dealing with, and learning from, what scientists too often consider messy, that is, what escapes general, so-called objective, categories (p. 120).

Inspired by slow-food movements as a way to bring consumers and producers closer together, Stengers's slow science proposition (2018) is not about interdisciplinarity. As she points out, slow science is about building alliances. It is about 'taking seriously or paying attention ... [to] the way scientific disciplines have been shaped by their exclusive, quasi-symbiotic relationship with industry' (p. 99).¹⁰⁸ 'Slowing down', Stengers argues, is meant for scientists to regain the ability to 'present themselves in a non-insulting way to members of other collectives, that is, in a way that enables a process of relation-making' (pp. 100–101). Therefore, as they are caring and decolonial (Chapter 1), alliances between people and science, subjectivity and objectivity, matters of fact and matters of concern (or, in Stengers's lexicon, 'fast' and 'slow' science) are crucial to feminist para-ethnographies. Importantly, these alliances are mediated by the 'availability' to new modes of sensitivity between humans and non-humans (Despret, 2004) of a 'distributed amatorat' of connoisseurs (p. 9).

Stengers's 'slow science' is about allowing complexity and enabling a 'relational dimension of health' (Hinchliffe et al., 2018, p. 6), I would add. In this sense, geographer

¹⁰⁸ For a longer discussion about the links between science and industry, see Chapter 4 (particularly in relation to science policy frameworks).

Steve Hinchliffe and colleagues' concept of 'healthy publics', which refers to the assemblage of 'lay expertise and lived experiences alongside biomedical and social science as well as humanities to reconfigure problems or generate collective outcomes' (p. 8) complements well Stengers's 'slow science' proposition (2018) as well as my own elaboration of 'feminist para-ethnographies'. This is because 'healthy publics' enables a type of 'engaged research' (Hinchliffe et al., 2018) that provides 'opportunities to change dominant systems of knowledge, and creates possibilities for new practices and care pathways' (p. 7). These 'new practices and care' are especially important for non-academic partners (so-called 'lay public'), excluded and marginalised from 'mainstream' science and ways of doing science, including ecosystems and issues around trans-species health.

To ensure the benefit of 'non-academic partners' (p. 7) is necessary to craft relations of trust as well as to negotiate expectations. In this sense, feminist para-ethnographies shares many points with participatory action research (PAR), in particular PAR's focus on 'the centrality of the dialogical relationship between theory and practice', 'the politics of participation in the research process', and a 'commitment to work with (as opposed to on) subordinate, marginalized, and oppressed groups to improve and empower their position within society' (Jordan, 2008, pp. 601, 602, 603). The socialisation of embodied bodily experiences, I anticipate, opens up the possibility to disclose silenced forms of inequalities as well as new ways of tackling and resisting them. It is a way of delivering social change and justice through participatory action, I suggest. This brings to mind Anne Pollock's work on the troubled history of heart disease research and its associated racialised medical technologies in the US (2012). Drawing on rich ethnographic data on cardiac surgery as a site of a racialised history of biomedical technology and medicalisation, Pollock insists that medical treatment should be a site of social and political contestation.

Hence, in its transformation from private embodied biology into 'socialised biology' (Riley, 1983), feminist para-ethnographies as 'slow science' (Stengers, 2018) and 'engaged research' (Hinchliffe et al., 2018) figures as an individualised or personalised biosocial healthcare initiative at the service of social needs. A 'women-centred analysis' (Rapp, 1999, p. 4) is crucial to my proposition, because of the historical importance of women's bodies to account for the viscosity of knowledge and the materiality of experience (Federici, 2004; Martin, 2001). In feminist para-ethnographies, the de-medicalisation and socialisation of care are the principal elements of biome

restoration. In this way, it offers a window of opportunity to remodel the individualistic rhetoric of microbiome science. This involves the re-embodiment of microbes by revaluing and de-individualising embodied experiences, turning them into shared bodily experiences (i.e. socialised biology) for the collective good, for the commons.

Lastly, it is important to remark that the ‘interdisciplinarity’ of feminist para-ethnographies is not about generating ‘seamless knowledges and unified politics’ or ‘conceptual monocultures’ (Wilson, 2015, p. 171). It is not my purpose to erase the tensions, gaps, and discontinuities in the distinct ways of producing and enacting knowledges and practices in the sciences and the social sciences and humanities. In other words, feminist para-ethnographies does not try to ‘settle’ matters (Callard & Fitzgerald, 2015, p. 20). Likewise, inspired by Wilson’s ‘gut feminism’ (2015), I would like to reanimate feminist theories ‘by an engagement with biology— particularly a phantastic biology and a biology of the periphery’ (p. 171) through my proposition of feminist para-ethnographies as an intervention in microbiome science. However, unlike Wilson’s proposition, feminist para-ethnographies is socially driven. That is, over experimentation, feminist para-ethnographies privileges the co-generation of knowledges-practices of engaged research (Hinchliffe et al., 2018), of social justice.

5.6 Conclusion

Drawing on my embodied experiences of childbirth, ethnographic fieldwork on microbial ecologist Dominguez-Bello and her team’s research about the vertical transmission of microbes, and (mostly) feminist literature on scientific knowledge production (Despret, 2004; Latour, 2004; Stengers, 2000, 2018), in this chapter I have proposed and developed feminist para-ethnographies as a caring, ‘slow science’ (Stengers, 2018) and ‘engaged research’ (Hinchliffe et al., 2018) intervention in the biomedical field of microbiome science.

In the first section of the chapter, I have focused on ‘matters of fact’ by drawing on my ethnographic fieldwork on a team of microbiome scientists working on the microbiology associated with the mode of delivery at birth (Dominguez-Bello et al., 2010a). The microbiology of reproduction is a controversial field of research. I have illustrated these controversies through the lens of my embodied experiences as a woman in labour and GBS carrier in pregnancy, offering a ‘lived’ and ‘socialised biology’ example of the ‘microbiomisation of gender.’ In doing so, I have demonstrated that what in the previous chapters I framed as the ‘microbiomisation of race’ (Chapter 3) and the

‘microbiomisation of class’ (Chapter 4) intersects and entangles with the ‘microbiomisation of gender’. In other words, my embodied experiences as a GBS ‘carrier’ in pregnancy amounts to the intersectionality of microbiomisation processes.

I have then showed that while the general scientific consensus and clinical practice subscribe to the Pasteurian ‘sterile womb paradigm’, the post-Pasteurian ‘in utero colonisation’ hypothesis has gained wide public attention and acceptance. This divorce between both views, which translates into or extends to a divorce between what matters to scientists (‘matters of fact’) and what matters to people (‘matters of concern’), not only leads to conflicting information but also to clinical advice and procedures that increase the administration of unnecessary antibiotics during prenatal and postnatal periods as well as in infancy, for example. This, in turn, produces class-based bioinequalities (Fassin, 2009), as those from lower SES will already have less microbial diversity, thereby being more susceptible to the effects of antibiotics, especially in terms of AMR (see Chapter 4). Trying to encapsulate all these aspects, the main question this chapter addressed was: how to reconcile both (i.e. matters of fact and matters of concern, ultimately science and people), how to foster a ‘critical friendship’ (Rose, 2013), that is, a friendship able to generate assemblages between the sciences and the social sciences and humanities, between scientists and people, and overall, between matters of concern and of fact (Despret, 2004; Latour, 2004; Stengers, 2018)?

