THE HUMAN MICROBIOME: THROUGH THE LENS OF ENVIRONMENTAL GEOGRAPHY

By

John Lyman

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Committee Members:

Eric R. Sarmiento

Colleen C. Myles

Introduction

While human bodies are made up of approximately 30 trillion human cells, we are also home to over 100 trillion "friendly microbes" that have evolved along with us. There are over 10,000 species of these bacteria and fungi; all performing various tasks in order to survive. These different microbes and their diverse tasks, when functioning in a balanced ecosystem rich with biodiversity, help us survive by fulfilling needs our bodies cannot perform for ourselves, or by aiding in these processes (Blaser 2015).

Some of these microbial traveling companions are rather controversial. Due to issues like dysbiosis, a reduction in microbial diversity, certain species can become pathogenic, or harmful to us. The idea of reducing diversity gets extraordinarily complex when the concept of scale is introduced. In and on our individual bodies, a lack of microbial diversity can allow a benign community to become pathogenic if they are left unchecked by their natural predators or competitors, similar to keystone species in nature (Lorimer 2016). This can cause a number of issues in a person and sometimes, in the worst-case scenario, death. On a larger scale, such as the global microbial community, humanity's willingness to embrace tools, or weapons, like pasteurization, vaccinations, and antibiotics, have changed human microbial diversity on a global scale. Indeed, there is mounting evidence that humanity's current plagues (diabetes, autoimmune diseases, allergies, to name a few) were born in part from our indiscriminate use of the very same tools that were wielded to protect us (Bach 2002; Blaser 2015).

In this paper, I examine some of the ways in which human microbiome research has begun to reshape our understanding of what exactly it means to be human, and how this affects our place in the global ecosystem. The goal of this paper is to use an environmental geography lens to review several literatures that are central to our emergent understanding of the human microbiome. I argue that fundamental shifts in conceptions of our bodies as complex ecosystems comprising trillions of microbial citizens call for a conservationist approach to managing these ecosystems. The purpose of this review paper is to encourage ethical and thoughtful ways of continuing this research and using the data it produces. It is almost inconceivable how many of these "friendly microbes" exist within and around us, and that makes every decision we make as humans and as stewards of this planet that much more complex. My goal of this work is to encourage a higher level of scrutiny of previously dubious decisions, such as over-use of antibiotics, and consider that these once-small decisions have the power to be genocidal to the tiny life forms that coexist with(in) us, with considerable ramifications for human well-being.

My analysis consists of four main sections. In the first section, I provide background on the Human Microbiome Project (HMP) and the history of human microbiome studies. In the second section, I focus on the research involving the physical and psychological effects of dysbiosis in the gut microbiome, as well as how diet has been found to influence the populations of those microbes that inhabit the gut. The third section analyzes research on anthropogenically caused "modern plagues". Allergies, autoimmune disorders, diabetes, and the obesity epidemic have all received human help in their spread and tenacity. The fourth section examines Post-Pasteurianism, and how this food movement is setting the course for policy that would cover far more than raw milk cheese and kombucha. I conclude the paper with some discussion of the

possible futures of microbiome research, and a plea to proceed with caution and with care. Like Uncle Ben says, “With great power comes great responsibility.”

A Brief History: Microbial Ecology & the Human Microbiome Project

Microorganisms were first discovered by Antony van Leeuwenhoek in 1676, while he was using a homemade microscope to view pepper that had been floating in water for roughly three weeks (Farrell 2016; Robinson et al 2010). He describes this moment: “I saw therein, with great wonder, incredibly many very little animalcules, of divers sorts…” (Farrell 2016, 7). Leeuwenhoek was seeing bacteria, and he refers to them as tiny animals. Two hundred years later began the golden age of microbiology, spurred by people like Louis Pasteur, the French chemist who introduced germ theory, and Robert Koch, the German physicist who discovered the bacterial cause of anthrax. Over the next century, research focused on culturing bacteria in order to identify whole communities and analyze the interactions and relationships, what is known today as microbial ecology (Robinson et al. 2010). These interactions, particularly how they influence the diversity of bacterial populations within humans and what constitutes a healthy balance, as well as the consequences of a change in human micro biodiversity, led to the Human Microbiome Project (HMP).

