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Living Through Multispecies Societies: Approaching the Microbiome with Imanishi Kinji

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Abstract
Recent research about the microbiome points to a picture in which we, humans, are living through nature, and nature itself is living in us. Our bodies are hosting – and depend on – the multiple species that constitute human microbiota. This article will discuss current research on the microbiome through the ideas of Japanese ecologist Imanishi Kinji (1902-1992). First, some of Imanishi's key ideas regarding the world of living beings and multispecies societies are presented. Second, seven types of relationships concerning the human microbiome, human beings, and the environment are explored. Third, inspired by Imanishi's work, this paper develops the idea of dynamic, porous, and complex multispecies societies in which different living beings or species are codependent on others, including microbiota and human beings.

Keywords: microbiome, multispecies societies, environmental ethics, Imanishi Kinji, Japanese philosophy

1. Introduction

The natural environment that surrounds us is understood in many worldviews to be a simple receptacle for human activities. Yet, recent research about the human microbiome points to a different picture, in which we, humans, are living through nature, and nature itself is living in us. Our bodies are hosting – and depend on – the multiple species that constitute human microbiota. This paper brings ideas of the Japanese ecologist Imanishi Kinji (1902-1992) into dialogue with recent developments in the research of the human microbiome. This interdisciplinary paper lies at the crossroad of environmental ethics, Japanese philosophy, and transdisciplinary sciences around the microbiome. It draws contributions from Imanishi's work that are relevant to understand our relationships to the human microbiome and highlights how these contributions could influence our understanding of what it is to be human and what our place in the world is. This paper's conclusions sketch how we relate to and live within dynamic, porous, and complex multispecies societies. They open a range of further questions and possible fields of research in environmental philosophy and policy, public health, multispecies studies, interdisciplinary and, among others, cross-cultural sciences.

The first part of this paper outlines the current scientific view of the human microbiome to then explore Imanishi's "World of Living Beings", more specifically his ideas regarding the world of the individual living being, multi-level multispecies societies, and territorial communities. From these ideas, the second part distinguishes seven tentative types of relationships concerning the nexus human

microbiome – human beings – and the environment, which are examined by returning to and reflecting on contemporary scientific microbiome research. The third and last part attempts to re-imagine our bodies, our communities and our world as complex and multiscale multispecies societies.

Before entering these parts, a question remains: What is the human microbiome? Human beings and the microbiological world are closely interconnected. In and on our bodies, less than half of the cells are human cells (Gilbert et al. 2018), while it is estimated that there are trillions of bacteria living in the human body (Rhodes, Gligorov, and Schwab 2013), and up to four millions distinct nonhuman genes in the human body (Feldman 2004, 205). These microorganisms live in different parts of the human body, such as the oral cavity, the vagina, the skin, and the intestine, which contains "more microorganisms than all of our other colonized sites combined" (Frank et al. 2013, 30).

Microorganisms that compose the human microbiome and the human body are in symbiosis. More specifically, different microorganisms have different types of relationships with the human body, from parasitism – where one partner benefits and the other is harmed –, commensalism – when one organism benefits while the other is indifferent –, and mutualism – in which both organisms are benefited by their interaction (Frank et al. 2013, 29). Notably, in many cases, the microorganisms that inhabit our bodies can play either parasitic, commensal, or mutualistic roles, "depending on the context" (Blaser 2006, 115).

The microbiome is a biome – a community of living beings having similar life forms and existing under similar environmental conditions – composed of microorganisms. It was proposed as an "ecological framework" defined as: "a characteristic microbial community occupying a reasonably well-defined habitat which has distinct physio-chemical properties. The term thus not only refers to the microorganisms involved but also encompasses their theatre of activity" (Whipp 1988). The human microbiome has been conceptualized in different ways (Hooper and Gordon 2001, Fierer et al. 2008, Gligorov et al. 2013, Morar and Bohannan 2019). Some suggested conceiving human beings as human-microbe hybrids, or as superorganism (Goodacre 2007). The human microbiome can also be conceived as "a collection of diverse ecological communities that interact with each other, the host, and the environment" (Foxman et al. 2008, 3). This view highlights the "interactions between component organisms and their dynamics" (Foxman et al. 2008, 3), and the effects on the host are seen as the results of these interactions. This latter view is the closest to the one explored in this article.

2. Imanishi Kinji's World of Living Beings

The Japanese ecologist Imanishi Kinji (1902-1992) conducted research regarding the animal world. Born in Kyoto in 1902, he studied agriculture at Kyoto University and practiced extensively mountain hiking (Saitō, 2014). In the end of the 1920s and in the 1930s, Imanishi used to meet regularly with the Japanese Philosopher Nishida Kitarō (1870-1945), the founder of the Kyoto School

of Philosophy (Asquith 2011, 17). He specialized in entomology and obtained a doctorate from the science faculty at Kyoto University in 1940. He wrote *The World of Living Beings* (*seibutsu no sekai* 生物の世界) in a hurry and completed it in 1940. As he explained himself: "If I died [in the war], at least I would like to leave the trace of the fact that such a biologist was living somewhere in Japan" (Imanishi 1972, 3)[1]. Imanishi's work does not focuses only on insects, but he also studied animals and their worlds. He is considered as a key founder of the renowned Japanese school of primatology. According to the primatologist Franz de Waal, Imanishi's ideas have "silently invaded" contemporary sciences (de Waal 2003). In the second half of Imanishi's life, his most famous work discusses theories of evolution such as Darwinism.

