

## FRONT MATTER

### Half title page

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For just over a decade, scientists have been able to study the previously unexplored microbial world. The microbial communities that co-inhabit the world with us human beings constitute what is known as the 'microbiome', and scientists are revealing that it has a huge great impact on both our health and that of the environment. This book illustrates how scientists explore this microbial world that lies between biology, medicine and computer science, thanks to advanced sequencing technologies. The research practices of scientists take place in the dialectic between a 'molecular vision' and an 'ecosystemic' vision, the former being the molecular scale of the microbial genome and the latter a macro-scale linked to the fact that microbes are interdependent with the biosocial environment. In this process, biology, medicine, computer science and anthropology are reconfigured in their convergence and this leads to reconsidering what it means to be human and our role in a world that exists and persists thanks, and above all, to microbes.

### Title page

Main title: Metagenomic Futures

Subtitle: How metagenomic is reconfiguring health and what does it means to be human

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### **Foreword**

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"I'd like to study the anthropology of microbes". It was with these words, which then became the title of the book, that Roberta first introduced me to her plan. And despite knowing more or less what anthropology was and microorganisms being my subject, I didn't have the faintest idea what they meant. Trying to hide my ignorance – when would a teacher ever admit to not knowing? – I asked her what *exactly* she meant by 'anthropology of microbes' and, sensing my despair, she tried very patiently to explain it to me in child-friendly language. After her explanation I still didn't really know what she was talking about, but the idea seemed so crazy that I couldn't not encourage it so I happily agreed to her integrating into our research team to study this mysterious "anthropology of microbes".

It was only after reading the draft of the book that I finally realised what Roberta meant by those terms. I certainly don't want to deny readers the pleasure of finding it out for themselves in these pages, but I do find it strange that I personally was able to understand it only after my research team and our scientific work had been described from the outside. Probably, this couldn't have been any different, seeing as I then discovered that both us and the scientific community we refer to are part of this same definition. The book, therefore, provides us with a mirror for appreciating aspects of our work and laboratory life that we didn't even suspect existed. I suspect this also means that the way we do our scientific research will be influenced by them to a certain extent, but that is a matter for the future. What is more important here is that the reader has the chance here to understand *what* a laboratory like ours does when it researches into "microbes" and *how* it does it, and that this is described and reported by Roberta to a depth and from a perspective that would never have been possible if the book had been written by somebody inside the laboratory.

One distinctive aspect of the laboratory I run is its multidisciplinaryity: computer scientists, microbiologists, mathematicians, biotechnologists, doctors and dentists. Interacting with different disciplines is second nature to each and every member of the lab and perhaps also a crucial element in the generation of new scientific knowledge. The leap into anthropology is much more daring though, requiring an elasticity that we weren't accustomed to. I think this is due to the fact that the main disciplines in our lab are all based on a clear concept of "evidence". A mathematical concept is a law if formally demonstrable, a biological phenomenon real if experimentally reproducible and a biomedical discovery proven if it fulfils certain statistical conditions. This – as I understand from my discussions with Roberta – is not necessarily the case for anthropology. And this was precisely the barrier that stopped me from grasping the meaning of "anthropology of microbes" before reading fully the draft of the book. For someone like me, used as I am to having to formally justify and prove any significant statement, understanding how there can be science and knowledge without these preconditions – and hence exactly what the "anthropology of microbes" really is –

wasn't easy. But this book describes and builds a bridge between these disciplines and makes it crossable by the reader no matter what his or her starting point.

Also, biomedical and anthropological research – or at least the way both I and Roberta do research – have a point in common, namely, that of using an investigative method based on direct experience, on doing it in person. Only rarely do I ask students to systematically read and study the scientific literature on a given subject. What happens much more often is that, starting from an aspect or result of interest, I suggest that the student poses a further question and analyses the specific data in order to get an answer. In most cases I have a vague idea of how a study should be set up, but how to proceed with the analysis is often depends on originality and intuition, in a context of scientific rigour. The student won't get an overall understanding of the whole subject, but she will get an experience of how the research process works by dirtying her hands with a specific problem and thus be in a position to ask ever more ambitious and pertinent questions. In the same way, Roberta joined our research team to get an experience of what we do and how we do it without asking for descriptions from the people already involved. Seeing such similar approaches to research in such different disciplines is intriguing.

The understanding of what the “anthropology of microbes” is that I got from reading the chapter drafts also influenced the way I responded to Roberta's request for me to check and possibly correct the more technical passages about our work. While not wanting to upset biologists with less-than-strict definitions of basic concepts and computer scientists with excessive simplifications of their procedures, the approach I have adopted has been that of keeping as much as possible to the way Roberta understood or interpreted us. Basically, it will be easier for the reader to get an idea the work of a metagenomics lab from Roberta's point of view rather than by using our insider definitions. And this new sensitivity of mine to the value of how we are seen and interpreted, as opposed to how we ourselves define what we do and what we study, makes me realise that the “anthropology of microbes” has already affected me more than I thought.

