WHY BIOMEDICINE NEEDS AN ECOLOGICAL THEORY OF THE BODY

by

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Abstract

Family physicians were surveyed and interviewed during the COVID-19 pandemic to determine their perception of both pathogenic and symbiotic microbes. Evidence from a brief survey, a series of interviews and a review of recent literature suggests that a paradigm shift is occurring away from the germ theory of disease causation and towards an ecological theory of the human body. Conceptions of the human body are shifting from seeing the body as a nation-state at war with invading microbes towards an ecological view which sees human bodies as forming and embedded within microbial ecosystems, which are themselves under ecologic threat. The global challenge of antimicrobial resistance requires cross-disciplinary collaboration and a better understanding of how differing conceptions of the body and microbes may influence the success or failure of policies designed to minimize the inappropriate use of antimicrobial medications in clinical practice. Further research is needed to develop policies that encourage microbial stewardship as an alternative approach to antimicrobial stewardship.
Lay Summary

Practicing Family Physicians were interviewed and surveyed during the COVID-19 pandemic to understand how they perceive and respond to microscopic life forms such as bacteria and viruses. This research was performed to help address the problem of antibiotic drug resistance which is partly caused by the overuse and misuse of antibiotics to treat illness. There have been efforts to reduce unnecessary use of antibiotics, but these efforts fall short of showing the results required to have an impact on this serious problem. Antibiotic resistance is a global problem and needs to be addressed using interdisciplinary knowledge, including that of social scientists who can help doctors and policy makers make changes. Knowledge from this study can help us understand human bodies as part of natural ecological systems, including microscopic ecosystems within and outside of the body. An ecological understanding of how microbes and human bodies interact is essential to help confront the problem of antibiotic resistance.
Preface

This research was designed by the author under the supervision of Dr. William McKellin.

Research data was collected and analyzed by the author. Approval was obtained through the UBC Behavioral Research Ethics Board, certificate No. H20-01025 approved June 18, 2020.
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List of Abbreviations

AMR - antimicrobial resistance
CMV - cytomegalovirus
H1N1, H5N1 - refer to specific severe strains of the influenza virus.
Pip-Tazo - piperacillin/tazobactam
UTI - urinary tract infection
Glossary

Antimicrobial – a natural or synthetic substance that can kill or block the growth of microorganisms.

Antimicrobial resistance – the immunity that some microbes develop to antimicrobial medicines such as antibiotics.

Antimicrobial stewardship – the effort to limit the overuse of antimicrobials to prevent antimicrobial resistance.

Biomedicine – the system of westernized medicine such as that practiced in Canada.

CMV - cytomegalovirus (a common virus that is usually not a clinical concern in healthy individuals)

Dysbiosis – a state of ecosystem imbalance in the human microbiome which is associated with ill health.

Pathogen – a microbe which causes harm to the organism it infects.

Pip-Tazo - piperacillin/tazobactam (a powerful antimicrobial drug)

SARS-CoV-2 – the name of the SARS (sudden acute respiratory syndrome) virus that causes COVID-19.

Superbug – a vernacular term to describe a microbe that has developed antimicrobial resistance to most or all currently available antimicrobials.

Symbiosis – describes an interdependent and mutually beneficial relationship between two living organisms.
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Chapter 1:

1.1 Introduction

“The modern doctrine of bacteriology is a gigantic mistake… we are already at the parting of the ways… it is safe to predict that, ere long, it will come to be recognized that these various bacilli play a beneficent role in the economy of Nature.”
- Dr. Granville Bantock, M.D., Consulting surgeon, Samaritan Free Hospital, London (Bantock 1899, 4)

When Granville Bantock addressed the British Gynecological Society in 1899 he was taking issue with the accepted germ theory of disease causation and proposing an alternate understanding of bacteria. It has taken over one hundred years for his prediction to come true, but the importance of beneficial bacilli in the ‘economy of Nature’ is now well accepted. This paper explores why and how the medical conception of microbes and ‘germs’ has changed in recent years.

It is still often suggested that our skin is the ‘first line of defence’ against microbes such as bacteria, viruses and fungi, which must be “kept out” to avoid infection and illness (Padbury 2008). A concept of the human body as separate from and threatened by external microbial entities underlies the germ theory of disease causation, which was developed by scientists such as Louis Pasteur and Robert Koch during the latter half of the 19th C. (Byndloss and Baumler 2018). Germ theory established bacterial pathogens as the leading cause of communicable diseases and has altered the course of human history by enabling humanity to confront and largely suppress lethal infectious diseases such as diphtheria, tuberculosis and syphilis (Rappuoli 2004). A conceptual notion of the human body as a “nation state” has served for many years as the dominant conceptual framework for how doctors think about these kinds of infectious agents (Martin 1990).
An alternative conception of the human body now exists which does not represent the body as a nation state, with borders and boundaries separating it from its microbial environment. This alternative representation views bacteria and viruses as being essential to the healthy physiologic function of the human body, which itself functions within a larger ecosystem. For example, skin is viewed as not just a ‘line of defense’ against microbes, but also as the habitat of important beneficial species (e.g. *Staphylococcus epidermidis*). These species interact with skin and immune cells and can bolster the body’s defenses against infection by harmful pathogens (Eisenstein 2020). The typical microbes associated with the human gut come from a range of bacterial phyla, including *Bacteroidetes, Firmicutes, Actinobacteria, Proteobacteria and Verrucomicrobia*. These bacteria share their habitat with other lifeforms such as archaea, yeasts and phages (Lynch and Pedersen 2016, 2371). This diverse collection of beneficial bacteria and other species has co-evolved with humans and collectively performs numerous micro-ecological functions which are essential to human development, immune system formation and function, digestion, metabolism, and cognition (Lynch and Pedersen 2016; Van Treuren and Dodd 2020). Indeed, the gut ecosystem has been ascribed the physiologic significance of a ‘microbial organ’ because of the essential roles the various species play in human health (Eckburg et al. 2005).

This evolving understanding of the microbial ecologies of the human body is reflective of a paradigm shift whereby the human body is now understood as inseparable from nature, and the millions of years of coevolution between humans and microbes are acknowledged. Human bodies and microbes are now seen to be deeply co-evolved and inextricably interdependent: “tightly bounded, autonomous humans simply do not exist, and microbial activity orchestrates
the entanglement between the natural and social worlds. To think of micro-organisms as germs to be eradicated is to completely underestimate their worth” (M. Lock 2018a, 467).

This paper explores these contrasting paradigms as they are manifest in clinical practice: the paradigm of the body as a nation state as compared to the paradigm of the body as an ecologic process. I argue that an ecological view of the body is most commensurate with current microbiologic and social scientific knowledge and is most useful when considering issues such as antimicrobial resistance and global viral pandemics. The advantages of the ecological paradigm are made explicit through consideration of the clinical challenges described by the family doctors who participated in this study. I asked family doctors about their perceptions of microbial life forms because, as clinicians, they regularly deal with microbes such as bacteria, viruses, and fungi.

In the “body as a nation-state” model, microbes are generally seen as intruders and threats which can be neutralized by antimicrobials. Until quite recently most patients would recover from infections treated with common antimicrobial medications such as penicillin and tetracycline. However, patients and populations are increasingly colonized by microbes with resistance to traditional antimicrobials, which are now losing or have lost their effectiveness (Council of Canadian Academies 2019). Antimicrobial resistance is a predictable outcome of the inherent capacity of microbes (including bacteria) to rapidly adapt and evolve to escape the effects of the medications used against them (Madhav 2020). The more that antimicrobial drugs are used, the more microbes develop ways to resist the effects of these drugs. Antimicrobial resistant microbes both within and outside of patient bodies have become a serious global threat due to the widespread overuse of antimicrobials in multiple settings (Sugden, Kelly, and Davies 2016)iii. A conceptual model of the human body which recognizes
the ecological complexities of the microbial worlds the body inhabits and supports is more helpful than a nation-state model when confronting the challenge of antimicrobial resistance.

Clinical decisions about the use of antimicrobials are made based on social as well as scientific factors. Social factors include how doctors and patients themselves define and understand the human body and the relationship of that body to microbes such as bacteria and viruses. Other contributing social factors include the relationship between doctor and patient, and a further network of social relationships which extends beyond the clinic to the larger society and the medical community at large. My research was designed to assess the family physician’s role in these networks, given their job to prescribe antimicrobial drugs when needed. An understanding of how different actors in these networks conceptualize the human body can help in clarifying the social factors driving such decisions. It can also help clarify the degree to which such conceptions of the human body are historically and socially mediated constructions.