As a response to the previous question, in the third section of the chapter I have turned to how the social sciences approach the ‘factualities’ around the microbiology of reproduction. In doing so, I have analysed my postpartum experience as a ‘matter of concern’ through the lens of the feminist literature on reproduction, mainly through the work of feminist anthropologist Emily Martin (2001). Despite the potentialities of the NHS service ‘Birth Reflections’ regarding a distributed care practice between medical staff and patients, I lived it as an exculpatory device. I have then situated my experience within a body of feminist literature suggesting that women lose their political agency during medical interventions in labour, becoming a medium or receptacle who (or better ‘which’) facilitates new life (Franklin & McKinnon, 2002; Martin, 2001; Rapp, 1999). Although this type of analysis offers valuable critical reflection, this approach has an important limitation: this kind of critique does not build alliances that assemblage and gather (Latour, 2004).

Bringing ‘matters of fact’ together with ‘matters of concern’, in the fourth and last part of the chapter, I have proposed and developed feminist para-ethnographies as a ‘slow

science' (Stengers, 2018) and 'engaged research' (Hinchliffe et al., 2018) intervention aimed at the socialisation of care and the delivery of health justice through the transformation of silenced and private embodied experiences into shared experiences. In making this assemblage, I have argued that feminist para-ethnographies needs 'connoisseurs', that is, 'agents of resistance against a scientific knowledge that pretends it has general authority' (Stengers, 2018, p. 9). Embodied experiences as part of connoisseurs' repertoire make 'available' (Despret, 2004) new identities, new ways of knowing and making knowledge, and, crucially, new forms of intervention (e.g. medical diagnosis and therapeutic data).

CONCLUSION

In this thesis, I have proposed and developed the ‘microbiomisation of social categories of difference’ as a social sciences and humanities conceptual and empirical framework through which to critically examine the repercussions and implications of human microbiome science in society.

The message that we, humans, ‘are 99 per cent microbial’ has become the motto of scientific translations of human microbiome science. This message has often led to some celebratory and preliminary claims and analyses in social and cultural studies of the human microbiome, particularly in terms of the inauguration of a new scientific area away from anthropocentrism (Benezra et al., 2012; Cohen, 2009; Dupré, 2012; Hird, 2009). For example, anthropologist Amber Benezra and colleagues (2012) have argued that human microbiome research offers ‘a more profound view of our “humanness”—transforming our categories of “community”, “individual”, and “life”’ (p. 6380). I must admit that, initially, I also succumbed to the hype of the human microbiome, especially at the beginning of my doctoral degree. At that time, I was passionate about the potentials of human microbiome research in terms of a new, liberatory, and symbiotic onto-epistemology of science; a new paradigm rejecting atomistic conceptions of the body and the warfare rhetoric of immunity. The repeated ‘fact’ that ‘ten out of one cells’ in the human body are microbial rather than human (Knight, 2014) made me wonder what happens, then, to human immune systems. Because, since the immune system became a scientific concept in the 1960s (Moulin, 1989), its main role, according to immunology, was based on two elements: self-preservation (of the *human* body) and self-defence (*against microbes*) (Chapter 1). As I experienced during my bachelor’s degree in Biology, this idea was unquestionable in scientific training and teaching as well. How is immunity (re)conceptualised, (re)mobilised, in the light of the human microbiome? I wondered. This initial question was then transformed into the main research questions I address in this thesis: How is human microbiome science shaping and reconfiguring biomedical practice and experimentation and older scientific and popular ideas associated with the immune self? Is microbiome science qualifying alternative modes of scientific knowledge production that include more-than-humans (i.e. microbes, environments)? Are there vestiges of the immunological past (i.e. biological essentialism, liberal subject) percolating the epistemic, ontological, and empirical values of microbiome research?

Symbiosis is one of the most commonly mobilised terms in discussions and debates around human–microbe relations in the life sciences, social sciences, and humanities alike. Symbiosis, in biology, refers to an intimate long-term relationship between two different organisms. There are three types of symbiotic relationships: (1) mutualism, which means that both organisms get benefits from the relationship; (2) commensalism, in which one benefits and the other experiences neither benefit nor harm; and (3) parasitism, in which one of the organisms benefits at the expense of the other. When (mainly) popular texts and media news on microbiome science refer to symbiosis, it rather means human–microbe relations based on the ‘kinder’ types of symbiosis, namely mutualism and commensalism. Contrary to what I would personally have liked to have found, however—that is, a new science putting an end to centuries of scientific imperial patriarchy structured around human exceptionalism—my research findings signalled to an opposite and ‘parasitic’ direction.

In spite of the expectations around the human microbiome regarding a communal *more-than-human* ontology and practices (Braun & Whatmore, 2010, p. 20) based on microbial generosity (Hird, 2009) and human–microbe coexistence (Nading, 2014), human microbiome science is, still, a very ‘human’ field of postgenomics. In particular, human microbiome science is focused on very specific diseases (rather than health states): obesity, diabetes, cancer, IBS, asthma, and rheumatoid arthritis, to name a few. These autoimmune, inflammatory, and metabolic disorders affect a very small segment of ‘humanity’: those humans from high-income countries. Hence, the ‘human’ of human microbiome science is very restrictive. Not to mention that human microbiome science does not include microbes in the picture, as others have argued (Hird, 2009),¹⁰⁹ neither a commitment to ‘transspecies health’ (Hinchliffe, 2015). Likewise, the fundamental contribution of this thesis is to show that the scientific discourse of symbiogenesis (Margulis)—co-evolution, cooperation, and coexistence—that microbiome science takes up as its ethos remains in the epistemological dimension of this biomedical area. This means that the practices and experimentation sustaining human microbiome science are based on very different, if not opposite, values to those of coexistence between microbes, bodies, environments, and worlds. As my research findings demonstrate, human

¹⁰⁹ I am particularly referring here to what sociologist of science Myra Hird calls ‘microontologies’ (2009), which involve attending to microbial ‘alliance-making in the absence of either human representation or mediation’ (p. 18). She has also suggested that ‘the most important meetings are not between humans and animals, but between microbes and microbes’ (p. 130).

microbiome science, in practice and experimentation, is based on parasitism. The thesis therefore raises important questions about who benefits and who does not benefit from human microbiome science? I argue, first, not all humans, and certainly not microbes. Second, the main beneficiaries are privileged humans from rich strata of rich (i.e. Western) countries (i.e. the rich of the rich) (Chapter 4).

Microbiomisation

Human microbiome science is sustained by an immuno-logic of inclusion and exclusion. It instantiates new forms of difference—immunitary privileges based on a higher microbial diversity—and reproduces old ones: structural differences in society and neo-colonial practices of expropriation of nature (e.g. microbes). I encapsulate this overarching argument in the term of ‘microbiomisation’. Originally introduced by anthropologist Stefan Helmreich (2016), I call ‘microbiomisation’ the material-semiotic processes by which human microbiome science takes social groups as pre-existing ‘natural’ phenomena and biologises them by attributing microbes and microbial profiles to them.

