A Rhetorical Genealogy of Bacterial Psychology

by

Jennifer R. Saltmarsh

B.A. in English, University of California, Berkeley, 2007

M.A. English Composition, San Francisco State University, 2011

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This dissertation was presented

by

Jennifer R. Saltmarsh

It was defended on

August 8, 2019

and approved by

Cory Holding, Assistant Professor, Department of English, University of Pittsburgh

Stephen Carr, Associate Professor, Department of English, University of Pittsburgh

Richard Doyle, Edwin Earle Sparks Professor, Department of English, Pennsylvania State University

Dissertation Director: Don Bialostosky, Department of English, University of Pittsburgh

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Jennifer R. Saltmarsh, PhD

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This dissertation traces the historical trajectory of an idea: that we can learn about human perception and sensation by studying how microorganisms make decisions. Alfred Binet—experimental psychologist and master hypnotist—first put forward this idea in *The Psychic Life of Microorganisms* (1888). To investigate how Binet's claim came to life eighty years later, I focus on research that I call "bacterial psychology." This research studies microbial relations to, and influence upon, humans. To engage this research I approach rhetorical theory in two primary ways. First, I practice rhetoric of science in the traditional sense when I analyze scientists' metaphors about microbes, which lean towards anthropomorphism. I engage rhetorical theory differently when I suggest we can use microbiome research to enhance theories of the body, to see suasive agency at the material and bodily level. In doing this, I step outside the established bounds of rhetoric of science—but with the intention of broadening the field and fostering dialogue between rhetoric and microbiome research.

As the biological sciences explore the terra incognita of our non-discursive interactions, the exigence increases for humanities scholars to join conversations that are redefining the human. Our bodies and minds are being framed as distributed and composed of a multiplicity of agents, challenging assumptions about autonomy, individuality, and genetic determinism. Additionally, I argue that understanding ourselves as enmeshed with our environs enables us to be more responsive, and responsible, to our environs and to each other. To this end I synthesize research on microbial ecology with philosophies and worldviews that faded as the sciences developed, such as indigenous ecological knowledge, ancient Buddhism, and panpsychism—the idea that mind is derived from feeling and exists even in primitive life forms. In cross-pollinating these ideas with rhetorical theory and microbial ecology, I contribute to conversations in animal studies, ecological, and cultural rhetorics that question the locus of self. I conclude by synthesizing rhetorical theory on group identification, hypnosis, and suggestibility with microbiome research that echoes Binet's suggestion—that microbes make decisions and we can learn about ourselves by studying them.

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1.0 Introduction

This dissertation traces the historical trajectory of an idea: that we can learn about human perception and sensation by studying how microorganisms make decisions. This idea seems to have been first put forward in *The Psychic Life of Microorganisms* (1888) by Alfred Binet, an experimental psychologist and master hypnotist—who also invented the IQ test. The year prior to *Psychic Life* he published another book, *Animal Magnetism.* Though I do not spend much time with Binet's work itself, I do suggest that his research interests and practices are important to keep in mind while reading the following chapters because by the end we will return full circle to Binet's suggestion, by way of the rhetorical conundrum of hypnosis and suggestibility. In between here and there I investigate how, eighty years later, microbiologists would animate Binet's argument about human-microbial evolutionary relations, helping to create conceptual space for later microbiome research.

To investigate how Binet's claim came to life so many years later, I engage rhetoric in two primary ways. First, I examine microbial researchers' language choice, which at times leans towards the anthropomorphic. When I engage microbiology in this way, I practice rhetoric of science in the traditional sense. I engage rhetorical theory from a different angle when I suggest that current microbiome research can help us to expand theories of suasive agency, to see agency as material, decentered, and distributed across bodies. When I do this, I step outside the established disciplinary bounds of rhetoric of science—but with the intention of broadening the scope of the field.

I only discovered Binet's work because I was reading Julius Adler, a prominent biochemist who cited Binet to argue that we should study bacteria to better understand our own psychology and neurobiology. But before I had heard of Binet, this project began to emerge from my reading Sandor Katz's *Art of Fermentation*. What I had initially assumed was simply a fermentation handbook, would inevitably transform the way I understood my body in relation to the world that envelops it. In his introduction, "Fermentation as Co-evolutionary Force," Katz arrays an assortment of cultural and scientific sources. He explains that "...fermentation is a natural phenomenon much broader than human culinary practices; cells in our bodies are capable of fermentation..." Given this, he argues that "humans did not invent or create fermentation; it would be more accurate to state that fermentation created us." In one swift move, Katz upends human exceptionalism, and reframes humans as the product of microbial metabolic processes. I was captivated because I had also been considering some essays in rhetorical theory that obliquely echoed Katz's claim. I wasn't sure what to do first: use rhetoric to understand what microbiome research was saying about human decision-making, or use microbiology to understand what rhetoric is at the biological level. This project is my attempt to do both at once.

George Kennedy initiated a conversation on animal rhetorics with his essay "A Hoot in the Dark: The Evolution of General Rhetoric." Here, he reframes what he thinks rhetoric is: *not* primarily a human art or science, but rather, the *emotional energy* that exists prior to speech and conscious intent. Kennedy suggests that humans and animals share a "'deep' universal rhetoric," and that "speech would not have evolved among human beings unless rhetoric already existed." In doing this, Kennedy extends the potential for rhetoric to any life form that can give signals. Twenty years later, in her essay "Creaturely Rhetorics," Diane Davis acknowledges Kennedy's claim, but with a caveat. She argues that what Kennedy calls

> "rhetoric" is itself dependent on an always prior *rhetoricity*, an affectability or persuadability that is due not to any creature's specific genetic makeup, but to corporality

> more generally, to the exposedness of corporeal existence. To be affectable, persuadable, is to be always already affected, persuaded, which means: always already responsive. Rhetoric is not first of all an essence or property "in the speaker," but rather, an underivable obligation to respond, that issues from an irreducible relationality.

Some key phrases from this conversation between Kennedy and Davis stuck with me: from Kennedy, the idea of a "deep universal rhetoric;" and from Davis, the "exposedness of corporeal existence" and "an irreducible relationality."

At the time, I took all of this to mean that rhetoric is not just an art that humans practice. Rather, before this, something akin to rhetoric occurs in our bodily processes—making the body an open system that engages in a primordial, material dialogue with its environs. This framework enabled me to understand the body and environs as one, in material terms, even though I had already encountered this idea abstractly, though without quite grasping it. Although I had found the Kennedy and Davis essays compelling, I was initially unsure about what to *do* with them. But Sandor Katz's proclamations about fermentation grounded the Kennedy and Davis readings in a material, even if invisible, subject matter.

Though Kennedy and Davis approach the topic of animal rhetorics a bit differently, they both challenge Kenneth Burke's classic definition of man as "the symbol-using animal." Though symbol use clearly plays a role in human cultural identification, Kennedy and Davis both point to the invisible, ineffable, and perhaps unconscious aspects of persuasion. These aspects of rhetoric resist neat methodologies, they resist our familiar pedagogies. One might ask: how could we even begin to teach Kennedy's "deep universal rhetoric," or Davis's "irreducible relationality" in any practical way?

Wanting to better understand what Katz meant when he said that fermentation created *us*, I followed his footnotes to *What is Life?* by Lynn Margulis and Dorian Sagan. First, they explain the biochemistry of fermentation. Then, they poetically rephrase how fermentation happens inside of our bodies. "In the normal waking state," they say,

> human bodies burn sugars aerobically, using oxygen atoms drawn from the air. But in strenuous activity the body reverts to a distinct metabolism; muscles ferment sugars in the same anaerobic way invented by early bacteria. When stressed, our bodies thus 'remember' the times before the atmosphere became suffused with oxygen. Such physiological flashbacks represent past environmental conditions and the bodies that evolved to live in them. In a very real sense, all beings today retain traces of Earth's earliest biosphere.

Margulis and Sagan turn the body into a geo-historic window, a portal between bacteria and atmosphere, between microcosm and macrocosm. Their analogy of muscles fermenting sugars as a *physiological flashback* is particularly striking because it is a *visual* metaphor that depicts an *in-visible* process: tucked away deep inside our muscles, muscles which we never *see*, muscles which don't *see* anything at all. This metaphor brought to life both Kennedy's "deep universal rhetoric," as well as Davis's "irreducible relationality."

Another of Katz's footnotes stood out on name alone—"Bacteria are Small but not Stupid: Cognition, Natural Genetic Engineering, and Socio-bacteriology." James Shapiro wrote this article to persuade his peers that they should see bacteria differently. Shapiro does three things in this article that further enlivened the Kennedy and Davis essays: First, Shapiro says that bacteria are able to "commandeer the basic cell biology of 'higher' plants and animals to meet their own needs." If this was true, I wasn't sure how to *not* call it persuasion—even if the process he refers to involves no words, no images, and no conscious awareness. This sounded like Kennedy's "deep universal rhetoric." The second thing that struck me was Shapiro's declaration, that "it has long been customary to draw comparisons between bacterial chemotaxis [the movement towards attractants or away from repellants] and the operation of a neurosensory system." It was conceivable that comparing bacterial movements to neurosensory systems was simply a convenient descriptive device. However, I couldn't help but wonder about a material basis for this analogy. The third thing that Shapiro references, which sounds unavoidably rhetorical is quorum sensing, a keyword in bacteriological research. Quorum sensing describes the intercellular chemical signaling process by which bacteria detect their population density to "synchronize the gene expression of the group, and thus, act in unison". Something about the quorum sensing process reminded me Davis's "irreducible relationality".

At that time, I had also been studying non-verbal and non-conscious forms of persuasion, phenomena such as crowd psychology. So, the term quorum sensing set off a series of disruptive, inquiry-driven aftershocks:

Are the scientists who use this term anthropomorphizing?

Is that ok if it's only bacteria?

But, is it really anthropomorphizing if bacteria were making decisions billions of years before humans?

Can organisms make decisions without brains?

Are the scientists also parenthetically implying something about human decision-making?

Are they allowed to do that?

These questions were compounded by the fact that quorum sensing happens pretty much anywhere bacteria congregate, places like inside the human body. I couldn't shake the idea that—through our microbiota—humans might unconsciously enact some kind of physical analog to quorum sensing. Seeing the imaginative impact this metaphor had upon *me*, I wondered how it affected the scientists who used it daily. Could a trained professional bracket off this metaphor's cascade of curiosities in a way that I could not? This flurry of unknowns led me to use rhetoric to parse how bacteriologists were talking about "decision-making," and to use bacteriology to parse what rhetoric or persuasion might look like at the pre-symbolic, bodily level—and how this might manifest at the level of human culture.

Raymond Williams calls *culture* "one of the two or three most complicated words in the English language…mainly because it has now come to be used for important concepts in several distinct intellectual disciplines and in several distinct and incompatible systems of thought" (49). And Katz is profoundly struck by

> the fact that we use the same word—culture—to describe the community of bacteria that transform milk into yogurt, as well as the practice of subsistence itself, language, music, art, literature, science, spiritual practices, belief systems, and all that human beings seek to perpetuate in our varied and overlapping collective existences...I have searched—without success—for examples of cultures that do not incorporate any form of fermentation. (6)

This compounded meaning of culture makes sense, even if only obliquely, when we consider that the cells in our body are capable of fermentation. Culture requires bodies and arises out of bodily congregations. And, cultures exist within, and unfold processes deep inside of, our bodies. Williams explains that "in all its early uses," culture "was a noun of process: the tending of something, basically crops or animals," but by the early sixteenth century the metaphoric use had also entered the vocabulary and "the tending of natural growth was extended to a process of human development." *Culture*, as applied to the physical process of a "germ culture" would not be used until the 1880s (ibid). In a way, science's culturing of microbes has led us to also attempt to culture ourselves (in the physical sense) via microbes (though we have been doing this unconsciously through diet since before we were humans). Katz states that ferments "predate our consciousness of how to manipulate conditions so as to guide their development. But our consciousness did develop, and as part of that, so too did the fermentation arts...our ability to [ferment] is as much a product of coevolution as the person, plant, yeast, or bacterium...coevolution encompasses even culture" (5-6). Katz renders culture, coevolution, and consciousness as an elegantly knit braid, with the trouble of consciousness as the main strand. The already-sophisticated feedback between bacteria and humans has now entered into conscious human awareness, and we now attempt to consciously mediate our dietary interactions with them. Seeking a material solution to a visceral, metaphysical problem, I read *The Art of Fermentation* to heal digestive ailments and what I presumed were related mood symptoms. I believed that the microorganisms in the food I ate were healing me physically, and that their collective tendencies somehow figured into my own collective tendencies with other humans.

The mystery of this process made it all the more compelling, as did the fact Hippocrates prescribed whey, which was also a fashionable health drink in the seventeenth century, before anyone knew about microbes. Paul Feyerabend is famous for proclaiming that "anything goes" in producing novel scientific theories. He argues that science is "an essentially anarchic enterprise" and that "theoretical anarchism is more humanitarian and more likely to encourage progress than its law-and-order alternatives" (1). Feyerabend posits that "there is no idea, however ancient and absurd, that is not capable of improving our knowledge. The whole history of thought is absorbed into science and is used for improving every single theory" (27). Quorum sensing speaks to the mysterious interplay of conscious and nonconscious processes we experience when making decisions, which makes it stand out (almost glaringly so) within otherwise standard scientific discourse. The mystery this term evokes may have led to its success. In "Learning the Grammar of Animacy," biologist Robin Kimmerer offers the example of "puhpowee," a Potawatomi word that refers to "the force that causes mushrooms to push up from the earth overnight" (128). She was stunned to discover that this word exists because Western science has "no word to hold this mystery," but rather, tends to use terms that "define the boundaries of our knowing. What lies beyond our grasp remains unnamed" (ibid). In a similar vein, J.A. Shapiro says that "bacteria possess elaborate developmental and behavioral capabilities typical of higher organisms […] they display biochemical, structural and behavioral complexities that *outstrip scientific description*" (1988). Microbial ecology supports worldviews that Western science tends to overlook (perhaps due to the language constraints of objective scientific discourse) but which may help us to restore relations with our environs. Evelyn Fox Keller modelled the collection *Keywords in Evolutionary Biology* after Williams' collection of keywords. She explains the need for such a volume in evolutionary biology:

> …it is precisely because of the large overlap between forms of scientific thought and forms of social thought that 'keywords'—terms whose meanings chronically and insistently traverse the boundaries between ordinary and technical discourse—can serve…as indicators of the ongoing traffic *between* social and scientific meaning and, accordingly, between social and scientific change. (5)

As microbiome research contributes to evolutionary biology, it also contributes to the confluence between scientific and social thought. Like the rest of evolutionary biology, microbiome research could be used to make unethical claims, or to provoke wonder and curiosity about our relationships with other organisms.

One of my aims with this dissertation is simply to begin a conversation about metaphor use that could drive future concepts about the relationship between evolution and social reality. In his work on medical rhetoric (specifically, the analogy of “cadaver as gift”), Kenny Fountain draws upon Cicero's definition of analogy as "one of the figures of emphasis that 'leaves more to be suspected than has been actually asserted'" (173). The originators of the phrase “quorum sensing” did not directly state that bacteria and humans make decisions in similar ways—they did not comment *at all* upon the anthropomorphic spirit of the term. Perhaps they had no idea that microbiome research would reveal as much as it has about our bodily enmeshment with bacteria. Fountain (citing the Graves' research) shows that physicists use analogies as a mode of invention, which changes how they think about experimental data, and also shapes the way we perceive objects, but he adds that their use “may have unintended consequences" (173-74). Those who coined the term quorum sensing may not have intended to imply anything at all about humans, but nevertheless may have encouraged later scientists to imagine further implications. Fountain (citing Gentner et. al) explains that "[w]hen analogies do work, they foster significant insights, particularly when they connect back to an audience's prior knowledge” (174).

In *Crystals, Fields, and Fabrics: The Metaphors that Shape Embryos* (1976), Donna Haraway builds upon Mary Hesse's work, arguing that there is no correct literal description of anything by which an analogy should be judged (10). She offers Hesse’s example: “'nature becomes more like a machine in the mechanical philosophy, and actual, concrete machines themselves are seen as if stripped down to their essential qualities of mass in motion'” (ibid). Haraway adds that a metaphor “leads to a searching for the *limits* of the metaphoric system and thus generates the anomalies important in paradigm change” (9). “Analogy and primary referent,” she argues, “are both altered in meaning as a result of the juxtaposition” (10). Daniela Bailer-

Jones similarly says that an analogy is more than a "teaching aid or dispensable illustration, and can tell us what the system under study is like" (50). She cites James Clerk Maxwell, who argued (1871) that recognizing the formal analogy between two systems "leads to a knowledge of both, more profound than could be obtained by studying each system separately" (ibid). I suggest that analogies between human and bacteria behaviors drove knowledge of both in the way that Maxwell, Haraway, Hesse, and Bailer-Jones describe. At first, quorum sensing likened bacterial decision-making to human decision-making by alluding to legal proceedings, but eventually the bodily dimensions of human decision-making began to resemble bacterial decision-making. Before marine researchers coined the term quorum sensing, Lynn Margulis coined the term holobiont, which she defined (generally) as a "symbiont compound of recognizable bionts" (2). Whereas quorum sensing took off immediately, holobiont laid mostly dormant for over a decade. Holobiont accrued new textures once scientists began using it to explain coral-microbe symbiosis, which required knowledge of quorum sensing behaviors. Soon after, holoboint would also be used to describe human-microbe symbiosis.