### **Acknowledgements**

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## **CHAPTER 1 – INTRODUCTION**

Microbes<sup>1</sup> are everywhere. They can cause pandemics like the coronavirus SARS-CoV-2 one – gaining momentum as I was writing the introduction to the original Italian version of this book in

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<sup>1</sup> Microbes are microscopic and, generally, single-cell living things that are found all around and within us and are too small to be seen by the naked eye. The most common types are [bacteria](#), viruses and fungi.

the late 2020 winter – and yet be extraordinary allies to human health. Before the arrival of SARS-CoV-2, the micro-phobia that reigned supreme in the last century was being replaced by a kind of micro-philialia. The positive aspects of our cohabitation with microbes first became a topic of both scientific and popular debate a little more than ten years ago, when scientific evidence could be produced of the enormous biodiversity and quantity of microbes living together, in us and around us – the so-called ‘microbiome’<sup>2</sup>. The subject fascinated me right from the start, ever since first reading about it in 2014. The idea of health as a property not just of one body but as the emergent property of a network of relationships is the common thread that runs through all my research, beginning with my study of allergies. This theme is then broadened in my studies of health policies and processes of belonging to specific communities. Having an ecosystemic view of health actually means taking the broader theme of ‘cohabitation’ into consideration: if we reformulate health as a property of encounters and a result of coexistence rather than as a property of bodies in themselves, then talking about health means asking ourselves how we can live together beneficially in a world where, like it or not, we are all caught up in an entanglement of relationships with humans and more-than-humans alike.

Twenty years ago, when I first came to medical anthropology, the normal way to find out something about how health was thought of and practiced was to conduct research on patients, doctors and/or in medical institutions. But I realised that the conceptions and practices of health were being redefined by technology and scientific research at an ever increasing rate and so I moved on from studying (para)medical spaces to studying laboratories. And so, laboratories – laboratories where researchers study the microbiome – are the main setting of this book. What I wanted to understand in particular was how the narrative about symbiotic coexistence between microbes and human beings came to be translated into laboratory practice. The microbiome is often described as the new panacea for all ills – be it losing weight, improving your mood or vanquishing tumours – but very few people know what it really is or, as yet, what its real application possibilities are. I was curious to find out for myself whether scientific research really was in the middle of a paradigm shift towards conceiving health as an aspect of an ecosystem rather than of single organisms.

This book recounts this ethnographic experience, showing how research into the microbiome is trying to build a bridge between two different visions. One, the classical view – often criticised for being reductionist – sees the microbiome community as made up of single entities. The other view is ecosystemic and tends to explore the relational dynamics of the microbiome

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<sup>2</sup> The microbiota is the ecological community of microbes living in a natural environment; the microbiome describes the genomes of those microbes.

community, both internal and external. This integration and change of perspective is neither easy nor without its difficulties and risks, but very intriguing when placed in the context of understanding future horizons in the social and natural sciences.

In order to understand the actions, logic and feelings of the researchers in the lab, I had to immerse myself in the world of sequencing technology, big data and artificial intelligence (AI)<sup>3</sup>, very different to the world I was used to. And I had to learn a new language, like any anthropologist wanting to study an exotic community. This made it possible for me to 'see' microbes the way researchers do, understand their reasoning and appreciate the merits of their approach whilst also seeing its limitations. This move was necessary to allow me, an anthropologist, to enter into dialogue with the narratives and practices of science. In writing the book I have attempted to give emphasis to the silent or implied social-political dimensions of microbiome research. It is thus not only an anthropological analysis but also an actual experiment in interdisciplinary collaboration, based on the conviction that the ability to cope with the complex challenges that await us in the future (pandemics, climate crises, poverty, discrimination, social injustice, relationship with technology, etc...) depends on our capacity to combine different disciplinary approaches and sensitivities.

As for the theoretical contribution the book can give to anthropological debate, I put forward a critical reflection on some recent trends, namely the ontological turn and posthumanism. As regards the ontological turn,<sup>4</sup> I shall attempt to reorient the debate on the reality of multiple worlds towards an analysis of the social impact these have. Anthropology, I think, cannot content itself with merely knowing that multiple worlds exist. Starting from this important observation, the crucial thing is to analyse what the ethical-political and cultural consequences of certain configurations of reality are. Critically reflecting on the impact of all this becomes essential in an ever more pragmatic and fast-moving world. In my discussion, I shall go on to analyse how epistemic practices (laboratory practices based on a specific way of creating knowledge) give shape to certain configurations of reality rather than others. And in doing this I shall attempt to show the potentials but also the limits of posthumanism, or rather of all those approaches that quite rightly shift the

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<sup>3</sup> A branch of computer science that studies the theoretical bases, methodologies and techniques of designing hardware and software systems capable of performing as well as – and sometimes better than – humans.