The empirical basis of this argument is grounded in my ethnographic fieldwork on microbial ecologist Dominguez-Bello’s study, the MHC project (Chapter 3). Through the lens of this particular study, I argue that human microbiome science relies on comparative research on the genetic (microbial) variation of human populations. The microbiome of ‘uncontacted peoples’, such as the high Oricono Yanomamis of Venezuela or the Peruvian Amerindians of Checherta, is a reservoir for microbiome science. This means that the microbiome of non-Western peoples and territories is not a side project or a specific ‘approach’ within the field but, rather, constitutes a key element of this new area of scientific knowledge production. Likewise, one of the principal contributions of this thesis is to show that the ‘microbiomisation of race’ establishes the basis of the ‘microbiomisation’ of other social categories of difference, particularly of class (Chapter 4) and gender (Chapter 5). Put differently, the basis or conditions of existence of human microbiome science is based on an articulation based on the microbial ‘makeup’ of non-Wester(nised) communities, societies, and locales, while its results and therapeutics—that is, the health contributions of this biomedical area—are only applicable to medical conditions affecting rich nations (i.e. inflammatory, autoimmune, and metabolic diseases) (Chapter 3).

In particular, **Chapter 3** demonstrates that the individual dimension of human microbiome science, although sustained by microbial DNA data from human populations through bioprospecting practices, gains meaning through informal online networks of pseudoscientific microbial-related evidence. Drawing on empirical data from different online microbiome initiatives (including the AGP, the HFP, and BG) and material from interviews, I argue that microbiomisation not only rests upon (1) the bioprospection of DNA from human and nonhuman populations, but also, and equally importantly, upon (2) the economic, social, and cultural capital of consumers (mostly from Northern richer nations) who engage in microbiome profiling online platforms such as the AGP. I associate this second trend of the process of microbiomisation with what medical anthropologist Didier Fassin calls ‘bioinequalities’ (2009).

While in Chapter 3 I focus on the ‘microbiomisation of race’ as the basis of other processes of microbiomisation, **Chapter 4** refines and explores the dimension of bioinequalities by showing that not only is human microbiome science targeted at diseases affecting high-income countries, but that those (humans) most likely to benefit from microbiome scientific knowledge production are rich strata from rich societies. Establishing links between microbiome science and AMR, an understudied theme in social and cultural studies of postgenomic science, this chapter argues that a diverse microbiota is not accessible to everyone. The more affluent, the more microbial diversity, the less susceptibility to AMR and vice versa. This social stratification of microbes and immunities, in turn, reflects the ways in which entanglements between neoliberal capitalism and the life sciences are lived and experienced differently in and by different bodies. I refer to these processes as the ‘microbiomisation of class’, a notion that I align with philosopher of science Isabelle Stengers’s concept of ‘inventive fiction’ (1997). The microbiomisation of class as an ‘inventive fiction’ involves informing microbiome science (and, to a lesser extent, AMR research) about the relevance of ‘questions or possibilities that were not taken into account’ (Stengers, 2018, p. 9) in the scientific production of the human microbiome but that have become important. The imperative question in this regard has to do with the fact that, in neoliberal capitalist societies, the biology of health and well-being is becoming a privilege instead of a right.

Drawing on my embodied experiences of pregnancy and childbirth as a GBS ‘carrier’ and ethnographic fieldwork on the microbiology of reproduction, **Chapter 5** demonstrates the intersectionality of microbiomisation, in particular the microbiomisation of gender and class. In humans, the microbiome transmitted from

mother to child at birth (i.e. vertical transmission of microbes) already harbours resistance bacterial genes resulting from horizontal bacterial reproduction (i.e. AMR). The implications of this are paramount in the sense that the limited access to healthy lifestyles that individuals and communities from lower socio-economic backgrounds experience often translates into lack of microbial diversity and therefore into an (immunity) predisposition to AMR. This reasoning extends to the vertical transmission of microbes, because babies born to mothers from a low or lower SES will have less diverse microbiomes. In other words, they will ‘inherit’ their mother’s microbial homogeneity, which is, in turn, a result of social exclusion. Class, therefore, is always already social and biological. Gender and class within this context potentially become part of a bioinequality. In other words, privilege can be socialised as a form of bioinequality.

While my scope is limited to one aspect of microbiomisation (i.e. how microbiome science biologises social categories of difference), it is among my principal objectives as well to shed light on and establish the basis for further research into process(es) of microbiomisation. For instance, microbiomisation as an analytical device to critically examine human–microbe relations, I anticipate, would serve to analyse how human microbiome science is shaped and reshaped by self-governing practices of the body (Rabinow & Rose, 2006; Rose, 2007) and citizen science projects (see Chapter 3).

Theories, methods

Social categories of differences—race, class, and gender in particular—have been at the core of cultural studies since its inception (Centre for Contemporary Cultural Studies, 1982; Gilroy, 1987, 1996; Gilroy, Grossberg, & McRobbie, 2000; Hall, 1978; Hoggart, 1958; Williams, 1958). I situate the theoretical repertoire of this thesis, however, around three main bodies of literature in cultural and social studies of (postgenomic) science: (feminist and decolonial) STS, body studies, and anthropology of science. As I have discussed and elaborated in **Chapter 1**, this thesis updates cultural studies of immunity by including a biosocial and critical perspective on human microbiome science. This is, in fact, one of the main contributions of the thesis. I have complemented biopolitical frameworks on immunity (Cohen, 2009; Esposito, 2008, 2011; Goffey, 2015) with more contemporary accounts of biosocial literature (Landecker, 2016; Lee & Motzkau, 2013; Meloni, 2014a, 2014b; Nading, 2014, 2015a, 2015b, 2016), multispecies studies (Kirksey & Helmreich, 2010; Helmreich, 2009, 2016; Paxson, 2008), feminist technoscience debates around biome depletion, ecosystems degradation, and care practices (Haraway,

2016; Puig de la Bellacasa, 2011, 2015; Stengers, 2015, 2018; Tsing, 2015) and decolonial theories of *Buen Vivir* (De La Cadena, 2010; González & Vázquez, 2015; Gudynas, 2011; Harding, 2016; Lanza, 2012; Leon, 2012; Walsh, 2010).

The conceptual richness and thickness of these debates, however, have some downsides. This is especially true in terms of what has been excluded by what was included. A retrospective on classical sociological works on identity politics and structural differences in (capitalist) societies along with critical race studies—black feminist theory, in particular (see Weheliye, 2014)—and ecofeminist, indigenous, and feminist STS frameworks (Harding, 1987, 2006, 2008, 2011; TallBear, 2013) are the principal theoretical absences in the thesis. Hence, although I engage with decolonial theories of *Buen Vivir*, there is an absence of non-Western bodies of literature as well as methods that I am committed to tackle in my future research.