There is no verifiable record that quorum sensing enabled the perspective shift that would enable the holobiont theory. Their chronological proximity may be a simple coincidence. Nevertheless, I take quorum sensing as a pivotal turn in scientists' comfort with comparing two systems that were once considered separate and distinct. In the chapters that follow I explore the discontinuous thread of Alfred Binet's idea that we can learn about human perception and sensation by studying how microorganisms make decisions. In chapter one, "Bacterial Motility Spells the Death of Man," I track biochemist Julius Adler's work during the 1960s and 70s. He mostly followed expectations of scientific objectivity in his efforts to develop a defined medium for studying bacterial motility, as well as the technology to observe it. Around this time, Foucault claimed that the concept of "man" was an elaborate fiction created through the objective language of the human sciences that attempted to know "man;" and, consequently, that a return to subjective language would spell the "death of man" (Order). Julius Adler used subjective language to describe bacterial movements and perception of environment; he also hoped to learn about human perception by studying bacteria, and speculated (via Binet) about the correspondences between them. In doing so, I argue that Adler welcomed into bacteriological discourse "language," subjectivity, humanist concerns—and consequently a Foucauldian "death of man."

In chapter two I show how evolutionary biologist Lynn Margulis used expressive language and Western science to challenge Western notions of self, and boldly attempted to shove "man" off a cliff. I discuss Margulis' work on the once-controversial Gaia and Endosymbiotic theories to illustrate her contributions to deep ecology and her rhetorical inclinations, both with colleagues and the broader public. I focus on her speculations about the spirochete (bacterial) ancestry of our neurons, and her petition that we "compare consciousness with spirochete microbial ecology." I suggest that this work echoes Whitehead's claim that "in the real world it is more important that a proposition be interesting than that it be true. The importance of truth is that it adds to interest…" (259). Margulis' expressive style engaged the public in theories that were otherwise mostly ignored or condemned by the scientific community because they could not yet be falsified. I suggest that asking the public to entertain these ideas is not as scientifically irresponsible as it was made out to be—as it encourages us to see ourselves as ecologically enmeshed organisms. In arguing the spirochete origin of our sensory nervous systems, Margulis echoed Binet's earlier claim (regardless of whether she was aware of it). I suggest that Margulis' theories could prompt us to see encounters with opponents as opportunities for generating novelty, and conclude by considering the overlap between microbial ecology, ecological literacy, and Indigenous traditional ecological knowledge.

In chapter three I discuss the value of metaphor and ambiguity in microbiology—especially quorum sensing—which encouraged scientists to see bacteria as social creatures. I track marine biologists' discovery in the 1960s that bacteria produced certain kinds of bioluminescence, research that began to blur distinctions between intentional choice and automatic reflex, between organism and environs. I argue that this metaphor plays upon vague and unstated assumptions, attitudes, and feelings about our own decision-making processes, and propose that the aesthetic delight of bioluminescence and quorum sensing eventually led bacteriological researchers into the human nervous system. The anthropomorphic tinge of quorum sensing may have encouraged scientists to see not only bacteria, but also humans, differently—particularly in their relation to each other. I discuss the consequences of quorum sensing in light of panpsychism, the ancient and oft-ridiculed idea that opposes both idealism and Cartesian dualism. Steven Shaviro distills panpsychism as the theory that "even rocks have minds…mind is a fundamental property of matter itself…thinking happens everywhere [and] extends all the way down…" (p. 85-86, 2014). Affirming panpsychism also means affirming, "as Whitehead does, that every *thing* makes a decision" (*ibid*), and to "redefine in terms of affectivity" or "feeling," rather than "cognition or computation" (p. 13, 2010). This would mean understanding "thought as affectivity"—something "prior both to life and to consciousness" (*ibid).* Believing that "life is derivative of feeling, rather than the reverse," Shaviro says, would transform how we perceive "our ecological position in the world" (*ibid*).

In chapter four I discuss human-bacteria nervous system symbiosis through three overlapping research areas: microbial endocrinology, microbiota studies, and the holobiont/hologenome theory. This research can broaden our theories of body, sensation, and agency which could, in turn, inform science's understanding of organismic relation. Field innovator Mark Lyte says microbial endocrinology joins microbiology and neurobiology, and explains that microorganisms "not only respond to, but also produce the very same neurochemicals [present in] mammalian systems," (2016) with signals passing between host and microbiota through the microbiota-gut-brain axis. As Michael Naafs puts it, bacterial quorum sensing molecules have "crosstalks with host hormones" (2018. p. 5). Similar to the bioluminescent squid, our microbiota produce effects on us, though not as perceptible, which echoes Brian Massumi's assertion that "the vast majority of the world's sensations are certainly nonconscious" (14). To conclude the dissertation, I arrive full circle at Diane Davis's "irreducible relationality," and her declaration that, "the body is not a discrete phenomenological entity. It's unclear where it begins and ends." We have long sought the defining feature that makes humans different, such as symbol use, but we could also look for similarities. Davis explains that Burke's belief in isolated nervous systems led him to also believe that group identification is a symbolic act. Burke may be correct when he says we attempt group identification through symbolic acts, but his assumption that we are isolated nervous systems now seems misguided, and his theory of identification highlights our cultural conundrum of individuality.

If our nervous systems are connected, then we need theories of persuasion that take this as a starting point. Our likelihood of being persuaded (or not) may have less to do with our own agency and autonomy than we have believed. Our permeability to beliefs and attitudes may arrive not just through our eyes and ears, but also our skin. Developmental Biologist Scott F. Gilbert argues that "the stories biologists tell are civics lessons," so it's "important to get the stories right" (xiv, 2004). Haraway seconds Gilbert's notion of a civically-responsible biology (1997, p.117).

These two thinkers, well versed in biology, philosophy and rhetoric alike, and have both written about the holobiont theory, and its implications for being human. Pierotti and Wildcat, scholars of Indigenous science note that biologists are accustomed to being asked, "what good is the work that you do?" They say this question “contains the hidden assumption that if what we do does not directly benefit human beings in some way it is without value,” and answer that “our work teaches us more about the other members of our community and how to live with them…” (2000, p. 1339). Researching bacteria to better understand humans is a roundabout, indirect method. Haraway calls our messy and ongoing processes of becoming naturecultures, processes which she says have been flattened into tidy binaries over the past few centuries by Great Divides like "animal/human, nature/culture, organic/technical, and wild/domestic" (2013, p. 15). Attempting to undo these tidy categories, Haraway suggests we consider “companion species…a permanently undecidable category, a category-in-question that insists on the relation as the smallest unit of being and analysis" (165). Seeming to allude to human-bacteria symbiosis, she argues that "[s]pecies, like the body, are internally oxymoronic, full of their own others, full of messmates, of companions" (ibid). It may be necessary to see the human body as a network of ecological systems, nested within larger ecological systems, if we are to repair our relations with the planet and other organisms.

2.0 Julius Adler: Bacterial Motility Spells Death of Man

> The attribution of humanlike consciousness and intentionality…to nonhuman beings has been indiscriminately termed "anthropocentrism" or "anthropomorphism." However, these two labels can be taken to denote radically opposed cosmological perspectives. Western popular evolution, for instance, is thoroughly anthropocentric but not particularly anthropomorphic. On the other hand, animism may be characterized as anthropomorphic but definitely not anthropocentric: if sundry other beings besides humans are "human," then we humans are not a special lot.
>
> —Eduardo Viveiros de Castro

> Anthropologization is the great internal threat to knowledge in our day.
>
> —Foucault, *The Order of Things*

In his Encyclopedia of Life Sciences' (2001) entry for "bacterial chemotaxis," Michael Eisenbach begins by briefly defining it as a "phenomenon in which bacteria *actively modulate* their direction of movement so as to approach chemoattractants (favourable, usually nutritious chemicals) and avoid chemorepellents (unfavourable, usually noxious chemicals)" (1, *italics* *mine*).[1] In the short opening paragraph, Eisenbach offers a brief history of the field: "The phenomenon of bacterial chemotaxis was discovered by W. Engelmann and W. Pfeffer in the 1880s. Thorough investigation of the phenomenon started in the 1960s with the quantitative, genetic and biochemical studies of J. Adler" (*ibid*).[2] This passage highlights three pieces of important information: that bacterial chemotaxis is largely considered to have been discovered by Engelmann and Pfeffer in the 1880s;[3] that Julius Adler seems to be *the* twentieth-century expert on bacterial chemotaxis (his research enabled by advanced technology); and that there's a significant historical gap in research on bacterial chemotaxis, roughly eighty years long. Nothing much seems to have happened with research on bacterial chemotaxis between the 1880s and the 1960s. Also note, there's something rhetorical and philosophical about the definition of chemotaxis—it is either movement towards the good or away from the bad.[4]

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1. I would like to draw attention to the term "actively modulate" because it connotes decisive behavior without explicitly stating that bacteria are *consciously* or *intentionally* making decisions. Though most bacteriologists are not prone to metaphysical speculation, the field's interest in consciousness and intent has begun to grow.

2. Eisenbach can be considered a central authority in contemporary bacterial chemotaxis; he has published extensively, is well cited, and went on to publish the textbook *Bacterial Chemotaxis* (2004).

3. Antony van Leeuwenhoek first discovered bacteria and reported on their motility in the late 1600s, though it would be more than two centuries until Engelmann (1883) and Pfeffer (1884) would demonstrate that "bacterial movement was not arbitrary" but rather, that "bacterial cells exhibited directed movement toward certain stimulus and away from others" (Lux & Shi, "Chemotaxis-guided Movements in Bacteria" 2004, 207-08).

4. I'll say more about this on pg. 25. In a sense, bacterial motility represents the good and the bad both for bacteria, and for humans in relation to bacteria. As I'll show in this chapter and chapter three on quorum sensing, the pathogenic lens and the communicative lens were a bit antithetical. It would be some time before bacteria could be seen as both friend and foe.

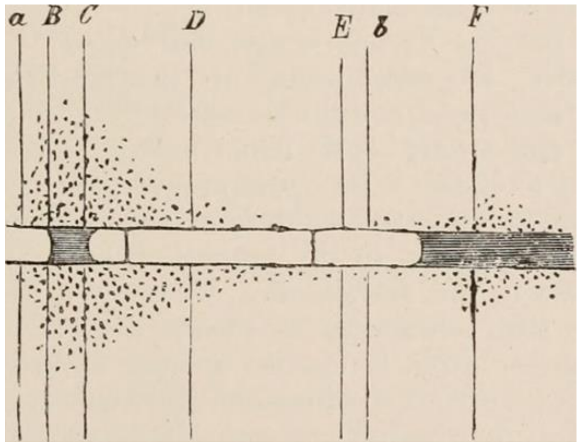

Figure 2-1 Engelmann's Action Spectrum Experiment.

Oxygen-seeking bacteria (represented as dots) revealed which wavelengths of light stimulated photosynthesis. Image credit: J.E. Greaves, Agricultural Bacteriology, 1922 (pg.109). Public domain.

Although they discovered and named it, Engelmann and Pfeffer did not delve very far into their research on bacterial chemotaxis. Rather, studying bacterial chemotaxis was a means to a different research end. Engelmann was a renowned physician mainly interested in muscle excitation and contraction in animal tissues; and he and Pfeffer both (separately) seem to have been primarily interested in using bacterial chemotaxis to demonstrate that photosynthesizing plants and algae produce oxygen (Drews 2005, 26). Engelmann was able to prove this with his "action spectrum experiment": he diffracted light through a prism, and onto motile aerobic bacteria and algae; the bacteria would then congregate near the chloroplasts that received the most favorable spectrum of light stimulation, and therefore produced the most oxygen.

Up to that time, there seems to have been little interest in bacterial movement (much less whether bacteria had any agency in their movements). Engelmann and Pfeffer were more interested in how plants create oxygen and how muscles twitch. The practical, human good related to this knowledge was more readily apparent than the abstract good associated with understanding bacterial motility in and of itself. Enter Julius Adler, some eighty years later.

Though Adler's research on chemotaxis is highly technical, and remains firmly rooted within disciplinary bounds, he occasionally speculates about the evolutionary relationship between bacteria and humans. Specifically, Adler references experimental psychologist Alfred Binet's nineteenth century work to obliquely argue (without having to risk arguing in his own words) that we should consider bacterial motility alongside human psychology. And Alfred Binet, for his part, had drawn heavily upon the scientific research of his time (including that of Engelmann and Pfeffer) to argue that microorganisms exhibit agency in their motions. That Julius Adler would cite Binet, an experimental psychologist from the late nineteenth century, is surprising. Given Julius Adler's otherwise straight and narrow empirical research, as well as the broader context of what it meant to do objective, twentieth-century science, he could have raised eyebrows by citing Binet, but I can find no evidence of intellectual backlash for his doing so.

In the next section I offer relevant background information on Binet's research interests. Then, I analyze three of Julius Adler's major articles on bacterial motility to highlight how, over the course of a decade, Adler began to represent bacteria more like subjects rather than objects. Throughout the chapter I refer to Eduardo Viveiros de Castro to explain this development in terms of Amer-Indian ontology, an example which serves as a counterpoint to what he calls the "anomaly" of Western-scientific ontology. I end by considering this anomalous ontology from another angle, with Foucault's 1966 claim that the concept of "man" was created through the objective language of the human sciences that attempted to know "man"—and that a return to subjective language would spell the "death of man" (*Order of Things*). At the same time Foucault was working on his archeology of the human sciences, Julius Adler was beginning to speculate about the correspondences between human and microbial perception. He began doing this as early as 1966, though he would not make recourse to subjective language via literature and psychology until 1975. This discussion paves the way for the following chapter on Lynn Margulis, who explicitly and repeatedly used literary techniques in her attempt to invert humans' self-supposed status in a natural hierarchy.

2.1 Binet's Foray into Microbiology

> Perilous, because they [the human sciences] represent, as it were, a permanent danger to all other branches of knowledge: true, neither the deductive sciences, nor the empirical sciences, nor philosophical reflection run any risk, if they remain within their own dimensions, of 'defecting' to the human sciences, or of being contaminated by their impurity; but we know…the slightest deviation from these rigorously defined planes sends thought tumbling over into the domain occupied by the human sciences: hence the danger of 'psychologism,' of 'sociologism,'—of what we might term, in a word, 'anthropologism'…
>
> —Foucault, *The Order of Things,* 348

Though this project investigates the rhetorical and historical contours of what I am calling *bacterial psychology*, Alfred Binet is the only psychologist whose work I will discuss. Until quite recently any psychological research involving bacteria seems to come from bacteriologists, not psychologists. Binet wrote and researched in the decades around the turn of the twentieth century, when disciplinary boundaries were still blurred enough that a psychologist could study microorganisms with an eye to human concerns — a brief aperture of time when psychology was taken seriously as an experimental discipline in its own right but before microbiologists had outlined and staked out their own territorial claim. The following passage (which Adler borrows, as I will discuss later) is from Binet's preface to *The Psychic Life of Micro-organisms* (1888).[5] This book began as an essay, but Binet chose to expand it into a book to answer those who criticized the argument he put forth in the essay version, that microorganisms sense their environs and exercise choice in basic acts of survival:[6]

> If the existence of psychological phenomenon in lower organisms is denied, it will be necessary to assume that these phenomena can be superadded in the course of evolution, in proportion as an organism grows more perfect and complex. Nothing could be more inconsistent with the teachings of general physiology, which shows us that all vital phenomena are previously present in non-differentiated cells. (Binet [1888] as quoted in Adler [1975])

From today's vantage point it seems as though Binet's Psychic Life was not given much consideration during his own time, as there are few references to it in late nineteenth century publications. I only found Binet's book because I encountered it in Adler's article. That Adler would reach back to a seemingly insignificant, archaic piece by a psychologist suggests that in the

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5. The remainder of Binet's book also invites fruitful rhetorical analysis, given that he digests and challenges the nascent field of microbiology. But for the purposes of this project I refer only to Binet's preface, which reveals the polemics that shaped the conversation around micro-organismic decision-making during that time. In chapter two I also briefly discuss how Binet's notion of humans as colonies of protozoans anticipates similar claims of Lynn Margulis.

6. The OED defines *psychic* as: "1. Of, relating to, or generated by the human mind or psyche; psychological; mental.", with the usage example "1883 *Brit. Q. Rev.* July 14 The varied stimuli, psychic and physical." The next entry is also worth mentioning: "2. *Theology*. Relating to the natural or animal soul, as distinct from the spirit," and offers the usage example "1889 *Bibliotheca Sacra* July 399 The psychic, or animal, man, is the natural man of this present age."

1970s Adler encountered either resistance to, or disinterest in, the idea that "psychological phenomena" are present in primitive life forms. Bacterial motility had also gone largely ignored for a similar duration of time. Adler seems to have resurrected interest in both motility and "psychic" phenomena at once.