The question of what our relationship with the concrete world can be is central in the Japanese philosophy of the 20th century[2]. Several authors proposed to approach the world from our human and situated experience and warned against the attempt to abstract it – or the environment – from the concrete relations of human existence. They attempt to think of the world from the concrete relations that can be observed and lived. For example, at the same period, the Japanese philosopher Watsuji Tetsurō (1889-1960) conceptualized the idea of *fūdo* to capture how the natural surroundings and the cultural understandings and practices of a society mutually influence each other through time (Watsuji 2004). Watsuji's idea of *fūdo* also echoes the word "milieu" in ecology, and Uexküll's "Umwelt" concept[3]. The idea of milieu reflects the fact that, as human beings, we do not experience the world and the environment neutrally and abstractly; instead, we experience our surroundings as webs of meanings and possibilities for actions, which is influenced by our socio-cultural imaginary and practices (Droz 2018). These reflections are also present in contemporary concepts of biocultural habitats (Rozzi 2018) and socio-ecological systems (Partelow 2018) that attempt to grasp the intertwined relationships between human societies and the ecological world.

Specifically, some of Imanishi's ideas are useful to question and approach the relations between species and communities of species, in particular the question of the microbiome. This article adapts some ideas of Imanishi to approach relationships between different species in the microbiome or between microbiotical species and humans. For Imanishi, each living being has its own world, and is part of the world of living beings. He writes:

> "the world of living beings can be conceived as something composed with two extremes which are the individuals and the world. Each individual is at the center of its own world,

[1] Unless otherwise indicated, the page numbers for Imanishi's quotes refer to the Japanese edition of "*Seibutsu no sekai*" of 1972. All quotes from Imanishi are our own translations, informed by other translations in English (Imanishi 2013), German (Imanishi 2002), and French (Imanishi 2011).

[2] This appears clearly in Nishida Kitarō's (1870-1945) philosophy, as well as in Yamauchi Tokuryū's (1890-1982) in his major book: *Logos and lemma* (Yamauchi 1974, Jannel 2020).

[3] On the similarities and the differences between the concepts used by Uexküll, Watsuji, Imanishi, and the idea of "milieu", see: Berque 2014.

> while interacting with the whole world through societies of species, synusiae[4], overlapping synusiae, and the whole community" (Imanishi 1972, 135).

There are two key aspects here: how each living being perceives and builds its own world from its surroundings, perceptions and needs; and how all living beings relate to each other and compose together "the world of living beings". In other words, at the same time, living beings have their world, and compose a world.

2.1. The world of the individual living being

Imanishi is very careful regarding the first aspect. Concerning research about animals, he warned that "we [humans], try to understand the world of living beings from our human point of view [...]. Therefore, we can only pretend to interpret their lives and their worlds in human terms" (25). In other words, we cannot speak from the perspective of other living beings, be it animals or plants. Therefore, we cannot speak neither from the perspective of the microbiome, or from any particular individual microorganism who is part of the human microbiome. Still, we could try to imagine what the world would be for them, and it would be very different from ours. Imanishi explains:

> "The environment that a living being can recognize is, for this living being, the only environment; it is the world. The living being is the master of this environment. This means that a living being does not control only its own parts, but goes beyond its individuality to integrate its environment." (Imanishi 1972, 65)

Thus, even if the world is only one, it is different for each, as is the environment in which each living being lives and that each recognizes. Imanishi insisted that "to recognize the environment is to start dealing with it" (*hatarakikake* 働きかけ, 151). Along the same line, James Gibson later defined affordances as: "The affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill. […] It implies the complementarity of the animal and the environment." (Gibson 1979, 127).

Living beings are recognizing or knowing their world, each in their own ways, thereby cocreating their world. Their world and themselves are co-dependent and coevolve. Their ways of life are understandable only within a system that integrates their environment, and the environment is part of the world that co-evolved with them (Asquith 2011, 25). This relation of codependency and coevolution between a particular living being and its own world means that neither can be understood independently. Imanishi insists that neither has precedence over the other. This type of explanation of the relation of codependence and co-emergence is a recurrent theme in Japanese philosophy, rooted in

[4] Imanishi describes "synusia" as follow: "a synusia is a structure, a common society, resulting from the gathering of individual societies of living things. Every society that constitutes a synusia is in a relation of reciprocal opposition and cannot tolerate the others. Nevertheless, since they hold mutually the existence of the others and take the others for delimiting themselves, they maintain a mutual balance. We could even consider that they are mutually complementary considering that they fulfil, by this mean, their own society." (Imanishi 1972, 104)

Buddhist philosophies[5]. Similarly, a human being cannot live without its microbiome and many microorganisms living in or on the human body could not flourish *in the same way* without the human body.

Imanishi repeatedly questions the limitations of what can be controlled and governed by the living being, be it its environment or its own body. He suggests that the living being and its body are integrated with their own world by nature; they are inseparable. The living being regulates and controls itself and its world thanks to being integrated with its environment through its body. Regulation and control are spatially expressed and can be operated only within a specific sphere or frame (Imanishi 1972, 57), which are limited by what the living being can recognize, that forms its own world. Further, Imanishi writes that if we consider the environment as something that the living being cannot freely build and change, we must deduce that "the environment enters until the inside of our bodies" (73). In other words, our body, which cannot be freely constructed and transformed, is in some way "an extension of the environment" (73).