It is also worth noting that the analytical and empirical framework of microbiomisation I develop in the thesis could be indeed expanded and applied to other social categories of difference, such as sexuality, (dis)ability, or nationality. The reason that I focus on (the microbiomisation of) race (Chapter 3), class (Chapter 4), and gender (Chapter 5) is related to the empirical data and materials from my ethnographic fieldwork on human microbiome science, my embodied experiences, and critical analysis of scientific publication on the topic, media news, popular texts, and policy analysis. To put it in a more orthodox academic lexicon, this thesis has followed and used a ‘deductive’ rather than an ‘inductive’ approach to data analysis.

In this respect, another key contribution of this thesis is methodological. In **Chapter 2**, I reformulate the concept of the para-ethnographic, that is, ‘a way of dealing with contradictions, exceptions, and facts that are fugitive’ (Holmes & Marcus, 2008 , p. 596), as a feminist intersectional method that entangles embodied experiences with ‘fugitive’ qualitative data in technoscientific claims and quantitative research. The research design of the thesis, under the framework of ‘feminist para-ethnographies of human–microbe relations’, serves, in turn, to challenge ‘more-than-human’ (Braun & Whatmore, 2010) methods of multispecies ethnography. Here, embodied experiences entangle with more conventional qualitative data, which include an exploratory pilot project, ethnographic fieldwork on human microbiome science, participation in international microbiome conferences and meetings as both research training and data collection, a digital media analysis of the online microbiome community, and critical analysis of microbiome scientific and popular science literature.

Feminist para-ethnographies: *Informing* and *intervening* in microbiome science

Apart from establishing the conceptual and empirical means to critically examine processes of microbiomisation, the other key outcome and contribution of the thesis is to establish the conceptual and empirical basis for initiating a conversation and, ultimately, building alliances between critical studies of science and human microbiome science. In doing so, in **Chapter 4** I formulate the concept of the ‘microbiomisation of class’ as an ‘inventive fiction’ (Stengers, 1997) *informing* microbiome science about what was not foreseen or taken into account in the scientific knowledge production and empirical practice of microbiome research (mostly in terms of health disparities). **Chapter 5** brings forward a parallel dimension of ‘feminist para-ethnographies’, beyond its original methodological application (Chapter 2): feminist para-ethnographies as a ‘slow science’ (Stengers, 2018) and ‘engaged research’ (Hinchliffe et al., 2018) *intervention* in microbiome science. This other dimension of feminist para-ethnographies is a critical science studies response to the immuno-logic of inclusion and exclusion of microbiome science that this thesis examines, evidences, and exposes. Feminist para-ethnographies involve the socialisation of care and the delivery of health justice through the transformation of silenced and private embodied experiences into shared and collective experiences.

Unlike interdisciplinary approaches in the sciences, the ‘slow science’ of feminist para-ethnographies entails situating patients, especially the unprivileged, at the centre stage of this approach (see also Hinchliffe et al., 2018). It is about reclaiming and retaining the messiness of the world, against the erasure of data that truncates the linear and seemingly ‘objective’ scientific knowledge production, particularly women’s embodied experiences of health and disease. The role of social scientists here as *connoisseurs* is crucial. *Connoisseurs* listen to, interpret, and analyse embodied experiences along with ‘patients’. They liaise with relevant healthcare workers. They become the medium through which these private individual experiences become socialised. It is through this socialisation of embodied bodily experiences that feminist para-ethnographies is able to offer sustainable, or—using Haraway’s term—‘Chthulucenic’ alternatives to biome depletion (Chapter 1).

In the co-production of feminist para-ethnographies, *connoisseurs* rely upon inter-literacy, a skill which is increasingly common, particularly among feminist theorists and STS scholars. As Lisa Blackman (2016a) argues, ‘it is important to acquire ... inter-

literacy' in order to 'situate oneself and engage in interdisciplinary research'.¹¹⁰ In this sense, I believe that I could not have captured the complexity and layering of the re-enactment of immunity by the human microbiome without a broad scope; without mixing methodologies and theoretical frameworks, without mingling disciplines and structures of thought, without *risking*. A risk which is at the same time concomitant with the pressures of becoming 'interdisciplinary', a condition that affects the life sciences and humanities alike and, by extension, twenty-first-century academia. As a matter of fact, most (financially) valuable funding is most likely to be awarded to inter-, trans-, and multi-disciplinary research. As I hope to have demonstrated, my project embodies an interdisciplinarity which is critical to the official interdisciplinary demands of private funding bodies and governmental 'innovation' strategic plans.

Inter-literacy as a precondition of interdisciplinarity is a challenge. To conceal or deny the difficulties involved in achieving it would be untruthful to the research process, to the thesis, and, ultimately, to the reader. This thesis springs from my academic biography, mingling my undergraduate knowledge in the field of biology with my postgraduate expertise in cultural studies. To construct a coherent account of an entangled reality situated at the intersections of biology, culture, and politics, I have navigated at the intersections of all these different modalities of thought. Hence, not only did I have to acquire substantial knowledge and expertise in microbiome research and AMR and some background on epigenetics, but I also had to update my conceptual and methodological skills in anthropology of science, STS, and science policy. Anthropologists would perhaps accuse me of perverting the dimension of ethnography, its 'thickness', and therefore the reality of the particular. Science and technology scholars might do the same, disapproving the lack of attention paid to ANT and its 'actants'. Foucauldians might emphasise the inattention to biopower and biopolitics. These speculations might or might not happen. I have nevertheless decided to defend the multiplicity of the conceptual and methodological approaches that populate the thesis.

My proposition of feminist para-ethnographies is a result of the inter-literacy I acquired as part of the research process and the writing of this doctoral dissertation. Likewise, for feminist para-ethnographies to be realised, to become a reality, they need to be transversal, collective processes of co-generation and co-production (Hinchliffe et al., 2018). This would involve building alliances (Stengers, 2018) between research

¹¹⁰ Here, Blackman is referring to Franklin (2013).

partners in the social sciences and humanities and the life sciences, but crucially, between academic and non-academic segments in society. In particular, patient groups as well as grass-roots movements around health justice, including reproductive rights. This, in turn, brings another dimension of feminist para-ethnographies to the forefront of analysis: resistance.

While I conceive feminist para-ethnographies as material-semiotic tools for *informing* and *intervening* in the life sciences, in *microbiome science* particularly, it is also crucial to understand feminist para-ethnographies as a social sciences and humanities device of **resistance** through the *re-embodiment* of *microbes* (via the registration, documentation, and analysis of embodied experiences of human–microbe relations). As I will explain in what follows, the re-embodiment of microbiomes and microbes becomes a form of resistance to neocolonial practices of disembodiment involved in bioprospecting microbial biodiversity.

Feminist para-ethnographies: *Resisting* in the humanities and social sciences

Microbiome studies such as Dominguez-Bello’s MHC operationalise the microbiome of indigenous populations and environments for the benefit of the few (Chapters 3, 4, and 5). Microbiome science is very much a Cartesian science. According to feminist theorist Silvia Federici (2004), a Cartesian science involves scientific rationalisation and disciplining of the social body (p. 145). It revolves around a hierarchy between mind and body parts, which, in turn, is part of the theoretical premises of the work discipline required by the capitalist economy (p. 149). A Cartesian science is about a slave-owner relation with ‘nature’; with the ‘Other’, I would add. It dominates, it exerts power. It is, after all, about an immuno-logic of inclusion and exclusion.