Though disciplinary boundaries were still porous enough Binet could publish something like *Psychic Life of Micro-organisms*, by this time most scientists were studying bacteria as pathogenic organisms. The phrase "bacterial chemotaxis" did not exist during Binet's time and the vocabulary used to discuss chemotaxis was not yet developed, as it would be during Adler's time. Nevertheless, Binet did have a similar research agenda, albeit with an as yet undeveloped lexicon. Though Adler studied chemotaxis in a highly objective way, he relied upon Binet's open inquiry style and subjective approach to bacterial phenomena. In retrospect, Binet's idea that we ought to study bacteria to learn about humans appears particularly prescient, especially because he was a psychologist, not a microbiologist. To better understand the nature of Binet's risk-taking, I refer to Howard Berg's 1975 review article "Chemotaxis in Bacteria"[7]. In a section glossing the classic literature on chemotaxis, Berg affirms that

> Leeuwenhoek, Muller, Ehrenberg and Cohn all were aware of the swarms of bacteria which collected around bits of food or near the surface of a culture (9), but the first systematic studies of these accumulations did not appear until 1881-1884 (10-13). This was the age of medical microbiology, the period in which Koch published his methods for the study of pathogenic organisms […] and Pasteur developed the vaccines for anthrax, swine

7. Not to be confused with Adler's experimental report with the same title, published the same year

erysipelas, and rabies. Those interested in sensory phenomena were ahead of their time (14). (Berg, 1975, p. 119-120)

With the emergence of medical microbiology, bacteriologists focused intently on how to prevent bacteria from ending or impairing the quality of human lives. The integral, beneficial, non-pathogenic relationships between bacteria and humans were not yet understood or appreciated. Medical microbiology would first learn how to battle bacteria before it would learn how to cooperate with them. Though understandable, the field's tunnel vision at that time nevertheless pushed to the fringes those scientists interested in sensory phenomena. Given that micro-organismic sensory phenomena were not considered worthy of study in their own right, it would make sense that Binet's work on microorganisms went mostly ignored until the 1970s. The field's pathogenic lens obscured bacteriologists' vision of bacterial perception, decision-making, and sociality[8]. A lens designed to view certain creatures as enemies would obstruct the ability to simultaneously see them as allies, much less as constitutive symbionts.

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8. In "Sociomicrobiology: a Personal Perspective on an Emerging Research Area," E.P. Greenberg describes his experience as a researcher during the 1970s, when bacteriologists learned how to see bacteria as social creatures. Greenberg would later go on to coin the term "quorum sensing" in the 1990s. His story of the revelatory process that took hold of bacteriology suggests that the pathogenic lens was still quite dominant in the 1970s and well into the 1990s. This dominance of the pathogenic lens may help to explain why Adler had to mine the late nineteenth century for alternative ways of seeing and understanding bacteria. Elsewhere, Greenberg says that "Up until the later part of the past century, microbiologists believed that with rare exceptions bacteria did not practice sociality; this was in spite of the fact that growing bacteria as colonies on agar plates was and still remains a cornerstone technology for the discipline. Just the terminology 'colonial' or 'colony growth' implies some sort of social interactions. [With the exception of a few scientists] working on myxobacteria, a special group of social bacteria, the eyes of microbiology did not see social interactions among individual bacteria. The longstanding view that bacteria were by-and-large

Though Binet discussed microorganisms in a philosophically provocative way, he did not use language in a provocative way. He challenged the way scientists thought about microorganisms and choice, but played by the rules as far as word choice goes. Both Kuhn (*Essential Tension*) and Rorty (*Philosophy and the Mirror of Nature*) argue that a linguistic revolution is prerequisite for instigating a corresponding philosophical revolution.[9] It's also important to note that Binet's claims entangled epistemological with ontological questions. It was okay to study bacteria in and of themselves, as objects, but to study them to attempt knowledge of the human psychic experience might turn bacteria into subjects, making for messy ontological matters. John J. Kineman explains why and how psychology was inevitably separated from the biological sciences:

> Historically, natural science became simplified by avoiding problematic fields such as psychology. This simplified the job by reducing its scope; however, it did not simplify our explanation of nature… [T]he complementary separation between two theories or disciplines…is not a requirement of nature, but has to do with our lack of knowledge and with different assumptions or theory elements" (1991, p. 55).

Adler's effort to push bacteriology into conversation with psychology by briefly quoting Binet might seem like a fairly trivial and conventional move (especially when compared to Lynn

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asocial creatures began to crumble in the 1990s with rapid developments in the areas of quorum sensing and biofilm research. Now it seems apparent that the same selective pressures that led to the evolution of sociality in animals are forces for evolution of sociality in bacteria, and we see and appreciate social behavior in bacteria (Camilli and Bassler, 2006; Parsek and Greenberg, 2005)." (Greenberg, 2011)

9. As I will discuss in Chapter 4, terms such as "quorum sensing" may have helped research into bacterial multicellularity take off in the 1990s.

Margulis's work just a few years later). However, Adler's effort also seems to be the first (published) attempt by a bacteriologist to re-establish a discursive link with psychology. While Adler's prose is ripe with mechanistic metaphors, he nevertheless encouraged other bacteriologists to consider bacterial motility alongside human psychology. This was no small risk on Adler's part. As Latour points out,

> When rationalists deride the time before the "epistemological break," […] it is because this earlier "episteme" was making too many connections between what they called the micro- and the macrocosm […] one of the principle causes of the scorn poured by the moderns on the sixteenth century is that those poor archaic folks, who had the misfortune of living on the wrong side of the "epistemological break," believed in a world *animated* by all sorts of entities and forces instead of believing, like any rational person, in an *inanimate* matter producing its effects only through the power of its causes […] the accusation of anthropomorphism is so strong that it paralyzes all the efforts of many scientists in many fields—but especially biology—to go beyond the narrow constraints of what is believed to be "materialism" or "reductionism." It immediately gives a sort of New Age flavor to any such efforts, as if the default position were the idea of the inanimate and the bizarre innovation were the animate. Add agency? You must be either mad or definitely marginal. (480-81, C.M.)

Add agency is exactly what Binet did when he synthesized his era's research on bacterial motility. Perhaps Binet attempted this at a time when there simply were not enough interested members among the scientific audience, as modernity was beginning to find its full stride. And though Adler followed Binet's lead, he himself was not considered mad, marginal, or New Age; I suggest that this is because a shift was beginning to occur in microbiology, one that allowed a space for open-ended speculation about the evolutionary relationships between humans and bacteria.

In his analysis of Amerindian ontologies, Viveiros de Castro echoes Latour when he argues that "somewhere along the line…the West got everything wrong, positing substances, individuals, separations, and oppositions wherever all other societies/cultures rightly see relations, totalities, connections, and embeddings. Because it is both anthropologically anomalous and ontologically mistaken, it is the West, rather than 'primitive' cultures that require explanation" (483). Science tries to guard against the kind of "primitive" explanations that Latour and Viveiros de Castro name. Binet's argument gestured toward vitalism, which might be called his era's equivalent of animism, or a "new age flavor." For example, Binet begins his preface by admitting "the existence of a vitalism…an aggregate of properties which properly pertain to living matter and which are never found in inanimate substances. Among these properties of life we classify psychological phenomena" (iii). However, Binet also asserts that *this type* of vitalism has nothing to do with the Vitalist doctrine arguing that "properties and forces are superadded to living matter." Rather, the vitalism Binet admits of is fully materialist, for he asserts that it "concerns the properties that are inherent in [living matter]—the properties that characterize life" (iii). Binet makes clear that he does not believe in an ethereal, spiritual force animates living matter.[10] However, despite his adherence to a materialist philosophy, Binet still tends toward animism in some ways. Binet had

10. It may be possible to call Binet a proto-organicist because he rejected mechanistic/reductionist explanations, as well as vitalist (supernatural) explanations. Organicism is an attempt to reconcile a third way between mechanism/reductionism and vitalism (Gilbert and Sarkar, 2000), but it was a philosophy developed by mid-twentieth century developmental biologists. This would explain why Binet tried to differentiate his kind vitalism from the less scientific kind of vitalism.

something of the shaman about him. As Viveiros de Castro defines shamans are individuals able to cross

> ontological boundaries deliberately and adopt the perspective of nonhuman subjectivities in order to administer the relations between humans and nonhumans…in many respects, the exact opposite of the objectivist folk epistemology of our tradition. In the latter, to know is to objectify—that is, to be able to distinguish what is inherent to the object from what belongs to the knowing subject and has been unduly (or inevitably) projected into the object. To know, then, is to *desubjectify,* to make explicit the subject's partial presence in the object so as to reduce it to an ideal minimum…what is not objectified remains unreal and abstract…Amerindian shamanism is guided by the opposite ideal. To know is to personify, to take the point of view of that which must be known. Shamanic knowledge aims at something that is a someone—another subject. The form of the other is *the person*. What I am defining here is what anthropologists of yore used to call animism…[however,] the personhood or subjectivity of [nonhumans] is considered a nonevident aspect of them. It is necessary *to know how* to personify nonhumans, and it is necessary to personify them in *order to know*. (468-69).

Like Viveiros de Castro's description of the shaman, Binet suggested that microorganisms exhibit agency, and attempted to understand why they make certain choices, so that he might enrich the field of human psychology. Binet was also a prominent practitioner and researcher of hypnosis and animal magnetism, and experimented extensively with states of nonconscious behavior.[11] In

11. At the end of chapter four I revisit the issue of hypnosis via the question of suggestibility. Though Binet does not seem to have explicitly drawn a connection between microorganism and the human unconscious, to me it does not

attributing agency to microorganisms we might say that he was *not* afraid of *personifying them in order to know them*, as Vivieros DeCastro might put it. Given Binet's interest in the relation between humans and nonhumans, and in crossing ontological boundaries as a theorist and practitioner of animal magnetism and hypnosis, I understand Binet as a quasi-shamanic figure of his time and place[12]. When Julius Adler turned to Binet's work from eighty years prior, he demonstrated a similar interest in crossing ontological boundaries in the service of epistemological concerns, and vice versa. Adler did seem to escape ridicule for suggesting a connection between bacterial and human sensory perception, perhaps because he also produced a vast body of objectively-oriented scientific knowledge,[13] and left his speculations as brief side notes. And, he did this in the more permissive cultural milieu of the 1960s and 70s.

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seem coincidental that Binet, an expert in hypnosis and other non-conscious states, would be interested in the bacterial ancestry of our sensory perceptions.

12. In Animal Magnetism (1887) Binet says [animal magnetism] is "a question as old as the world itself…which, although constantly rejected and disclaimed by learned bodies has always reappeared, and is still in the process of evolution…It concerns scholars to trace the course of animal magnetism through the ages, and to seek for its remote beginnings in the customs of ancient peoples. We refrain from such historic studies, for which we are incompetent, and propose merely to sum up the conclusions of science with respect to animal magnetism, and consequently only to speak of its history so far as this history has left its traces on the present state of the question. From this point of view, it is unnecessary to go back to an earlier period than that of Mesmer and his immediate predecessors" (1-2).

13. Margulis did not escape such ridicule, and did indeed acquire what Latour calls a "New Age flavor" within the scientific community for her involvement with the Gaia theory.

2.2 Julius Adler Traipses around New Age-ncy

In this section I show how Adler cautiously maneuvered around Binet's issue of the "psychic life" of microorganisms over the course of a decade, from 1966 to 1975, in three different articles about chemotaxis and chemoreception (detecting and responding to chemicals, respectively). Adler first published "Bacterial Chemotaxis" in 1966, when he was still fairly new to this area of research; in 1969 he published "Chemoreceptors in Bacteria;" and he published a revised version of "Chemotaxis in Bacteria in 1975." Both of the two later articles are heavily cited classics in the field. Though he doesn't seem to change his mind about bacterial motility over the course of these ten years, he did begin to make more adventurous claims as his ethos developed and new empirical evidence arose through advances in microscopy. He subtly shifts and negotiates his representation of bacteria during the decade spanning the publication of these three articles.[14] In the two later articles he speculates about implications for humans only in the

14. Though Adler came close to saying what Lynn Margulis would say about the evolutionary relationship between bacteria and the humans only thirteen years later, he did not go nearly as far as she would. I present my reading of Adler before my reading of Margulis in the next chapter to highlight the substantial differences between the two researchers—Margulis's bold style, Adler's conservative. Adler was more firmly embedded within the discipline of bacteriology. He limited his discussions to empirically verifiable research and hesitated to make strong claims that could not be tested. Lynn Margulis, an evolutionary microbiologist, did not abide disciplinary boundaries, made imaginative leaps from the available evidence, wrote in a flamboyant style, and challenged scientific orthodoxies. Whereas Adler allied himself with other bacteriologists to create the requisite technology that would enable him to make certain claims, Margulis made claims that were untestable because the requisite technology was not yet available. Though both Margulis and Adler are both invested in questions of bacterial motility, and its relation to human behavior, each treats the subject in a distinct fashion. I present Adler's research in such a way that I can use it as a reference point for discussing Margulis's work in the next chapter.

the introduction and conclusion. By the time these two later articles appeared, Adler appears to imagine his audience as more broad and interdisciplinary (though he does not explicitly say so). Though his interests remain constant from one article to the next, he makes the boldest claims in the third article, his revised and updated version of "Chemotaxis in Bacteria" (1975). Here, he confronts psychology and human-related concerns, though mainly via style, delivery, and arrangement, by including passages from *Psychic Life of Microoganisms* and *Charlotte's Web*. This section highlights the reciprocal relation between Adler's values, and the knowledge that he sought—that is, how epideixis (values) works in tandem with apodeixis (proof).[15]

Although Adler's 1969 article is about chemo*reception*, the first sentence introduces the term chemo*taxis*: "Motile bacteria are attracted to a variety of chemicals—a phenomenon called chemotaxis" (p.1588). Here, Adler seems to equate *attraction to* chemicals with motility, or *movement toward* them (chemo- + taxis). The collapsing of attraction and motion into one phenomenon implies a kind of automaticity, as does Adler's second sentence, which contains the word mechanism: "Although chemotaxis by bacteria has been recognized since the end of the 19th century, thanks to the pioneering work of Englemann, Pfeffer, and other biologists, the mechanisms involved are still almost entirely unknown" (*ibid)*. The specifics of bacterial motility, as Adler explains them, are a black box. The unknowns of bacterial bodies seem to have led Adler to conflate attraction and movement, and to regard bacterial bodies and movements as mechanistic, automatic. Previous scientists' lack of clarity about the specifics of chemotaxis would

15. This will become increasingly important going forward into present-day bacteriology, which builds upon Adler-era knowledge about bacteria to develop our understanding of how human-bacteria symbiosis shapes human behavior, sociality, and culture.

understandably make it difficult to parse the difference between attraction and movement, and thus prevent them from confidently claiming that there even is a difference between attraction and movement. If there is no distinction between attraction to a substance, and movement toward it, then it would be safer to assume there is no agency in bacterial decision-making. That is, if attraction must equal movement then the movement is more like a reflex, and this does seem to be Adler's primary stance on bacterial motility. However, at other times his language use suggests that bacteria have something that at least resembles agency.

Adler breaks down into constituent parts the assumed mechanisms of movement through the following series of questions, although the questions also show him extending to bacteria a hint of agency in these mechanistic movements: "How do bacteria detect attractants? How is this sensed information translated into action; that is, how are the flagella directed? This article deals primarily with the first question" (*ibid).* Adler offers what his experiments have made known about bacterial detection of attractants, and accordingly, he discusses bacterial chemoreception in the active voice. He then switches to the passive voice when he asks how this detected information is *sensed* and *translated* into *action*; that is, he uses the passive voice to discuss the *unknowns of how* chemoreception is translated into motion (chemotaxis). The flagella *are directed*, though it remains unclear just who or what is responsible for this directing, and Adler's word choice does not suggest that these mechanisms are under bacterial control. Buried within the mystery of bacterial sensing and motility hides the human philosophical conundrum of blind reaction (automaticity) and the ability to decide (agency). Perhaps the agency correlated to receiving (sensing) chemicals would seem *less agential* than the agency correlated with deciding which movements to make *in response to* detecting or sensing them. Therefore, extending to bacteria agency of reception would be less risky than extending to them agency of motion. It is easy for humans to agree that even we do not have much choice about what our senses receive or perceive. However, it is more difficult for us to agree that we have no choice about our corresponding movements. If Adler were to assume that bacteria can decide what to do with their received sensory perceptions, he could have left himself open to accusations of anthropomorphizing.

Adler's shifting attitudes regarding bacterial agency and automaticity may be a consequence of and/or precursor to a paradigm shift that partially depended upon advances in microscopy. In his revision of "Chemotaxis in Bacteria," (1975) Adler points out the importance of technology in his research on motility:

> The motion of bacteria can of course be observed microscopically by eye, recorded by microcinematography, or followed as tracks that form on photographic film after time exposure (18,19). Owing to the very rapid movement of bacteria, however, significant progress was not made until the invention of an automatic tracking microscope, which allowed objective, quantitative, and much faster observations (20). A slower, manual tracking microscope has also been used (21). ("Chemotaxis," 1975, p. 343)

The two tracking microscopes he speaks of are discussed in the two articles he cites, "How to Track Bacteria,"(Berg, 1971) and "An Instrument for Tracking the Motions of Microorganisms in Chemical Gradients," (Lovely et al., 1974). These two articles were published during the five years that elapsed between his articles on chemoreception and chemotaxis. Adler described in great detail the biochemical sensing and motions of bacteria, but Berg built the instrument that allowed Adler to do this pioneering research. Berg's article cites four of Adler's articles, and he acknowledges Adler for his comments on the manuscript, so the two seem to have been close colleagues who approached bacterial motility with a similar worldview, and appreciation for technical precision. Akin to Adler, Berg says in his introduction that it "seems realistic to suppose that the molecular basis for behavior can be understood in bacteria because bacteria are relatively simple cells amenable to genetic manipulation, and that the principles which emerge will be relevant to sensory processes in higher organisms as well" (Berg, p. 868). Berg assumes that similarities in the chemical *sensing* process will be discovered, but he says nothing about similarities between higher and lower organisms' *agency* in making decisions after having sensed an environmental cue. Like Adler, Berg remains silent regarding bacterial agency in movement, yet firm in his convictions regarding sensory perception. This makes sense, given that it is easier to produce proof of how chemicals are received than it is to produce proof that an organism has *chosen* to move one direction instead of another.