How should we describe the relationship between humans and coexisting microbes in a way which is both relevant to clinical medical practice and up to the challenges we face for population health? We are used to thinking of bodies as bounded units because that is how they have been constructed in euro-western patterns of thought and language. But acknowledging that such units are constructions of a specific worldview opens the door to a conception of the body whose boundedness is of less importance than its role within functioning systems, both social and biologic.

In the Spring of 2020 a novel coronavirus known as SARS-CoV-2 appeared and has since dominated a fearful public discourse about microbes. SARS-CoV-2 has pre-occupied family physicians, who play a crucial role at the interface of the public and biomedical
conceptions of pathogenic microbes. Portrayals of the human body as being “under siege” by outside microbial invaders are common, highlighting concerns about “germs” and perhaps obscuring the importance of beneficial microbes to individual and ecosystem health. Understanding the human/microbe interface during a viral pandemic is clearly not an issue particular to individual bodies but involves the entire social body of the population. In this way, the SARS-CoV-2 pandemic has made clear how a pathogenic microbe can be of significance to the understanding of both personal and global social and biologic ecologies.

1.2 Literature Review and Theoretical Perspectives

In 1987, Lock and Scheper-Hughes asked medical anthropologists to problematize accepted conceptions of the human body by examining the biomedical and Cartesian dualistic assumption that “separates mind from body, spirit from matter, and real (i.e. visible, palpable) from unreal” (Scheper-Hughes and Lock 1987, 6). In an attempt to ‘begin the project’ of medical anthropology they assumed the body to be “simultaneously a physical and symbolic artifact, as both naturally and culturally produced, and as securely anchored in a particular historical moment” (Scheper-Hughes and Lock 1987, 7). These framing statements about the body remain helpful in the current context as they establish the constructed nature of biomedical conceptions of the body, and emphasize that perceptions of the body are historically and socially mediated and depend on disciplinary perspective. In problematizing accepted conceptions of the body, we may discover options for collaboration both within and beyond the biomedical community that did not exist under the historical hegemony of the germ theory of disease causation.
1.2.1 Advances in Microbiology

Stating that the body is a naturally and culturally produced artifact that is anchored in a historical moment calls for a review of the circumstances currently at play. To discuss family physician conceptions of the human body requires an understanding of how that body is currently described by scientists such as microbiologists. A physician’s understanding of the body is not the same as a microbiologist’s, but it is heavily influenced by the knowledge made available by these scientists. The practice of medicine is informed by the way in which the human body is represented by science, and that representation now includes new information about the constituent species making up the human body. A review of these new developments is relevant to how physicians’ conceptions may be changing.

A dramatic shift in the scientific understanding of the body has occurred over the last two decades coincident with advances in molecular biology that have enabled the genetic sequencing of previously unknown microbial species (Lynch and Pedersen 2016). Prior to the availability of gene sequencing technology microbes were identified by growing them in culture growth media (a substance in which bacteria can grow into colonies), which inherently excluded a vast majority of microbes that were not amenable to being cultured (Gevers et al. 2012). Until recently we have been unaware of the existence of most of the microbial species that exist in nature (Rappé and Giovannoni 2003). These diverse and numerous coexisting species are now the subject of enormous efforts to understand the role of such microbes in human health and disease.

It is a huge undertaking to understand and characterize all the microbial species that coinhabit the human body in symbiotic relationships. These organisms - the bacteria, viruses, fungi and archaea that live on our skin and inhabit our intestinal tract - and their combined
genomes are collectively known as the human microbiome (Lynch and Pedersen 2016). They provide us with traits we did not need to evolve on our own, such that humans can be thought of as having a “genetic landscape” which combines human with microbial genes (Turnbaugh et al. 2007, 804). A clear consensus has emerged among microbiologists that the human microbiome is an essential component of human physiology (McCarville et al. 2020).

Multicentre efforts such as the Human Microbiome Project (modelled on the Human Genome Project) set out to “understand the microbial components of the human genetic and metabolic landscape” (Turnbaugh et al. 2007, 804). The Human Microbiome Project ran from 2007 – 2016 and was funded by the National Institutes of Health to establish a baseline understanding of the healthy human microbiome for the benefit of the larger scientific community.

Ongoing multicentre research has led to widespread agreement among molecular and microbiologists of the importance of coevolved symbiotic microbes to human and other animal health and homeostasis (Gilbert, Sapp, and Tauber 2012; McFall-Ngai et al. 2013). Trillions of commensal microbes inhabit our guts and occupy every surface of our bodies, existing in intricate ecosystems and in symbiosis with their host. They have established symbiotic relationships with each other and with their human hosts over millions of years of co-evolution (Warinner et al. 2015). For example, the presence of the bacteria known as Bifidobacterium longum subsp infantis in infant guts is necessary for the digestion of human breast milk sugars, a process which is essential to the initial establishment of a healthy human microbiome and a healthy immune system. Other examples among many include the common gut commensals E.coli K12, Enterococcus faecium and Enterococcus faecalis which are thought to produce serotonin and dopamine, well-known neuroactive compounds that influence human behavior and cognition (McCarville et al. 2020, 157-158). The interplay between gut microbes and
neurologic function is now known as the microbiome-gut-brain axis (Bienenstock, Kunze, and Forsythe 2016).

We are just beginning to understand the mechanisms by which cohabiting coevolved microbes shape our development, our immunity, our metabolism, and our cognition (Fig. 1). Based on knowledge accumulated during and after the Human Microbiome Project, human bodies are now best understood biologically as multispecies organisms, and the concept of the biologic individual has evolved into a conception “in which interactive relationships among species blur the boundaries of the organism and obscure the notion of essential identity” (Gilbert, Sapp, and Tauber 2012, 326). The human gut microbiome is known to vary substantively between individuals and geographic settings and can be understood conceptually as a component of an ecologic system, the human body, which is not biologically autonomous. The following figure lists some of the known physiologic functions of beneficial gut microbes along with a list of human diseases known to be associated with microbiome function or dysfunction, demonstrating the systemic integration of human and microbial influences:
1.2.2 Human Bodies are Holobionts

An ecological approach to the body is reflected in the biological description of the networked human as a “holobiont” (Bordenstein and Theis 2015). The term holobiont refers to the “ecosystem that is an individual animal and its many microbial communities” (McFall-Ngai et al. 2013, 3233). With this understanding of a physical body, human bodies are no longer seen as autonomous entities, but rather as biomolecular networks composed of the host plus its associated microbes. Conceptualizing living bodies as holobionts demonstrates ecological thinking because, as with any ecosystem, the body is a collection of dynamic relationships involving its constituent species. Understanding and describing process and function become
of central relevance, while emphasis on the unit of ‘microbe’ or ‘body’ recedes. Human bodies are embedded within much larger ecologies and are affected by a dramatic loss of microbial biodiversity in the ecosystems in which humans live (Bello et al. 2018). Imbalances in microbial function within human body ecosystems (dysbiosis), as well as the loss of human microbial biodiversity, are now widely recognized as matters of concern for human health because of the association between dysbiosis and many chronic conditions including inflammatory bowel disease, asthma, and obesity (Yurist-Doutsch et al. 2014, 366).

It is time to consider the human-microbe relationship without the constraints of a modernist worldview that sees humans as exceptional and separate from the laws of nature. The model of the body as a nation-state can now be understood as a socially constructed conception of the body, reflective of outdated scientific knowledge which ignores the ecological reality of humans as embedded ecosystems.
Chapter 2:

2.1 Methods

This research study was conducted as part of a Master of Arts degree in the UBC Department of Anthropology in BC, Canada. The study was reviewed and approved by the UBC Behavioral Research and Ethics Board and was conducted between May and August 2020, during the SARS-CoV-2 global pandemic. Participant recruitment was by invitation distributed by the Shuswap North Okanagan Division of Family Practice, and through an online invitation from the Canadian College of Family Physicians. 21 doctors agreed to take a brief online survey regarding their experience of, and attitudes toward SARS-CoV-2 and the germ theory of disease causation. 13 of the 21 physicians were later interviewed in detail over the digital video platform Zoom. Several of the interview participants were physicians I have known personally during my many years of work as a family physician. All the participants except for one are family doctors in BC and practice in communities including Salmon Arm, Vernon, Vancouver and Courtenay. The remaining participant works in Edmonton Alberta.