One of the main outcomes of the thesis and principal objectives for future avenues of (postdoctoral) research is to configure feminist para-ethnographies as a material-semiotic device to tackle and resist Cartesianism in human microbiome science. The crucial point for doing so is the re-embodiment of microbes and microbiomes through the registration, documentation, and analysis of embodied experiences (of women in particular) of human–microbe relations. In fact, this re-embodiment of microbiomes and microbes can be read as a form of resistance to neocolonial practices of disembodiment involved in bioprospecting microbial biodiversity (Chapter 3). The re-embodiment of microbiomes ‘brings theory back to life’ (Ahmed, 2017, p. 10). My proposition (and

positioning) here concurs with philosopher Isabelle Stengers's (2007) defence of a kind of materialism able to reconnect with struggle, the kind of struggle that feminist Vandana Shiva engages with, for example (i.e. environmental activism, food sovereignty).

As she recalls with joy and wonder [Donna Haraway, ANC], human genomes can be found in only about 10 per cent of the cells that live in what we call our body, the rest of the cells being filled with the genomes of bacteria, fungi, protists and such. This is materialism of another kind, a kind that may be connected with the many struggles that are necessary against what simplifies away our world in terms of idealist judgements about what would matter and what does not (p. 9).

Hence, feminist para-ethnographies as an 'engaged' and 'slow science' knowledge practice (Chapter 5) of re-embodiment microbes responds to Stengers's materialist plea. It is about co-generating and nurturing a situated and personalised approach to human-microbe relations—embodied experiences are singular and situated events and the interpersonal variability of the human microbiome is huge—that does not compromise the sociality of care and caring practices.¹¹¹ Because, as Puig de la Bellacasa argues, care is also a practice of resistance (2011, 2015) (Chapter 1).

Holding human microbiome science accountable to justice and troubling histories and stories of inequalities through microbial re-embodiment is an imperative for the social sciences and humanities. This becomes all the more urgent in these times of 'neo-colonial ideological violence' (Mol, 2008), in which neoliberal governmentality favours the privatisation and individualisation of care by depleting public health services and the commons (Hinchliffe et al., 2018; Stengers, 2018). Hence, feminist para-ethnographies is a theoretical and methodological proposition for a future of (slow) knowledge practices of coexistence, care, and decoloniality, contesting, in turn, the colonial and racist origins of immunity in the Western world and its various ramifications in today's science and culture (Chapters 3, Chapter 4). Put differently, it acts as a response to the dyad capitalist-patriarchy and its ramifications in Western knowledge production. In addition, feminist para-ethnographies as *resistance* also involves tackling one of the limitations of the thesis by taking Wilson's 'gut feminism' (2015) call for a deeper, more evident, and experimental engagement of feminist theories with biological data seriously.

¹¹¹ Taking biological data about the huge interpersonal variability of the human microbiome—including microbial metabolism—seriously (Wilson, 2015) and bringing this together with the singularity and situatedness of embodied experiences means that we cannot approach human-microbe relations under a generalised and standardised population approach. That said, however, such interpersonal variability in human microbiome data suggests that it is highly susceptible to private biomedical ventures and personalised medicine initiatives (see Chapter 3). This is something which future critical engagement with the human microbiome would need to address.

I identify two major limitations of my proposition of feminist para-ethnographies. On the one hand, feminist para-ethnographies spring from (my own) empirical data and experiences that are situated in high-income countries (i.e. UK, Spain). However, I suggest that it can be applicable to LMICs to tackle microbial dysbiosis and, particularly, more serious forms of the latter such as AMR. This is because it is cheap and accessible (i.e. does not need expensive instruments or equipment) and it is based on critical human mass (alliances or collaborations between social scientists, clinicians, health workers, translators, etc.), thereby being a potential source of local income. On the other hand, one of the main difficulties I anticipate in their development and application in the current setting relates to the actual political climate: Brexit and the xenophobic hostile environment affecting healthcare (i.e. NHS) in the UK and, more broadly, the systematic dismantling of public health services across Europe.

Clearly, the realisation of feminist para-ethnographies as a therapeutic and diagnostic tool in human–microbe relations complementing biomedical intervention is not a given; far from it, especially in these turbulent times. Biome depletion, climate change, the precarisation of labour, the sinking of welfare states in Europe, the rise of far-right populism across the globe (US, Brazil, Philippines, UK, Venezuela, France, Italy, Spain, to name a few) have become among the biggest challenges of our times. In addition, the marketisation of Higher Education along with the limited funding sources for social sciences and humanities research—and their instrumentalisation (e.g. as mere means to explain science or to provide legal, bioethical frameworks, etc.)—complicates even more an already complicated and negative socio-political scenario. All these disturbing results of neoliberalism are destroying the ‘practical know-how, along with collective ways of acting, thinking, feeling and living’, as Stengers argues (2018, p. 80). Yet, like many other socially conscious scholars (Farmer, 1999, 2005; Fassin, 2009, 2013, 2014; Federici, 2004; Hayden, 2003; Hinchliffe, 2015; Hinchliffe et al., 2018; Hinterberger, 2012a, 2012b; Leon, 2012; Mansfield, 2012; Pollock, 2012; Puig de la Bellacasa, 2011, 2015; Rosengarten, 2009; Shiva, 1997; Smith, 1999; Stengers, 2018; TallBear, 2013), I have chosen to ‘stay with the trouble’ (Haraway, 2016). Furthermore, from a ‘gut feminism’ approach (Wilson, 2015), the aforementioned negative political scenarios of hostilities and aggressions to the social fabric might also be seen as ‘the necessary condition for every feminist engagement’ (p. 67). My way of ‘staying with the trouble’, my own enactment of ‘gut feminism’, as I hope to have demonstrated, was to develop a more sensitive and attentive lens for understanding social inequalities and

marginalisation: ‘microbiomisation’ and ‘feminist para-ethnographies’ as analytical, methodological, experimental, and ‘interventionist’ material-semiotic devices of resistance in ‘catastrophic times’ (Stengers, 2015, 2018).

Finally, I would like to conclude with this inspiring quote from philosopher Vinciane Despret (2004):

To ‘de-passion’ knowledge does not give us a more objective world, it just gives us a world ‘without us’; and therefore, without ‘them’—lines are traced so fast. And as long as this world appears as a world ‘we don’t care for’, it also becomes an impoverished world, a world of minds without bodies, of bodies without minds, bodies without hearts, expectations, interests, a world of enthusiastic automata observing strange and mute creatures; in other words, a poorly articulated (and poorly articulating) world (Despret, p. 131).

Responding to Despret’s argument, *feminist para-ethnographies* is my contribution to *re-passion knowledge* through the de-individualisation and socialisation of biomedical practice and experimentation.