To investigate the sensory processes in microorganisms both Adler and Berg focused upon individual organisms and their reaction to man-made environments. The bulk of Berg's short article describes the new apparatus "which automatically remains focused on individual motile bacteria" (p. 868). He includes various technical diagrams of things like photomultiplier amplifiers, fiber optic bundles, coil drives, damping circuits, etc. Given that he invented the tracking microscope, Berg knew firsthand the intricacies involved in getting an individual bacterium to hold still long enough so that their motions could be studied, and he was the first to describe the views the new instrument offered: "The scene through the binocular is extraordinary. The bacterium being tracked seems to be stuck to the center of the field, turning this way and that trying to free itself, while the other bacteria drift in and out of focus, then to and fro, in apparent synchrony" (Berg, 1971, p. 870). Berg is forthcoming about the awe-inspiring view, as well as the somewhat distorted perception it affords. Through this technology the bacterium "seems to be stuck," and given this illusion of stuck-ness, the bacterial motions therefore appear as the bacterium's attempt to become unstuck. The microscope locks focus on a single bacterium for the sake of witnessing the intricacies of its bodily movements, so the individual is seen apart from the group, which nevertheless moves "to and fro, in apparent synchrony."

This "apparent synchrony" that Berg mentions in passing is not a trivial matter, given later discoveries about bacterial multicellularity. When Berg wrote this, however, the implications of this apparent synchrony were not yet fully appreciated, although the behavior had been previously recognized.[16] The emphasis at the time was on the individual bacterium. Berg notes that due to the difficulty of observing a single bacterium, there have only been studies of a few large species of bacteria, or of the "bulk accumulations" of smaller species. Regarding these "bulk accumulations," Berg cites a 1957 article by Roderick Clayton, who describes the purpose of his study as analyzing "in a semiquantitative way the factors of taxis and motility, and thus to provide a basis for understanding some of the patterns of accumulation […] of microorganisms" (Clayton, p. 312). Berg's microscope sacrifices attention to the more panoramic perspective that Clayton desired, in favor of studying an individual bacterium apart from its context and the multitudes surrounding it.[17]

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16. Antony van Leuwenhoek was the first person to see bacteria under a microscope. When the Royal Society responded with incredulity at his approximations of the number of "animalcules" he had observed in a drop of water, Leeuwenhoek replied with the following in 1677: "For my computation is as uncertain as that of those who, seeing a large flock of sheep being driven, tell you, by sight alone, how many sheep there are in it. The most exact manner to do this is to imagine that the sheep walk together broadwise in a certain conjectured number, and to multiply this number with the conjectured length of the flock, and thence to conclude the size of the flock" (quoted in Egerton, p. 4). Though Leeuwenhoek's guesstimate would eventually be accepted, his comparison animalcule to sheep group movements would go unnoticed. For more on how scientists learned to see bacterial multicellularity, see E.P. Greenberg, "A Personal Perspective"; and J.A. Shapiro, "Bacterial Multicellularity."

17. Although it was easier and simpler to study bacteria in groups, scientists did not see the value in doing so, and instead put their efforts into developing the ability to study the individual bacterium. This is not surprising, given the cultural emphasis placed on

The other article that Adler references is written by Lovely *et al.* (1974), in which they describe a variation of Berg's tracking microscope that they developed. According to the authors, their instrument offers various important features that Berg's did not: more control for the human operator, and a simplified design; a much larger swimming chamber that allows recording of longer trajectories; this in turn allowed for varying defined gradients of chemotactic stimulants (Lovely, p. 683). It seems as though this instrument was an attempt to allow for a more natural interaction between observer and observed, and would also minimize the sense that the bacterium was "stuck," as happened with Berg's microscope.

The recent availability of the Lovely and Berg tracking microscopes allowed Adler to develop his research on motility, which he published in his 1975 chemotaxis article. Adler was keen on the quantitative, efficient and *objective* work that these new bacterial tracking devices allowed for; however, the crisp magnifications they offered also seemed to enable a more *subjective* view of bacterial movements, as is evidenced by the language he uses to describe these newly visible movements. He explains,

> In the absence of a stimulus […] a bacterium such as *E. coli* […] swims in a smooth, straight line for a number of seconds—a 'run,' then it thrashes around for a fraction of a second—a 'tumble' (or abruptly changes its direction—a 'twiddle'); and then it again

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the individual during that time. It would take two more decades before bacteriologists would see the value in studying bacterial group behaviors, as I will discuss in Ch. 3 on "quorum sensing."

swims in a straight line, but in a new, randomly chosen direction (22). (A tumble is probably a series of very brief runs and twiddles.) (Adler, 1975, p. 343). [18, 19]

"Runs," "tumbles," and "twiddles,"—playful terms made possible by new microscope technology—add both character and purpose to bacterial movements, whereas before there was only a black box of mechanistic mystery. Although these terms don't necessarily anthropomorphize bacterial movements, they do attribute to them a storybook mammalian flair.

In addition to this playful language Adler also begins the 1975 article in a much looser way, with an epigraph excerpted from *Charlotte's Web*. But with this spirited passage Adler attempts to make a serious claim about the evolutionary roots of decision-making. The excerpt ends with Charlotte the spider explaining her bloodthirsty ways: "But I can't help it. I don't know how the first spider in the early days of the world happened to think up this fancy idea of spinning a web, but she did, and it was clever of her, too. And since then, all of us spiders have had to work the same trick. It's not a bad pitch, on the whole" (E.B. White, 1952). This playful opening seems out of place in *The Annual Review of Biochemistry*, but the passage obliquely raises serious implications about the relationship between human and bacterial behavior, implications which cannot be fully appreciated until the end of the article. Readers going into it are unaware of where Adler will lead them by the end; they only know that this is an article about bacterial chemotaxis, and here is a spider speculating about her evolutionary predecessors. The passage seems to argue

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18. This was likely an affordance of the Lovely *et al*. microscope, which allows for chemical gradients, due to the much larger bacteria swimming chamber.

19. Adler seems to have borrowed the terms "run" and "twiddle" from Berg and Brown, who take credit for coining the terms "run" and "twiddle" in their 1972 article, which Adler cites as "22" in this passage. Adler does not make clear who came up with the term "tumble."

that the anatomy of a creature delimits its range of possible activities. A spider's body is fit for spinning webs and eating captured prey. A spider may be able to decide how to spin a web, but regardless, if it wants to eat it must spin a web. Charlotte also hints at a sense of wonder and mystery in her own web-spinning abilities. At this point we might assume that Adler uses the passage to remark upon bacteria's ability to decide, while simultaneously limiting that ability to decide. The analogy seems to argue that even though an individual bacterium can make decisions, its options are limited. However, by the article's end we will learn that Adler wants to argue a larger point about the evolution of animal behavior, and bacteria as the ur-decision-makers.

Adler begins the actual body of this article in the same way he began the chemoreception article—by defining chemotaxis (*not* chemoreception)—except this time he defines it as "the movement toward or away from chemicals" (341). Here, Adler *does not* conflate the *movement toward* a chemical with the *sensing of and attraction to* that chemical, as he did in his earlier chemoreception article. This new distinction between attraction and movement—as discrete actions—seems to attribute a bit more agency to bacteria. If *attraction to* a chemical (via chemoreceptors) does not necessarily equal *movement toward* it, then it seems as though some semblance of choice may be involved on behalf of the bacterium. The analogy also leaves unclear whether Adler believes decisions are made by the bacterium, the bacterium's body, or some unknown component within the bacterium's body.

Citing three different review articles, Adler notes that the research on bacterial chemotaxis prior to 1965, "although valuable, was carried out in complex media and was largely of a subjective nature (4-6)." Adler does not say what he means by "subjective," though complex media in this sense means broth or pond water, the traditional media for studying bacteria ever since eighteenth-century debates about spontaneous generation, and arguably even further back, if we count

Leeuwenhoek's late seventeenth century experiments with pepper and spice infusions. Given the subjectivity and complex media, "it was therefore necessary," says Adler, "to develop conditions for obtaining motility and chemotaxis in bacteria in defined media (8-11)[20] and to find objective, quantitative methods for demonstrating chemotaxis" (342). Alder's paring of the words "objective" and "quantitative" makes it sound as though qualitative and descriptive techniques might land more on the subjective end of the spectrum. Additionally, isolating for variables is standard practice in scientific experimentation, so Adler is quite correct when he states that creating a defined medium would garner consensus from his scientific community that his methods were objective. However, despite his desire for objective methods, Adler went to great lengths to create the conditions for them; he had to manipulate the conditions the bacteria lived in, and new tracking microscopes had to be developed. The articles Adler cites (8-11) about developing defined conditions under which to study chemotaxis are all his own articles because he pioneered the chemotaxis research of his time.

In this experimental exchange between bacteria and humans surfaces an element of psychology that may be easily overlooked because objective scientific methodology has become habitual over the centuries. When an experiment involves manipulating the behavior of other organisms in order to understand their relation to humans, the underlying motive for the experiment undercuts the aim of objectivity. For example, in order to watch bacteria go through their most mundane of motions, human societies (scientists and the

20. Articles 8-11, which Adler cites here, are all his own. They include his earlier version of "Chemotaxis in Bacteria," 1966; "The Effect of Environmental Conditions on the Motility of Escherichia coli," 1967; "Chemoreceptors in Bacteria," 1969; and "A Method for Measuring Chemotaxis and Use of the Method to Determine Optimum Conditions for Chemotaxis by *Escherichia Coli,"* 1973.

publics whose collective wealth supports the scientists' research) had to labor extensively to create apparatuses that were the culmination of three hundred years' collective desire and effort. In their pursuit of this accomplishment, the first people to finally witness bacterial movements in high resolution (like Adler and Berg) were already fairly certain that they could learn from these movements and behaviors something about human perception and sensation. Their own particular understanding(s) of human behavior could not have disappeared from their imaginations as they devised methods, isolated particular variables, and chose certain behaviors they found worthy of study. Even the defined medium, though aiming at objectivity, was engineered to produce behaviors deemed interesting or relevant to human life. How does an organism respond to pure attractant? Pure repellent? A manipulated, controlled admixture of the two? This is not just a bacterial concern, but a human concern as well.

Though Adler made every effort to create a defined and objective medium, and use quantitative methods, he nevertheless *also* turned his experimental objects into subjects—as is evidenced by the language he and his colleagues created to describe bacterial movements. In doing so, they also played upon the edges of the western scientific worldview. Viveiros de Castro argues that rather than "reducing intentionality to obtain a perfectly objective picture of the world, animism makes the inverse epistemological bet" (469). I suggest that when Adler achieved enhanced visual access to individual bacterial movements, he also began to (perhaps inadvertently) attribute to bacteria shades of agency. Viveiros de Castro continues:

> True (shamanic) knowledge aims to reveal a maximum of intentionality or abduct a maximum of agency…A good interpretation, then, would be one able to understand every event as in truth an action, an expression of intentional states or predicates of some subject. Interpretive success is directly proportional to the original magnitude of intentionality that

> the knower is able to attribute to the known. A thing or a state of affairs that is not amenable to subjectification—to determination of its social relation to the knower—is shamanistically uninteresting. (469-70)

Once scientists began to study microorganisms in their own right, became curious about the intricacies of their movements (and gave them playful names), created media specially designed to encourage certain behaviors, and argued about their evolutionary relationships to us, they also began to subjectify them and make them interesting to humans in new ways.

While bacteria had long been interesting to humans as *agents* of disease, somehow humans were unable to attribute *agency* to them until they got a better view. We might be skeptical when the terms "shamanism" or "animism" are used in conjunction with science; however, we might likewise be skeptical that these (apparently) primitive human impulses are completely extricable from scientific practice, despite centuries-long efforts to erase them with dry, technical language and (supposedly) disinterested methods. The *desire for* objective knowledge, coupled with a subjective interest in that knowledge, creates a ripe tension. Researching bacterial decision-making in a complex (brothy) environment (rather than a defined, controlled gradient) had permitted a complex array of environmental cues that would allow scientists to see more complexity in bacterial decision-making, though the context may have been too chaotic to discern any meaning from the bacterial motions. Regardless of subjective interest, Adler's methods did allow him to create contexts in which he could *imagine* bacteria as isolated mechanical respondents within a controlled environment, rather than as socially-bound agents within collective, complex, and wild environments.

Adler says that "[b]acterial chemotaxis can be dissected by means of the following questions" (*ibid*). The word "dissected" here suggests that bacterial motility is a compilation of parts, rather than a fluid, organic phenomenon. However, given his conflation of the terms *chemotaxis* and *chemoreception* in his previous article, it is interesting to note how much more defined his questions have become by this time:

1) How do bacteria move in a gradient of attractant or repellent?

2) How do bacteria detect the chemicals?

3) How is the sensory information communicated to the flagella?

4) How do bacterial flagella produce motion?

5) How do flagella respond to the sensory information in order to bring about the appropriate change in direction?

6) In the case of multiple or conflicting sensory data, how is the information integrated? (Adler, 1975, 342)

Here Adler separates reception and movement in a way that suggests a machine-like division between attraction, repulsion, body parts, decisions, and movements. His questions are empirically-driven, and represent normal science attempting to work on practical puzzles at hand. Whereas before he simply sought to know how bacteria detect chemicals, here he wants to investigate the varieties of bacterial motions in response to a human-controlled mixture of chemicals. His questions this time contain two active-voice constructions (move, detect), one more than his previous line of questions but he still uses passive voice constructions, which seem related to the unknowns of bacterial anatomy. The questions "how is the sensory information communicated to the flagella?" and "how do the flagella respond to sensory information…?" both assume that the chemoreceptors (and the act of reception itself) are separate from the flagella—

that the bacterial body is divisible into distinct parts that are stitched together via still unknown transmission lines. These questions show that Adler supposes the flagellum produces motion as a distinct entity, seemingly apart from the bacterium it is part of. In Adler's wording the organism does not appear to be a unified whole. The question "how is the information integrated?"—a fully passive construction—imagines the bacterial body as a computational device comprised of distinct and separate components.

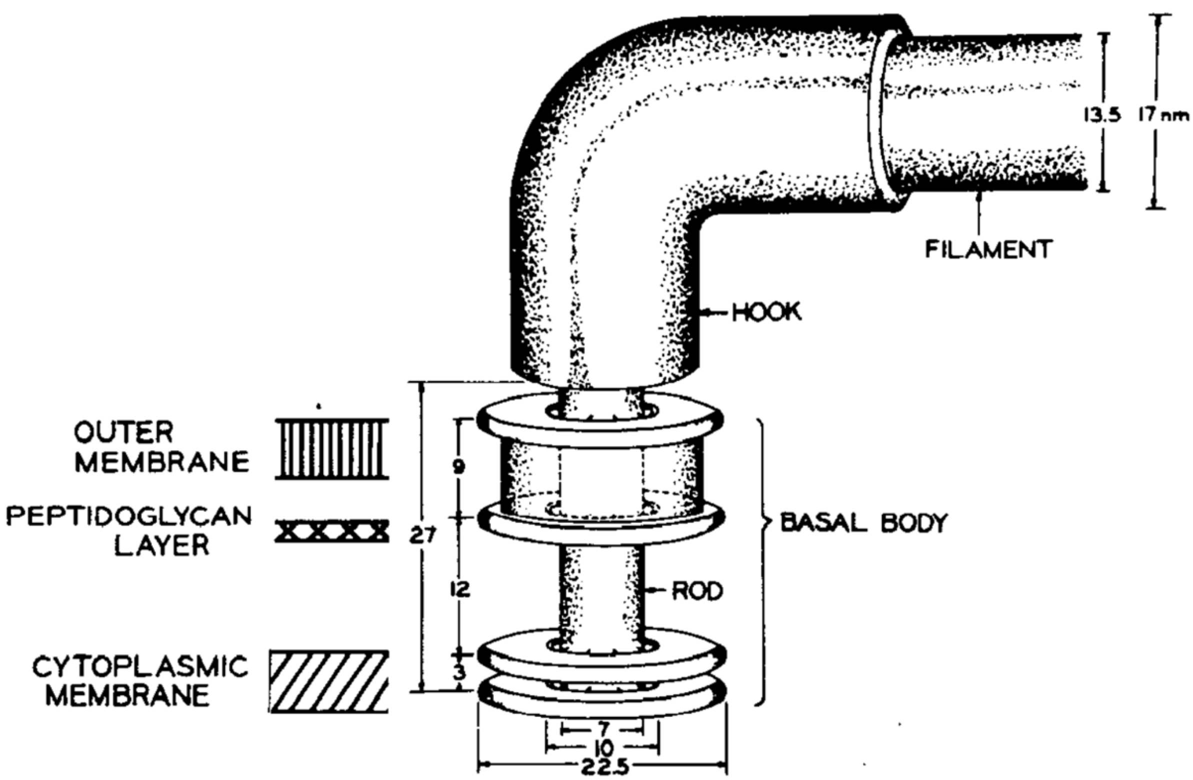

Figure 2-2 Fine Structure and Isolation of the Hook-Basal Body Complex of Flagella from Escherichia coliand Bacillus subtilis (dimensions in nanometers).M. L. DePamphilis, Julius Adler. Journal of Bacteriology, Jan 1, 1971, © American Society for Microbiology.