The Human Microbiome Project

In 2007, the National Institute of Health gathered a sample group of 242 “healthy” adults to be used as test subjects to help us better understand the microbial makeup of the human microbiome (Methé et al. 2012). What constitutes a “healthy” adult, according to the Human Microbiome Project, will likely be of great importance for individuals who desire to use treatments derived

from this research, as fitting within these parameters would increase chances of a microbiome-based therapy achieving predicted outcomes. There were 129 men and 113 women, with a goal of 20 percent of the sample group to be minorities. The inclusion criteria states that the subjects needed to be between 18-40 years of age, able to provide signed and informed consent, and had to give blood, oral cavity, skin, nasal cavity, and stool specimens. Female subjects were additionally required to give vaginal samples and have regular menstrual cycles. Using contraception methods was not an exclusion criterion unless said method was a hormone vaginal ring. The exclusion criteria were too great in number to all be listed here, but some of the exclusion criteria were: a body mass index (BMI) of greater than or equal to 35 or lesser than or equal to 18; blood pressure higher than 160/100, and the use of systemic antibiotics within the last 6 months. Once these "healthy" subjects were identified, they were tested in 15 and 18 sites, respectively, as women were tested in three sites in the urogenital tract. This brought the total specimen sample to 11,174, after the original 5,298 sample sites were resampled up to three times per subject (Methé et al. 2012).

The study revealed that the number of microbial cells in and around our bodies outnumbered the number of germ cells from parents ten to one (Lorimer 2016). The ratio of genes residing within the human microbiota to our own is 130 to one (Schneider and Winslow 2012). This should cause a paradigm shift in how we conceive of individual entities, and the guidelines for approach and administration of medicine and healthcare. No longer will a medical strategy based solely on the individual be sufficient. Later, I will argue that an ecological and conservation approach based on the idea of a complex balance in a community between a multitude of interrelated organisms will best serve those suffering from afflictions caused by imbalances of the

microbiome. Human microbiome research has rigorously analyzed the balance of the various microbial populations present in the human gut.

The Gut Microbiome - The Psychological, the Physical, and the Dietary

For over a century, the microbiome of the human gut has been the subject of much research and exploitation. In the early 1900's, companies and individuals peddled myriad types of purported cures and treatments under the name "probiotics" for what they referred to as "autointoxication", or sometimes "intestinal toxemia", which were being blamed for causing everything from melancholia to neuroses (Bested et al. pt. I 2013). While we now know that gut microbiome dysbiosis causes several notable health issues, this cultural phenomenon was blown out of proportion due to "...charlatanism, shysters, and pseudoscience" looking to profit from the ill-conceived, and often misunderstood, writings of a few prominent 20th century physicians (Bested et al. pt. I 2013). This stigma impeded the progress of research and our understanding of a vital part of our functioning microbiome. Contemporary science has shown that there was some truth to the myth, and that gut health is inextricably tied to our psychological well-being, our physical health and immune system, and that diet is a strong influence on our intestinal microflora.

The Psychological

As early as the late 1800's, after Louis Pasteur's ground-breaking germ theory of disease had become widespread, physicians like Charles Bouchard, Hermann Senator, and Thomas Oliver, were publishing work that made it sound as if our digestive tracts, and the colon in particular, were all but fighting against us, and that fecal matter was innately poisonous (Bested et al. pt. I

2013). While these ideas were popular, there was not a consensus among physicians, and the vague nature of digestive issues made testing and proving treatments difficult. This opened the door for a bouquet of products claiming to increase vitality and treat depression, all by aiding the bacterial flora of the intestines. Though there was genuine progress in gastroenterology made during this time, the lack of a holistic approach from physicians and the tendency of drug companies to put earnings before altruism cast a dark shadow over this work and this period in medical history (Bested et al. pt. I 2013). By the 1930's, the sensationalism of this research had waned, and the fervor would not return for decades.