<sup>4</sup> The 'ontological turn' is a wide-ranging and diversified approach in anthropology difficult to do justice to in a footnote but whose arguments will be developed in the course of the book. In general, however, we can say that its various authors propose doing away with the distinction between interpretation (constructionism) and reality (positivism), nature and culture, human and nonhuman, material and information, and similar opposites, in the attempt to go beyond dualisms, categories and identities, but also in order to recognise the equal value of different culturally determined ways of experiencing reality. These theoretical constructs are to be replaced by fluid, emergent, contingent and multiple ontologies (realities). For a detailed discussion, see the book by some of the major proponents of this turn (Holbraad & Pedersen, 2017) and also the internal debates and criticisms (Candea, 2011; Carrithers et al., 2010; Heywood, 2012; Holbraad et al., 2013; Laidlaw, 2012; Pedersen, 2012; Pellizzoni, 2015; Povinelli, 2016, 2021; Scott, 2013) with which this book aspires to dialogue.

central analytical focus to beyond the human. The biopolitics inherent in posthumanism can inflect in many ways, which have to be analysed case by case. This, ultimately, brings the 'human' back into play, which is also where anthropology, the study of the *anthropos*, begins.

### **1.1 Why microbes?**

But why should microbes, tiny creatures not even visible to the naked eye, be of importance to anthropology – essentially about humans?

To start with, consider the fact that there are more microbes in a single teaspoon of soil than there are stars in the Milky Way. Microbes constitute 90% of the ocean biomass. As has been noted:

The microbial world is not really a good expression. It is not a world, it's not a planet, or a constellation. It's not even a universe, for there are 1,000,000,000 times more bacteria in the world than stars in the sky. Imagine the microbial 'world' as billion universes each made of thousands or millions of galaxies and you have some idea of the scale of the challenge of microbial ecology (Curtis, 2007, p. 1)

Terrestrial biodiversity is guaranteed mostly by microbes, despite animals and plants being more visible. Microbes are in the clouds, up to 30 miles above the earth's crust, miles beneath the Earth's surface and in the darkest oceans. They can survive at extremely high temperatures and encased in ice. They can live in a dormant state for millions of years in the harshest of environments.

Microbes are some of the most adaptable organisms of all and reproduce very quickly. This is why we are thinking of colonising other planets starting with forms of microbial life and why the first alien life form to be discovered here will probably be microbial. Life on Earth originated from microbes – its only inhabitants until relatively recent times in geological terms – and their physiological processes are very important for human beings: we would not survive without the environmental conditions they guarantee. This is what led biologist Stephen Jay Gould to say that the Earth has been – and always will be – in the “age of bacteria” (O'Malley, 2014, p. 8).

Microbes are part of our identity as human beings. From 50% to 90% of the cells in a human body are microbial. The composition and activity of microbes are central aspects of processes that affect our health – such as metabolism, immune and endocrine system function – and they even affect our mood and personality. And things such as diet, childbirth methods (natural vs caesarian), antibiotics and ways of interacting with other humans and the environment shape and alter our microbes, just as they contribute to configuring us and our health. Health is no longer described as the property of an organism whose immune system works to repulse and kill enemy invaders. We have entered an era where we are told that interrelating with a myriad of microbes is not only unavoidable but necessary and that it lies at the basis of our wellbeing. We can thus begin to think

of organisms as ecosystems and, consequently, of health as the emergent property of a dynamic ecosystem with permeable boundaries, rather than as a property of single bodies.

Microbes, then, despite their tininess, have to be taken seriously by anyone wanting to understand what it means to be human and what health is; especially by anyone inquiring – as I am – into the role of humans in a world bigger than they are, a theme that has become particularly urgent in the light of the climate crisis and the growing awareness of the interdependence between humans and nonhumans. As I was writing this introduction (the last thing to be done when writing a book) to the Italian version in March 2020, the world was just starting to be in the grip of the SARS-CoV-2 coronavirus pandemic. Hygiene guidelines and vaccines – reasonable and necessary as they are – are not enough to stop it happening again. What this pandemic is forcing us to remember is that the destiny of microbes is closely linked to our own and that perhaps now is the time to start looking more seriously and responsibly at the modalities of this coexistence.

## **1.2 Humans and microbes: the relational and posthuman perspective of anthropology**

Anthropological interest in microbes, both as an object of study and source of inspiration for theoretical and methodological developments, has been growing in recent years (Hamer, 2015). Donna Haraway, in *When Species Meet* (2007, p. 4), writes that it would be more accurate to configure the human body as “us” rather than “I”, as most of our body cells are microbial: “I am vastly outnumbered by my tiny companions”<sup>5</sup>. Individual identity, she argues, is the result of interaction, a process of becoming, with many other entities: “to be one is always to *become with many*” (2007, p. 4) but the existence of these many does not “precede their relating” (2007, p. 17). In other words, according to Haraway, identity is not a predetermined characteristic of an individual but something created through interaction amongst what she calls “companion species”. As noted by anthropologist Myra Hird (2009, p. 84), “asking what bacteria have to do with humans is, in other words, asking the wrong question”. Years earlier, Edward Evan Evans-Pritchard (1940, p. 36) had reached similar conclusions when observing the profoundly interactive relationship between the Nuer and their cattle: “It has been remarked that the Nuer might be called parasites of the cow, but it might be said with equal force that the cow is a parasite of the Nuer, whose lives are spent in ensuring its welfare.” Or, as Haraway says, it seems that “we have never been human” (2004, p. 2), echoing Bruno Latour’s famous ‘we have never been modern’. According to philosopher Michel Serres (2007), the key to identifying the concept of relationship is the figure of the ‘parasite’. In biology, parasitism is one of the possible modes of interaction between different organisms, which