Adler's diagram, with its precise lines and curves makes the flagella, and the place where it attaches to the basal body, resemble a machine, robot, or plumbing, more than it does an actual living body. He made the environment more complex than his previous experiments by including both attractants and repellents, so that he could observe a bacterium responding to conflicting stimuli, though outside the context of a larger group dynamic. Understandably, the importance of a larger group dynamic would only be realized later, when quorum sensing research demonstrated that bacteria detect both environmental cues and their population density, at which point population density effectively becomes an environmental cue, a crucial factor in decision-making. However, it is important to keep in mind that Adler's decision to research isolated bacteria demonstrates underlying assumptions about what motivates organisms to respond—attractants and repellents before social context.[21]

Though Adler standardized the laboratory study of bacterial movements to understand them as predictable, mechanical, even computational structures, he also assumed bacteria have agency, despite his lack of concrete knowledge of certain processes. Take for example the section

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21. Deborah Gera studies thought experiments in the *Dissoi Logoi* which "contrast two types of people…to determine the roles played by heredity and environment in the acquisition of knowledge and moral values" (2000). Similarly, Adler's behavioral-genetic experiments (using gradients of attractants and repellents) attempted to inform his (understated) hypothesis that we can learn about human perception by studying bacterial motility. Gera says that ancient Greek *thought* experiments were quite similar to ancient Greek *scientific* experiments, which "were not used as a neutral means to decide between two competing theories, but rather were intended to prove or refute a hypothesis" (*ibid*). George Duke describes the *Dissoi Logoi* as a "major source for sophistic relativism," as it presents "competing arguments on five theses, including whether the good and the bad are the same or different, and a series of examples of the relativity of different cultural practices and laws" (2012). Perhaps without realizing it, Adler designed his research studies to place bacteria within (materially) rhetorical situations (relative to their basic needs), and he then described their physical responses. There is something familiarly rhetorical about his method, particularly its excavation of underlying motives.

titled “Integration of Multiple Sensory Data by Bacteria,” which is only four sentences long. First, Adler states that “Bacteria are capable of integrating multiple sensory inputs, apparently by algebraically adding the stimuli (17)” (p.353). This algebra is something bacteria naturally do, but Adler has developed procedures by which to manipulate bacterial computational procedures to investigate how they function. “For example,” he continues, “the response to a decrease in repellent concentration could be overcome by superimposing a decrease in concentration of attractant (17)” (p. 353). At one moment he discusses bacteria as though they were simply doing math equations, which lends an air if inevitability, but the next moment he extends to them a kind of agency within their algebraic, computational behavior: “Whether bacteria will ‘decide’ on attraction or repulsion in a ‘conflict’ situation (a capillary containing both attractant and repellent) depends on the relative effective concentration of the two chemicals…” (*ibid*). Although he does not yet understand how bacteria accomplish the math, he nevertheless assumes it is mechanistic. “The mechanism for summing the opposing signals is unknown” (353). The term “quorum sensing” had not yet been invented, and the few bacteriologists studying the phenomenon of autoinduction (later called quorum sensing) during this time were still struggling to convince their peers that this kind of decision-making is a general bacterial behavior trait. Therefore, Adler’s use of the word *decide* and *conflict* to explain bacterial movements at this point could have been a bit of a leap and/or risky word choice. This would explain why he places both words in scare quotes, and why he continues to use mechanistic terminology when referring to the decision-making capacity that he has extended to bacteria.[22] Recall Adler’s excerpt from *Charlotte’s Web,* which

22. Colleagues could have easily accused Adler of taking anthropomorphic liberties with this kind of language use, but I have found no objections to it. Perhaps bacteria are so *unlike* humans that anthropomorphizing posed no ontological risk.

implies a kind of programing, but with a choice. Similarly, he here extends to bacteria the ability to decide, even though his stylistic choices mark this ability as tenuous.

Though Adler's article addresses experts, explaining the biochemical details of bacterial motility, such as the cytoplasmic membrane's role in binding particular proteins, he nevertheless ends by offering an open-ended suggestion that bacteria might teach us something about behavioral biology and neurobiology. Up to this point, Adler had not even commented upon the Charlotte's web excerpt that he used as the epigraph to the article, but he now refers to it in passing toward the end of the article, in a section titled "Relation of Bacterial Chemotaxis to Behavioral Biology and Neurobiology":

> The inheritance of behavior (see opening [Charlotte's Web] quotation) and its underlying biochemical mechanisms are nowhere more amenable to genetic and biochemical investigation than in bacteria. From the earliest studies of bacterial behavior (2, 3, 89-91) to the present (8, 10, 24, 42, 50, 92, 93) people have hoped that this relatively simple system could tell us something about the mechanisms of behavior of animals and man. Certainly, striking similarities exist between sensory reception in bacteria and in higher organisms (16, 24, 42, 92, 93). (Adler, 1975, p. 354)

Humans have historically studied bacteria to improve human existence. Adler assumes that bacteria have behavior mechanisms, but he also assumes that humans and animals have behavior mechanisms, at least to some extent. Perhaps it's not that he assumes bacteria have so much agency, but that higher organisms do not have as much agency as we've imagined. This philosophical turn at the end of Adler's treatise on bacterial mechanics makes clear his own and previous scientists' human interest when studying bacteria, even though he strived to create objectively-controlled chemotaxis experiments. Adler ends the piece much as he began it, with an accessible excerpt from a non-scientist, framing the broader implications of his research for peers who may not be attuned to the philosophical questions arising out of bacterial motility studies. Though Adler is a mechanistic-leaning scientist, he cites Binet, an anti-mechanist experimental psychologist who wrote a treatise on bacteria during the time he also wrote about hypnosis and animal magnetism, practices which had inspired public fear about human agency and intention. Adler's article concludes with the following excerpt from Binet's *The Psychic Life of Micro-organisms* (1888), which I offer once again:

> If the existence of psychological phenomenon in lower organisms is denied, it will be necessary to assume that these phenomena can be superadded in the course of evolution, in proportion as an organism grows more perfect and complex. Nothing could be more inconsistent with the teachings of general physiology, which shows us that all vital phenomena are previously present in non-differentiated cells. (as cited in Adler, 1975)

Much like his use of the *Charlotte's Web* epigraph, Adler uses this excerpt from Binet without much comment, allowing Binet to speak for him, to say what Adler may not quite be able to say, as he is neither a novelist, nor an experimental psychologist. In contrast to Adler, Binet does not say *maybe, perhaps,* or *possibly* (as Adler does in the next excerpt). The only *if* that Binet includes is a cautionary one. *If* we deny that psychological phenomena exist in lower organisms, then we must assume that it can be tacked on at some later evolutionary moment. Binet positions himself as a man of science by allying himself with basic physiology and evolutionary theory, to argue that primitive cells share something fundamental with all other living organisms. Adler dons Binet's philosophical conviction and E.B White's playful imaginings, however briefly, at the beginning and end of an article he wrote in otherwise dry, technical and objective language. These bookended quotes open up Adler's work conceptually.

Compare the way Adler concludes with Binet in the 1975 article, to the way he had previously concluded with the following excerpt from his 1969 chemoreception article. Although by that time he was already suggesting a correspondence between bacteriology and neurobiology, this passage is not as bold as Binet's proclamations that Adler would cite six years later; here Adler proceeds with caution (and without Binet):

> The study of such stimulus-response systems in bacteria *may* have relevance for neurobiology and for behavioral biology of higher organisms. *Possibly* the chemo-receptors of bacteria are related to chemoreceptor sites in animal chemoreceptor cells, and *perhaps* knowledge of the way in which bacterial receptors function *might* lead to an increased understanding of the mechanism of smell and taste and other kinds of sensory reception (44). (Adler, 1969, p.1596, *italics mine*).

Adler's prose at this point is riddled with qualifiers—*if, may, possibly, might, should,* and *perhaps*—and he limits the importance of bacteria to higher organisms because he mentions only the more primitive chemoreception systems, taste and smell.[23] He continues to speculate cautiously, discussing the unknown but hopeful possibilities of flagellar signal transmission. He surmises that any signal being transmitted from the receptor to the flagellum would be electrical in nature, and resemble the relationship between muscles and nerves:

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23. In the endnote (44), Adler declares: "it is noteworthy that sensory receptor cells of animals generally contain, or are derived from, flagella (or, what is essentially the same thing, cilia); indeed, the suggestion has been made that animal receptors have evolved from single- celled, flagellated organisms." He credits this idea to both J.A. Vinnikov and R.M Eakin (separately); they each presented at the same symposium where Adler presented an early paper on motility, "Chemotaxis in Escherichia coli," in 1965. It would seem as though these ideas were in the air, and Adler grabbed onto and developed them within the parameters of his own research.

> If there is an electrical signal that transmits information from the bacterial receptor to the flagellum, it might be similar to changes in membrane potential in higher organisms. The response of the flagellum to this signal may, in some ways, resemble the response of muscle to a nerve impulse… the bacterial system [should be] a favorable one for studying simple forms of behavior and perhaps even some primitive kinds of 'learning.' From such studies might emerge a set of facts and concepts that can be applied to investigations of more complex phenomena in higher organisms. (Adler, 1969, p.1596, italics mine)

Adler seems to hope for a possible translation between bacteria to human along the lines of taste and smell, in order that "more complex phenomena in higher organisms" may be studied, though he does not here name what these more complex phenomena might be.

It's interesting to note that three years before this 1969 article, Adler had already stated the case more boldly in the first, 1966 version of "Chemotaxis in Bacteria":

> Modern studies of biology have revealed a universality among living things. For example, all organisms have much in common when it comes to their metabolism and genetics. *Is it not possible* that all organisms also share common mechanisms for responding to stimuli by movement? Just as the higher organisms' machinery for metabolism and genetics appears to have evolved from processes already present in the lowest forms, so it is possible that the nervous system and behavior of higher organisms evolved from chemical reactions that can be found even in the most primitive living things. From this point of view *one may hope* that a knowledge of the mechanisms of motility and chemotaxis in bacteria might contribute to our understanding of neurobiology and psychology. This is not a new idea. Binet expressed it in 1889 in his *Psychic Life of Microorganisms*… (Adler, 1966, p. 715, italics mine)

It is unclear why Adler seemed more confident in saying this in 1966 than he did in 1969, or even in 1975. His earlier qualifiers (is it not possible? and one may hope…) are much more direct, allowing more authority to himself, and placing more responsibility upon the reader for any feelings of skepticism, while instilling in allies the assuredness that it is ok to hope for fruitful connections between bacteria and human psychology. We might assume that this is what he meant in 1969 with his more cautious statement about applications to the "more complex phenomena in higher organisms." Also more cautious is the way he cites Binet, in passing rather than with a lengthy excerpt as he would in 1975. I can only speculate that Adler began to behave more cautiously in 1969 because he received some kind of pushback for his statements in the 1966 article.

2.3 Adler's Latter Day Speculations: In Search of a Reductionist Agency?

To conclude this chapter I look briefly at one of Adler's more recent publications, in which he offers a working hypothesis to explain the still-mysterious processes behind bacterial decision-making. Here, he makes more explicit his worldview and assumptions, using more elaborate metaphors that rely upon a recognizable human system: factory management hierarchy. In "My Life with Nature" (2011) he presents his concept of *The Boss*: "the thing inside every organism—humans, other animals, plants, microorganisms—that is in charge of the organism. I don't mean this in any mystical or spiritual or religious sense, but rather I mean it in terms of chemistry and physics" (60). This fear of being misconstrued as a mystic resembles Binet's materialist vitalism, which he distinguishes from the kind of vitalism which supposes that psychological phenomenon can be "superadded" at some later point in evolution. Some thirty-five years after "Bacterial

Chemotaxis," Adler became comfortable claiming outright that bacterial sensory systems have common roots with our own. His concern about being labelled a mystic is shared by Binet and Margulis, so it would seem as though this fear comes with the territory when comparing bacterial behavior with human sensation and psychology.

Adler admits that The Boss can be elusive, and that "certainly the evidence for [the boss] is poor, but I think it's true, and at least it's a hypothesis to be tested" (*ibid).* Regardless of his lack of proof, his belief in an ultimate boss is so firm that he imagines the Boss's power must necessarily be elusive, because it cannot be found. He postulates that the control the boss exerts "is not always direct: Many aspects are delegated to managers, who delegate to foremen, who delegate to workers. So far it is largely the workers that have been studied, and sometimes the foremen are revealed, and rarely the managers, but The Boss has remained largely hidden" (*ibid*). In their effort to locate "the mechanism that dictates a response," Adler says his research team might "return to *E. coli* (since The Boss would be universal, it would be found there, too) to learn if there is a mechanism that overrules all other mechanisms" (*ibid*). Here Adler uses colorful metaphors to bridge the gaps in available knowledge.

Geophysicist James W. Kirchener has argued that metaphors "constitute a whole class of untestable theories […] My point is not that metaphors are useless—but that they are untestable. Treating a metaphor as a scientific proposition that is factually true or false is simply a waste of time (1991, p. 40). Adler, however, does hope to test his Boss metaphor—though perhaps he does not consider it a metaphor. [24] Viveiros de Castro alludes to the heuristic importance of lapses in

24. In Chapter 3 I will discuss a tendency in bacteriology to see metaphors as "not just metaphors," per Pamela Lyon's and James Shapiro's analyses.

explanation which occurs in an animist worldview, and sets this in contrast to the western scientific worldview. He says that, as opposed to animism, our objectivist epistemology

> considers our commonsense intentional stance as just a shorthand that we use when the behavior of a target-object is too complicated to be broken down into the elementary physical processes. An exhaustive scientific interpretation of the world would for us be able ideally to reduce every action to a chain of causal events and to reduce these events to materially dense interactions… (470).

While Adler does adopt a "commonsense intentional stance," he does not seem to use "The Boss" as "just a shorthand." Rather, he seems takes the boss metaphor seriously enough that he hopes to test it, though he plans to do so in the service of locating the mechanism that can finally reduce an action to a chain of physical events. He fits squarely in neither the objectivist nor the animist camp, but rather, somewhere on a jagged spectrum between the two. In accordance with his management metaphor, Adler includes the following diagram, reminiscent of both a bureaucratic flowchart and a computer program, to illustrate his hypothetical boss theory:

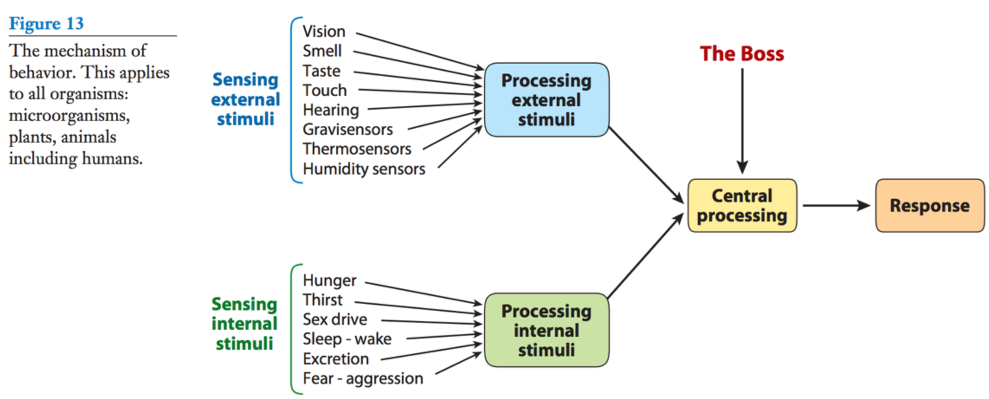

Figure 2-3 "The Boss". Annual Review of Biochemistry, Vol. 80, 2011, Julius Adler.

The various sensing inputs and processing units reflect the computer metaphor that now permeates our culture, and this extended metaphor lends a sense of computational inevitability. The Boss seems to have agency, while depriving other entities of agency. Adler's reductionist hypothesis adds agency in order to then subtract it.

2.4 Transitional Conclusion: From Adler's *E. coli* Psychology to Margulis's Spirochete-Mind

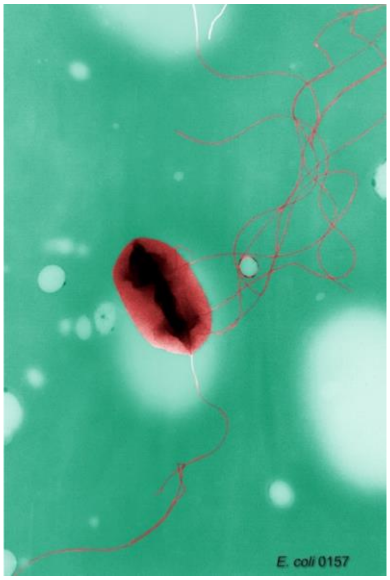

Figure 2-4 ***E. coli.*** **Elizabeth H. White, M.S. Centers for Disease Control. 1995, Public Domain.**

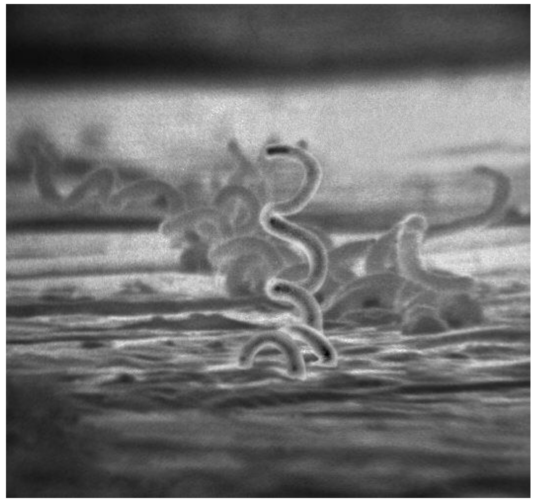

Figure 2-5 "Treponema Pallidum" (syphilis spirochete). Dr. David Cox. CDC, Public domain.