Along this line, the human microbiome could be considered as an extension or a part of the environment of human beings. Imanishi suggests that the word "living being" can be used for plants and animals, also for amoeba, but a priori not for cells, which are the components of a living body, while he points out to the difficulty of drawing such a clear limit (41-42). Nevertheless, he insists on the importance of the body, and notes the difficulty to determine a concrete border between body and life (64)[6]. From the perspective of the living being, the body can be seen simultaneously as a medium to interact with the environment, and as an extension of the environment. These considerations point towards a worldview where bodies and the environment are porous, and the borders between them, as well as the extent of our control on them, are blurred and possibly flexible. In other words, living beings could be understood as *living through* nature and the world (Droz, 2020). Imanishi writes:

> "Living, for living beings, means the subjectivation of the environment *through* the body; and, inversely, the environmentalization of the subject *through* the body." (Imanishi 1972, 152, emphasis added)

Inspired by Imanishi, this paper suggests that the human microbiome and the several types of relationships concerning the human microbiome exemplify the porosity and dynamicity of living *through*, both in terms of the subjectivation of the environment and the environmentalization of the

[5] Such ideas are fundamental in Classical Indian Buddhism, and more specifically the concept of "dependent co-arising" or "conditioned co-arising" (*pratītyasamutpāda*), which does not define a relation of causality but the synchronical arising of, at least, two elements through a relation of functional dependency to the other. This concept is philosophically discussed by Yamauchi Tokuryrū in his major book *Logos and lemma*. There exists no English translation of this work, but a French one was recently published. (Yamauchi, Berque, and Jannel 2020, 175-216).

[6] For example: "the body is the expression of the way of life. It is *through* the body that the living being and the environment interact, and the foundation of this way of life lies at the heart of these interactive and reciprocal negotiations" (Imanishi 1972, 150, emphasis added)

subject. Before diving more into these questions, what multispecies societies are for Imanishi must be clarified.

2.2. Multispecies societies and territorial community

How do living beings live together? How do they relate to each other and compose together "the world of living beings"? Imanishi explored these questions at length. In *The World of Living Beings*, he builds his argument step by step, adding complexity and revising previous assertions as he writes the book. In this article, two key concepts were selected and developed from Imanishi's work: Multispecies societies and territorial communities.

Studying animal species, Imanishi proposes ideas such as "complex societies", "societies of same level" (which he himself translates as "synusia"), and mentions complex composed societies. Here are some of the key building blocks of Imanishi's argument:

> "We know that what we called "individual" (as the gathering of cells), "society" (as the gathering of individuals), or synusia (as the gathering of societies) – as the elements of a system based on every of its different parts –, are constructing in the world a world of living things." (104-105)

Further, he describes how different categories of living beings (mammals, vertebrates, etc.) cohabit and how they compose structured societies. These societies of same species also interact with each other. He proposes to see "societies" composed by different groups of different species as "communities", or "complex societies" (116)[7].

Imanishi analyses the relations of species sharing a common habitat between each other from the perspective of societies to complement the widespread perspective focusing on individuals (Imanishi 1980, 107). He observed how Schistonota[8] were agglomerating in different groups that avoided contact between each other by dividing the space of the same river depending on the speed of the waterstream. From this perspective that puts societies in the spotlight, he describes how each species lives in their own space. The keyword he uses to this end is the concept of "*sumiwake"* (棲み分け), which he translates as "habitat segregation" (110). The Japanese word "*sumiwake*" is composed of "*sumi*", which means to inhabit, to live, and "*wake*", which means to separate, and hints to a separation of the habitats. It refers to a process —and not a fixed state of affairs, as it is also used as a verb— meaning that species divide their habitat (*sumiwaketeiru* 棲み分けている, 107). Imanishi develops the idea of a fragile "demarcation line between two similar species" (133), like a moving dynamic equilibrium line of forces between two societies of similar species, according to which each group would adjust their behaviours.

[7] He distinguishes these "complex societies" from "complex synusiae", the latter being a set of societies that are all "at the same level".

[8] Schistonota (*hirata kagerō* ヒラタカゲロウ) is a suborder of mayflies in the order Ephemeroptera.

Imanishi thus expresses the sociality of a species of animal or plant both intrinsically and extrinsically (Berque 2015, 178) Intrinsically, the idea of complex society encapsulates how the members of the same species or group, together, form a society. Extrinsically, the concept of habitat segregation sheds light on the relationships between different species that, together, form a society. Finally, for Imanishi, these societies and multispecies societies are closely linked to their habitat. Together with their environment, multispecies societies compose the world of living beings, that is, Nature[9]:

> "This territorial community of all living beings, it is nature as we see it. Meanwhile, starting from the individual to society of species, to synusiae and to overlapping synusiae, it forms in this sense the only wide-encompassing society of living beings" (Imanishi 1972, 128)

All living beings that share a specific habitat form together the "world of living beings" —which is distinct from the world of each individual living being. This "world of living beings" (*seibutsu no sekai*) amounts to nature. The territorial communities are interdependent and interconnected regionally, but also globally, at the planetary level.

All in all, Imanishi provides a wide-encompassing view on the world of living beings that accounts for: how each living individual perceives and builds up its own world (2.1.); how living individuals compose societies (2.2.); and, how these societies interact with each other and share their habitat; and how all living beings compose together "the world of living beings".