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<sup>5</sup> Microbes and microbial relationships also play a central part in her latest work, *Staying with the Trouble* (2016), a kind of exercise in anthropological imagination about how to live well at the dawn of the sixth mass extinction.



are defined as symbiotic interactions<sup>6</sup>. Parasitism is a relationship between two organisms in which one (the host) is harmed by the other (the parasite), which benefits. The other two modes of interaction are commensalism (one organism benefits and the other doesn't) and mutualism (both benefit). Recent discoveries about microbes have blurred these rigid distinctions by demonstrating their situational and variable character. The various modes of interaction between microbes are grouped under the 'symbiotic' processes category which can – according to the circumstances – have negative, neutral or positive consequences (Gordon, 2012). Forcefully reemphasising what Dutch microbiologist Baas Becking had hypothesized in the 1930s (Sapp, 2004), biologist Lynn Margulis has more recently argued that only symbiotic processes exist. According to Margulis, the categories of parasitism, commensalism and mutualism derive from an economic logic that has little to do with science. The conceptual importance of the symbiotic paradigm led to the coining of the term “symbiopolitics” by anthropologist Stefan Helmreich, which he defines as “the governance of relations among entangled living things” (2009, p. 15). In recent years, the social significance of symbiotic relationships has itself become an investigation theme and theoretical perspective (especially in English-language social anthropology) (Candea & Da Col, 2012; Wolf-Meyer & Collins, 2013). The theme of the 2015 ASA conference (Association of Social Anthropologists of the UK and Commonwealth), for example, was ‘Symbiotic Anthropologies’. The fact that relationships are of primary importance to the existence of single entities has, however, been discussed by anthropologists for some time. The anthropology of kinship, *in primis*, has emphasised how the importance of relationships (Carsten, 2000) goes beyond our existence as biological bodies, thus deconstructing the idea of the ‘autonomous person’ (Strathern, 1992). The fact that the boundaries of the body are not necessarily the boundaries of the human was being widely analysed in anthropology well before the interest in microbes began. The classic formulation “mindful body” (Scheper-Hughes & Lock, 1987) rendered explicit the link between the phenomenological experience of having a body and the social and political influences involved in not only perceiving but also giving form to bodies (Lambert & McDonald, 2009; Pizza, 2012). The concept of incorporation tells us that the body is not separate from its environment but actually emerges with it into becoming, a process that involves not only physical and material aspects but also awareness of existence: “the body is a ‘setting in relation to the world,’ and consciousness is the body projecting itself into the world” (Csordas, 1990, p. 8). The idea of “emplacement” (the incorporation of places) (Howes, 2005, p. 7) adds environment to the body-mind dialectic while the concept of “body ecologic” (Hsu, 2007) emphasises the mutual resonance between the human body and what exists outside it. The diverse links formed between human beings and their environment are, according to

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<sup>6</sup> *Symbiosis* means ‘living together’.

Tim Ingold, the real substance of bodies, as admirably described in his “ontology of dwelling” (Ingold, 2000, 2008, 2011), according to which ‘to be living’ means first of all being able to weave relationships with one’s environment. Thus, recent anthropological debate about microbes opens no entirely new theoretical horizons, but it definitely constitutes an occasion to strengthen existing ones, working together with colleagues from the natural sciences (Benezra et al., 2012).

### **1.3 What does it mean to be human? Towards an anthropology of nonhumans**

Taking the profound interdependence between humans and microbes as a starting point, the answer to what it means to be human can be found by trying to see the world from a microbial perspective. In other words, understanding what it means to be human can be achieved by exploring what it means to be more-than-human. Studying those different to me in order to better understand myself lies at the basis of anthropology, a discipline that examines what it means to be human by analysing the particular forms assumed by humanity in specific socio-cultural situations and comparing them. Comparison is a fundamental step in anthropological methodology because understanding how others have decided to give form to their existence encourages us to make better sense of how we live. One of the main difficulties in anthropology is trying to grasp the point of view of someone radically different to me. This difficulty increases when the objects of study are microbes or more-than-humans because they do not talk, or rather they do it in not easily understandable ways.

In recent years, so-called ‘multispecies ethnography’ (Kirksey & Helmreich, 2010) has proposed extending classical ethnographic methods to the study of more-than-humans. There are various multispecies approaches, and the more experimental of these attempts to make communicative, perceptive and sensorial contact with a range of more-than-humans. In these efforts we must always be aware of the risk of anthropomorphising more-than-humans, given the basic differences and communicative asymmetry. The ability to give sense to the world is, most probably, an attitude not limited to humans and it is thus important for anthropology to attempt to understand more-than-humans. However, I find that we are more able to enter into relationships with others – be they humans or more-than-humans – when we recognize our differences at the ontological (what we are), epistemological (how we understand), and socio-cultural and political (the world we collectively produce and reproduce) levels. In this work, what this translates into is studying microbes through the interpretative and representative human abilities that make them important social actors and analysing how this occurs in specific ways.