Interview data was collected through a series of semi-structured Zoom interviews, which were recorded with participant consent and transcribed using pseudonyms. Interviews ranged in length from about thirty minutes to over an hour. Analysis focused on the interview data. Survey data confirmed the interview data with regard to physician attitudes towards SARS-CoV-2 and the germ theory of disease. Interview data was analyzed using NVivo software to look for themes and to characterize physician perceptions and attitudes toward issues identified from the interviews.
2.2 Results

Survey responses were anonymous, but survey data could be located by postal code and revealed participation from multiple locations in Ontario, Alberta and British Columbia. 17 out of 21 respondents have been in practice more than 20 years while 3 of the others have been in practice between 10 and 20 years, making this a very experienced cohort of physicians. 10 of the 21 respondents work both in community and hospital settings, 9 work in the community only, and the remaining 2 are purely hospital-based. At the time of the survey only 6 of the respondents had cared directly for patients with COVID-19. All 21 of the survey respondents agreed that future zoonotic pandemics such as COVID-19 represent a serious concern. When questioned about the usefulness of the germ theory of disease as an approach to infectious disease, almost half (8 out of 11) of the respondents were ambivalent. (See appendix A).

The 21 survey participants were asked to identify the sources of information they accessed to stay up to date on COVID-19 related information. The most popular sources were professional bulletins or newsletters, followed by government and health authority bulletins. Physicians also relied heavily on professional journals and on conversations with trusted colleagues (Table1). Knowledge about the SARS-CoV-2 virus may therefore vary depending on professional network and choice of information source, which is likely to vary by medical specialty. This may explain variations in how doctors from different disciplines prioritize certain viral characteristics over others.

In the interview component of the study, analysis of the data led to the identification of five major themes. These themes are discussed below under the following headings:
conceptions of the body, viruses as biologic agents without intent, the body as a situated host, antimicrobial stewardship, and uncertainty.

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Table 2.1 Popular Sources of COVID-19 Information for Family Doctors (ranked by preference from 1 – 7 with numbers representing numbers of doctors making a particular choice).

2.2.1 Conceptions of the Body

A central theme which emerged from the interviews was that of the conception of the human body. This theme appeared when participants were asked to comment on the usefulness of the “battle” rhetoric of SARS-CoV-2 that is apparent in public discourse. “Battle” rhetoric is rooted in the widely utilized concept of the “body as a nation state”, which is historically embedded in biomedicine and likely underlies assumptions many doctors make about the immune response (Martin 1990). Nonetheless, physicians tended to respond with ambivalence (author comments are in italics and preceded by my initials):
“… it’s somewhat uniting to have a common foe and to… rally around that kind of terminology but… there are places in the world that will not defeat coronavirus… and when we use that terminology it implies that they are losers,… there’s a negative side to it for sure.”

**JB:** So… *is that something that there can be winners and losers from in that metaphorical way?*

“Yeah, I mean… we’re not going to impress the virus with our effort, we’re not going to intimidate it with our effort… there’s no need for patriotism or rallying around to defeat it, there’s just need for practical day to day solutions and approaches.”

Several of the doctors quickly drew an analogy between the military rhetoric being deployed in the public sphere about SARS-CoV-2 and the language commonly associated with cancer. Their discomfort suggests that the nation state paradigm is well established in the biomedical lexicon. One participant explicitly expressed concern about military rhetoric in cancer care:

“… a ’courageous battle against cancer’… I guess my eyes are a little more open to that… how that kind of terminology can leave people behind, because there are people who will not beat cancer and never can based on their diagnosis, so what does that say for their effort, you know, if they’re, they’re just going to die, did they not try hard enough?”

Another doctor voiced a similar concern, while providing an alternative to conceptualizing of SARS-CoV-2 as an invading army:

“I kind of think that COVID seems to be, in the popular media seems to be projected as this terrible foreign thing that is coming and invading us rather than a very slight variation on things that have been around for thousands, tens of thousands of years and, … I find that the military language is just, I just have to kind of push it off because… it just seems to be such a political thing and… it really, really grates me when I hear these terms, ‘oh, and she lost the battle against cancer’, ‘oh, it was a hard fight and she stood up strong’, [instead of] somehow saying, ’okay, cancer is going to take me at some point, I’m going to live with this and I’m living with cancer and I’m moving forward’. You know, the fact that you’re not fighting it and doing this, if you make a decision not to do chemo and radiation then, then you’re weak, you know……and you’re losing the battle and……I’ve always found that grating, all the… medical discussion that uses military terminology.”

Physicians in this study resisted a view of the human body as a distinct entity in a state of war with either pathologic microbes or cancer cells. Many of the respondents declined to
use military metaphors when describing interactions between the novel coronavirus and the human body. For example, one of the most experienced physicians had this to say about the idea of a body at battle:

*JB* “Did you notice that, that this, sort of the way language was being used as… almost like a battle?”

“Yes, I think, ah, we use that kind of language a lot in medicine… certainly in oncology, you know… Fighting cancer and… yeah.”

*JB* “What do you think… about that?”

“Well, I think it’s um… I think it’s reflective of a paradigm, uh, it’s reflective of a paradigm that doesn’t take into account balance and, uh, a more holistic view of our body and our body’s relationship to the environment and I, I would include that same critique of, of the cancer war analogy as well, you know… in my perspective cancer cells are, our body’s cells that have become dysregulated for some reason, they’re not the enemy, they are a reflection of a substantive dysregulation, how do we correct that dysregulation then?”

This physician seems to understand the body as a complex ecology rather than as a discrete unit at war with outside invaders, whether they be cancer cells or microbes.

A different physician raised the importance of social determinants of health as important by locating the pandemic as part of an ongoing historical process rather than as a battle between microbes and humans:

“I think it’s [military metaphors] harmful actually, because I think it creates this impression that the, the microbial world out there is this enemy that we need to, and if only we’re strong enough and have the right battle plan then we’ll get rid of it and save the humans, rather than realizing that this is an ongoing process and this isn’t the first time this has happened and it’s certainly not going to be the last time, that we need more to manage the social determinants of health and stuff around it rather than trying to battle against this one virus.”

These comments are reflective of a perspective on human immunity and health that does not construct the body as a nation-state fighting an army of invading pathogens.

### 2.2.2 Viruses as Biologic Agents without Intention

Participants were asked to characterize the specific microbes they interact with in their clinical work, with an emphasis on SARS-CoV-2. Unlike the non-medical discourse which has
tended to adhere to the “battle metaphor”, these doctors described SARS-CoV-2 as an unbiased agent driven purely by a biological imperative to reproduce itself by taking over the host cell mechanisms. These physicians tended to comment on the public perception of the virus as an enemy rather admit to having such a perception themselves. The model of the ‘body as a nation state’ was not dominant in their discourse. Rather, they used language and terminology in keeping with an ecological understanding of how viruses and human bodies intersect. The following quote is one example of many that describes the virus as having a single purpose - to replicate within a host cell:

“the virus is not really an enemy. [Laughs] I don’t think the virus is an enemy… I think we just manage it like we’ve managed every other pathogen that’s out there or illness as if you understand it… I think the virus doesn’t have any particular agenda other than viability... the virus, viruses have one agenda, it’s to copy themselves and that’s it.”

This description of the novel coronavirus as a simple biological entity with no malevolent intent or agenda contrasts sharply with the sense of fear and threat elicited by the battle metaphor that has been commonly deployed by political and public health authorities. One doctor described the effects of the virus favourably compared to the consequences of human conflict and aggression, viewing the virus as less harmful than humans on the scale of harmful colonists:

“referring to something as a war against a virus is ridiculous because, uh, I mean, a war is an ideological thing and this is biological, like this virus has no ideology… and the virus is not violent… the virus does not rape and colonize people and extract people’s resources, the virus is a virus, it is what it is.”

Rather than thinking of the virus as a uniquely pernicious foe they describe it as just another microbe for humans to accommodate and adapt to.
The physicians interviewed also noted the difficulty that members of the public have in accepting a more ecological view of the virus, and suggested that people may be unable to accept that the pandemic could be mediated by a natural agent without any overt intent:

“I think people are incapable of thinking of a, of a biological entity that is acting without conscience. I, I mean, honestly, viruses are designed to reproduce, …it’s not like there’s some superior intelligence that is down directing them and I think that’s what’s really hard for people to understand, and particularly, I, I don’t mean this patronizingly, ….they think that… it’s this mean-spirited thing that’s coming after us [laughs] and it, it has no mind, it’s not, it’s not anything, you know, it’s up to us to understand how it’s spread and… how our behavior is changing it.”

When describing how human bodies may adapt to or accommodate SARS-CoV-2 the doctors were quick to invoke the human immune response as being of critical importance to variations in clinical outcome, and in doing so portrayed the host response as being of perhaps greater relevance than the virus itself. This description is typical of the responses:

“I sort of describe a virus as being something that lives in the world between living animals as we think about it and inanimate objects, meaning that it can reproduce but it doesn’t need to eat, it doesn’t make waste, it doesn’t breathe… but it’s a parasite on our cells that uses our cells’ machinery to its advantage to replicate and that a lot of it’s, a lot of the symptoms we develop are… as a result of our immune system itself causing these symptoms as a way of trying to fight it off… that it’s a non-thinking, non-breathing thing which lives, exists to replicate.”