APPENDIX A: Theoretical perspectives in immunology

Immunology is the science that studies how the organism defends itself from a variety of threats such as pathogens, harmful substances, or foreign tissues, focusing on the molecular mechanisms by which immunity is acquired. The key of this discipline is to investigate how an organism can preserve its integrity, and since its inception in the first half of the twentieth century, immunology has assumed that the immune system's vital function is to discriminate self from non-self. However, the distinction between self and non-self is only characteristic of animals with 'adaptive' immune systems (i.e. immune systems that can 'learn' after repeated exposure to pathogens) such as jawed vertebrates, whereas the immune system of invertebrates is defined as 'innate', since it does not experience changes after repeated exposure to harmful substances.

It was the Russian zoologist Elie Metchnikoff who first aligned immunity with the mechanism of self-defence when, in 1881, he recognised that a specialised cell, known as the phagocyte, has a role in inflammatory responses by defending the organism against microbial infections (Crist & Tauber, 2001, p. 116-117). For Metchnikoff, the phagocyte—the “eating” or “digesting” cell that protects the organism by engulfing bacteria and harmful substances—is an autonomous entity in itself that has evolved due to its defensive character (Crist & Tauber, 2001, p. 121). Metchnikoff's theoretical fusion of a Darwinian perspective on natural selection with a Bernardian atomistic vision of the organism, together with Paul Ehrlich's discovery of antibodies (1897)—proteins produced by lymphocytes (B cells) whose function is the recognition of 'foreign' substances (antigens)—established the grounds of the molecular focus that has prevailed in twentieth-century studies on immunity.

In the following, I provide an overview of the principal theoretical perspectives in immunology, old and new.

1. Clonal selection theory: Self/non-self discrimination

In the first half of the twentieth century, the main issue for immunology was to elucidate how antibodies are formed and how they can distinguish between a diverse array of antigens (Howes, 2008, p. 272). During the 1950s, Danish immunologist Niels Jerne proposed a hypothesis which stated that prior to any contact with the antigenic substance, there is a vast number of antibodies circulating in the body. When the antigen enters in the body, it selects a particular antibody, inducing a reaction by which a B lymphocyte

cell reproduces or clones the same type of antibody in order to prevent infections (Cohn, 2001, pp. 67–69; Howes, 2008, p. 273).

In 1957, Frank Macfarlane Burnet developed his ‘clonal selection theory’ by working on Jerne’s previous model. Following Burnet’s model, it is the antigen itself which attaches to a B cell, triggering the clonal expansion of the latter. Subsequently, each clone produces only one antibody of the same type as the ‘parent’ B cell. In this way, there are enough specific antibodies for neutralising antigens, giving empirical evidence to support the idea that the immune function is based on a self and non-self discriminatory model.

It was later discovered that B cells produce two types of clones: plasma and memory B cells. Plasma cells generate identical copies of the antibody-producing-cell, or B cell, while memory cells’ function, rather than with the differentiation that occurs with plasma cells, lies in the development of immunity after repeated encounters with the pathogen that has caused the first infection. In 1983, Susumu Tonegawa suggested that the diversity of antibodies is due to a genetic mechanism by which plasma and memory cells (B cells) as well as T helper cells (cells that triggers B cells’ activity) recombine, mutate, add, and delete genes between them, which explains why there is a vast range of antibodies that can effectively recognise a multiple array of antigens (Cohn, 2001; Howes, 2008, pp. 273–274). However, it is exactly this specificity and precision of the immune system that is problematic for Burnet’s model, since due to this genetic mechanism of somatic rearrangement, antibodies are able to identify self-antigens, which can induce autoimmune diseases.

So how is it possible that, normally, an autoimmune response is not produced? This question led to the idea of immune tolerance (Brent, 2001). In short, theories supporting the self/non-self model maintain that immune tolerance is achieved by the elimination of self-reactive cells. Self-reactive B cells are eliminated in the bone marrow and T cells in the thymus. This is known as “central tolerance”. But because central tolerance can fail, meaning that some cells can escape to other regions of the body, there are additional regulatory mechanisms or ‘peripheral tolerance’ (Brent, 2001, p. 47).

Due to its wide support within some sectors of the scientific community, as well as its pervasiveness via media representation (Martin, 1994), the self/non-self model remains the universalised understanding of the basic principles of immunology (Carosella & Pradeu, 2006). Yet there are various experimental and theoretical gaps in vital matters

such as pregnancy or organ transplantation that challenge its preponderance as the unique explanation of the immune function. Likewise, throughout the twentieth century, alternative theories of immunity have emerged that question the epistemological and ontological principles that situate the immune system as a marker of biological identity. Amongst these hypotheses, the network theory and the danger model figure as the most relevant counterarguments against the clonal selection theory.

2. Network theory

In 1974, Danish immunologist Niels Jerne proposed the hypothesis known as the ‘network or idiotypic theory of the immune system’. Jerne holds that immune system cells are not merely characterised by the recognition of foreign substances (antigens), but importantly, they are also recognised and regulated by each other (Hoffman, 2011, p. 1). The immune system is then constituted by a dynamic network in which each cell interacts with several components of the system thanks to a variable region (V), which, due to a unique sequence of amino acids, can bind together with other molecules and lymphocytes of the system as well as to foreign substances. As such, Jerne’s articulation of the network theory breaks with Burnet’s model of self and non-self, since there is not an explicit distinction between self and other, but rather the immune system works by a lattice of molecular connections, altering states of activation and suppression (Howes, 2008, p. 278).

Drawing on Jerne’s model, Antonio Coutinho (1989) is one of the main proponents of a contemporary version of the network theory. Going beyond Jerne’s work, Coutinho suggests that the network’s functions are divided into central and peripheral activities. The central immune system consists on a connected reticulum of lymphocytes which maintain self-tolerance, whereas the peripheral immune system is composed by unconnected lymphocytes which, when stimulated by an antigen, trigger the immune response (Coutinho, 1989; Howes, 2008, pp. 278–279). Following Coutinho’s model, the immune system is extended to and interacts with the whole body and its function is guided by perturbed and unperturbed states of connectivity. This means that antigens are not classified as non-self but as perturbations of immune activity, implying that there is not foreignness but ‘only “self” and its perturbations’ (Howes, 2008, p. 279). This approach towards the immune system has been associated to a new systemic view grounded on an autopoietic regulation. For instance, advocates of the network theory hold that autoimmune diseases are caused by the inadequate connection of the network rather than

by the presence, as is generally thought, of self-reactive cells that are unable to distinguish between self and non-self (Stewart & Varela, 1989; Coutinho, 1989).

However, there are several empirical challenges to this theory, such as the lack of evidence of how the network is glued together or how the central and peripheral immune systems interact (SEP). Also, and in spite of its antireductionist vision on immunity, it could be argued it merely differs from the clonal selection theory in semantics. That is, whereas Burnet's model uses 'non-self' for refers to foreign antigens, Coutinho prefers the term 'perturbation'. The problem is that, after all, the perturbations that Coutinho is referring to are, in other words, foreign antigens. Thus, implicitly, the network theory seems to be relying on the self/other distinction.