A certain number of authors have applied this approach by studying the ways humans perceive and interpret microbes. Mark Davis and colleagues (2016) have demonstrated that Australians give little importance to the dangers of microbes, in the light of the awareness that there

is no solution to the fact of having daily and frequent contact with them. Alex Nading (2016), on the basis of his field study in Nicaragua, describes how relations between humans and microbes are conceived and managed in a specific area in the global South. Myra Hird (2009), on the other hand, conducted a pioneering ethnography in Lynn Margulis' laboratory, analysing how classical concepts such as identity and gender are reconfigured with the discovery of microbes. Erin Koch, with an ethnography in a tuberculosis research laboratory in Georgia where she worked as a technician, has demonstrated that the modes of interaction between researchers and microbes are neither exclusively 'biological' nor exclusively 'socio-cultural', but that the two modes are combined, giving rise to what Koch calls "local microbiologies" (2011, p. 83). In this, she makes specific reference to Margaret Lock's (1993) concept of "local biologies", a formula that identifies biological states determined by the interweaving of local material and cultural conditions.

Other authors have identified the connection that links microbes to humans in the political regulation of microbes. Amongst these there is Elizabeth Dunn, with her ethnography (2007) about a programme for the control and prevention of *E. coli* epidemics in the United States, and Heather Paxson's ethnography (2008) on producers and lovers of raw-milk cheese in Vermont. On the basis of their case studies, these authors proceed to a critical examination of the concept of biopolitics<sup>7</sup>. Paxson, for example, talks of "microbiopolitics" and her work shows how the government of bodies, in her specific case, is mediated by the regulation of microbes.

#### **1.4 Transformations of biopolitics**

As news of human genome sequencing results first began to spread, anthropologist Paul Rabinow<sup>8</sup> noted that the concept of *bios* itself was changing in the wake of recent scientific discoveries: "we now have a more problematic understanding of the *bios* in biopower. [...] precisely how changes in *bios* will interact with old and new forms of power relations is open to question, and the evolution must be observed and analysed" (Rabinow, 1999, p. 15). In a subsequent publication, he and Nikolas Rose (Rabinow & Rose, 2006) confirmed the need to reassess the concept of biopower and its derivatives in the light of recent developments in molecular biology that were reformulating the *bios* in a significant way. According to the authors, the distinction between *bios* and *zoe* – or rather between man as a 'political animal' (*bios*) and life as a universal force that goes through and unifies everything and everyone in a non-specific way (*zoe*) – was diminishing. A number of authors have posed this same question in anthropology and proposed a series of formulations that help shed light

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<sup>7</sup> 'Power over life', or rather how political regulation depends on the management of biological life.

<sup>8</sup> Seven years earlier, Rabinow proposed the term 'biosociality' in the light of emerging evidence that collective identities and forms of aggregation and sociality between humans were based on shared genetic traits (for example, between people with a particular genetic mutation or rare disease) (Rabinow, 1992).

on the innovative consequences of the changing concept of biopower. “Microbiopolitics” (Paxson, 2008), “Gaiasociality” (Helmreich, 2003), “geontopower” (Povinelli, 2016) and “ecobiopolitics” (Olson, 2018) are some examples. This book introduces no new terms, but proposes to focus attention on this debate, or rather, on how technology is laying the basis for a rethinking of *bios*, biopower and biosociality.

Ethnographic interest in the different ways biopower is developing is not limited to the field of microbes. We have realised that we live in a world where everything is connected and dynamically transforming. Not by chance, terms such as ‘financial ecosystem’ and ‘digital ecosystem’, despite having very little to do with ecology, are becoming ever more pervasive in a disproportionate way. Environmental governance is becoming more and more integrated not only with political and economic governance but also religious (see the *Laudato Sii* encyclical of Pope Francis), medical and scientific (e.g. so-called ‘planetary health’ (Horton & Lo, 2015) and ‘One Health’ (Hinchliffe, 2015)). Perhaps, though, the potential of this new ecosystemic perspective that forces to rethink and – in some cases – demolish the categories, ontologies and hierarchies that are taken for granted in the global North has not yet been sufficiently explored. In 1976, in his concluding lecture at the Collège de France on the theme *Il faut défendre la société*, Michel Foucault underlined the difference between sovereign power (the right of life and death over subjects) and biopower: “*faire vivre et laisser mourir*” (to make live and to let die), or rather, a socio-cultural and political-economic configuration that encourages and facilitates the life of certain entities while necessarily leaving others to die in silence. Thus, the question that underlies the way science gives significance to microbes and the relationships we have with them is: who or what are we encouraging and facilitating to live and who or what, as a consequence, are we leaving to die?

### **1.5 From microbes to the microbiome. Methodological aspects of a laboratory ethnography**

In recent years my research has focused on analysing the specific ways microbes become social actors, drawing on recent discoveries in metagenomics. Metagenomics is the study of microbial communities in their natural environment (*in vivo*) using advanced DNA sequencing techniques. Sequencing produces an extremely vast and complex mass of data (big data) which are collected, manipulated and processed computationally using algorithms and, often, artificial intelligence (AI) techniques in order to perform highly specific analyses. As yet, to my knowledge there are no existing ethnographies on metagenomics, although the need for them has been expressed (Keck, 2017).