In 2004, a series of experiments on mice performed by Noboyuki Sudo at Kyushu University, Japan, revealed that "...gut microbes could affect the development of hypothalamic-pituitary-adrenal (HPA) reaction to stress." The report also stated that "...the series of events in the gastrointestinal tract following postnatal microbial colonization can have a long-lasting impact on the neural processing of sensory information regarding the endocrine–stress axis" (Sudo 2004, 354) In other words, despite the rampant profiteering of the late 19th and early 20th century involving bogus probiotic treatments based on pseudoscience, the gut-brain axis is a tangible reality. Not only does this communication exist, "...it has been shown that stressful experience can lead to altered gastrointestinal motility, secretions, and blood flow; while, in turn, such alteration in gastrointestinal function is transmitted to the brain and can ultimately bring about the perception of visceral events such as nausea, satiety, and pain" (Sudo 2005, 353). This illustrates that stress can affect the makeup, or local diversification, of the gut microbiota causing myriad issues throughout the human ecosystem, such as chemical imbalances in the brain resulting in depression, or irritable bowel diseases (IBD) in the gut, and one can influence the

other interchangeably (Bested et al. pt. III 2013). Microbial populations can be changed rapidly due to high growth rates and an ability to adapt at a high speed, evolving quickly to their surroundings. This rapid evolution can allow for great change, positive or negative, depending on what a person eats, which is then processed by the microbiota. The process of balancing populations can take generations with species competition in the wild. This same process may only take a few weeks in the human microbiome (Costello et al. 2012, Venkatakrishnan et al. 2021).

The Physical

The physical manifestations of gut microbiome dysbiosis have a longer, and more documented, history than the psychological symptoms. This is likely due to the quantifiable nature of physical illnesses and is not hard evidence of the psychological afflictions being less prevalent throughout history. "IBS is the best characterized and most widely studied functional gastrointestinal disorder: it is a source of considerable discomfort for many and potentially disabling for some" (Shanahan and Quigley 2014, 1555). Irritable bowel disease (IBD) and irritable bowel syndrome (IBS) are household names in the modern, developed world. These diseases can wreak havoc on the body, and often the mind and spirit of patients. The symptoms of intestinal bowel diseases are noted to be exceptionally pronounced if patients have suffered physical or emotional trauma in their youth (Shanahan and Quigley 2014). These patients, feeling as if they must constantly be near a bathroom, or even sequestered in their own homes, can make a patient feel robbed of their freedom to move and live their lives with confidence. Treatments involving manipulation of the intestinal microbiota are anticipated to have a high rate of success with IBD, as "Nearly every mouse model of IBD requires the presence of the intestinal microbiota for colitis to develop"

(Damman et al. 2012). However, IBS may be a bit more elusive as it has no biomarker to aid clinicians in diagnosis, and symptoms and signs of progression can vary widely between individuals (Shanahan and Quigley 2014).

A treatment known as fecal microbiota (or matter) transplant (FMT) has had some success. Consumption of feces, or coprophagy, goes back centuries as a treatment, originally documented in Chinese medicine, albeit executed in a less modern fashion and consumed fresh, fermented, or dried (Petrof and Khoruts 2015). While technology and methods have evolved, the purpose and outcome are the same. Intestinal microbiota is taken from a healthy donor and is then given to a patient to introduce a balanced microbial population in the hopes that it will spread. This treatment is most commonly used, and approved, for *C. difficile* infection (CDI) (Petrof and Khoruts 2015, Shanahan and Quigley 2014).

There is hope to treat intestinal bowel diseases with therapy based on modulation of the gut microbiota, but there are several factors making this a difficult future to attain. More accurate biomarkers are necessary, particularly for disease risk (Shanahan and Quigley 2014). There must be a new form of probiotic "...beyond lactobacilli and bifidobacteria…", and while fecal matter transplant (FMT) has been approved for treating *C. difficile* infections, there must be more trials with the varying subsets of IBD (Shanahan and Quigley 2014). The complexity and diverse range of ecological niches within the gut make it difficult to alter our internal microbial ecosystem once established, similar to affecting change in an external ecosystem. However, changes in a person's diet, particularly an increase in dietary fiber, can increase the diversity of the intestinal microbiome (Venkatakrishnan et al. 2021; You et al. 2021).