3. Multispecies relationships

As shown by Imanishi's work, the world of living beings is a web of relationships between, for instance, individuals, species and groups of species. The example of the human microbiome appears to illustrate this complex web of relationships. Multispecies relationships can be approached at different scales, and not all relationships have the same strength. This part explores these different relationships from a micro-scale up to a more abstract global scale. As a foreword, these relationships are of mutual influence, but the scale of the specific effects, and the nature of these effects is set aside and requires further scientific research. The following discussion is based on the current available evidence, approached from philosophical lenses inspired by Imanishi's work. Building on Imanishi's perspective, we distinguished seven types of relationships concerning the human microbiome. The figure below illustrates the seven types of relationships that this paper draws from the human microbiome (Figure 1).

[9] For Imanishi, the idea of nature includes the community of all living beings, and the productions of these communities.

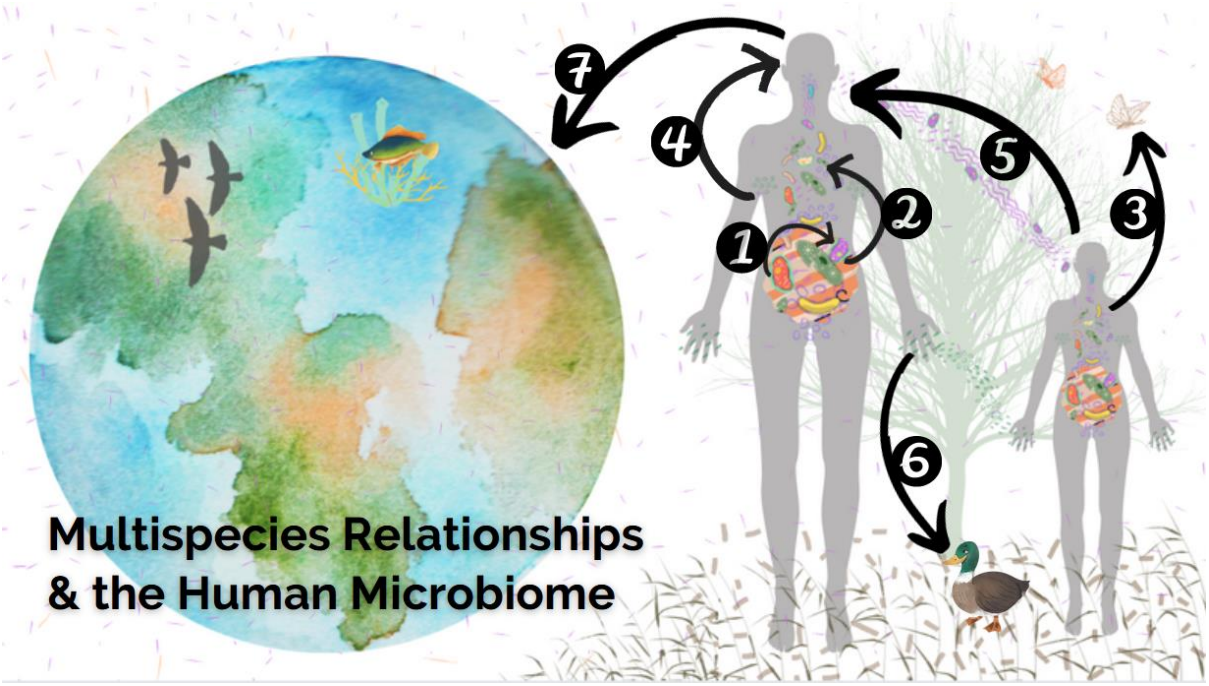

Figure 1: Multispecies relationships and the human microbiome - Seven types of relationships (own figure). This Figure offers a representation of the seven relationships discussed in this article: (1) Relationships between species within the human microbiome, and between microorganisms; (2) Relationships or absence of relationships between regional microbiomes within the human body; (3) Relationships between the human microbiome and the external environment; (4) Relationships between the human microbiome and the host; (5) Relationships between different human beings' microbiomes; (6) Relationships of local human communities with their local environment, in light of the microbiome exchanges with the surroundings; (7) Relationships between human beings and the environment. The duck represents animals, including domesticated animals, walking on soils that also host a countless of other living species. The butterflies and the tree illustrate the external environment as including other living species such as insects and plants. The thickness of the arrows does not represent different strengths of relationship.

1) Relationships between species within the human microbiome, and between microorganisms

A characteristic of Imanishi's work on the world of living beings is that he pays close attention to how an individual of one specific species relates to other individuals in the same species, and from other species. From there, a first type of relationships between species within the human microbiome, and between microorganisms was selected.

From the reviewed scientific evidence, we know that diverse species of microorganisms live at different places within and on the human body. The microbial community composition varies upon time, external factors, the regional microbiomes, and the sites within an organ system. The human newborn receives microbiota from the mother, and the microbial population changes throughout the life, depending on various conditions, from the ways of life to the occurrence of diseases (Johnson and Versalovic 2012) (Johnson and Versalovis 2012). The human microbiome comprises hundreds of bacterial genera and species, dominated by the *Bacteroidetes, Firmicutes, Actinobacteria* and the *Proteobacteria* (Dekaboruah et al. 2020) (Elakshi 2020). The population of these species vary among individuals and sites within the human body.