For these physicians, the host response is of central relevance when thinking about the effect and agency of the novel coronavirus. A view of the virus as a marauding intruder is not, in the minds of these physicians, an accurate portrayal of what is in fact a biologic interaction occurring between microbe and host.

2.2.3 The Body as a Situated Host

As the interviews progressed it became clear that the doctors preferred to see the human body as a host, with complex socially mediated factors paramount in determining the relationship between microbe and human. Although most of the respondents lacked a
sophisticated technical understanding of the microbiome (only one of the participants had advanced premedical training in microbiology), they expressed enthusiasm about the idea of human hosts as complex ecosystems or symbiotic assemblages. One doctor spoke of her excitement at the thought of moving away from germ theory toward a more microbiially inclusive view of the human holobiont:

"I haven’t really thought about germ theory in a long time... [the holobiont] is a potentially exciting way to look at disease and... disease risk and... it speaks to more general health measures, right, like... not using antibiotics, healthy living, eating, really sort of back to basics... and we’ve gone a long way from that... I think it is a paradigm shift and......in a way it’s kind of exciting, it’s potentially an exciting opportunity... so innovation and change... Interesting, interesting topic!"

This topic of human/microbial symbiosis was explored further. The individual with a microbiology background found ecosystem analogies to be useful in conversations with patients. She gave an example of the usefulness of reasoning ecologically with patients on the topic of vaginal health and dysbiosis:

"Bacterial vaginosis is a really good example of this... I’ll be like, you know... ‘it’s got like a little ecosystem in there... everything keeps everything else in check. Every once in a while, you’ll have one particular type of organism or species that gets out of whack compared with the other ones and so these are some ways that you can address that...’ Introduced species that turn out to be their own versions of invasive things, like that sort of stuff... I use... the ecosystem analogy... not infrequently."

Another doctor spoke eloquently about the idea of “balance” when describing the immune system:

“What I have always found missing in medicine is an understanding of balance and how we have been focused in medicine using small molecule drugs and monoclonal antibodies to force the immune system or force metabolism more or physiology in one direction... the intention in, ah, you know, what is commonly termed allopathic medicine, is to, is to force what’s wrong in, in essentially the opposite direction, but... that is not designed to bring the body back into balance, it’s designed to force it in the other direction and typically to treat the end result of the disease rather than the underlying problem and there isn’t a conception of all this, and there isn’t a conception that the immune system is an orchestra, really, and it’s comprised of many dozens or hundreds of these interacting pathways that all need to be highly coordinated and, and balanced... if we simply, uh, block one of those, one receptor in that orchestra, it’s like
stopping a single instrument playing so the song will sound different…but it isn’t shifting that entire orchestra from playing the wrong song to playing the right song. So, I think if, if we are to create a medicine that addresses health, we need to look at the body and the body’s processes in a fundamentally different way, we need to think of it not as a machine where we’re, you know, replacing a defective part and shifting the part that doesn’t work but then we’re trying to understand how to bring that orchestra back into balance…”

Yet another experienced family doctor utilized an explicit ecologic metaphor when describing the effect of antibiotics on the gut flora of his patients:

“I think I would say, honestly, I think microbiome first when I look at people and I see that they’re on an antibiotic I just see this… this big, lush forest just turn into a desert, that’s kind of the, the image I have in my brain as to what’s actually happening in the lining of the gut.”

For these physicians the human body is intuitively understood as a host to a balanced microbial ecosystem.

The transcripts also suggest that these doctors conceive of the human host as being embedded in a much larger network of influences, including socioeconomic inequality. One physician expressed concern that by pinning hopes on a vaccine cure we might be neglecting the deeper structural issues that have made COVID-19 so much more lethal in some populations than in others:

“I kind of think that if we’re really looking to reduce morbidity and mortality then we need to equally address… chronic health issues like diabetes and obesity and smoking and all... because we may get a vaccine for COVID, but this is going to happen again and, and then we’ll still be left with the same profile or population who are, who have terrible diets, who have socioeconomic issues and... long-term health issues…”

A similar point was made by another of the participants:

“I just think that there is this massive global expectation about when a vaccine is coming, as if that’s going to be the end of our problems… it’s highlighted the inequities in health access but also things like racism in our society and how... people of certain races have been disproportionately affected by COVID and they’re... on the front lines and there’s not a lot of motivation to help those people long-term.”
Not only do these respondents conceive of a socially situated human host body, they also view that body as existing within its own macro-ecologic context. Several of the doctors I interviewed drew connections between their own experience of working in the COVID-19 epidemic and larger pressing issues such as biodiversity collapse and the climate emergency. On the topic of the role of host factors in determining the effect of a new pathogen, one respondent raised the issue of pollution as being of concern:

“You start to look at the context and the, the host as much as you look at the infecting agent and... looking at factors from the environment that could be influencing that because we do have a massive infiltration of industrial chemicals into not only the ecosystem but our own bodies. The CDC does a survey every couple of years of industrial chemicals in the American population, take a random sample and extrapolate to the population and the average American has 40 to 60 ... chemicals in their body in amounts that are relevant to the psycho-neuro-immunological endocrine system in the same quantities and the same concentration range as those chemicals...”

JB “So, do you think that when you’re thinking about what you’re calling host resistance ... that we need to be looking at these larger issues?”

“Oh, absolutely, I think we’re, we’re flying blind right now because we, we stare away from, I mean, it’s not the way a doctor’s mind is trained, you’re trained to look at the person in front of you, look at the condition they have, relieve their symptoms then address what you can of an underlying disease process... and yet, we relatively seldom look at the broader picture, we don’t look at the, the, the ecosystem and it’s contents and our interaction with it..., we don’t even have scientific disciplines that do that very well, we, we have to, you know, resort to cross-disciplinary studies because we don’t have a focused, you know, way of looking at context and agent together..., this, I believe, will become highly significant in the next 15 or 30 years because we are still emitting these substances into the ecosystem.”

When asked about the relevance of SARS-CoV-2 having crossed the species barrier to humans one respondent drew explicit connections between COVID-19 and other global environmental issues:

“Yes, I think that’s relevant. I had this conversation because I mentioned that I have been working on... with medical students on a climate project... ...so the students work on a variety of different topics,... one resident just did a review on antimicrobial resistance in the context of climate health and how that impacts it,... but I think there are lots of things that we need to consider... about how we interact and what our relationship with our environment is and as we move and urbanize into typical animal habitats......we’re increasing our exposure to animals. I mean, that’s how Ebola came
from bats… so, H1N1, these are all from viruses that mutated such that they could cross over into humans…”

*JB* “So, do you think that there’s implications then for human health in the future by the fact that we’re seeing this pattern of viruses transmitting, you know, across from other species? I’m sort of drawing that conclusion from what you’ve just said.”

“That’s the correct conclusion, except for one thing… I don’t see it in the future, I see it happening now… and having happened in the past.”

The recognition of the connection between human health and global ecology is also reflected in the following response to a similar question regarding zoonotic diseases (diseases that move between humans and other animals):

“We have to take a very, very far upstream approach to this issue. Because, it’s not isolated, I mean, there have been 3 coronaviruses in succession, starting in 2002 and, with each of them, we’ve, we’ve developed, you know, sort of acute medical interventions of sorts that seem to be somewhat helpful for some people but they’re, but, you know, how many times, this is the classic preventive model, you know, the people swimming down the river drowning and then you finally go upstream to find out who’s throwing them in the water. And, and I think it turns out to be us throwing the virus into the water and infecting ourselves and that’s a more challenging situation because there are economic, agricultural, um, social implications to addressing this issue, but on the other hand if we don’t it’s like, it’s like climate, the climate crisis. If we don’t look at it in a multifactorial, multidisciplinary, across the board contextual way, we are just going to, I, I won’t use an expletive, but we are going to waste our time.”

For these physicians, the body seems to be viewed as a socially situated human host, dependent for its health on the integrity of the microbial ecology it hosts and on the macro-ecology within which it resides.

### 2.2.4 Antimicrobial stewardship

Family doctors bring a unique set of priorities to their clinical encounter with a patient. They must navigate a tension between the interests of that individual patient and the priorities that public health places on the collective well-being of populations. Most of the participants in this study admitted to occasionally prescribing antibiotics in ways which were not in accordance with the recommendations of antibiotic stewardship campaigns, while
simultaneously agreeing with the importance of reducing the inappropriate prescribing of antimicrobials at the population level. They acknowledged that they take multiple factors into consideration in making decisions, and the “stewardship” of the antibiotic itself is not always paramount. Some of the interviewees pointed to inconsistent clinical practice guidelines which advocate for antibiotic stewardship in some settings but encourage reflexive antibiotic use in others. One of the doctors remarked that commonly used guidelines recommend antibiotics as a treatment for respiratory infections in certain populations, even though these illnesses are usually of viral origin, and even though antibiotics have no effect on viruses:

“my career I guess has spanned 35 years so... I’ve been swayed by drug industries, by lack of evidence-based guidelines... I know... that almost everything is viral so that’s a good starting point... I really prescribe very few antibiotics... the guidelines, for example, for COPD [chronic obstructive pulmonary disease], which are antibiotic based, don’t ask for us to question whether or not it’s bacterial or viral so these people go on antibiotics.”