Although it has been known for a long time that human beings coexist with large numbers of microbes, it has only been for ten years or so that researchers have been able to characterise the

genomes<sup>9</sup> of microbial communities populating specific environments (e.g. the ocean, the soil, plants, human or animal bodies) or parts of them (e.g. a marine current, certain soils, a plant stem or roots, human or animal intestines or oral cavities). These sets of genomes are known as microbiomes. The accounts in this book are based on ethnographic work carried out between 2014 and 2020, first of all in a metagenomics laboratory in the University of Trento, the Segata Lab in the *Center for Integrative Biology* (CIBIO). I also attended conferences on the microbiome, analysed scientific articles and media and, during a research period in the United States – in California, where much of the sequencing technology and analysis is concentrated – I conducted interviews with prominent figures in the world of metagenomics. Studying scientific research anthropologically does not mean taking it as a model. In June 2018 I attended a conference on symbiosis in the University of San Diego marine biology department, in a hall overlooking La Jolla bay. When there, I interviewed Pete Greenberg, a scientist who had known Edward Wilson, the founding father of sociobiology, when he was at Harvard. In the 1990s, Greenberg coined the term ‘quorum sensing’, the intercommunication system used by microbial populations based on the exchange of biochemical signals between cells to convey information needed for survival and regulate the genetic expression of various actions such as movement, cell transformations, DNA transfer and acquisition and symbiotic interaction. What Greenberg liked about his work, he told me, was that microbes can also tell us how to rethink our own sociality. This remark actually reflects the intrinsic limit of the sociobiological approach, namely, the tendency to take biology as an unequivocal truth, from which a better understanding of society or a socio-anthropological theory can be derived. What this line of reasoning ignores is the fact that scientific truths themselves derive from concepts modelled on sociocultural practices and that talking about ‘biology’ means talking from a certain cultural point of view: “the specific epistemic cultures through which we know local biologies closely interact with these biologies” (Niewöhner & Lock, 2018, p. 688). And nor does studying a research community anthropologically mean treating it as a separate unit. I was actually interested in trying to understand how negotiations between the differences and similarities within a scientific community, and also between that community and other social spheres, give form to a specific scientific and social narration of microbes. For this reason, this book is also about history: the history of how microbes came to be a topic of interest in a broader scientific debate involving ecology, medicine and molecular biology that develops in different ways according to geopolitical location. Clearly, this historical account will not have the completeness and depth that a true historian would be capable of, but nor is it intended to. My use of history is at the service of anthropology. Its purpose is to facilitate, enrich and participate in the

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<sup>9</sup> Set of genes in an organism.

ethnographic work so that we can put into context what we observe in this highly topical, future-oriented field.

The tendency to study the future is becoming widespread in anthropology (Appadurai, 2013; Salazar et al., 2017), and with good reason. Exploring future scenarios is a necessary requirement for entering into dialogue with other disciplines about what kind of future scenarios we actually want and are able to imagine and achieve. I have become increasingly convinced, however, that if we want to understand the future we have to base ourselves solidly on the study of the present and past. The anthropological gaze into the future, in my opinion, emerges more as a specific variant of research questions that anthropologists have always been asking rather than as a radical renewal of its methods. This is thus a book in which past, present and future are in continuous dialogue.

There are, in fact, different interpretations of what microbes are, and these have varied over the course of history according to worldviews, interests and technological resources (known in social studies of science as 'sociotechnical apparatus'). But they can also differ within the same research group and between different research groups in the same discipline. Bruno Latour was among the first – and definitely one of the most influential – to draw attention to how scientific knowledge is negotiated and “black-boxed” (1999), or rather obscured and removed. Scientific knowledge of microbes is thus not an absolute truth but derives from a socio-materially constructed social process. Microbes – like any other scientific ‘fact’ – are not actually “matters of fact”, or rather permanent and absolute given entities, but “matters of concern” (2004).

Latour's thoughts on science, expressed over the last 40 years, are definitely useful, as is the idea of microbes as “matters of concern”. Personally, however, I feel more aligned with the analytical approach of Maria Puig de la Bellacasa, who proposed that scientific entities should be considered “matters of care” rather than “matters of concern”. She argues that Latour's concept remains at a rational level and underpins a specific political orientation “compatible with contemporary majoritarian democracies dealing with ‘issues’ of ‘public concern’” (2011, p. 88), which sees the role of the social sciences as akin to that of a diplomat or mediator figure. According to Puig de la Bellacasa, the social sciences cannot limit themselves to illustrating and analysing the various instances and interests involved in the construction of scientific facts. In this approach there lingers a kind of political ambiguity. The concept “matters of care” infers a stronger practical, emotional and ethical involvement, activated when we become aware of and make explicit the values that guide not only our studies but also our role as social scientists, asking ourselves “what are we encouraging caring for?” (2011, p. 92 emphasis in original). A similar criticism is made by

Kim Fortun, who argues that in the current era of social and ecological crises<sup>10</sup> the answer given by the Latourian sociology of associations is too weak, because it is “a functionalist semiotics, with little history, paradox, harsh conflicts of interest or possibilities for play. [...] In the insistence on the meso - a sociology of association - cross-scale interactions and structural conditions seem to be written off.” (Fortun, 2014, p. 315). Latour’s sociology of associations, by anchoring itself to the values of rationality and mediation, rules out a whole series of ‘awkward’, marginal interferences. And it also rules out those affective, practical and often undervalued aspects that allow numerous social actors and scientific entities to emerge and persist (see also Bear et al. 2015). Natasha Myers (2015) has shown how affective, sensory and even bodily engagement, far from being extraneous to science, are actually its driving force.