3. Danger Model

In 1994, immunologist Polly Matzinger proposed a renewed explanation of the immune system, the 'danger model', which challenges traditional immunology's focus on foreignness. In Matzinger's model, the immune system is triggered by a 'danger/alarm' signal produced by cellular substances in response to cellular or tissue damage. It is then that this 'danger' signal activates the antigen-presenting cells in order to launch the immune response (Matzinger, 2002, pp. 201–305). Thus, contrary to Burnet's theory of self and non-self by which the immune system develops a sense of self in early life, 'learning', later on, to distinguish between self and other, the danger model suggests a more flexible approach to immune function, relying on the 'local health status of tissues' rather than on selfhood (Howes, 2008, p. 276). This is an important point that seems to also overcome the weakness of network approaches to the immune system since, in Matzinger's model, the immune function is not so focused on targeting 'foreign' antigens as it is on the repair of cellular and tissue damage. Moreover, it also answers the recurrent unsettled matter concerning the clonal selection theory: what counts as foreign. For instance, is food foreign? How come the presence of bacteria and viruses in the organism does not produce an immunal response? These questions, with two cases that have been challenging classical immunology for decades, namely pregnancy and transplanted organs, seem to be solved if we take the danger model as a plausible theory for understanding the immune system.

In fact, Matzinger's model leads to the dismantling of the previous dualities (self/non-self, interior/exterior) and militaristic rhetoric ('attack', 'defence', 'invaders') from which discourse around the immune system was grounded. As she writes:

We become a habitat, welcoming the presence of useful commensal organisms and allowing the passage of harmless opportunistic ones. With such an immune system we live in harmony with our external and internal environment (2001, p. 8).

Its alleged reconciliation between external and internal environment along with the rejection of selfhood makes the danger model a seductive theory for humanities scholars working on critical accounts of immunology (see Howes, 2008; Martin, 2010; Weasel, 2001, p. 19). However, some authors have suggested that the extent to which the danger model breaks with the discriminatory self and non-self theory is uncertain, and requires further examination because the model does not provide any empirical basis for how the immune system's danger signal avoids the activation of self-reactive cells (Howes, 2008, pp. 277–278).

Hence, as has been argued, these perspectives in immunology present, to different degrees, several challenges that complicate their empirical and theoretical basis. While I have signalled some of them, such as transplanted organs or pregnancy, there is another challenge that implies the centrality that immunology has given to the molecular aspects of the immune system: the environment. In other words, immunology has been omitting the context (read 'environment') in which the organism is embedded.

4. Immunity and the environment: A new epoch for immunity?

The fact that immunology has exclusively concentrated on the molecularity of immunity stems from the spectacular promises that the Human Genome Project has generated in the life sciences. However, 'the book of life' could be said to have turned into 'the book of deception', since 'the evidence from sequencing of humans and other organisms simply did not support the view that genes were distinct units, each of which code for a single protein' (Rose, 2013, p. 17). Thus, rather than deciphering the 'code of life' and giving straightforward answers about how to approach human health and disease, the HGP revealed the exceptional complexity of life (see Cole & Goodwin, 2001; Rose & Rose, 2012). Consequently, the life sciences have turned their attention to what is known as 'epigenetics': changes of gene expression by which, without altering the DNA structure, cells attain different kinds of properties as a result of environmental influences—from psychological to ecological—throughout the course of life. Significantly, epigenetic changes can be inherited.

Epigenetics, which seems to be the cornerstone of organismal plasticity and milieu–organism interplay, is in fact the new ‘hot area’ within the life sciences (Guthman & Mansfield, 2012; Lock, 2012; Rose & Rose, 2012; Rose, 2013). Within immunology, there are several authors that have been calling for a reorientation of this discipline, not only by addressing the molecular mechanisms of the immune function but also, importantly, their regulation and organisation within the environment (see Gilbert & Epel, 2009; Ulvestad, 2007).

In fact, this new approach requires the need to conceptualise the immune system differently since, as Tauber signals (2012):

Conceiving the immune system as a system unto itself is a truncated formulation, for the functional autonomy (or ‘internal activity’ [Coutinho 1991]) of immunity fails to recognize the full context in which the immune system functions. Such a fully contextualist sensibility builds from the dialectical interchange the immune system has within the host (however its boundaries are drawn) and with the external world.

The implications of such a reconfiguration in the understanding of the immune system mean that the ‘defense of singular selves is replaced with models describing the interactions of individuals in a community of others’ (Tauber, 2008, p. 271). Therefore, accounting for the interplay between organisms and environment seems to be the pending subject of immunology and, to a great extent, of the life sciences.

While the vision of the immune system as guarantor of a microbe-free bodily interior is quintessential to classical immunology, a newly established field at the intersections of microbial ecology and genomics, microbiome research, shows that microbes are not only inherent to the formation of *life on Earth* but to the human itself.

The microbiome is commonly defined as ‘the ecological community of commensal, symbiotic, and pathogenic microorganisms that literally share our body space’ (Lederberg, 2001). However, this description goes without saying that non-human animals and plants also exhibit relationships with symbiotic, commensal, and pathogenetic microorganisms, from which the latter is the less frequent form of life in animals and plants.

Molecular biologist Joshua Lederberg, who won the 1958 Nobel Prize for Medicine for his work on ‘transduction’ (i.e. the transfer of DNA from one bacterium to another by a virus or viral vector), coined the term ‘microbiome’ in 2001. Until then, microbes had been largely ignored as determinants of health and disease. More than a decade after the term came to light, microbiome research has become a fast-moving field

within the latest bioscientific innovation. Originally fostered by the United States National Institutes of Health (NIH) initiative ‘the Human Microbiome Project’ (HMP)—launched in 2007—the primary hypothesis has been concerned with the implications of the microbiome in chronic diseases such as diabetes or obesity, inflammatory and autoimmune diseases such as arthritis, asthma, and cancer. However, prior to determining the role of the human microbiome in health and disease, researchers have to characterise the microbial genome sequences of the human microbiome.

Since the HMP started, a vast amount of scientific literature has shaped and is shaping the understanding of the complex entanglements between microbes and the human body. A task which is extremely complex and arduous since the microbiome is different in each person, is composed of trillions of microbes, and fluctuates greatly in composition due to environmental changes such as diet, physical surroundings, stress, etc. Furthermore, microbiome studies demonstrate that microbes, far from being recognised and identified as ‘foreign invaders’ by the immune system, constitute the human body and are essential for immune function.

While nowadays, it is a widely known fact that one can increase immunological performance with attention to diet, exercise, or rest being the most popular mode of self-enhancement, with vitamins especially promoted as designed for boosting the immune system, the microbiome adds a key dimension to the contemporary understanding of the immune system: the immune system is dynamic, but such dynamism depends, at the same time, on microbes and the environment and vice versa. Such an intricate ‘entanglement’ along with the great variability of life forms is especially interesting for social sciences and humanities scholars, as it can possibly illuminate questions in relation to changing ideas of selfhood and the understanding of human biology as socially embedded (Meloni, 2014a) and the medical commercialisation of new ‘bio-objects’ (Vermeulen et al., 2012) such as microbes (i.e. probiotics). Moreover, it also provides a privileged insight into contemporary biomedicine, revealing its current preoccupations, empirical settings, and ‘translations’ into society; ‘translations’ that can, tentatively, bring forward societal transformations. In fact, biomedical knowledge and experimentation constitute another angle of what it means to be human and of how to approach questions related to human vitality, a vitality that is concerned with the ‘rights to life ... the value of life, the future of life’, features that, in turn, are fundamental traits of contemporary biopolitics (Rose, 2013, p. 4). Thus, when translated into the public domain, the biological knowledge about the immune system is (in the West) related to as ‘self-management and self-governing

practices', by which individuals try to potentialise their well-being (Rose, 2013, p. 6). Such practices reveal that modern biology is not all about destiny (i.e. genetic disposition), since environmental factors and habits are also critically affecting our molecular configuration.