Another hospital-based physician noted an escalation in the use of powerful antibiotic combinations in any patient hospitalized with febrile neutropenia (a condition characterized by low immunity with fever).

“I, in my life, before I started working here, I probably used Pip-Tazo a handful of times...and now I use Tazocin all the time.”

JB “And why is that? Is that just a guideline that you’re getting or is that because you have resistance to... other antibiotics?”

“It’s the guideline for febrile neutropenia. You’re supposed to use either a fourth-generation cephalosporin or a Tazocin.”

JB “Yeah, yeah, it’s pretty, it’s pretty interesting and pretty scary in some ways, yeah.”

“Yeah. And especially because often times it, you know, it gets better after a couple of days of antibiotics and you’re like, ‘oh man, should I have used this in the first place?’”

The same individual went on to address the issue of how to decrease the use of strong antibiotics in the context of a tertiary care hospital where specialists routinely treat people according to standardized protocols:
“[It’s] really challenging to… educate… big groups within our physicians or to convince big groups within our profession, I mean, particularly surgeons…surgeons and, ah, you know, intensivists* because they’re just throwing the big guns out there all the time…”

The sense of being caught in the middle when deciding between the risks and benefits of antibiotic use pervades many of the interviews. One physician described the difficulty of weighing this decision in a given patient:

“I do think that you’re kind of stuck clinically if you have this critically ill person who’s got, uh, [a] respiratory syndrome and… they’re critically ill…you kind of have to give them antibiotics until you prove that they don’t have something that’s bacterially mediated, otherwise you’re, you know, potentially lose an opportunity for intervention… and guidelines really clearly demonstrate a mortality cost to waiting.”

A decision whether to prescribe antibiotics to a given patient is complex and requires clinical experience and judgement. Doctors are expected to act as gatekeepers for the antibiotic supply according to generalized antibiotic stewardship guidelines. None of the doctors I spoke with felt that patients consider the issue of antibiotic stewardship to be important. Patient expectations and clinical time pressures may be more likely to influence how many physicians prescribe antibiotics. One doctor explained the dilemma this way:

“When I started in Emerg I think I probably used them [antibiotics] more because I was under the impression that people that came into Emerg,… wanted an antibiotic anyway and I would be so rushed in my treatment that I would think, uh, whatever, I, I just kind of, sort of, processed them through and get them out of here and I’ve got to get on to the next people and so I believed that using an antibiotic was just, giving them a script for an antibiotic was easier. But then I started trying to have more… clipped conversations… the conversations that don’t work for, I find, for most people is to use the argument that we need to be careful with our antibiotics because we need to save them for serious infections. Patients only care about themselves, for the most part… they go, “I don’t care if you don’t prescribe it for anybody else because you want to save it, I want you to give it to me …because I want to be rid of this.”

“So, if I’m telling them that the reason, I don’t want them to use the antibiotic is ‘cause there will be community, increased community resistance, they could give a shit… I don’t ever use the community resistance argument anymore because people could care less.”
The interview transcripts indicate that at least some primary care doctors feel that antibiotic stewardship is low on their patients’ list of priorities when discussing the risks and benefits of antibiotic use.

Some physicians acknowledged a change in the perception of antibiotics that has occurred over recent decades. One of the doctors described the shift in perspective that she has experienced in her own career:

“I feel more lucky because we kind of have grown up in our careers with this knowledge that overuse of antibiotics… negatively impacts populations. I… would say the worry though has been primarily in protecting the antimicrobial, because we basically, we’re worried that we would run out of useful medications because there would just be resistance……but I think now the new knowledge is saying that this is actually causing… disease, like asthma or… more bowel things. I think that was not sort of known for us in the beginning, I think we were more worried about just having effective antibiotics… and I think the last 5 to 10 years there has been a shift where we’ve learned more and more……about the fact that actually this is lacking… that dysbiosis is now actually responsible possibly for things like asthma… and that I didn’t think we knew when we were in school.”

I asked all the interview participants if they thought that “protecting the patients and their microbiome” might be a more compelling argument for decreasing the use of antibiotics than “protecting the antimicrobial”. All the participants agreed this would be more effective, suggesting other physicians have also experienced this shift in perspective.

2.2.5 Uncertainty

The theme of uncertainty pervaded most of the interviews I conducted and reflects another dimension of the tension that family doctors experience as they navigate and negotiate between the interests of the public and of the individual. The physicians expressed their own uncertainty about information sources and decision making, uncertainty about the nature and outcome of the pandemic, the effect of uncertainty on patients and the public, and a sense that
uncertainty may be a factor in the rise of misinformation and conspiracy theories in a fearful public who are looking for easy answers.

In the early days of the pandemic physicians were lacking basic information about the clinical management of COVID-19 and faced uncertainty about what to expect. Table 1 reveals the variety of information sources they referred to at the time. Uncertainty was expressed by a hospital-based physician who had this to say about her experience of the information and communication coming from her health authority:

“… nobody knows anything, the rules change every 15 minutes, and nobody knows what’s going on… so every time we have an issue where we need to deal with something we have to consult… with our management or with… with the website… so at the institutional level I don’t think that the… information is forthcoming but we use, we all depend on different resources and right now I depend on the Edmonton Journal actually… whether you get it from 10 sources or whether you get it from one source, either way, it’s not forthcoming.

Concern about rampant misinformation and a belief in the need for peer review as a fundamental feature of a scientific approach to the pandemic is evident in the interview transcripts. The sense that the public lacks accurate information was expressed by one of the doctors as follows:

“So, now they have access to a variety of information but there’s no filter… there is a filter but it’s not, the filter isn’t guided by [a] kind of… knowledge base that’s more valid or validated. So, I think it’s… it’s interesting to see how… you know, populations receive their information and what our role in that is…”

The rise of conspiracy theories as powerful narratives influencing public behavior seems to have coincided quite powerfully with the COVID-19 pandemic. This frustrates the doctors I spoke to who feel a responsibility to communicate accurate information:

“So, the reading has shifted from kind of actual coronavirus, sort of like scientific and medical sort of reading, and then sort of shifted into this whole, the misinformation pandemic, you’ve heard about that… which is sort of like, you know, as this is picking up steam and everyone is an armchair expert because they have access to the internet, people are feeling really emboldened to kind of make proclamations in their social media channels and in their public personal lives that may amplify misunderstandings or
misinformation… and one of the things that we, I think, as a medical profession have a responsibility to do is to correct that.”

The fear of the unknown was thought to be at the core of the problem of uncertainty. As one physician recounts:

“… there (are) a lot of people for whom this is just sort of this invisible ghost floating through the air and potentially killing your family and I mean that is kind of terrifying. I mean, that’s, that’s the first plague or the 7th plague, which plague is it… It’s the unknown, it’s the unknown fear that people, it’s the unknown enemy, it’s the unknown enemy that… that people are afraid of and have some agency over but… kind of misapply that often to, you know, wiping down their Triscuit boxes…”

Another expressed a similar concern about rampant misinformation in the public sphere:

“I think for every valid… bit of information that’s out there there’s at least, you know, almost twice as much of… misinformation out there and the general public has no idea how to interpret or… you know, screen for that information… that’s I think probably the biggest difficulty in managing the whole situation is just, ah, having trust… in the information out there. It’s amazing, you know, the stuff that comes out and the people who you maybe wouldn’t think would believe some of the stuff out there…”

The sense of tension between the ideas expressed in the public arena and those relevant to the individual patient in a clinic setting is evident in these comments, reiterating the challenges that family doctors face when trying to navigate these competing needs and interests. Family doctors are accustomed to navigating tensions between public and individual narratives but uncertainty about how the virus is conceived by an individual in a clinical setting, or by a given element of the public, creates an added level of difficulty that physicians must navigate. For example, one of the respondents mentioned the uncertainty that doctors experience when people decline standard treatment guidelines:

“I do a bunch of obstetrics and somebody was positive for group B strep… the recommendation would be for …penicillin administration during the labor and we had this huge discussion and this huge, documented refusal…because that person did not want that and, and that’s also a challenge, right… where you say, okay, what are the risks and the benefits and the risks in that regard, I wouldn’t take those risks myself, you know, the, the potential for a septic baby is horrific… if you can explain those risks and benefits thoroughly then that’s that individual’s choice, right?
Interviewees appeared to wish to avoid erroneous information or oversimplifications about antibiotic risk that may confuse people and lead to an even less helpful public counternarrative.
Chapter 3: Discussion:

Society is facing significant challenges in the form of pathogenic viruses and antimicrobial resistant organisms (“superbugs”). Microbes that can readily evolve to be resistant to vaccines or antibiotics are a major threat to human health. This study was centred on how the clinical practice of biomedicine conceptualizes the role of the microbe itself. The following discussion is centred around five major points: 1) New knowledge about coevolved microbial ecosystems and networks both inside and outside of the body encourage a new biomedical conception of the human body as a holobiont. 2) There is no uniform biomedical conception of the human body, but considering the body as a boundary object may help explain discrepancies and promote better collaboration between different disciplines. 3) Host bodies are most accurately understood as situated in social and biological networks and processes. 4) The extent and importance of dysbiosis both individually and in population studies should prompt us to reconsider our public health approach to antimicrobial resistance, such that emphasizing the concept of microbial stewardship complements the judicious use of antimicrobials. 5) The issue of uncertainty underscores the reality of biological precarity and the macro-ecologic implications of anthropogenic environmental degradation.