Understanding and illustrating how, to Segata Lab researchers, microbes are neither purely “matters of fact” nor purely “matters of concern” but rather – and above all – “matters of care”, has been relatively natural and straightforward for me. Indeed, I was welcomed with great intellectual generosity and respect by the members of the Segata Lab and its coordinator, Nicola Segata, and was thus able to become part of the group, both in a formal work context and informally. Microbes are things they care about, in both their epistemic practices and daily experience.

In this process of getting close to the practices and also the logic and sensitivities of the researchers, however, I also encountered some ‘interferences’, which I have subsequently referred to in my writing as events or points of view that introduce doubts, discontinuities and frustrations within the main narrative. These were happening not only in the outside world (science scandals, commercial speculation, etc...) but also in Segata Lab itself, probably partly because of my presence there in the laboratory<sup>11</sup>. In Segata Lab there was one figure in particular – Paolo – who, while participating enthusiastically in the lab work, expressed a series of ideas which at times coincided with my own analysis. Paolo could be defined as ‘marginal’ to the group; not because he was unimportant or nobody cared about him, but because he had the kind of background and character that cast him as a source of disagreement and provocation. Paolo was well-accepted in the group and this was made possible because of his role, acknowledged by all – himself included – as a ‘joker and nuisance’.

After reading the first draft of this book, Nicola’s main concern was the question of representativeness. As a statistician, he was justifiably worried that the reporting of different and at times discordant points of view might affect the generalisability of what I was describing. I

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<sup>10</sup> Kim Fortun too qualifies as an anthropologist and activist. Her research focuses on environmental disasters and toxicity.

<sup>11</sup> Cristina Papa, in her book *Antropologia dell'impresa* (1999), stressed that her presence as an anthropologist triggered a reflective, critical process in the workers with positive consequences in terms of productivity.

understand and respect Nicola's point, but anthropology has a different logic to statistics: the objective is not to prove a rule but to probe between the rule and the discordant voices, as these voices broaden and enrich the understanding of the phenomenon being studied. In an ethnography, dissident voices are precious things, not a bias to be eliminated. Thus, in writing this book, I have combined Latour's figure of the mediator with my efforts to understand the point of view of the 'natives' I analyse. But also, as suggested by Fortun, I have combined the figure of the diplomat with another one: "more agitator than peacemaker, more animator than activist, enabling articulations and movements that could not have happened before" (2014, p. 322).

### **1.6 Audience and content**

This book can be read at different levels. I wrote it making reference to the anthropological community: when talking about the microbiome, I address traditional anthropological themes such as the tension between nature and culture and I discuss relatively recent theoretical and methodological trends such as posthumanism, the ontological turn and multispecies ethnography. I also reflect on how anthropological practice changes whenever technoscience is studied, especially the kind of highly technologized science studied by me.

This leads me to consider – in an anthropologically sensitive manner – themes from the philosophy of science such as scientific realism and the difference between theory and practice in experimental situations, and themes from the sociology of science such as the growing automation and digitalisation of our lives and biology by big data, algorithms and artificial intelligence. The book is also suitable for those wishing to explore the themes of medical anthropology. In fact, I find myself rediscussing, and in some cases revising in the light of the ethnography, a series of traditional concepts in this field such as biopolitics, biosociality, medical citizenship, etc.

Finally, I hope it will make interesting reading for those in field of metagenomics, for microbiologists and biologists – both computational and classical – and for those in the fields of technology, statistics, big data, algorithms and artificial intelligence. In general, the book is an attempt not only to understand specific scientific practices and logics but also to foster dialogue between them and anthropology, emphasising the differences, similarities, misunderstandings and potentials of their coming together.

Finally, I also hope the book can be read by a wider audience, or rather, by people interested in the microbiome and wanting to go beyond the news they get in entertainment magazines. I refer here to all those who find the microbiome intriguing not just because it – maybe – beautifies their skin or regularises their bowels, but also because it destabilises the traditional categorisation that normally sets us apart from 'nature', to which it suggests new ways of relating. Although I make



reference to highly specialised scientific debates in the book – both in the human and biological sciences – I have made every effort to render them as accessible as possible. In the case of the natural sciences the language is necessarily approachable because I myself am no expert, so the descriptions I give are already the result of an initial process of translation and comprehension. The book has undergone a number of revisions thanks to the help of generous colleagues in microbiology, biology and informatics, but some imprecisions may have been inadvertently overlooked; for these I apologise in advance. As for the anthropological language, I have tried to explain every term, paradigm and concept and outline its historical significance within the anthropological debate.