What species can live in what site of the human body depends on the habitat conditions, for instance, on what acidity or basicity (as measured by pH) a species is tolerant too. This separation of habitat of different species echoes Imanishi's idea of habitat segregation. For example, the skin includes a wide range of habitat covering about 1.8m2 with specialized niches (Chiller, Selkin, and Murakawa 2001). The mouth hosts one of the most diverse microbiomes, and some microorganisms in the oral cavity inhibit the establishment of many other microorganisms (e.g. *Streptococcus salivarius* strain K12 (Wescombe et al. 2009)). In many cases, the myriad of microorganisms present on and within the human body is not strictly passive; some microorganisms interact – or could interact – with each other and with their habitat. For instance, some residents in the human oral cavity contribute to process some complex carbohydrates, such as gluten (Helmerhorst et al. 2010), while others synthesize vitamins (Dagli et al. 2016).

Within a particular site, microorganism species interact with each other, sometimes indifferent to their sharing of habitat, sometimes resisting another species' colonization. In the conceptualization of the microbiota as an ecological community, "each species or strain of the microbiota interacts with other members of the microbiota and with the host" (Foxman et al. 2008). Yet, according to Foxman and colleagues, the interactions among microbiota "remain almost completely unexplored", and most research focuses on the "independent relationships between each member of the microbiota and its human host, but not among the microbiota themselves". There is a knowledge gap possibly related to "the inability to culture most bacteria from our world, including from our own bodies" (Handelsman 2008). Nevertheless, regarding the relationships between species within the human microbiome, and between individual microorganisms, based on insights from other ecosystems and species communities, it is likely that several species of microorganisms cohabitating sometimes also collaborate and have mutualistic relationships, meaning that their coexistence mutually benefit each other – and potentially the host, too. In a way, these relationships of interdependence between microorganisms reflect what Imanishi has described regarding the animal world.

2) *Relationships or absence of relationships between regional microbiomes within the human body*

Imanishi clearly distinguishes individuals, species, and groups of individuals within a species, that form societies. He explores concepts to capture various scales of organizations of living beings, such as societies of species. He discusses how there are societies composed of the same species, and societies composed of different groups of species and investigates how these relate to each other and share the same habitat. From there, we draw a second type of relationships that encompasses relationships between regional microbiomes within the human body.

According to scientific research on the human microbiome, some territorial microbial communities have relationships with one-another, that is, some microorganisms can move from a

community to another. For example, the *Proteobacteria Neisseria* can be found in the mouth microbiome and in the stomach, while other microorganisms are specific to particular sites within the human gastrointestinal microbiome (Martinez-Guryn, Leone, and Chang 2019). Some oral microbes are continuously moving in the gastrointestinal system by ingestion, but some of them cannot remain in other sites, or can promote some disease when staying (Schmidt et al. 2019). In other words, the same species of bacteria that flourishes in one microbiome could perish or harm another microbiome. Some microorganisms can travel – or be moved between the several regional microbiomes in different sites of the human body (skin, oral cavity, respiratory tract, gastrointestinal tract, urinary tract, and vagina). Regional microbiomes are not uniformly inhabited, for different species colonise distinct areas within a regional microbiome. To reinterpret Imanishi's thought, this could be described in terms of habitat segregation and territorial microbial communities within the human body.

3) *Relationships between the human microbiome and the external environment*

If different societies of microorganisms have their habitat in different sites within the human body; they do not exclusively inhabit within the human body and some of them can change of habitat, including in the external environment outside the human body or in other animal species. Imanishi insists that habitat segregation is dynamic and can change depending on environmental constraints, as well as depending on the behaviours of organisms. He discusses closely the question of scale concerning different multispecies societies and territorial communities. In addition, he focuses on the perspective of the individual animal *from the perspective of this individual animal*, and not the perspective of the researcher. In the context of the microbiome, this points to the fact that from the perspective of a microorganism, a proper habitat can be inside the human body or outside. Therefore, what consists of a habitat for a particular microorganism does not necessarily overlap with the categories we, human researchers, use. From there, we draw a third type of relationship: the relation between the human microbiome and the external environment.

Studies show that some microorganisms travel beyond the human body (Callewaert, Ravard Helffer, and Lebaron 2020; McCall et al. 2020). For instance, the human skin microbiome is impacted by the living environment of the human host (Ying et al. 2015; Vandegrift et al. 2019). Beyond the human microbiome, the diversity of microorganisms in ecosystems on Earth is too vast and research too fresh to be estimated. In the environment outside the human body, microorganisms can travel surprisingly large distances, for example through winds, rains, rivers, currents, as well as riding on migratory birds, mammals, fish and insects. Four main processes drive the biogeography of both micro- and macro-organisms: selection, drift, dispersal and mutation (Hanson et al. 2012; Vellend 2010). Microorganisms can travel particularly far through distance and time, because they can become dormant, that is, have an extremely low – almost absent – metabolism, especially during periods of unfavourable environmental conditions (Cáceres and Tessier 2003). Many microorganisms 'sleep' most of their lifetime, and the longer they do (sometimes millennia), the further they can be dispersed

before dying. They can become active and increase their population when they encounter suitable environmental conditions, and some can while dispersing, too. Some microorganisms return to their source environment after dispersion, some 'wake up' before arrival to their destination – suggesting that they are somehow able to detect it –, some interact with other environmental elements to orient their travel, and some even hitchhike on migratory species (Grossart et al. 2010). These considerations prompted Mestre and Höfer to propose the idea of "Microbial Conveyor Belt": a "global, recurrent, and spatially cyclical dispersion of microorganisms" (Mestre and Höfer 2020). Microorganisms travel the world through this conveyor belt and find suitable habitats in faraway seas and lands around the globe. Doing so, they "permanently connect very distant communities, the ecosystems that they inhabit, and the biogeochemical cycles in which they play key roles", such as carbon and nitrogen fixation in soils and oceans (Mestre and Höfer 2020, 7).