Both Julius Adler and Lynn Margulis speculate that the flagellum is a precursor to thought. Adler does this through his study of *E. coli*, Margulis through her study of spirochetes, bacteria characterized by their morphology: an internal flagellum that lends the body its corkscrew shape and correlated motility style. According to both Adler and Margulis, a primordial motility is hypothesized to be the locus of thought. From what I can tell, Margulis and Adler did not work together, nor did they cite one another, and they have very different scientific investigation and writing styles; nevertheless, they seemed to be arguing similar positions around roughly the same time. One might say that key difference between them can be drawn according to Donna Haraway's assessment of organicists (vs. reductionists): "all twentieth century organicists have resisted reduction of biology to physics and chemistry" (*Crystals*, 194). Adler studied bacterial motility, and was a biochemist above all, but he was nevertheless fascinated by the idea that "psychological phenomena" must be present in bacteria—that there was some kind of correspondence between microcosm and macrocosm. He devoted his attention to the individual bacterium and largely ignored relations between bacteria, other organisms, and environment. On the other hand, relationality drives much of Lynn Margulis's work, which is more organicist in nature, reflecting Haraway's pronouncement that "the relation is the smallest possible unit of analysis" (*Companion Species*, 20).

In the following chapter, I analyze Lynn Margulis' speculations about the complex and chaotic spirochete-brain, among other bacterial phenomena perhaps relevant to the human brain. Though Margulis's wild musings and ecological approach contrast sharply with Adler's tightly controlled biochemical, genetic laboratory experiments, both acknowledge that they lack hard evidence for their speculations about agency, which they admit are based upon their established professional intuition. Whereas Adler speculates about the inner workings of the individual bacterium, Margulis speculates that our consciousness originates in the ecological, group dynamics of bacteria. Whereas Adler affords the individual bacterium a rational and orderly decision-making process that reflects industrial society, Margulis argues that our consciousness reflects the tangled mass of bacterial desires that constitute our minds.

Increasing visibility seems to have factored into a return to speculation about bacterial decision-making and its relationship to human consciousness. In these speculative attempts, assumptions about human nature will understandably color speculations about bacterial behavior and vice versa, so that it becomes difficult to parse whether the metaphor is just a metaphor, or whether scientists are discovering empirical truths about consciousness and self. Both Adler and Margulis believe that psychological phenomena exist in bacteria, but they take very different approaches to this hypothesis. A wide philosophical gap spans Adler's hypothesis of the isolated Boss and Margulis's speculated tangle of spirochetes. While animistic undercurrents surface in Adler's earlier research, in the end he also appears to be largely committed to a fully western notion of the individual, firmly rooted in the agency of the individual bacterium. Nevertheless, as

I argued earlier, though his experimental methods adhered to disciplinary expectations of scientific objectivity, they were simultaneously steeped in the subjective hopes of learning about human perception through bacteria, as well as the subjective language he used to discuss those hopes.

In the *Order of Things* Foucault argues that objective language was vital to constructing scientific objectivity and the corollary concept of man. He explains that during "the entire modern *episteme*," which begins at the end of the eighteenth century and

> still serves as the positive ground of our knowledge, that which constituted man's particular mode of being and the possibility of knowing him empirically—that entire *episteme* was bound up with the disappearance of Discourse and its featureless reign, with the shift of language toward objectivity, and with its reappearance in multiple form. If this same language is now emerging with greater and greater insistence in a unity that we ought to think but cannot as yet do so, is this not the sign that the whole of this configuration is now about to topple, and that man is in the process of perishing as the being of language continues to shine ever brighter upon the horizon? Since man was constituted at a time when language was doomed to dispersion, will he not be dispersed when language regains its unity?...Ought we not to admit that, since language is here once more, man will return to that serene non-existence in which he was formerly maintained by the imperious unity of Discourse? (386)

In Adler's work we can witness bacteriology welcoming in language and the human. Though it does seem plausible that a return to rich language in the sciences might undo the particular concept of man constructed by objective language (the attempted view from nowhere), it does not seem plausible that man will "return once more to [a] serene non-existence…formerly maintained by the imperious unity of discourse;" we might wonder whether such a state ever existed. What does seem plausible is a renovated concept of the human as dispersed, both in biology and agency.

I began with an epigraph from Foucault: "Anthropologization is the great internal threat to knowledge in our day." I would modify this statement to say that anthropologization is the great internal threat to "man" as we have understood this concept for the past few hundred years. A revised concept of the human being as inherently dispersed may facilitate an understanding of our ecological situatedness. In the following chapter I show how evolutionary biologist Lynn Margulis fully embraced language to undermine the Western notion of the individual and isolated self, as she attempted to shove man off a cliff.

3.0 Lynn Margulis: Ecological Literacy and the Spirochete-Mind

> We no longer believe that we need the land in order to think correctly. But, *perhaps we're wrong*. Perhaps the increasing ecological disarray that we see around us and the ever-increasing rapidity with which species are slipping into extinction [and the] air that we breathe and the water we drink is losing its integrity and its healthfulness, suggests that there is something amiss in our thinking…
>
> —David Abram

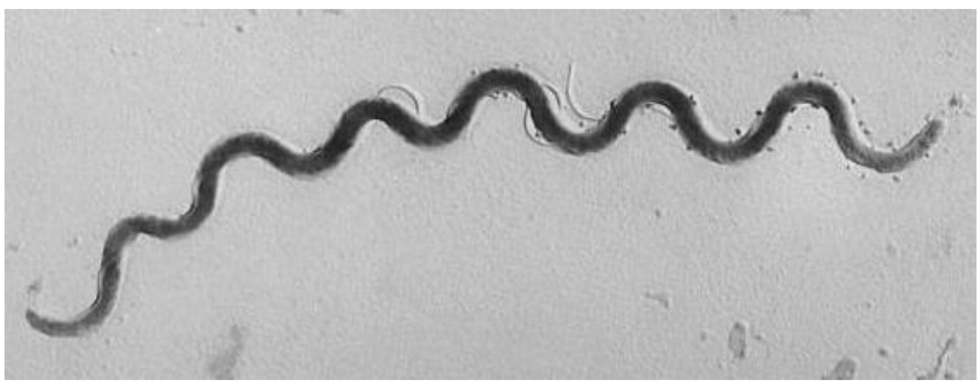

Figure 3-1 Spirochete bacterium, CDC, Susan Lindsley. Public Domain.

In the previous chapter I discussed Biochemist-geneticist Julius Adler's focus on the inner-workings of individual bacterial motility, to the exclusion of group interactions. Lynn Margulis's work complements his well, because she emphasizes microbial ecology and an expansive perspective. Her essay "Speculation on Speculation" seems to imagine both interdisciplinary intellectuals and the general public as the audience; it ends with a small request, while also hinting that this small request is somehow an imposition: "All I suggest it that we compare consciousness with spirochete microbial ecology" (Dazzle, 55). A nearly audible sigh of exasperation emanates from this brief sentence, as if Margulis were also parenthetically asking, "what's the big deal, why can't we deliberate this question?" Today, microbial ecology is a valid and recognized field in its own right, but in 1986 Margulis and colleagues wrote a scientific paper called "Microbial Communities," in which they explained that "because they are invisible to the scrutiny of naturalists, most microbial communities have escaped description" (Margulis et al., 160). Naturalists are less interested in biochemistry and genetics, and more interested in relationships, studying a species in its environment, which includes other organisms. However, though community ecologists "have the background to analyze microbial communities," they usually lack the training necessary to "distinguish the member populations" (*ibid*). Citing Sonnea and Panniset (1983), Margulis et al. say that "the first step in traditional microbial studies requires removing the organisms from their communities" (*ibid*), which somewhat defeats (or at least delays) the purpose of studying them in their communities.

To understand the fuss about comparing consciousness with spirochete microbial ecology, we first need to acquaint ourselves with spirochetes: the corkscrew-shaped phylum of bacteria that thrive in diverse ecosystems. Though the majority of Margulis's audience will never know spirochetes as well as she knew them, we can at least understand them in terms of their typical habitats and how they are different from other bacteria, both in form and in the motility that arises from their form. Spirochetes live as digestive symbionts in cow stomachs, and as free-ranging mudflat dwellers (Margulis spent a considerable amount of time in mudflats). They also manifest as syphilis and Lyme disease in the human body. Though often considered as either benign or beneficial in other contexts, when things get personal we tend to understand spirochetes as pathogens. If a microbiologist speculated (without hard evidence) that our neurons evolved from spirochetes and that our synapses are the gaps between these spirochete descendants, reaching for one another, theorists of scientific rhetoric would rightly want to analyze her language choices about the bio-architecture of our neural networks—that holy grail of humanity.

In this chapter I ask my audience to suspend disbelief and the critical impulse for a moment, to consider the implications of Margulis' hypothesis, that our neurons are the posterity of ancient spirochetes. This is part of Margulis' broader theory of *endosymbiosis* (or *symbiogenesis*), which explains that eukaryotic (plant, animal, "higher organism") cells developed when one bacterium *ingested* but did not *digest* a smaller bacterium—which then evolved into organelles (such as chloroplasts and mitochondria) required for the eukaryotic cell. [25] With the endosymbiotic theory Margulis became famous for explaining how primordial novelty enters the living world (beyond

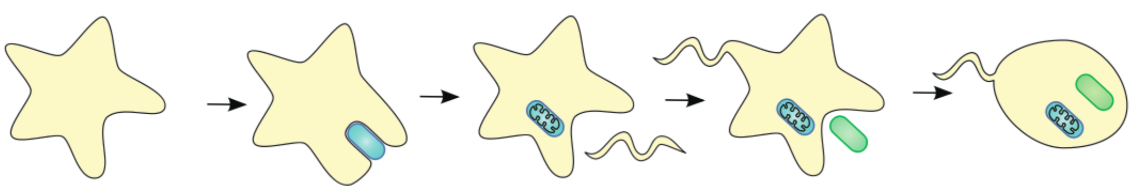

Figure 3-2 Endosymbiosis. Joran Martijn, Ettema Lab, Uppsala University

the accepted theory of evolution through random genetic mutations). In her related, latter-day work on spirochetes she suggests that human thinking and consciousness (a different kind of novelty) also arose in this way. Noting Margulis' emphasis on "the creation of novelty" in

25. Margulis proposed the endosymbiotic theory 1967, which was ridiculed until verified with DNA sequencing in the 1980s.

evolutionary processes, philosopher of microbiology Maureen O'Malley illustrates Margulis' opposition to reigning ideas about evolution—using Margulis' own words: "According to present-day Neo-Darwinian evolutionary theory, the only source of novelty is claimed to be by incorporation of random mutations, by recombination, gene duplication, and other DNA rearrangements" (as quoted in O'Malley, 2015).[26] As I will elaborate in the next section, Margulis tended to butt heads with Neo-Darwinists (particularly Richard Dawkins) around the idea of endosymbiosis/symbiogenesis, even though she *did* agree that gradual genetic mutations do play a role in evolution. "The abundant evidence for symbiogenesis," she says, "does not rule out evolution by gradual accumulation of chance mutations […] But it is equally if not more clear that permanent encounters play a major role in evolutionary change. Symbiotic partnerships merge

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26. It is important to note that Neo-Darwinism itself is not a unified theory. Take, for example, the theory of "punctuated equilibrium," which Gould and Eldridge put forth in 1972, and which Gould eventually worked into a book. Larry Gilman explains that punctuated equilibrium "argues for much faster speciation than traditional evolutionary theory, but does not involve the proposition that new species appear in a generation or two" (as reticulate evolutionary theory does). Gilman says the two standout elements of punctuated equilibrium are 1) "that change happens rapidly, by geological standards, during speciation" (and due to rapid environmental change); and 2) "change happens slowly or not at all after speciation" (2014, p. 3588). To further situate punctuated equilibrium, take for example the theory of reticulate evolution which as Natalie Gontier explains, makes the tree of life look more like a web. Reticulate evolution induces "rapid evolutionary change characterized by a network-like pattern of horizontal crossings and mergings that often precede a pattern of vertical descent with modification. This contradicts *standard* neo-Darwinian evolutionary theory that understands life to evolve gradually by means of natural selection that brings forth a bifurcating or ramificating pattern…Reticulate evolution today is a vernacular concept for evolutionary change induced by mechanisms and processes of symbiosis, symbiogenesis, lateral gene transfer, hybridization…and infectious heredity" [via viruses] ("Reticulate Evolution Everywhere*,"* 2015, p. 2, italics mine).

sensibilities and metabolisms…" ("Wind," 225). Margulis's term "merging of sensibilities" attracts my attention at a time when rhetoric, traditionally conceived, seems to succeed more at repelling, rather than merging, the sensibilities of citizens both nationally and globally. I am curious about the extent to which our difficulty entering into dialogue with seeming opponents might mirror our difficulty entering into dialogue (of sorts) with our environs: could it be that our failure to engage with other human perspectives indicates something about our failure to engage with the perspectives of our environs and the nonhumans within them? This chapter offers material that attempts to entertain Margulis' hypothesis: to compare consciousness with spirochete microbial ecology, to broaden our conceptions of relationality and develop ecological literacy—without arguing for or against the truth value of her claims.

Though we can't draw hard and fast parallels between the microbiological and the human, we can nevertheless imagine the implications of the idea that our brains might be an evolutionary "merging of sensibilities." There is currently little interest in this aspect of Margulis's endosymbiotic theory, and we do not know whether she is right or wrong. Regardless, I take her exasperated request as a challenge similar to the kind presented by science fiction: an invitation for readers to participate in world-building, or as I will discuss shortly a Whiteheadian becoming as the "creative advance into novelty" (*Process and Reality*, 29). Margulis's attempts at explaining novelty offer a material way to re-theorize human societies' relentless efforts at compromise and cooperation, as alternatives to annihilation of self and/or other. Accepting this invitation entails learning to see rhetoric and persuasion as not only cultural and linguistic processes, but also as material and biological processes. Clashing cultures tend to meld in unforeseen ways, for example when interlocutors validate and incorporate an opponent's viewpoint in an attempt to defeat them. Or take, for instance, early Christian rebranding of pagan holidays, and the emergence of creole languages that occur during colonization. When human cultures make contact, both victims and aggressors tend to undergo profound, unanticipated transformations.

Humanities scholars will be understandably concerned about relying on the cultural authority of science to reconfigure theory, for fear of reifying working scientific models. However, Margulis' hypotheses about spirochete's role in consciousness can be placed into conversation with Indigenous cosmology, or the Buddhist theory of no-self, for example. Margulis herself even references eastern religious theorist Alan Watts to make a point about the illusion of self. My goal is not to use science and/or religion to "prove" anything about the other, but rather, to show how very different human rhetorical traditions, spaced thousands of years apart, similarly challenge current western ideals about the human ecological position. Scientists are not alone in defying reified western notions of the self. Similar models that attempt to uproot the idealized version of the isolated individual are available on either end of the millennia—whether proposed via intuitive, spiritual, speculative, or scientific methods. In the previous chapter I highlighted animistic/shamanistic undercurrents in Julius Adler's (otherwise reductionist) descriptions of bacterial motility; here I highlight Margulis's more explicit challenges to western conceptions of self.

Later in this chapter I discuss Margulis's "Speculation on Speculation," along with the "The Uncut Self," which she co-authored with her son and longtime writing collaborator, Dorion Sagan. Both essays are from their collection *Dazzle Gradually,* and challenge idealized notions of self via Margulis's insight on bacterial evolution. Like the microbiologists I discuss in the other chapters, Margulis and Sagan juxtapose seemingly disparate cellular and human systems, defying anthropocentrism by flirting with anthropomorphism: "Whether we are discussing the disappearing membranes of endosymbiotic bacteria on their way to becoming organelles or the breakdown within the global human socius of the Berlin Wall, we must revise the rectilinear notion of self, of the bounded I. Alan Watts pejoratively referred to it as 'the skin-encapsulated ego'…" (*Dazzle,* 17). They undermine our concepts of self (and separateness) through appeals to both the known and the unknown. For instance, elsewhere they argue that not knowing "the causes of our behavior does not mean that it is 'free' in the sense of not caused. Much of our would-be agency, which we perceive to issue smoothly from the ego, will, or 'I' (but which is probably a kind of oversimplifying biological interface), appears to owe much to heretofore-undetected symbiogenetic actors" ("Wind," 218). My goal in this chapter is not to prove or disprove these statements, but rather to entertain them, to explore the implications and features of Margulis's model that may inform how we imagine interactions between the individual and collective will.

To accomplish this I use Whitehead's particular notion of the *proposition,* as a way to engage with current theories of bacteria-human relations. Whitehead explains that "propositions were first considered in connection with logic," and that there is a "moralistic preference for true propositions" (*Process and Reality*, 259). These two factors, he says, "have obscured the role of propositions in the actual world…Indeed, some philosophers fail to distinguish propositions from judgments…But in the real world it is more important that a proposition be interesting than that it be true. The importance of truth is that it adds to interest" (*ibid*).[27] If Whitehead's seemingly flippant attitude toward truth causes concern, he elsewhere affirms that "of course a true

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27. Take, for example, PJ Cataldo's helpful contrast between Whitehead's version of the proposition and Aristotle's: "…[F]or Aristotle a proposition contains reference to what is believed to be an actual state of affairs—either positive or negative—as a predicable [that which may be predicated or affirmed] within the proposition […] Whitehead's theory does not have such an element […] because of this built-in aspect of the Aristotelian proposition, its defining value is its truth value"(Cataldo, 1982).

proposition is more apt to be interesting than a false one" (*Adventures of Ideas*, 244). Approaching working theories about human-bacteria relations *as propositions* (rather than arguments proper) allows us to locate and discuss overlapping interests in microbiology and rhetorical theory. If we wait until these working biological theories are settled, we will miss the opportunity to participate in theory-building about embodied decision-making. Questions of human vs. bacterial agency, theories of microbial evolution and the human microbiome are emotionally-charged, and therefore we can open them up by considering them as propositions to be entertained, rather than arguments to be proved. I draw on Sydney Hooper's "Whitehead's Philosophy: Propositions and Consciousness,"[28] because this lens seems particularly fruitful when applied to Margulis' endosymbiotic theory (both those aspects that have been verified scientifically, and those that have not). Margulis openly speculates about spirochetes' role in human consciousness, and her hypotheses (offered without hard evidence) resemble Whiteheadian propositions. Hooper offers various definitions of the proposition, from various angles, but he first of all claims that propositions are "very important for *the introduction of novelty into our world*, and indispensable for 'consciousness' and the higher phases of experience" (59, italics mine).