Chapter 2 illustrates how metagenomics has emerged against the backdrop of previous scientific traditions that look at microbes as social actors in the course of history, at different latitudes and in different disciplines. The chapter goes to the roots of the Western biomedical concept of individual microbes as pathogenic agents and contrasts it with the approach of Russian biologists, which subsequently evolved into environmental microbiology. The chapter shows how metagenomics is the outcome of a conciliation process between these two different interpretations, and how this also underpins traditional biological categorisations such as that of the place of humans in nature and their relationships with microbes.

Chapter 3 discusses how the microbiome, identified by metagenomics, brings with it the prospect of a new concept of health, at the crossroads between the social and biological sciences, and how this is part of the postgenomic revolution or, more precisely, epigenetics. This development in traditional genetics replaces the gene – which was seen as the basic determinant of the biological destiny of all living beings – with something more complex: the processes that take place at the interface between gene and environment. The chapter lays the theoretical foundations for integrating an anthropological perspective with microbiome research, focusing on the concepts of ‘environment’ and ‘nature’. With the analysis of a project of microbiome bioprospecting in the global South, the chapter ends by looking at how the ‘environment’ and ‘nature’ are enacted in microbiome research with regard to the practices of racialising and categorising human groups and how this creates both frictions and opportunities for dialogue with an anthropological perspective.

In chapter 4 the ethnographic part of the book begins, illustrating what it means to researchers to see microbes *in vivo* using the technology they have available to them. To this end, the chapter describes the epistemic practices of bioinformatics (also known as ‘dry’) and traditional (‘wet’) biology, analysing the differences, similarities, exchanges and translations between the two approaches. The chapter also aims to illustrate how the application of big data and artificial

intelligence is not something automatic but has to go through a series of stages in which the interpretive skills of both wet and dry researchers are fundamental.

Chapter 5 ethnographically explores the epistemic practices of bioinformatics, showing how these are based on a pragmatic approach that prefers achieving concrete goals – no matter how imperfect or approximate they are – to pursuing ideal principles or abstract schemes<sup>12</sup>. The illustration of the role of pragmatism within microbiome research allows us to identify the precise role of reductionism and realism within that approach and to consider both the opportunities it presents and its limits *vis a vis* anthropological experimental practice.

Chapter 6 illustrates the ethical and political implications – also in relation to categories such as race and gender – of the pragmatic approach, illustrating some of the discussions that animate both the research community and the everyday life of the lab and outlining the researchers' biographies. This leads not only to a reconsideration of some of the anthropological debates at the heart of the ontological turn but also to a revision of the criticisms made by the social sciences of algorithms, big data and artificial intelligence. This, in turns, prompts a critical reflection on the methods and approaches of an anthropology of technoscience.

In chapter 7 we come out of the laboratory to illustrate a number of famous metagenomics 'scandals': the discovery of the bubonic plague in the New York metro, the politics of scientific publishing and microbiome applications in personalised medicine. All these cases highlight the risks of a pragmatic approach if not integrated with critical reflective thinking. In the concluding part of the chapter I argue for the need to use a critical and reflective approach in the study of technoscientific practices, also stressing its importance in analyses of 'practices' of any kind.

In the case of microbiome science, this leads to asking questions on a bigger scale than those inherent in the 'molecular view' of microbes. In chapter 8 I outline the shift from the 'molecular' to the 'ecosystemic' view as a historical re-emergence of aspects of the cybernetic paradigm that have remained silent in molecular biology but that are necessary if we are to respond to the conceptual challenges posed by the microbiome, which are multiscale.

Chapter 9 illustrates how, in metagenomics, the ecosystemic view – despite all its political ambivalences and the critiques made by authors in the social sciences – functions as aspirational technology, or rather, as technology that not only describes relationships but which, in selecting and

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<sup>12</sup> I use the expression 'pragmatic approach' in the terms outlined above because it fits with the ethnographic situation I analyse. I do not intend to enter into the philosophical debate about pragmatism (a late 19th century philosophical tradition with several variations which saw practice and concreteness as the primary epistemological references in theory) as this would be beyond the scope of this paper (my thanks to Silvia Gherardi for suggesting I reflect on this). In chapter 7, on the other hand, I critically discuss some of the degenerations and potential negative effects arising from a simplistic use of the 'philosophies of praxis'. For an illustration of the continuities and differences between pragmatism and the contemporary 'practice turn'. See Višňovský, 2018.

describing them, actually creates them. On this basis, I envisage an interdisciplinary collaboration between metagenomics and anthropology that is capable of reconfiguring the pragmatic approach in the context of a multiscale reflection on the meaning, scope and ethical-political impact of technoscientific practices.

The conclusion was written at the beginning of March 2020, under the shadow of the COVID pandemic outbreak, which was just beginning. The main themes of the book are summarised focusing in particular on the methodological and theoretical proposals discussed in the previous chapters, and how these may help to make sense of this new era, now opening with the pandemic.

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