Many of the microorganisms that exist outside the human body probably never enter into contact with human beings, while playing key roles in the ecosystems that support human life. Some do enter into contact with humans without any mutually beneficial or harmful interaction. Other microorganisms that existed for a long time outside of the human microbiome can enter into contact with humans, mutate, and sometimes lead to diseases, such as zoonotic diseases that can lead to pandemics (IPBES 2020).

4) Relationships between the human microbiome and the host

The mutual influence between the individual animal and its environment lies at the heart of Imanishi's work. As described above[10], he explains the transformation of the individual animal by its environment, and the transformation of the environment under the influence of the individual. Regarding the human microbiome, this echoes the relation between the human microbiome and the host, the host being the environment of the microorganism.

The relationships between microorganisms and the human host can be mutually beneficial, indifferent to, or harmful to the human host. The human microbiome is playing a key role in human health. For example, digestion relies on diverse microorganisms hosted by the gastrointestinal system. Microorganisms living in,or entering the human body can also cause inflammations and diseases, and research have been relating some specific microorganisms or disruptions of the human microbiome to cancer, asthma, and others (Martinez-Guryn, Leone, and Chang 2019; Cox, Ege, and Mutius 2019). By secreting nitric oxide, bacteria can even control host DNA expression in what has been described as a form of interspecies communication (Seth et al. 2019). The human microbial communities also act as diplomats with external microorganisms, or as protectors and key actors of human immunity. For instance, the skin is a first line of physical protection from "external aggressors", and the skin

[10] "The environment that a living being can recognize is, for this living being, the only environment; it is the world. The living being is the master of this environment. This means that a living being does not control only its own parts, but goes beyond its individuality to integrate its environment." (Imanishi 1972, 65)

microbiome is central in this function (Callewaert, Ravard Helffer, and Lebaron 2020). Along this line, Scott Gilbert, Jan Sapp and Alfred Tauber point to a paradigm shift in conceptions of the immune system, and depict it as "managing its microbial (dis)entanglements with two arms": the body's armed forces, and a regulatory network, "passport control", which "has evolved to recognize and welcome those organisms that help the body" (Gilbert, Sapp, and Tauber 2012, 332). This perspective hints to an "ecological model of immunity as involving a multispecies community" that includes "the proactive recruitment of, and experimentation with, new microbes" (Lorimer 2016, 69). Moreover, some studies suggest that the microbial communities living within our gastrointestinal system could influence our moods – they might even influence our experience of ourselves and the world[11].

5) Relationships between different human beings' microbiomes

Imanishi's exploration of multi-scaled multispecies societies sheds light on the ways different individuals and different species relate and compose multispecies societies. This idea can also be applied to the relationship between microbiomes inhabiting different human bodies, at different scales. There can be a relationship between the microbial communities of different human beings (Morar and Bohannan 2019). Some microorganisms can travel from a human host to another, by direct physical contact or through air and other fluids. The most important transmission of microbiomes, both in terms of population and diversity, between two human individuals is from the mother to the newborn (Johnson and Versalovis 2012). Yet, we exchange microorganisms daily with each other throughout our life. Infectious contagious diseases, such as the flu, are an example of exchanges of microorganisms between individuals, one of the very few exchanges we pay attention to when they cause noticeable symptoms. Pandemics are a large-scale example of widespread transmission and exchanges. In general, transmission can happen by direct contact, droplet spread, but also by "indirect transfer of an agent from a reservoir to a host either by being suspended in air particles (airborne), carried by an inanimate objects (vehicle borne), or carried by an animate intermediary (vector borne)" (Dicker et al. 2006; IPBES 2020). Beneficial microorganisms can also be transmitted between individuals (e.g. Finlay and Arrieta 2017), as exemplified by the practice of fecal microbiota transplantation (Wang et al. 2018). Microbiomes can also "produce chemical signals used in social communication" (Archie and Tung 2015).

These suggest that habitat segregation – in Imanishi's sense – of the microbiome does not depend exclusively on environmental factors, but also on the behaviours of the different living beings.

[11] The gut microbiome has been shown to play a crucial role in the bidirectional communication between the gut and the central nervous system, including endocrine, humoral, metabolic and immune routes. That is, the gut and the brain are connected, "allowing the brain to influence intestinal activities, including activity of functional immune effector cell; and the gut to influence mood, cognition, and mental health" (Appleton 2018). Research has linked mood disorders to microbial diversity and taxonomic compositions different than in healthy individuals (Huang et al. 2019).

Microbial habitat segregation remains a separation of habitat between different communities of microorganisms, but the microbiomes of different human hosts still have exchanges and evolve also through mutual influences. In the specific case of the human microbiome, the habitat segregation of microorganisms is also greatly influenced by the behaviours of the hosts, namely, human beings.

6) *Relationships of local human communities with their local environment, in light of the microbiome exchanges with the surroundings*

As explained earlier, for Imanishi, the diverse multispecies societies are closely linked to their habitat. He describes this phenomenon as territorial communities that are interdependent and interconnected regionally. Regarding the human microbiome, the diverse multispecies societies of the human microbiome can be explored in relation to their territorial communities – in Imanishi's sense –, as well as the relationships of local human communities with their local environment, in light of the microbiome exchanges with the surroundings.