The Diet

Discovering that your body is not entirely "you" can be disconcerting. Learning that your complete physical makeup is, on a cellular level, actually more bacteria than you, could possibly induce a panic. The lifeboat to cling to while floating through this existential sea of bacteria, fungi, and parasites, is that you have control over your diet. Your diet is what you are choosing to feed your intestinal microbiota, and directly affects the diversity of your gut microbiota.

The composition of your intestinal microbiota begins during labor and through delivery, with the baby acquiring *Lactobacillus* and *Prevotella* bacteria from the mother's vagina (Albenberg and Wu 2014). Cesarean section (C-section) babies are first colonized by bacteria found on the skin, such as *Staphylococcus*. Even at the earliest stage of development, diet begins to shape the gut microbiota, and it has been established that breast milk is the ideal sustenance for an infant. It should be noted that there have been advances made in the production of formula, but these formulas lack "...bioactive compounds in human milk that contribute to physiological functions such as absorption and digestion of nutrients, immune protection, and defense against potentially pathogenic gut microbes." (Albenberg and Wu 2014). These early stages of life are unstable and chaotic, as the low level of microbial diversity is similar to a tug-of-war. It is now widely accepted that antibiotics, particularly in youth, have an enormous impact on the gut microbiota diversity through later stages of life. In many cases, these changes are permanent.

By the age of three, the gut microbiota will appear similar to that of an adult, with a higher amount of microbial diversity, and more stability. From here, the question becomes: what types of food will encourage a healthy, diverse microbial ecosystem? While there are exceptions to the

rule, fiber is what develops niche areas in the gut. Decreasing the amount of fiber in your diet forces the microbiota to compete, allowing only the strongest to survive, ala Darwin's Theory of Evolution. Changes in the daily intake of fiber have the ability, or consequence, of dramatic shifts in microbial diversity in the gut, and the Western diet (high-fat, low dietary fiber) is depleting this bacterial diversity at an alarming rate. Hunter-Gatherers, like the Hadza of northern Tanzania, consume an average of 80-150g of dietary fiber in a single day. This is close to dietary fiber consumption estimates of a Paleolithic diet. The average person in the US consumes less than 20g of fiber a day (Venkatakrishnan et al. 2021). Diet is an effective, accessible tool for an individual who wishes to modulate their gut microbiome (Albenberg and Wu 2014).

How Help Became Hurt: Human Microbiome Dysbiosis and Modern Plagues

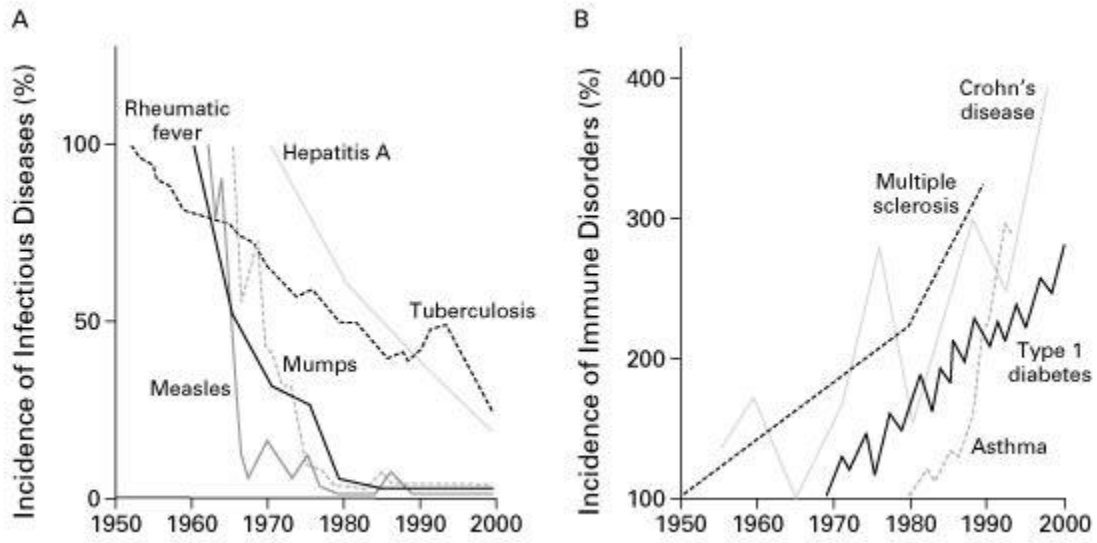
Germ theory helped establish the paradigm that microbes and bacteria cause disease, and therefore ought to be eliminated. Since adopting this disease framework, the developed and industrialized world has seen a reduction of incidence of infectious diseases (Bach 2002), longer lifespan, and exponential population growth, to name a few of the benefits to this binary approach to microbial life. Jamie Lorimer describes this as an "'anti-microbial' geography". In essence, the world is united in a pursuit of "...control and/or eradication of infectious diseases" (Lorimer 2017). There is growing evidence, however, that human-microbe relations are more complex than we once imagined. Autoimmune diseases, allergies, and obesity are all increasing at an alarming rate (Blaser 2015, Velasquez-Manoff 2013), despite advances in medical science and public health and sanitation. The following section discusses some of the issues we are