APPENDIX B: Semi-structured interviews and informal conversations

All interviews were semi-structured, and the duration ranged from thirty minutes to two hours. Before the interviews, I provided all participants with an informed consent form and all of them agreed to have their real name used in the thesis.

All interviews were digitally recorded and transcribed.

In the following, I indicate the formal semi-structured interviews I have conducted. I provide the name of the participant, their affiliation, and the date of the interview.

- Dr. Heda Saadeh (Babraham Research Campus), 15 April 2013.
- Dr. Jean F. Ruiz Calderon (Faculty of Biology, University of Puerto Rico), 28 January 2014.
- Dr. Maria Gloria Dominguez-Bello (Faculty of Biology, University of Puerto Rico/Langone Medical Centre NYU), 28 January 2014.
- Selena M Rodriguez (Faculty of Biology, University of Puerto Rico), 29 January 2014.
- Dr. Waleska Sanabria Leon (Faculty of Anthropology, University of Puerto Rico) 28 January 2014.
- Professor Martin Blaser (Langone Medical Centre NYU), 6 February 2013.
- Dr. Zhiheng Pei (Langone Medical Centre NYU), 6 February 2013.
- Professor Daniel Littman (Skirball Institute of Biomolecular Medicine, NYU), 7 February 2014.
- Professor Graham Rook (Medical Microbiology, Division of Infection and Immunity, Faculty of Medical Sciences, UCL), 21 April 2017.
- Professor Tim Spector (Genetic Epidemiology, King's College London and Guy's and St Thomas' Hospital), 29 June 2017.

Informal conversations (27 January 2014–29 January 2014)

These were conducted with collaborators and undergraduate and graduate students of Dominguez-Bello during my stay in San Juan.

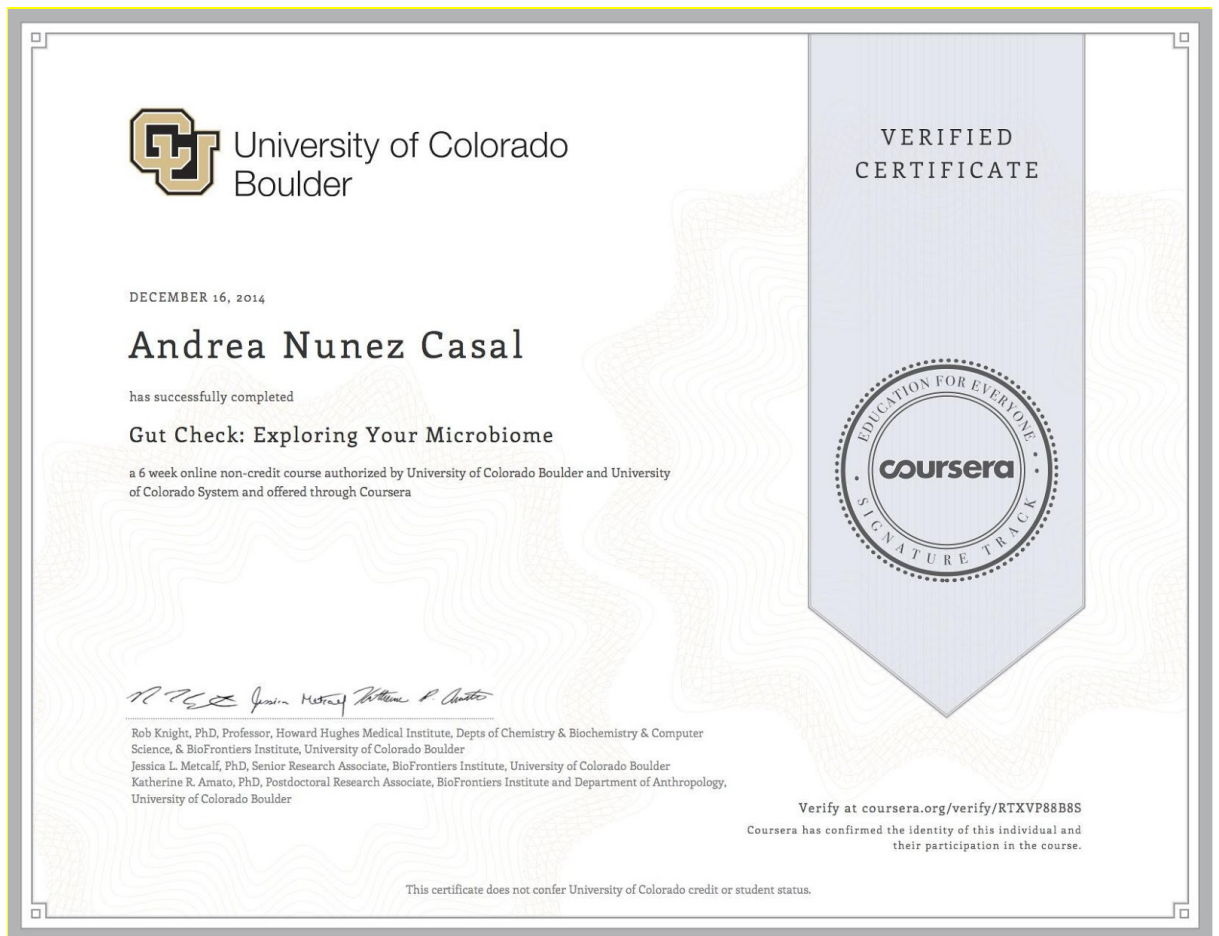
- Carlos O. Lopez Ortiz (Faculty of Biology, University of Puerto Rico).
- Daniela Vargas Robles (Faculty of Biology, University of Puerto Rico).

- Kassandra M. De Jesus (Faculty of Biology, University of Puerto Rico).
- Bryan J. Rios Nieves (Faculty of Biology, University of Puerto Rico).
- Dr. Filipa Godoy-Vitorino (Microbial Ecology and Genomics Laboratory (MEGL)).
- Dr. Humberto Cavallin (Faculty Architecture, University of Puerto Rico).
- Dr. Luis Pericchi (Faculty of Mathematics, University of Puerto Rico).

All named above were aware of my activity and, in the case of Carlos, Daniela, Bryan, and Kassandra (undergraduate students), they have also signed the informed consent form. I decided to do so because their names appear in Chapter 4. I did not conduct an informal interview with them because they were not directly involved in ‘Microbiomes of Homes across Cultures’, the microbiome study led by Dominguez-Bello that I was documenting.

With respect to the rest, they haven’t signed the informed consent because the interaction I had with them was very brief, and thus I did not gather any relevant data from our fleeting encounter.

APPENDIX C: Certificate microbiome online course ‘Gut Check’



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