Observations of the interrelations between human health, the human microbiome, and the external environment inspired research to explore the relationships of the local human communities with their local environment in light of the microbiome exchanges with the surroundings. Specifically, recent studies investigate how we, humans, could design our living environment in a way that favours beneficial microbial exchanges (O'Doherty et al. 2016, Houston et al. 2017). For instance, some have explored the impacts of the built environment on health, mediated by changes in the microbiome, and proposed pathways to intervene in the built environment in order to reduce exposure to hazardous microbes and encourage exposure to beneficial microbes (Medicine et al. 2017). Some studies suggested that biodiversity interventions – exposing children to highly biodiverse surroundings in contrast with less biodiverse surroundings like urban environments – could have significant beneficial effects on health, through exposure to a "wide spectrum of environmental microbes, including microscopic invertebrates, protozoa, fungi, archaea, and viruses" (Roslund et al. 2020). Others suggest shifting urban planning towards multispecies cities and landscapes with green infrastructure such as urban parks and green roofs "designed to promote beneficial interactions between humans and environmental microbiota" (Robinson and Jorgensen 2020, 343).

The reasoning that underlines such initiatives rests on the premise that humans have co-evolved with diverse microorganisms within biodiverse surroundings, and that this co-evolution is central to the resilient immune system. Then, the shift of some populations to highly urbanized and less biodiverse environments could explain the rise in some immunological dysfunctions and allergic disorders. In other words, we suffer the consequences of disturbing our relationships with our old friends microorganisms – hence this reasoning is sometimes referred to as the "Old Friends hypothesis" (Rook, Raison, and Lowry 2014). It would suggest a novel interdisciplinary approach to public health around the nexus of the environment, the microbiome, and human health (Flies et al. 2017). This view meets approaches that bridge human health, environmental health and animal health,

such as planetary health and "One Health" (van Bruggen et al. 2019; IPBES 2020; Prescott and Logan 2017; The Lancet Planetary Health 2017). These approaches face various challenges, concerning implementation, but also knowledge –there remain important knowledge gaps, for instance in the specific health benefits of living in biodiverse environments for adults – and imagination (Gabrysch 2018). In other words, our relationships with other species, and the relationship between human communities and the local environment, could be re-imagined (Rupprecht et al. 2021).

Imanishi's ideas of multi-scaled multispecies societies provides us some keys to re-imagine the relationships between different species inhabiting a place. Specifically, habitat segregation does not mean a simply spatial or geographical distribution; instead, it concerns the specific relationships of a species or a community to the milieu or the local habitat. Moreover, Imanishi's work also highlights the intertwinement and mutual influences of multispecies societies in their various relationships with diverse habitats. From there, the human body and its human microbiome could be considered as a small-scale multispecies society, that is in interaction with other multispecies societies outside of the body, including those hosted in other human bodies. Multispecies societies could be considered at a larger scale that encompasses a territorial community, including groups of human beings and other species, and their microbiomes. A village and a city would be multispecies societies, including the wildlife, plants and animals living in a region. Moving upscale, biomes and even the biosphere could be considered multispecies societies. In the same way the expressions of "Japanese society" or "global society" are used, we could speak of regional multispecies societies, or maybe of a global multispecies society. Notably, moving upscale does not remove the existence of smaller-scale relationships and exchanges. Neither does it simplify its complexity. On the contrary, it can be assumed that the complexity of the web of relationships of a multispecies society increases when its scale is enlarged, for it includes more living beings and more diverse species and ecosystems. Therefore, these multispecies societies are complex in Imanishi's sense.

7) Relationships between human beings and the environment

Finally, notably throughout his book *The World of Living Beings*, Imanishi insists on how we, human beings, perceive and build our own world, namely, the relationships between human beings and the environment. The relationships composing the webs of the world of living beings are highly diverse, with different strength, and harmful, neutral, or mutually beneficial influences. The interconnected webs of relationships around the human microbiome were explored from the micro-scale up to the global scale. These explorations raise more abstract questions concerning how we imagine what it is to be human, our body, and our relation to the environment. Specifically, inspired by Imanishi's work and microbiome research, our bodies, our communities and our world could be re-imagined as complex and multiscale multispecies societies, as shown in the following part.

4. Our multispecies societies

The webs of relationships described above highlight the fact that an exclusively human society does not exist – and maybe it cannot exist, at least not for a society of human beings as we know them now. We live in multispecies societies that are interconnected at different scales with *other-than-human* living things. Different groups of the same species interact and live together (as in Imanishi's discussion of synusia), and we could imagine that different microbial societies continuously interact with human societies. In our daily life, we might not be aware of it, and we might not see it, but our bodies are travel hubs for some microorganisms, and our health depends on, and can be affected by it. Human health, animal health and environmental health are interdependent and interrelated as recent approaches of public health and planetary health recognize (IPBES 2020).