facing due to the “antimicrobial” approach to the world around us through sanitation practices, and the world within us, through antibiotics.

Autoimmune Diseases and Allergies

For all of civilizations’ triumphs over infectious disease, a wave of debilitating ailments now assails us from our very own immune systems. Autoimmune diseases and allergies abound in the developed world. Incidence of Type I diabetes has doubled in the last twenty years in the industrialized world. In 1999, one in 14 children had asthma, in 2009 it was one in ten (Blaser 2015). One in six children has eczema, while one in five adults have hay fever, and one in 250 has inflammatory bowel disease (Velasquez-Manoff 2013). These are only a few of the statistics regarding the rate of allergies and autoimmune disorders.

Jean-Francoise Bach published a paper in 2002 in which he states: "the main factor in the increased prevalence of these diseases in industrialized countries is the reduction in the incidence of infectious diseases in those countries over the past three decades.”



The graphs above come from Bach's paper and present an undeniable correlation between the decrease in infectious disease incidence and the increase in the incidence of immune disorders. There is also a geographic component: the incidence of these diseases decreases as one gets closer to the equator. Bach dismisses genetic and environmental factors as strong influences in these data, and instead focuses on socioeconomic status. The increased occurrence of hyperimmune diseases is certainly more associated with areas and regions possessing the benefits of wealth: modern medical care, sanitation practices, and water treatment technology (Bach 2002) These three factors, while being largely responsible for the exponential growth of the human population, removed our immune system's natural sparring partners, leaving a void in our human defense mechanism programming. Without these enemies whom we have coevolved with throughout human history, our immune systems have begun to turn on themselves (Bach 2002; Bilbo et al. 2011).

The notion of a rise in allergic and autoimmune disorders stemming from a lack of contact with microbes due to increased sanitation in the wealthy, developed world was originally proposed by Dr. David Strachan in 1989, and was later termed the "hygiene hypothesis" (Bloomfield 2016). In Strachan's report, he notes a correlation between the number of children in a household and the incidence of hay fever. Larger families were less likely to have children who suffered from this allergy, and he concludes this is because there is less spreading and sharing of infectious disease. Having fewer children per household and increased household sanitation, both signs of higher socioeconomic status, resulted in a higher likelihood of hay fever (Strachan 1989). Since 1989, the hygiene hypothesis has become more renowned, and has been conjoined with microbiome research. Biome Depletion Theory states that industrialized society has essentially

removed large swaths of the human microbial ecosystem, reducing bacterial diversity and therefore leaving the immune system unchecked. With little stimulus to "work out" the immune system, it begins to attack "...non-pathogenic self and non-self antigens" (Bilbo et al. 2011, 495). Knowing this, some sufferers of autoimmune disease have begun infecting themselves with hookworms to keep their immune systems in check.