3.1.1 The Human Holobiont

Anthropologists have offered helpful critiques of a binary discourse which describes the body’s relationship with microbes as an entrenched subject/object distinction. They have done this by thinking of bodies as socially and historically situated. For example, Bruno Latour’s actor network theory envisages microbes as acting with agency within social networks (Latour 1988), while Emily Martin historically located the battle rhetoric of immunologists in the Cold War era. Martin theorized that the constructed nature of the subject/object boundary in
immunologic discourse stems from a notion of human bodies as “imperiled nations continuously at war to quell alien invaders… nations which have sharply defined borders in space, which are constantly besieged and threatened” (Martin 1990, 421). Understanding some of the social and historical forces that have shaped biomedical discourse enables a paradigm change that can better reflect our new understandings of the complex interrelationships between humans and the microbial world.

Variations in biomedical conceptions of the body are evident in recent discourse about the human immune response. Infectious agents such as SARS-CoV-2 and multidrug resistant microbes are often personified in public discourse as the “enemy”. This tendency to attribute malintent to microbes is similar to the discourse around cancer care where battle metaphors are extensively used (Martin 1990). However, we now know that the human immune response to invasive pathogens depends on beneficial microbes which facilitate the development of the immune system and provide resistance to pathogenic colonization. Bacteriophages (viruses that live especially in the human gut and prey on bacteria) play another key role in human health and the immune response. With our new understanding of the holobiont, the concept of a “battle-line” separating the microbial armies from the citadel of the human body is a flawed metaphor. Cabrera-Perez et al. claim that “we have come to understand that rather than waging an endless war, the host and its prokaryotic colonists exist in a carefully negotiated armistice, with compromises and benefits that go both ways” (Cabrera-Perez, Badovinac, and Griffith 2017, 129). I argue that the concept of a “collaborative armistice” is better understood as a living ecosystem balance.

Descriptions of the human immune response provide other examples of a change in the biomedical discourse of pathogens. Using evidence from balanced host-virus relationships
Zinkernagel called for a redefinition of these relationships as biological responses, rather than as a way of discriminating between “self” and “non-self” (Zinkernagel 1996, 173). He began with a recognition of the coevolution and codependence of viruses and their susceptible hosts. When we consider the immune response in this more nuanced way we can acknowledge that an individual does not necessarily ‘fight’ a virus, but rather accommodates and adapts to it as part of an ongoing biologic process. Adaptation and accommodation are processes that occur within networks involving microbes and their situated human hosts. The representation of microbes as the “enemy” negates the complexity of the interlocking and constantly shifting networks of actants that form the coordinated host-virus adaptive immune response. These “actant networks” include not just microbes and people, but also other diverse actants such as host immune cells in the gut wall and beneficial viruses that prey on bacteria – all form part of a coordinated host-virus adaptive response.

It is perhaps difficult to conceptualize the human body as a biologic network nested within larger ecologic networks. Historically, biomedical thinking has been fixated on the concept of “units” rather than “networks”. Biomedicine as a field of knowledge has been very much entrenched in a view of the body as a “bounded, decontextualized unit” (M.N. Lock, Vinh-Kim 2018b, 36). This view of the body derives from the tradition of visual inspection and description through dissection that was developed by European anatomists. There is an “intimate relationship… between medical knowledge and insight… bodily representation, and the subjectivity of scientist/physicians, which is in turn informed by culturally shared values” (M.N. Lock, Vinh-Kim 2018b, 17). Our intellectually inherited predilection to view the components of our biologic environment as a collection of “units”, rather than as an array of complex inter-related “networks”, acts as a cognitive bias that impairs our ability to
appropriately embrace the concept of the human holobiont. The ongoing use of battle metaphors such as those discussed previously tend to further entrench an outdated view of the body as a 'nation-state'.

The idea that there is an inherent bias or a limited ‘frame’ that constrains our thinking about the body is useful. Kenneth Burke’s concept of “terministic screens” is useful in showing how language frames our perception of reality. In stating that “even if any given terminology is a reflection of reality, by its very nature as a terminology it must be a selection of reality; and to this extent it must function also as a deflection of reality”, Burke makes explicit the way in which language not only shapes our perception but also limits our perspective (Burke 1965, 88). Some of the ways in which biomedical perceptions may be limited are likely to be specific to the English language given its predominance as the global shared language of biomedicine. Michael Reddy offered what he called the “conduit metaphor” to describe how English speakers conceptualize communication as occurring in “units” that travel through space between people (Reddy 1993). Reddy’s point was that the English language itself creates a worldview for speakers which predisposes them to a bias in perception, such as favouring “units” over “networks”. Thinking of the body as an ecological process within a vastly larger ecological network may first require recognition of our existing language-driven cognitive bias. Yet becoming aware of the way in which we are constrained by language is not enough to allow us to think outside these constraints. We need other tools.

Another way of challenging the constraints of unit thinking in biomedicine may be found in the ethnography of infectious diseases. Pandemics can be understood as ecologic networks involving heterogeneous bodies and microbes. In her ethnography of H5N1 (avian influenza) in Indonesia in 2005, Celia Lowe proposes using the materiality of viral clouds as a prompt for
her analysis of the H5N1 pandemic. In thinking of the virus as existing and spreading in the form of a multispecies cloud, she states “Just as the collection of genomes that may appear in the rapidly mutating swarm technically known as a quasi-species cloud are heterogeneous and unpredictable, so, too, I found were the bodies, narratives, and politics that appeared in the multispecies cloud surrounding the natural cultural event known as H5N1” (Lowe 2010, 627). This approach allows her to think of bodies of diverse types – humans (epidemiologists, chicken farmers, virologists, ornithologists, public health workers, government ministers) and diverse non-human animals and microbes – all as participating in the multispecies event that was the H5N1 pandemic. Her choice of a cloud metaphor effectively negates any boundedness of these diverse bodies and their specific engagement with the H5N1 virus.

The traditional biomedical conception of the body is limited by the framing unit of the bounded individual, a construction of euro-western thought and language. Using ethnographic data to explore intersections of ecologic networks and the heterogeneous bodies in those networks may provide insights as to how physicians and others can learn to think outside the bounds of the constructed and standardized biomedical body. Evidence from this study suggests that some physicians are starting to view human bodies as components of a network comprised of an interrelated array of situated microbial and macrobiotic ecosystems, rather than as an isolated “nation-state” unit.

3.1.2 The Body as a Boundary Object

In any clinical setting involving infection the actors involved in medical decision making may include the patient, the family doctor, the medical microbiologist, the public health officer, and others. These different actors conceptualize the body differently depending on their disciplinary cognitive framing and past experiences. Data from this study suggests that family
doctors conceptualize the body as a host. Other research from the COVID-19 pandemic suggests that a single human body can even play host to multiple generations of the mutating virus: researchers in Boston have documented the emergence of multiple new viral variants in a single individual (Kanjilal et al. 2020).

Social science theories may help us to look outside the traditional biomedical “knowledge silos” of public health and clinical medicine by considering how different disciplines collaborate on a particular problem. The model of “boundary objects” may help us to understand the tension that arises between the need for generalizable findings and the naturally divergent viewpoints that arise in any healthy scientific endeavor (Star and Griesemer 1989). Boundary objects are scientific “objects”, either abstract or concrete, that “inhabit several intersecting social worlds, and satisfy the informational requirements of each of them” (Star and Griesemer 1989, 393). They help to mediate among different perspectives.