These considerations regarding the interconnectedness of the world of living beings echo the idea of multispecies well-being. Multispecies well-being is "the state of two or more species' interdependent needs being met" (Rupprecht et al., 2020). It rests on the assumption that the "needs of one species cannot be met independently, but rather requires the needs of other species to be met" (idem):

> Multispecies well-being emerges from and depends upon a set of complex relations shaped by the agency and transformative potential of all members involved, even if this agency and potential is expressed in different ways. From this derives the need for multispecies stakeholders; especially stakeholders representing the needs of other species in human multistakeholder spaces. (Rupprecht et al., 2020, 5)

The description of how multispecies relationships are weaved and how multispecies societies are composed and interact corresponds to the "external" set of questions approached by Imanishi, whereas these latter observations aim at Imanishi's more "internal" set of questions, namely, how each living individual perceives and builds up its own world[12].

We can only attempt to vaguely imagine how a microorganism within our gut perceives and builds up its own world, from a largely different sensory apparatus and nervous system than ours. From scientific observations of the behaviours and functioning of this microorganism, the story of its experience could be sketched from approximations and anthropomorphist extrapolations. Yet, as Imanishi explained, we can never *know* the world of a non-human living being from its perspective, while we are trapped in our human cognitive system. Still, these human-built narratives of the imagined life and worlds of other species can help us widen our own world. They can influence the webs of meanings and significations of the world we experience and live in.

This warning can be another key contribution of Imanishi Kinji – and Japanese environmental philosophy – to the contemporary debates around rethinking our relationships to the natural world and multispecies societies. We shall not forget that we experience the world through human sociocultural lenses. We cannot experience the world of other species from their perspective. Yet, we could

[12] These observations can serve as a foundation to develop ideas of multispecies sustainability, to approach planetary health and biodiversity conservation, as well as to rethink our relationships with other species, and to re-imagine what our world *is* (Droz 2019a).

welcome other species within the webs of meanings that compose our world, and we could give them a more central place as agents or stakeholders of our multispecies societies.

Living beings have their world and compose a world, as Imanishi's work shows. Each of the seven types of relationships concerning the human microbiome sheds light on a facet of the world of the human microbiome, as we, human beings, understand it. These facets could be approached as several worlds – or milieus – at different scales, with different multispecies societies. Imanishi's attempt to approach the world of living beings at different levels (individual, society, synusia, complex multispecies societies, etc.) highlights the need to pay attention to how these different levels of analysis influence each other, and that they should not be assimilated within one single milieu. Regardless of the scale or the analysis grid selected, these worlds are porous and interconnected. The analysis of the human microbiome in this paper highlights that we are living through the world, continuously interacting with diverse species, and that we are shaped by these interactions and shaping the world by them. Flows of air, water, and microorganisms keep crossing the porous and dynamic borders of our bodies and communities (Droz 2020).

We could rethink our world from such understandings of porous, dynamic and intertwined multispecies societies. They impact how we understand our body and self, as well as how we perceive and design the sociocultural and ecological milieus we live in. Porosity and dynamicity are two central ideas in this conception of our multispecies societies. Dynamicity unfolds through time, which is not abstract, but concretely channels multispecies societies. It could be hypothesized that time also channels multispecies societies' evolution. This hypothesis would be in line with Imanishi's description of how, within a single site, different groups of the same species can segregate their habitat and specialize through time.

Finally, to recognize the lenses through which we see and build our world, and to widen our worldviews to place ourselves within dynamic multispecies societies, could help us to shift our focus from our individual life and death to the ways in which we weave our life within these webs. These ways and the milieus that support them can be transmitted to others and continue to exist beyond our death. In other words, *how* we choose to live, as well as the values and projects that matter to us now can outlive us (Droz 2019b). Along this line, Imanishi notes that when we die, individuals who resemble us because they were shaped by the same milieu continue to exist. Because we leave behind individuals similar to us after our death, the place that we used to occupy in the world is preserved (Imanishi 1972, 79-80). It follows that *our* world and our milieu continue to exist beyond the individual's death. In other words, the world of living beings can exist in the future, because we exist and live it in the present. Then, it is ever more crucial to understand better how we build our world within multispecies societies, and how we could design milieus that embrace our place within multispecies societies through our present worldviews and ways of life – for they will shape and influence the future worlds of diverse species, including ours.

5. Conclusion

For Imanishi, living means the subjectivation of the environment through the body, and the environmentalization of the subject through the body (Imanishi 972, 152). Taken together, the seven types of relationships that interweave us with our microbiome and the environment exemplify this porosity and dynamicity of living *through* the world. Our discussion hints towards a more fluid way of living in the world. It draws a picture in which diverse species have their own place and their own role and do not overstep others' space unnecessarily – as in Imanishi's idea of habitat segregation. We live hosting other species and being hosted by other species. Each of us, as embodied individuals, are a part of microbial multispecies societies.

What are the implications for us to be living together with these multiple other species? How do we relate to each other within our multispecies societies? How can it influence environmental ethics and policy? This paper opens a plethora of questions that go beyond its scope. For instance, environmental ethics could be framed in terms of the place we, humans, leave to other species in our surroundings, and within our bodies. The complexity of the multispecies societies we live in far outstrips our understanding of it, and, despite a growing body of evidence, it will continue to be beyond our full comprehension for a long time. Then, as our health depends on these multispecies societies, the precautionary principle (Jonas, 1979) would urge us to be careful and refrain from disturbing too deeply the other species we share the world with and their habitats. The complexity of multispecies societies and their interrelations could imply a withdrawal of our interventionist urge to control and manage them, and the recognition of the fact that other species build their own worlds and contribute to our world (Houston et al. 2018). In place of trying to control and manage other species, we could try to understand them better in order to collaborate with them and to nurture the codependent relationships that bind us together.

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