Helminths & Beneficial Parasites

The image of a hookworm may, to some, seem like a creature from our nightmares, with a snakelike body and sharp teeth that allow it to drain human blood. There are 740 million people worldwide who are currently victims of these "...bloodsucking nematodes" most often found near the tropical regions of the globe (Bungiro and Capello 2011). Despite the incredible numbers of afflicted, *Ancylostoma duodenale* and *Necator americanus* continue to infect with little resistance, as infections are only common in poverty-stricken areas, symptoms vary widely, and medical treatments are expensive and not always highly effective (Bungiro and Capello 2011). While the people of the global south are struggling to free themselves of this scourge, many people in the global north who are suffering from allergies and autoimmune disorders are doing anything they can to get infected by these "gut buddies" (Lorimer 2016). This is a prime example of how our perceptions of the human individual has changed, as even hookworms, a parasite once targeted for extermination by the Rockefeller family for its deleterious effect on the working class, is now viewed by many as a necessary buffer, and even companion, to our immune systems (Velasquez-Manoff 2013, 52). There are reasons behind both sides of this dichotomy.

The prevailing factor influencing negative perception of helminth infection is socio-ecological. Hookworm infections cause morbidity in over half a billion people worldwide in low-income, rural countries. This puts hookworm infection second only to malaria in frequency of incidence (Bungiro and Cappello 2011; Lorimer 2017). These areas that suffer from hookworm morbidity are the very same places that have a higher rate of infectious disease, and lower incidence of autoimmune disorders (Bach 2002). In the global north, or developed, higher-income countries, there exist underground communities that help patients suffering from autoimmune diseases and allergies locate animals (worms), information through researchers and other experienced patients, and other advocates who encourage people to look to an ancient treatment, a so-called "gut buddy" if you will, to an illness caused by the excesses of modernity. In essence, the reintroduction of helminths to stimulate the ecosystem of the human immune system is comparable to the reintroduction of non-human ecological engineers, such as beavers, into an area in order to "rewild" and restore balance to an ecosystem (Lorimer 2020). This dichotomy of helminths as either an autoimmune treatment or a global health threat is relational geography between humans and microbes based on the socioecological boundaries of the global north and the global south (Lorimer 2017). Against this global political ecological backdrop,

It is believed that humans were originally infected with hookworms over 12,000 years ago due to domestication of dogs (Lorimer 2016). In fact, "the immune system has evolved in the constant presence of helminths, while helminths have evolved to dampen, rather than disable, the immune system of their hosts" (Allen and Maizels 2011, 384). This symbiotic relationship between humans and hookworms has been all but completely severed in the developed world, a result of public health and hygiene, running water and sewage systems, and modern medical treatments

(Bilbo et al. 2011). This eradication of parasites was originally celebrated as a freeing from the shackles of parasite-induced malaise and sometimes death. Now it appears that the blowback from this parasitic genocide comes in the form of a worm withdrawal. Since human immune systems have evolved to live in concert with worms, the loss of this old sparring partner is causing our immune systems to attack ourselves, resulting in a myriad of afflictions — Crohn's disease, IBD and IBS, allergies, and multiple sclerosis, to name but a few (Bilbo et al. 2013; Lorimer 2017; Velasquez-Manoff 2013).

The life cycle and function of the worm is summarized eloquently by Jamie Lorimer (2017, 545):

> Hookworms live in our guts and feed on our blood. They reproduce by laying their eggs in our faeces. Larvae hatch in warm, moist, shitty soil and seek to re-enter human bodies through the skin. Subsequent stages in the life cycle...see the larvae migrate to the heart, from where they eat their way into the lung. They are coughed up and swallowed, returning to the gut.

He continues to say that colonies of worms do not develop quickly and "...a modest 'wormload' can be tolerated without any symptoms." Not only are there often no symptoms, but there can also often be benefits of a helminth infection. There are people suffering from a number of autoimmune diseases who actively seek out *Necator americanus* in order to treat their illnesses. Moises Velasquez-Manoff, in his book *An Epidemic of Absence,* details his own experience of traveling to Tijuana in order to become infected. He describes paying $2,300 dollars for the

experience (Velasquez-Manoff 2013). Thus far I have focused on literature dealing with the microbes within us; I turn now to the microbial communities around us.