Considering the human body as a boundary object allows for the variability that we see in the way different actors engage in the context of infectious disease. For example, the concept of a body that informs a public health officer’s decision making is quite different from the concept of a particular body that a family doctor may have. Both are, again, different from a patient’s concept of their own body. If we were to consider the human body as a boundary object in this sense, the divergent viewpoints we have noted across these different actors can be understood in terms of intersecting social worlds. One of the key features of a boundary object is interpretive flexibility whereby the object in question is constructed differently by different viewers, and these viewers are required to reconcile differing meanings if they wish to cooperate. Constant negotiation and adjustment must occur between different actors for collaboration to occur. This reconciliation requires the “scientists and other actors contributing
to…. translate, negotiate, debate, triangulate and simplify in order to work together” (Star and Griesemer 1989, 389). The family doctors in this study are likely accustomed to facilitating such dialogues about the body, as conceived differently by each of the actors (epidemiologist, patient, microbiologist, microbial ecologist) that are involved in the management of a patient’s infectious disease.

A process of negotiation is necessary if we are to work collaboratively to address the issue of antimicrobial resistance at both the individual and the population level. Thinking of the body as a boundary object may be a useful theoretical tool to deploy when challenges in communication across disciplinary silos occur, as it allows for the interpretive variation at play in such contexts. There are multiple ongoing and varied scientific, biomedical, and personal agendas at play when a decision is confronted about a serious infection. The physician, patient, medical microbiologist, and public health officer (and others) may potentially all be involved in a reconciliation of the meaning of a particular infection in a particular body. This interpretive flexibility with respect to the human body is present across the medical community and it would be an error to assume a monolithic biomedical consensus on the nature of the body despite a dominant discourse.

The autonomous, bounded body is not just a historically mediated construction of biomedicine, but is also mutable and heterogeneous, even within a biomedical context. I have attempted to visualize the way these conceptions of the body may overlap in the biomedical context where different actants, including the patient, conceptualize the body differently depending on their position and experience (Fig. 2):
There has always been a tension between the interests of clinical biomedicine and epidemiology because one is interested in the individual body and the other is concerned with population health. When it comes to the use of antibiotics, the prescribing primary care physicians sit at the nexus of these tensions: they are tasked with making decisions that may have enormous implications for the patient involved, but also potentially for the larger community and society. The challenge of antimicrobial resistance and the pressure to minimize the use of antibiotics are examples of the intersection of competing tensions that relate to how doctors conceptualize the bodies they treat.

### 3.1.3 The Situated Host

One of the more striking things about the interviews was the consistency with which all the participants gravitated toward host characteristics as being of central importance to clinical outcomes. Whereas I had initially intended to speak to doctors about their perception of microbes, the conversations all gravitated toward their perception of the host/microbe relationship. In placing emphasis on that relationship rather than on the microbe the physicians
were instinctively emphasizing the coexistence of humans with other species, both beneficial and potentially harmful. A tendency to view the microbial world as external to the body may lead us to forget how critical host characteristics are in determining clinical outcomes involving infectious agents. The results of this study suggest that some family doctors are already inclined toward a focus on the situated host rather than on the objectified invasive microbe. This is relevant to the discussion of antimicrobial resistance.

Antimicrobial resistance is a challenge which requires enormous collaboration across disciplines and cultures, and where the individual’s and the group’s interests are often seen as explicitly at odds. The self-interest of patients revealed by the study transcripts is hardly surprising. Most ill individuals will prioritize their own immediate wellbeing over the future health of the population at large, and a moral argument about the importance of antibiotic stewardship will be of limited use in individual decision making. Family doctors practice patient-centred care which in anthropologic terms means situating an individual’s body in a social, symbolic, historical, and biological context when making clinical decisions. When that individual body is understood to be at risk of illness, decisions are made that may disregard the guidelines of population-driven public health guidelines. Physicians experience a constant tension between thinking of the individual while simultaneously thinking in terms of societal and ecologic networks.

3.1.4 Microbial Stewardship and Dysbiosis

We have thought of antimicrobials as essential to combat dangerous microbes but have not always considered the significant harms they may do to the many beneficial and commensal microbes on which bodies rely for health. Antimicrobials are significantly overused in our “germ” obsessed society and there is increasing concern about the consequent damage
they do to human microbiomes. A recent multicentre study in the United States demonstrated the absence of *Bifidobacterium longum* subsp. *infantis* (a critical gut symbiont needed to digest human breast milk sugars) in 90% of healthy infants (Casaburi et al. 2021). This finding suggests that there is a widespread state of dysbiosis in the general population in which the key ecosystem services of some beneficial microbes are missing. This is of extreme concern given the known importance of establishing a healthy and diverse microbiome in the first few months of life (Casaburi et al. 2021).

Given this and other evidence of widespread dysbiosis (Blaser 2014), one might question why public health campaigns to reduce antibiotic prescriptions in primary care have focused so extensively on stewardship of the *antibiotic*, rather than on the protection of the critical patient(host)/microbe ecology that is so central to human health (refer to Fig.1). This study shows that doctors may be attuned to the ecological risks of the overuse of antibiotics, yet may continue to prescribe them even while recognizing that they may not be helpful in a given patient. Guideline-driven recommendations that focus on antibiotic stewardship may be of limited benefit in changing behavior unless they recognize the importance that family doctors place on unique host factors when they make prescribing decisions. The study transcripts show that these doctors consider population-based guidelines as being of secondary importance to the interests of their patients when thinking about antimicrobial prescription. These findings are reflective of the patient-centred priorities and conceptions of the body that family doctors bring to the clinical encounter, priorities and conceptions that may differ from those of the public health authorities.

The concerning overuse of antibiotics and the prevalence of dysbiosis makes it increasingly urgent that we enable a view of human/microbial health that allows us to ask
critical questions about accepted practices, including how we approach antibiotic prescribing. Dysbiosis affects not only individual bodies but entire populations through its association with chronic and autoimmune diseases (Tanase et al. 2020; Wasko, Nichols, and Clark 2020). Identifying and foregrounding the ecological concern of dysbiosis in human individuals and populations could serve to reframe the problem of antimicrobial resistance. I propose that we shift the focus of the discussion from *antimicrobial stewardship* to *microbial stewardship*. “Microbial stewardship” emphasizes the importance of the microbiome to the health of the individual, and the importance of microbial ecosystems to the health of human populations. The concept of microbial stewardship allows us to situate the microbial world where we now know it belongs: at the centre of the health of the human holobiont. Using the idea of microbial stewardship when communicating with patients might allow family doctors to avoid some of the tensions that currently exist between the interests of the individual and that of the population.

3.1.5 **Uncertainty**

Physicians in this study identified uncertainty as a major feature of the COVID-19 pandemic. Especially at the outset, much was unknown about SARS-CoV-2 and medical and political decision makers had to contend with a frightening array of possibilities. The possible effects of burgeoning antimicrobial resistance also present a troubling range of uncertain outcomes. In both the current pandemic and in cases of superbug spread, ecological thinking helps in understanding host bodies as being embedded in larger, globalized ecosystems. Recognizing uncertainty as a fact in such complex and unpredictable networks leads to the conclusion that unanticipated effects and outcomes should be expected. This approach is at odds with a public health discourse which strives to make decisions based on measurable epidemiologic data and scientific certainty. The trouble is that data involving complex ecologic
systems is always incomplete and all outcomes cannot be fully anticipated. For example, when antibiotics first became available few people were worried about the development of antimicrobial resistance and dysbiosis. Yet these unanticipated effects of the overuse of antibiotics are now some of the dominant concerns of our day (Bello et al. 2018). It is often only with hindsight that we perceive the unanticipated outcomes of our actions involving complex ecologic systems. Accepting a reality that includes the inevitability of unintended consequences and unexpected events would help us to plan for and recognize new and emerging threats.

The public health discourse of COVID-19 exposed uncertainty in the larger social arena beyond the clinic. The lack of research data, particularly in the early days of the outbreak, caused political leaders and public health authorities to change recommendations as new information about the virus became available. In Canada we were initially told travel bans were ineffective, but as things progressed they were implemented. We were told masks did not reduce viral transmission prior to mandatory mask policies being widely implemented. These inconsistencies in messaging have been interpreted by some as a sign of weakness in leadership (Khamsi 2020). For a public which is largely conditioned to making decisions based on scientific “facts” this has been disconcerting, and in the context of a lethal pandemic there has at times been the sense that the experts may be fumbling, despite their efforts. It is hardly surprising that during the pandemic most authorities initially reverted to reassurance and clung to perceived “facts”, at least until the “facts” turned out not to be facts at all, rather assumptions based on incomplete information.