Our current position in geo-cultural history calls for the introduction of novelty, new ways of imagining and correcting the longstanding problems of ecological destruction and cultural

28. Though I am the one who suggests that we can entertain Margulis' hypotheses *as propositions*, it is no secret that Margulis and Sagan took an active interest in Whitehead's organicist and process philosophy. In 2013 they published (posthumously for Margulis) a co-authored essay, "Wind at Life's Back"—Toward a Naturalistic, Whiteheadian Teleology: Symbiogenesis and the Second Law," in which they argue that life *does not defy* the second law of thermodynamics, but conversely, that life is a process through which entropy is produced. Throughout the course of her career Margulis stressed that organisms are not static entities, but rather, dynamic processes.

clashes, which increasingly progress hand-in-hand. We bump up against seeming enemies in typical ways, even as we face the common threat of extinction; surviving together on this planet for much longer will require us to re-imagine our habitual modes of feeling our way through the world. Though propositions are not feelings *per se*, they have much to do with feelings. Hooper says that a "propositional feeling" arises when "entertaining a proposition"—it is a synthesis of "a physical feeling" with a "conceptual feeling" (Hooper, 59). Hooper describes the proposition as "a hybrid between pure potentialities and actualities," or in Whitehead's own terms, "'the tales that might perhaps be told about particular actualities'" (quoted in Hooper, 60). I suggest that we need to learn how to tell ourselves new stories about ourselves *as* ecological beings, which first requires us to re-conceive notions of self. Though we may be skeptical that telling tales could somehow suffice, Margulis and Sagan point out that we already do so. "Mammal brains, as Toxoplasma[29] shows, are open to 'control' (however unconscious) by foreign genomes. While we do not necessarily know the source of our behavior, we are quick to convince ourselves that the locus of our behavior originates entirely with us—we are adept at first person narratives" ("Wind," 219).

Our convictions about the nature of human agency begin to unravel with the discovery of microscopic phenomena that have always been at play. But we can revise our stories as we go. Margulis and Sagan propose we might turn evolution "on its head" to see it from the perspective of a "pan-microbial agency," which

29. Toxoplasma gondii is the unicellular brain parasite which housecats spread, and which has been shown to alter the behavior of both mice and humans in ways that benefit housecats.

> portrays cows as forty-gallon tanks for temperate storage of methanogenic and gas-digesting microbes. Trees are platforms for the solar exposure of cyanobacterial descendants in leaves. Animal, plant, and fungal life in general are instruments for the breeding of the ubiquitous mitochondria—descendants of respiring bacteria that are now holed up in but provide energy to the tissues of most all Earth's surface organisms. (*ibid*, 220).

Here, Margulis and Sagan are being provocative, momentarily jolting us into alternate perspectives. Don't trees exist so that we can breathe fresh air, build homes, and admire leafy splendor? "Despite the topsy-turvy truth of such stories," Margulis and Sagan admit that they are "provisional and can be deconstructed—in Derrida's sense of the term" by displacing a "mutually reinforcing conceptual hierarchy (here, putting microbes before men) but then, after an interim strategic period of reversing the usual hierarchy within a metaphysical pair, moving on from such a hierarchy (in which both 'opposed' terms are ultimately complicit) altogether"(*ibid*). In retelling the tales of cows, trees, and eukaryotic tissues, they hoped to "compensate for the distorted puffery of traditional evolutionary biological narratives featuring vertebrates" (*ibid*).

Because Margulis and Sagan wrote for the public with an essayistic style, essayist Joan Didion's remarks on the value and impact of storytelling upon our actual lived experience, are pertinent:

> We tell ourselves stories in order to live. The princess is caged in the consulate. The man with the candy will lead the children into the sea. The naked woman on the ledge outside the window on the sixteenth floor is a victim of accidie, or the naked woman is an exhibitionist, and it would be 'interesting' to know which. We tell ourselves that it makes some difference whether the naked woman is about to commit a mortal sin or is about to

> register a political protest or is about to be, in the Aristophanic view, snatched back to the human condition by the fireman in priest's clothing just visible in the window behind her, the one smiling at the telephoto lens. We look for the sermon in the suicide, for the social or moral lesson in the murder of five. We interpret what we see, select the most workable of the multiple choices. We live entirely, especially if we are writers, by the imposition of a narrative line upon disparate images, by the "ideas" with which we have learned to freeze the shifting phantasmagoria which is our actual experience. (*White Album,* 1979).

The imposed narrative line that Didion speaks of could be called speculation, or even propositional in the Whiteheadian sense that it adds interest to the lives we try to live well. We humans have made sense of the phantasmagoric fact of our existence for as long as we have been able to do so. One could argue that it is irresponsible for scientists to engage in this kind of storytelling. One could also argue that it is irresponsible for them not to. Margulis and Sagan make explicit the elements of storytelling in evolutionary biology and argue that the stories we tell ourselves about our consciousness make some difference *to* our consciousness and by extension, how we live our lives.

If we cannot yet know the truth or the falsity of a statement, (especially because so much boils down to a matter of perspective) we are left with what the statement sparks inside of us as we seek out parcels of truth. "A proposition functions as a 'lure for feeling.' It invites a subject to be its host, and promises, at least, some entertainment in return" (Hooper, 63). The vocabulary related to the proposition (lures, feelings, host) assumes that we are palpable organisms with bodily sensations, participating with our environs, and able to propagate the feelings that we host outward, back into the enveloping environs. Accordingly, propositions do not appeal to "belief," but to "feeling at the physical level of consciousness. As Whitehead puts it, 'they constitute the source for the origination of a feeling which is not tied down to mere datum.' Consequently, we see that such experiences as 'horror,' 'relief,' 'purpose' are primarily feelings involving the entertainment of propositions" (Hooper, 66). To entertain Margulis's theories (as propositions) also requires entertaining the essayistic form that she and Sagan employ in making them, as well as the personas Margulis assumes in doing so. These are vital elements of their propositions, which they offered to a public audience as "lures for feeling," to spark wonder and create possibilities. Taken together, the form and content of their essays echo Denise Gigante's assertions about the Romantics who articulated "the political significance of living form," (28) as well as "Romantic life science" which "addressed the complexity of the organism (or organic whole)" (29). Margulis and Sagan lure their audience as organisms capable of "hosting" certain propositions counter-intuitive to western ideology. When writing with Sagan, Margulis tends to make greater use of literary devices, but she also does so in her single-authored pieces, typically when she wants to discuss the interplay of human consciousness, microbes, and environs. In doing so, she melds textual and ecological literacies. While I do not ignore Margulis's rhetorical choices, I do choose to place more emphasis on how rhetoric and composition scholars might use her work to imagine alternate (but co-existing) theories about what persuasion is and does at a material level, given our biological enmeshment with our environs and other creatures.

In "Symbiogeny and the Rhizomatic," biologist Staley Shostak and cultural theorist Marcia Landy place Margulis's endosymbiotic theory in conjunction with Deleuze and Guitarri's rhizomatic theory and Whitehead's work on novelty, to encourage experimental scientists to work "in creative harmony with conceptual philosophers" (1). They explain that the longstanding hiatus between biology and philosophy can be traced back to "the reductionism of 17th century natural philosophers," proto-biologists who "reduced life to a concept of species identified as collections of individuals…" (*ibid*). They say this trend still manifests today as "the failure of many biologists to examine metaphysical questions" (*ibid*). I agree with their assessment, but given the powerful influence of the sciences over the centuries, this tendency is not confined to the biological sciences, and over the centuries it has also informed the way humanists think about the individual and agency. That is, humanities scholars could also benefit from reconsidering the human situation as a biological consortium if we hope to address serious metaphysical problems that prevent us from reinventing the ways we engage with each other and our environs. Rhetorical theory is an especially important area to accomplish the work of reconfiguring relationality.

If a scientist can delve into philosophy, rhetoric, and literature to draw out the human implications of microbial ecology, then humanities scholars might take similar risks in crosspollinating the disciplines. We can look to speculations like Margulis' to entertain new possibilities about how we interact with environs and nonhuman agents, as well as the idea that agency is materially dispersed beyond the traditional confines of the rhetorical situation, which various researchers are already doing in other ways. For example, Jenny Rice augmented the traditional concept of the rhetorical situation to create "a framework of *affective ecologies* that "recontextualizes rhetorics in their temporal, historical, and lived fluxes." She argues that "this ecological model allows us to more fully theorize rhetoric as a public(s) creation" ("Unframing," 2005). As Nathaniel Rivers and Ryan Weber point out, we have since seen "many productive uses of the ecology metaphor to describe the composition and circulation of texts," which they say has encouraged them to see "the public scene as a 'fluid framework of exchanges' rather than isolated incidents of discourse" (2011, p. 189).

Although this ecological framework has become a useful model for understanding the proliferation of influences at play in public acts of rhetoric, Matthew Ortoleva argues that the "ecology" metaphor still functions as primarily just a metaphor, and he argues that we need to address ecology more literally. Ortoleva adopts the term *ecological literacy* to name "the ways in which humans understand their interconnectedness to biotic and abiotic environments," and how "material and discursive relationships… are created, maintained, modified, solidified, and radically changed by acts of language" (2013, p. 66). To Ortoleva's take on ecological literacy, I would add that this influence occurs in both directions—our material relationships also radically change our acts of language—which becomes increasingly apparent as we scramble to communicate and "manage" the consequences of our more recent material exchanges with biotic and abiotic environments. Though Ortoleva is right to insist that we should acknowledge the link between the discursive and natural worlds, ecological literacy also requires great attention to non-discursive relationships, which constitute the majority of relationships in the world. Ortoleva anchors his definition of ecological literacy in the connection between "the discursive and the material, natural world," reminding us that ecology "is the science of relationships" (*ibid*). Given humankind's current predicament, ecology inhabits the nexus between discursive and non-discursive relationality, and this emphasis on relationality makes ecology particularly pertinent to rhetoric and literacy studies.

Gabriela Raquel Rìos combines Ortoleva's work on ecological literacy with Thomas Rickert's work on place. She argues that we rely upon a "dichotomous philosophy that [separates] environment/human/mind," but she reminds us that "Indigenous philosophies and rhetorics have always resisted such dichotomies" ("Cultivating," p. 65). Rìos uses the Indigenous concept of relationality which "recognizes the environment's capacity to produce relations," an "ontological position" which (according to Cajete) "sees humans as 'the Earth being conscious of itself'" (p. 64). I suggest that work like Margulis's can help us to re-imagine our connection to everything, to assume a basic, material correspondence between all organisms—realignments which I suggest are necessary to build the kind of ecological literacy that Ortoleva and Rìos propose. From her struggle to prove the endosymbiotic theory, to her hand in shaping James Lovelock's Gaia theory, Margulis figures the human as a bridge between the microcosm and the macrocosm. In Latour's summation, the Gaia theory suggests that "the Earth is a totality of living beings and materials that were made together, that cannot live apart, and from which humans can't extract themselves" (Latour, 2018). This inextricable intertwining of humankind with Earth's "totality" is a key feature of the ecological literacy that Rìos and Ortoleva advocate, but requires a considerable shift in perspective. Latour argues that "Galileo invented a world of *objects* placed beside each other, without affecting each other, and entirely obeying the laws of physics," whereas "Lovelock and Margulis sketched a world of *agents* constantly interacting with each other" (*ibid*). Similarly, Haraway says that Gaia names "complex, nonlinear couplings between processes that compose and sustain entwined but nonadditive subsystems as a partially cohering systemic whole…not reducible to the sum of its parts" (Haraway, 2016, 42).

In arguing that we are composed of microorganisms, Margulis is not saying that we *are* microorganisms, but rather, that we are the *relations* among them. Like Latour, Haraway argues that Gaia (the event and the theory) pushes us to rethink our very ways of thinking: "Gaia is an intrusive event that undoes thinking as usual" (p. 43). Margulis's work begins by assuming these entanglements and encourages the kind of ecological literacy that Ortoleva hopes we can accomplish: that humans understand "their interconnectedness to biotic and abiotic environments." Margulis passed away in 2011. Given her insistence upon a profoundly symbiotic view of life, it is perhaps fitting that there is no neat, cohesive narrative of her life's work. Her messy, mythological persona offers a springboard into engaging with her philosophy, rhetoric, and literacy *of* micro-organismic relationality. In the next section I offer a glimpse of her scientific persona through both consenting and dissenting voices of those who have worked with, against, and alongside her.

3.1 Lynn Margulis: Three Personas

3.1.1 The Heroine of Symbiogenesis

In his elegiac essay, "As Above, So Below," Andre Khalil says Lynn Margulis emphasized "in all her scientific work two phenomena—the fusing of distinct beings into a single being: symbiosis; and the interaction of organisms and their environments to create relational loops that led to regulation of many earth systems: Gaia theory" (18). Synthesizing the Gaia and Symbiogenesis theories in her popular writings, Margulis made ardent philosophical claims, creating a panoramic view of humans' role in microbially-driven earth systems. Khalil, a former student of Margulis, explains that her conceptual achievements redefine "how we understand organisms and the environment," as well as our own consciousness (*ibid*).

Former president of the American Society of Microbiology, Moselio Schaechter, identifies "two kinds of great scientists," those "known for their impressive experiments[30]," and those "who make groundbreaking theoretical syntheses. Margulis, he says, "was an example of the latter," due to her "transformative idea that eukaryotic cells (from yeasts to

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30. Julius Adler, whose work I discussed in the previous chapter, is a good example of a scientist "known for their impressive experiments."

vertebrates) evolved by acquiring and exploiting "other, smaller cells via the process of endosymbiosis, or symbiogenesis." ("Erudition," p. 14). Both Khalil and Scheaeter's glowing accounts of Margulis's impact on science are from *Lynn Margulis: The Life and Legacy of a Scientific Rebel,* edited by Dorion Sagan. However, a well-rounded perspective on Margulis's life work comes through an assortment of colleague's testimonies, and other accounts are not as positive. A cacophony of narratives bespeaks the unsettling nature of her work, and the extent to which she challenged the reigning scientific worldview. This cacophony might guide the assessment of her later, contested theories, and perhaps the long-term impact they will have upon the field.

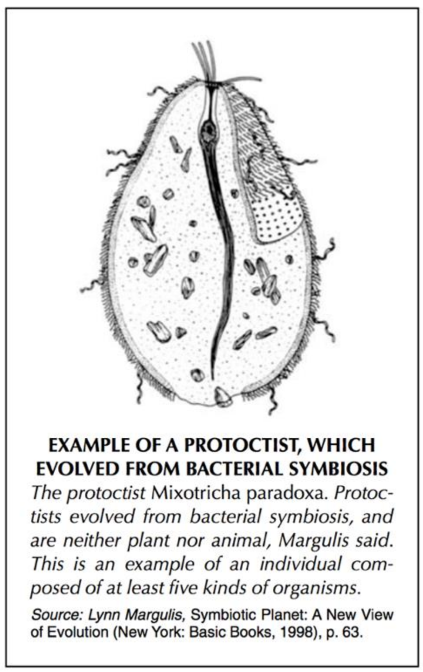

Figure 3-3 Example of a Protoctist. From: Symbiotic Planet: A New Look at Evolution by Lynn Margulis, copyright © 1998, 1999. Reprinted by permission of Basic Books, an imprint of Hachette Book Group, Inc.

3.1.2 Evolutionary Provocateur

Early on in her career, the endosymbiotic theory offered Margulis her first foray into contentious scientific battle with big names in evolutionary biology, though she first had to struggle to get the theory published. Later in life she reflected on her experience of accruing ethos in the scientific community, beginning in 1966: "… I wrote a paper on symbiogenesis called 'The Origin of Mitosing [eukaryotic] Cells,' dealing with the origin of all cells except bacteria […] The paper was rejected by about fifteen scientific journals, because it was flawed; also, it was too new and nobody could evaluate it." The paper was finally accepted by *The Journal of Theoretical Biology*. As Margulis recalls, at that time "I was an absolute nobody, and, what was unheard of, this paper received eight hundred reprint requests" ("Gaia," 1995). Well known for her combative stance toward theoretical opponents, she debated intensely over her contribution to James Lovelock's Gaia theory. Lovelock recalls that "Evolutionary biologists, especially neo-Darwinists, were among Lynn's favorite targets and soon the arguments became so fierce that at one point the talented wordsmith and neo-Darwinist Richard Dawkins referred to Lynn as 'Atilla the hen'…" ("On Lynn," p. 30). It's uncertain what nickname Dawkins would have conjured if Margulis were a man, but she made it clear that she believed gender figured into her research as well as her colleagues' reception of it. The opposition between natural selection and symbiogenesis views on evolution was, for her, tethered to gendered ways of being in the world. When an interviewer asked her, "Don't spirochetes cause syphilis?," Margulis's response led her to draw connections between spirochetes and the male reproductive system. She replied, "*If I'm right*," some spirochetes "are ancestors to the cilia in our cells," because spirochetes "are already optimized for sensitivity to motion, light, and chemicals." Repeating the phrase, "*If I'm right,"* she then explains that the "cytoskeletal system [which gives the cell its shape]—came from the incorporation of ancestral spirochetes […] Here [showing a video] we compare isolated swimming sperm tails to free-swimming spirochetes. Is that clear enough?" (Teresi, 2011. italics mine).