Post-Pasteurianism

As the modernized world has utilized antibiotics to kill potentially pathogenic microorganisms within ourselves, pasteurization is the technique developed to rid food of potentially pathogenic microorganisms before they enter us. While this paper argues that human-microbe relations are often beneficial, complex and mirror the interrelatedness of a natural, animal ecosystem, pasteurianism is not innately malicious. The goal of this paper is to encourage individuals and policy makers to avoid political paradigms that promote generalized anti-microbial policy (Speake 2011) over critical, scientific analysis, not to polarize the issue.

Milk

Prior to pasteurization, milk had been a cause of food borne illness, sometimes resulting in death. With milk being a household item, it is not surprising that it came under the scrutiny of the federal government (Kurtz 2013; Weisbecker 2007). In the early 1900's, as Americans left the countryside for more urban areas, it became more difficult to keep milk fresh long enough for consumption in cities (Weisbecker 2007). It was not long before people became ill, and even died, and milk was under the microscope for government regulation. In 1939, the U.S. Public Health Service had drafted the Model Milk Health Ordinance and began putting pressure on the local governments to follow suit (Kurtz 2013). Farmers and distributors fought back but given that there had been a multitude of illnesses and even deaths resulting from consumption of bad milk the new law was upheld. By 1987, federal law prohibited the selling of raw milk across

state lines. As of today, there are states where raw milk can be purchased, but the specifics vary widely. Due to this, there are still foodborne illnesses associated with raw milk reported every year (Kurtz 2013; Weisbecker 2007).

Pasteurization of milk was, ultimately, a decision for the benefit of public safety, and, in cases such as this, science was used to "...provide actionable solutions," which were prioritized over a more thorough scientific understanding of the harmful nature of the bacteria present in milk (Speake 2011, 539). Pasteurization technology was used as an 'atomic weapon' against bacteria, and pasteurianism has dominated food science for decades, discouraging advances in understanding microbial ecologies. It also paved the way for biopolitics that gave governments the power to force citizens to comply "...with compulsory pasteurization laws" (Speake 2011). This "biopolitical governance" as Foucault refers to it, is "...that policy measures seek to securitize the health of the population while maximizing the productive capacities of the national territory" (Sarmiento 2020, 323). These regulations favor large scale producers possessing the financial resources necessary to meet the federal standards, reducing competition from small scale producers, who may benefit from updated food safety policy based upon more recent studies of microbial science (Sarmiento 2020). Pasteurization and indiscriminate food regulation can also remove identity from food culture(s), "...for many...the presence or absence of microbes matters, in terms of not only individual and public health, but also the situated, power-laden political ecologies of place" (Sarmiento 2020, 321).

Biological Citizenship - Microbiopolitics

Heather Paxson (2007, 17) defines microbiopolitics as "The creation of categories of microscopic biological agents; the anthropocentric evaluation of such agents; and the elaboration of appropriate human behaviors vis-`a-vis microorganisms engaged in infection, inoculation, and digestion." The problem with the Pasteurian regime exists in limiting an individual's ability to "...invest in the potentialities of collaborative human and microbial practices" (Paxson 2007). Microbes play an integral role in many of the practices in organic farming, such as making compost. This process is nothing short of a miracle of earth efficiency, wherein microbes transform what is essentially garbage (leftovers from crops, food, and various farming tasks) into a soil additive that is beneficial for the soil, and its microbes, and contains no trace of synthetic fertilizers (Ingram 2010).

Another arena where government food regulations have been questioned is the regulation of kombucha, a fermented tea drink. In 2010, Whole Foods temporarily ceased sales of kombucha on the basis that some of the bottles may have contained more alcohol than the purported "less than 0.5%". This caused an entire industry, and their customer base, to become aware of the concept of food regulation regarding living microbes in their food. The Alcohol Tobacco and Tax Trade Bureau (TTB) put every kombucha manufacturer at risk of being shut down over less than 1% alcohol by volume (ABV). The purpose of processes such as pasteurization and agencies like TTB is to protect consumers by ensuring that foods and beverages available for commercial purchase are safe. Banning or restricting access to a product that promotes health and wellbeing, or insisting upon pasteurization which neutralizes the beneficial potential of a product, is contradictory to the goal of public safety. It can also undermine public faith in