There is a link between such uncertainty and a more global sense of precarity. Several of the interview participants made direct reference to human culpability in causing the
pandemic itself through deforestation and habitat destruction. This association has been confirmed by models which show a clear correlation between deforestation and the number of outbreaks of zoonotic diseases from 1990 - 2016 (Morand and Lajaunie 2021). Recognition rather than denial of our biological precarity could be a precondition to constructively moving toward realistic solutions to the larger concerns of antimicrobial resistance and global pandemics. Fear of precarity should not prevent us from developing the discourse of uncertainty so that people can learn to "stay with the trouble" (D.J. Haraway 2016). When Haraway urges us to investigate human/non-human “entanglements” with the natural world I believe she is calling for an honest grappling with precarity in a way which acknowledges our utter dependence on threatened webs of life. It is in thinking and speaking differently about the human body that the reality of humans as ecological beings becomes obvious.
Chapter 4: Conclusion:

This research paper is an investigation into how family physicians understand and define the microbial entities that they encounter in their daily practice. It has provided an opportunity to think critically about the human body in terms of its constituent microbial species and the ways in which that body is situated within biologic and social networks, particularly in the context of antimicrobial resistant organisms and pandemic viruses. The overuse of antimicrobial drugs in medicine and agriculture is linked to problems of antimicrobial resistance everywhere on the planet (Sugden, Kelly, and Davies 2016). This overuse must be urgently curtailed to avoid further exacerbating the problem of deadly superbugs which are resistant to most or all currently available drugs. Understanding the cultural and cognitive bias inherent in how biomedicine has historically constructed the human body as autonomous and separate from the microbial world enables us to conceive of the human body in a way that may help facilitate collaboration across disciplines.

The main microbe of interest for my study, SARS-CoV-2, has shone a bright light on our place as humans living in a microbial world. It joins a list of other zoonotic pandemic pathogens that have crossed the species barrier and have become invasive species in human ecologies (Rappuoli 2004; Wu et al. 2020). Like the others, SARS-CoV-2 acts at both a macro and micro-ecologic level, affecting both populations and individual bodies. Although current public medical discourse tends to rely on the nation-state paradigm in describing human bodies as being under attack by an invading foe, there are other and potentially more helpful ways of conceiving of the human body and its relationship to the microbial world. This study shows that physicians use ecological thinking to understand and describe SARS-CoV-2 and illustrates how an ecological theory of the “human body as holobiont” can advance biomedical
approaches to other microbial challenges, including the spread of superbugs and pandemic viruses.

In 1988 Donna Haraway called on us to recognize the embodied nature of all knowledge and reject the “conquering gaze from nowhere” (D. Haraway 1988, 581). Biomedicine has been the keystone of the arch that frames the “gaze from nowhere” because of its underlying assumption of a universal human body. This disembodied gaze has served us well over the past century, particularly if measured by the declines in the rate of premature death from infection, facilitated by the use of vaccines and antimicrobials. However, this essentializing gaze is inadequate in the age of globalized pandemics, antimicrobial resistance and biodiversity collapse. A more sophisticated view would be situated in the knowledge and recognition of a wide diversity of both human and ecologic biomes. The traditional biomedical construction of a universal bounded and autonomous body is clearly outdated. An evolving biomedical conception of the microbe/human symbiotic host body challenges the concept of the bounded individual and offers the alternative of a networked human ecosystem or holobiont. This new paradigm allows for the possibility of seeing “our former microbial adversaries as fellow holobiont travellers within an interrelated and interdependent biosphere”

Evidence from this study suggests that an ecological conception of the human body is replacing a model of the “body as a nation-state” in biomedical discourse. COVID-19 has made it clear that our bodies are anything but “nation-states” when it comes to the global flow of microbes. The current macro-ecologic crisis is seen by doctors to include the micro-ecologies of the human body itself. An ecological paradigm for how the body is understood in biomedicine offers new opportunities to discourage the overuse of antimicrobials, by focusing
less on *antimicrobial stewardship* and more on beneficial *microbial stewardship* when clinically appropriate.

Future research could explore microbial stewardship as an alternative to antimicrobial stewardship when attempting to influence rates of antibiotic use and diminish widespread antimicrobial resistance and dysbiosis. Systemic efforts to address antimicrobial overuse that focus excessively on antibiotic stewardship may be flawed because they assume a universal human body which denies the situated nature of medical knowledge and the heterogeneity of bodies and circumstances. Future research is necessary on how to further develop a model of microbial stewardship. Any such model would need testing and review after presentation to a larger cohort of family doctors and others including infectious disease specialists and epidemiologists.

Scholars such as Haraway and Latour have long argued that the macro-ecological crisis facing us all requires us to investigate human complexity and entanglements with other species without the constraints of either human exceptionalism or narrow biological determinism. The human holobiont, understood as a coevolved symbiotic assemblage, fulfills the need for a shared conceptual framing of the body and is recognized as an emerging subject of inquiry for medical anthropologists (Fuentes 2019). Theorizing the human body as a holobiont is a way to bridge the conceptual gap that exists between nature and culture, between natural and social sciences, and between human and environmental sciences such that productive analyses and solutions may be applied to difficult problems such as antimicrobial resistance. Ironically, it appears that decolonizing our modernist ideas of the body requires us to embrace and celebrate its actual colonization with a vast realm of trillions of microbial beings and non-living entities including viruses, fungi, archaea, and bacteria.
I believe that the biomedical paradigm of the body as a nation-state is no longer sufficient or appropriate to address problems such as antimicrobial resistance, global pandemics and even climate change. It is time to acknowledge and advance an alternative biomedical paradigm which favours a view of human bodies as complicated microbial ecologies which exist within, and are completely dependent upon, larger functioning ecologic networks. This study demonstrates that this change may already be underway among family physicians. As noted by Bruno Latour in his plea for a new politics of nature: “What counts is not if you are religious or secular, but if you manage to protect humans from being defined without the cosmos that provide their life support, and nature from being understood without humans that have collaborated with non-humans for eons” (Latour 2011, 73).

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i Archaea are single cellular organisms without nuclei which constitute a separate domain of life.

ii Phages, also known as bacteriophages, are viruses that prey on bacteria.

iii Antimicrobial resistance (AMR) is widely recognized as a threat to progress on sustainable development goals such as “health, food security, clean water and sanitation, …poverty and inequality” (IACGA 2019). A 2017 Canadian national task force report states: “Programs and policies that highlight education, awareness raising as well as professional and regulatory oversight will be required to reduce inappropriate prescribing, dispensing and use of antimicrobials in humans and animals and to conserve the effectiveness of new and existing antimicrobials” (AMR 2017, 18).

iv A minority of known bacteria can be grown in optimal conditions in controlled laboratory settings and then identified visually by microscopy. The technique of growing them is known as culturing.

v Viruses reproduce themselves by utilizing the machinery of the cells they infect in order to replicate themselves.

vi Bacterial vaginosis is a common symptomatic condition caused by unbalanced growth of certain vaginal organisms.

vii Clinical practice guidelines are commonly established in Canada and elsewhere by expert panels in order to encourage what is referred to as ‘evidence-based-medicine’ or EBM. They are recommendations based on the best available and peer reviewed scientific literature. In the absence of peer-reviewed literature, guidelines are based on expert opinion.

viii Pip-Tazo is an abbreviation of piperacillin/tazobactam which is an antibiotic combined with a beta-lactamase inhibitor (beta lactamase is a bacterial enzyme which provides a degree of antibiotic resistance to many bacterial species such as Staphylococci, Enterobacteriaceae, and many others).

ix Another way of saying pip-tazo.

x ICU specialist physicians

xi Health authorities in BC and Alberta are the government organizations which administer health care services.

xii Group B streptococcus is a common bacterium which can cause serious illness in newborns.

xiii Sepsis is life-threatening illness caused by pathogenic bacteria that can affect newborn infants.

xiv Other zoonotic pandemic pathogens include SARS, MERS, HIV, Ebola, and H5N1.

xv I credit this poetic phrase to Dr Ross McDonald who helped a great deal with the edits for this paper.
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Appendices

4.1 Appendix A: Survey results

How many years have you been in practice?

Do you work in a community or hospital setting, or both?
Have you cared for any patients with confirmed COVID-19?

![Pie chart showing 70.00% for Yes and 30.00% for No.]

The Sars-Cov-2 is known to have crossed the species barrier to infect human populations and there is concern similar events may occur in the future. Do you agree or disagree that this a serious concern?

![Pie chart showing 78.95% for Strongly agree, 21.05% for Somewhat agree.]

Strongly agree  Somewhat agree  Neither agree nor disagree  Somewhat disagree  Strongly disagree
Do you consider the germ theory of disease to be a useful concept for understanding infectious disease and human immunity now that we consider many microbes to be of benefit to health?