government regulatory agencies. In a paper by Christie Spackman, some of the kombucha consuming public share their thoughts on this: one says "... as a person with an immune deficiency, I LIVE off this stuff. It keeps me from having to drown in antibiotics." Another states, ''It is OK for us to consume aspartame, a proven lethal chemical, but it is not OK for us to consume Synergy? Big Pharma/Big Business ruled Government is at it again." (Spackman 2017, 57) Synergy is a brand of raw kombucha. Labeling our foods is an important practice, and it can help people in their decision-making process when they are purchasing foods and food products, but it would appear that the more pressing issue than a 0.5% discrepancy in ABV is that foods containing live microbes do not fit into the existing categories of bureaucratic management and regulation. If the TTB continues to operate with the mission to keep the public healthy and safe, it would be prudent to broaden their purview to include guidelines for raw foods and beverages, which can improve individual health.

Conclusion

In this paper, I have explored some of the ways in which human microbiome research has altered our perception of ourselves as human *individuals*. Mental illnesses do not manifest solely within the mind, nor are psychotropic drugs the only treatment, as we now understand the influence the health of the gut microbiota has on the brain and a person's mental wellbeing. In a sense, your mind is not (completely) your own. Physical ailments, such as *C. difficile*, can be treated with the help not only of a reconstitution of gut microbiota, but from a transplant from another person entirely. When you sit down to a meal in order to nourish yourself, you are joined by trillions of microbes that contribute directly, or via byproducts, to the processes necessary for your survival, and what you feed them (yourself) influences your entire ecosystem. The effects of taking

antibiotics do not end with your symptoms, but instead can kill entire populations of benign bacteria in your microbiome, possibly leaving you in a far worse physical state than your illness, as well as potentially creating antibiotic resistant strains of bacteria that could harm others. Infectious diseases and parasites, like helminths, have been a part of us and our evolution for over ten thousand years, and their recent absence in the bodies of people in developed parts of the world has caused an epidemic of autoimmune diseases. The live microbes present in unpasteurized foods and drinks can be consumed to promote health and become a part of our microbiome. We carry within us and around us entire ecosystems of microscopic life, this "other" that is also us, ever present and ever-changing. We influence these massive populations of minute bacteria with our every decision; and the bacteria, in turn, influence our health and well-being. Once trivial decisions involving antibiotics, hand sanitizer, and what to eat for lunch, now take on an entirely different level of import and consequence when weighed against the potential for causing a microbial imbalance.

The microbial ecosystems within us parallel the natural ecosystems and environments around us, to some degree; for instance, the concept of keystone species. Jamie Lorimer defines a keystone species as "... an organism that exerts disproportionate influence on an ecology relative to its abundance or body mass." (Lorimer 2020, 60) In Lorimer's book, Probiotic Planet, he describes how removing wolves from Yellowstone removed the perceived grazing barriers of the elk, so that they were able to decimate the vegetation. Reintroduction of the wolves saw the vegetation return. This same concept is being used for a predator in our gut, the hookworm, without which the immune system can run rampant and cause autoimmune diseases. The reinfection of hookworms has been shown to help regulate the immune system. An example of a possible,

future microbial conservation practice involves “ecosystem engineers”, like beavers and coral. These are species "...capable of creating, maintaining, and destroying a habitat." (Lorimer 2020, 60). In the near future, once the research has identified more of the populations of microbiota and their respective processes, it may be possible to introduce specific ecosystem engineers in order to modulate problematic bacterial diversities in any portion of the human microbiome, similar to fecal matter transplant, but with a more laser-like targeting system and quantifiable therapeutic dosage and a more predictable outcome. There has already been some success with using FMT to treat mental illnesses, due to the unidirectional communication between the gut and the brain (Meyyappan 2020).

The human individual can no longer be considered an isolated entity, whose thoughts and actions end and begin only with the parent cells. We are superorganisms composed of trillions of microbes enabling us to be more-than-human. Microbiome research can revolutionize how we approach virtually every aspect of human health, and how we situate ourselves in the larger ecosystem of Earth. It would be wise to use a conservationist approach, and, as Aldo Leopold said, "think like a mountain”. Consider the interrelated nature of all life around us, and all the life within us.

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