Though the relationship between spirochetes and syphilis was already established knowledge, she tacked on a contentious statement about spirochetes and sperm tails. As evidence she points to a correspondence in body shape, and when asked why these ideas are not generally accepted, she responds, "Do you want to believe that your sperm tails come from some spirochetes? Most men, most evolutionary biologists, don't. When they understand what I'm saying, they don't like it" (*ibid*). Considered as a propositional "lure," we can say that Margulis's assertions attracted too many adverse feelings. When asked whether she "ever gets tired of being called controversial," she did not answer the question, but instead insisted "I don't consider my ideas controversial, I consider them right" (*ibid*). Margulis insists that subjective biases have steered scientific arguments about evolution, but here she also seems to insist that she is objectively *right*. However, elsewhere she acknowledges her own subjective bias, a worldview of interdependence, which I will discuss in the following section. Near the end of her life, when Margulis was asked about her plans for the future, she responded:

> They're the same as they were forty years ago…We've won three out of four. We've won the bacterial nature of the cytoplasm, of course the mitochondria and the chloroplasts [also proved to be bacterial in nature], and they still won't let me publish, I'm still being rejected on the spirochete stuff, by some people, so that's what I want to do, I want to finish four out of four, not three out of four, four out of four…that's the plan" (excerpted from *Symbiotic Earth*).

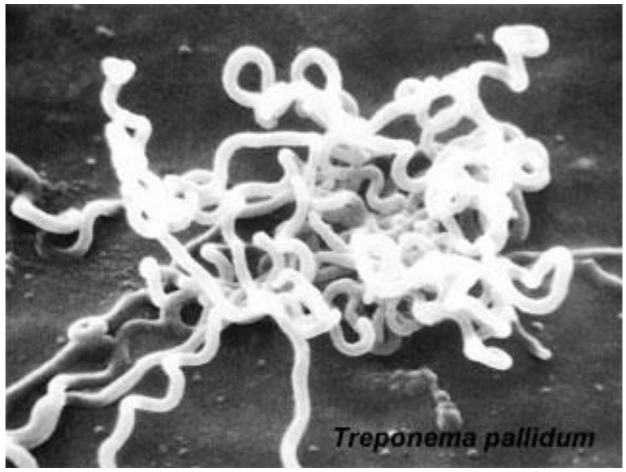

Figure 3-4 Cluster of syphilis spirochetes, CDC, David Cox, Public Domain.

Figure 3-5 Cluster of Neurons, Manchester Univerity, 2015.

Medical historian Deborah Hayden summarizes Margulis' prophecy, that "forward, backward, and sideways-moving spirochetes are the ancestors of motile cell structures such as sperm tails and sensory cilia. A part of this daring claim is that structures in axons and dendrites that allow communication between cells of the brain descended over a billion years ago from the innards of spirochetes" (Pox,22). Margulis's latter-day arguments put the idea of humankind at stake—contesting evolutionary relationships between spirochetes, sperm tails, cilia, and synapses—and still remain unproved. Margulis's colleague Mark McMenamin, writing in memoriam, remarked that she told him that Neo-Darwinsm is dead because its central concept, that "most major evolutionary changes occurred by slow accumulation of mutations," (2012, p.

27) lacked decisive scientific support. Comments like this attracted opposition from Richard Dawkins, famous for the "selfish gene" theory, one brand of Neo-Darwinism. However, after genomic sequencing validated symbiogenesis, he would eventually acknowledge her "sheer courage and stamina in sticking by the endosymbiosis theory, and carrying it through from being an unorthodoxy to an orthodoxy…This is one of the great achievements of twentieth-century evolutionary biology, and I greatly admire her for it" (Dawkins, quoted in "Gaia," 1995 Brockman, ed.). Though Dawkins graciously conceded on this point, he nevertheless disapproved of Margulis's brash argumentation style and her latter-day theories. "I have the feeling that she's the kind of person who just knows she's right and doesn't listen to argument […] in the case of the theory of the origin of the eukaryotic cell, she was right to be obstinate […] but that doesn't mean she's always right" (*ibid*). Though scientists do eventually end up being "right" or "wrong" at a factual level, facts are not all that is at stake in the evolutionary theories that Margulis and Dawkins argued about.

3.1.3 Pseudo-scientist? New Age Populist?

Jan Sapp, philosopher-historian of symbiosis theory, explains that Margulis encountered so much resistance because her theory of "[r]apid evolution by symbiotic leaps and not gradually through gene mutations and selection was tantamount to creationist thinking" ("Too Fantastic," 62). Even though Margulis opposed intelligent design and creationist thinking, the evolutionary biology community was concerned over theories that might facilitate creationist arguments. Sapp explains that there was not yet any real way to test Margulis's endosymbiosis hypothesis. He quotes microbiologist Roger Stanier, who in 1971 said, "Evolutionary speculation constitutes a kind of metascience, which has the same fascination for some biologists that metaphysical speculation possessed for some medieval scholastics. It can be a relatively harmless habit, like eating peanuts, unless it assumes the form of an obsession; then it becomes a vice." Sapp relates that Margulis told him she believed that Stanier was referring to her, and he agrees with her because Stanier's "views were certainly shared by most cell biologists and molecular biologists, too: one could not know the origin of cells, any more than one could know the origin of the genetic code. These were metascientific questions beyond empirical science" (Sapp, 62-63).

Although Margulis's speculative endosymbiotic theory was eventually proved by molecular phylogenetics, she would later receive further criticism for applying her knowledge of microbial ecology to help James Lovelock develop his Gaia hypothesis into a fully-fleshed theory. Mary Midgley puts the gist of this theory succinctly: "Earth and the life on it [is] an active, self-maintaining whole" (*Midgley*, 1). This idea, she says, has given Western intellectuals a case of double-vision— "One eye has seen this notion as a piece of Science, at first as a mistaken one, then, later, as one that may be partly accepted. But the other eye sees it as something visionary or spiritual, alien to science, perhaps hostile to it—perhaps a new truth, perhaps just a childish 'new age' fancy" (*ibid*). This latter eye that Midgley describes was the one through which Richard Dawkins, a particularly vocal critic, viewed Lovelock's Gaia theory. Though Dawkins does not explicitly mention Margulis, he does indirectly criticize her hand in the theory by focusing on the role bacteria play in it, a role which itself implicitly questions Dawkins' "selfish gene" theory:

> I don't think Lovelock was clear—in his first book, at least—on the kind of natural-selection process that was supposed to put together the adaptive unit, which in his case was the whole world […] I'm skeptical of the rhetoric of the Gaia hypothesis, when it comes down to particular applications of it, like explaining the amount of methane there is in the atmosphere, or saying there will be some gas produced by bacteria which is good for the

world at large and so the bacteria go to the trouble of producing it, for the good of the world. That can't happen in a Darwinian world, as long as we think that natural selection is going on at the level of individual bacterial genes. Because the individual bacteria who don't put themselves to the trouble of manufacturing this gas for the good of the world will do better. Of course, if the individual bacteria who manufacture the gas are really doing themselves better by doing so, and the gas is just an incidental consequence, obviously I have no problem with that, but in that case you don't need a Gaia hypothesis to explain that. You explain it at the level of what's good for the individual bacteria and their genes. (*Dawkins, 1995.*)

Though the bacterial role in the Gaia theory implicitly challenged Dawkins' "selfish gene" metaphor, Margulis and her allies also challenged the metaphor more explicitly in other ways. They recognized that society is at stake with the theories of evolution that scientists propagate into public forums. As Mary Catherine Bateson puts it, "The more we assume" that human characteristics are genetically determined "the less effort we are going to put into sustaining environments in which people will grow up as humane humans" (Bateson, 2018).

In *Symbiotic Earth*, his documentary about Margulis's work, John Feldman highlights the lineage of the "selfish gene" metaphor, recalling the full title of some later editions of Charles Darwin's book: "On the Origins of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life." Feldman presents various intellectuals who explain the consequences of the metaphors of "natural selection," and the later, related "selfish gene." In it, Bateson explains that Darwin, "in accounting for the phenomena that he observed…used a metaphor that he had been exposed to in other contexts. That doesn't make it right or wrong, but it does mean that you have to check where that metaphor is taking you next" (*Symbiotic Earth).* John Feldman, for his part, calls the "selfish gene" metaphor dangerous, quoting Richard Dawkins who writes, "we are survival machines—robot vehicles blindly programmed to preserve selfish molecules known as genes" (*ibid*). This way of thinking about evolution maintains the spirit of Darwin's emphasis on the "preservation of favoured races." Biological theorist Denis Noble says we don't realize that "many of our theories were metaphorical" and create distance from the facts "to the extent that if we take them too seriously we actually distort the facts" and "forget what the original observations were… there is no way in which a strip of DNA can be selfish" (*ibid*). For her part, Margulis asserts, "but of course it's just a metaphor, because a gene doesn't have a self, a gene is not a self. How can something be selfish if it has no self?" (*ibid*). To follow the idea of the "selfish gene" we need to believe that some enduring essence that we call our self is dictated by our genes. Dawkins emphasizes the power of the gene over the individual organism (which is more like a consequential manifestation of the gene). Feldman says that the "selfish gene" metaphor took off to the extent that it did because it was bolstered by Western culture, which "promoted the power of the individual over the community, one that was opposed to socialism and communism" (*ibid*). Whether we like it or not, evolutionary theories inform political and social theories, regardless of the author's original intent. Feldman says that because the selfish gene metaphor is

> presented as science, people take it as a truth. So, it further contributes to a culture of greed and selfishness. So, these two metaphors, survival of the fittest, and the selfish gene, are the basis of [what Margulis called] the Neo-Darwinian capitalistic zeitgeist, which is the pervasive belief that humans are genetically selfish and that success comes only by winning in competitive struggles. All else is childish sentimentality. [In contrast to Neo-

> Darwinians] Lynn and other scientists see in nature interdependent communities of organisms. (*ibid*)

It may not be possible to say whether Margulis's and Dawkins' respective worldviews inform their research interests and language choice, or vice versa. Regardless, neither one is shy about the larger cultural values embedded in their scientific thought. Though they both frame the issue as one of right vs. wrong, it may be more fruitful to examine how evolutionary theories play out within the cultural milieu (and vice versa).

Defending a reality based on the idea of interdependence (rather than selfishness), Margulis broadened the relevance of microbiology to earth science with her work on the Gaia theory, which would eventually evolve into earth systems science (Turney, *Lovelock and Gaia*). Her big-picture, proto-Earth Systems view arose from and feeds back into her knowledge of microbial metabolizing processes. Bypassing the right vs. wrong binary, astrobiologist David Grinspoon frames the Gaia hypothesis as more of a perspective,

> an approach from within which to pursue the science of life on a planet, a *living planet*, which is not the same as a planet with *life on it*—that's really the point, simple but profound. Because life is not a minor afterthought on an already functioning Earth, but an integral part of the planet's evolution and behavior. Over the last few decades, the Gaians have pretty much won the battle. The opposition never actually surrendered or admitted defeat, but mainstream earth science has dropped its disciplinary shields and joined forces with chemistry, climatology, theoretical biology, and several other '-ologies' and renamed itself 'earth system science'. (Grinspoon, 2016, italics mine)

As Grinspoon describes it, the interacting systems studied by earth systems science sound similar to endosymbiosis/symbiogenesis—the fusing of seemingly disparate parts into a functional whole.

This similarity is likely due to the fact that Margulis associated the serial endosymbiotic theory with the Gaia hypothesis (Gontier, 2015, p. 9), which Haraway calls an "intrusive event that undoes thinking as usual," a contributing factor to the pushback that Margulis received throughout her career (Haraway, *Trouble*, 43). Perhaps both camps can be "right." Perhaps organisms are both inherently selfish and inherently symbiotic. Perhaps these two truths need not be mutually exclusive.

W. Daniel Hillis, theorist of evolution and artificial intelligence, offers a fairly neutral perspective on Margulis, which also helps transition into the following section on Margulis's work as a public intellectual. Hillis explains that the rigid and structured standards of peer evaluation work quite well for incremental science, but that this system does not work when you want to change that structure. "When you try to do something that doesn't fit into a discipline or a standard theory, you usually make some enemies. Lynn Margulis […] didn't follow the rules and pissed a lot of people off;" and because her view of symbiosis "didn't fit into the popular theories and structure […] she went around the powers that be and took her theories directly to the public, which annoyed them all because she turned out to be right" (*Third Culture,* 145). In Margulis' case, the theories she took directly to the public were deemed dangerous because they jeopardized the illusion of scientific consensus about evolution, opening the door to attacks from the intelligent design community. Hillis adds: "If it's a sin to take your theories to the public, then it is a double sin to take your theories to the public and be right" (*Third Culture,* 146). Margulis and Dorian Sagan founded Sciencewriters Books, which they describe as "an educational partnership devoted to advancing science through enchantment in the form of the finest possible books, videos, and other media." Sciencewriters' orientation toward enchantment might be seen as problematic, because enchantment simultaneously appeals to both intellect and affect, perhaps muddling neat distinctions between the two, perhaps leading us to "get it wrong." However, this muddling also seems to help us to imagine new possibilities for seeing and interacting with reality.

3.2 Interlude: Locating Margulis within the Bigger Picture of this Project

In the remainder of this chapter I offer selections from a Sciencewriters essay collection, *Dazzle Gradually*, to unearth Margulis and Sagan's attempts at enchanting and educating the public about the enmeshment of microorganisms, biosphere, and human psyche. Whether her latter-day claims are correct still remains to be seen, but this truth-contingency is an important element of her style, as she was always gazing over the precipice of knowledge about such matters. In chapter one I explored Julius Adler's uptake of Alfred Binet's claim in 1888, that psychological phenomena are present in the most primitive of microorganisms. Although that claim corresponds with Margulis's speculations, Binet makes a related claim that corresponds with Margulis's work even more so. Binet references the single-celled amoeba *Difflugia urceolota*, which lives inside a shell composed of bits of sand; when the *Difflugia* touches a particle of sand, it contracts around it so that it passes into its body; when a daughter cell is born (through cell division) it already has a shell due to the parent's prior sand-collecting efforts.

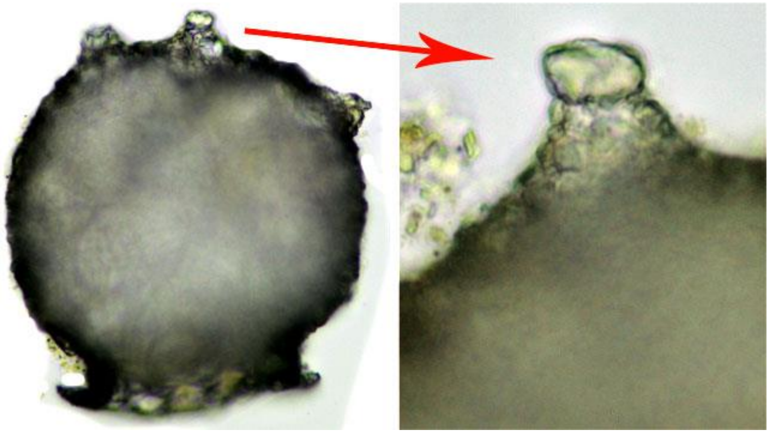

Figure 3-6 Difflugia urceolota, with a blunt spine, closed by a grain. Credit: F.J. Siemensma.

Binet uses this example to claim that the *Difflugia* "exhibits great precision" of "instinct" in its ability to distinguish

> the materials available for its purpose, but it takes only the quantity [necessary for] the young individual to acquire a well-built case; there is never an excess [...] the *Difflugia* does not act differently from animals possessing more highly complicated organizations and endowed with differentiated nervous systems [...] agreeably to the ideas of evolution now accepted, a higher animal is nothing more than a colony of protozoans [...] The epithelial cells that secrete the nails and the hair are organisms perfected with reference to the secretion of protective parts. Similarly, the cells of the brain are organisms that have been perfected with reference to psychical attributes. (1888, p. vii)

Though Binet does not specify which kind of microorganisms he has in mind when he refers to the organisms that make up the cells of the brain, his claim is nevertheless echoed in Margulis's claims about spirochetes and neurons.

Then, as now, we still don't understand exactly how our "psychological phenomena" emerged. If Margulis were to read this passage from Binet, she might argue that different properties emerge with new levels of complexity and organization, but she might also agree with Binet, that spirochetes (for example) are organisms "perfected with reference to psychical attributes" in some respects. It is not completely clear why (beyond morphology and rapid-fire motility) Margulis believes spirochetes were well-suited to evolve into neurons, but I will discuss the reasons she does give in the following sections. Margulis may very well be wrong about the ancestral relationship between spirochetes and neurons. Regardless, we can still entertain her opinion (as Whitehead suggests we entertain propositions to introduce novelty—that we are ecosystems woven into larger ecosystems; we may find some value in this activity given that Margulis spent decades studying spirochete ecology specifically, and microbial ecology broadly.

Though the human brain is neither mudflat nor cow rumen, it is housed within the human body, which is increasingly understood as a microbial ecology site. The human brain, then, may have more in common with mudflats and rumen than we have been able to understand during our centuries-long dream of individual autonomy and self-authorship. In the scientific article "Microbial Communities" (which I also discussed at the chapter's opening) Margulis et al. describe Lake Cisó (a small lake in Spain), and argue that its microbial ecology "can be thought of analogous to a multicellular organism "whose dimensions are determined by those of the lake basin" (169). As humans begin to perceive other kinds of entities as microbial communities, scientists will likely draw upon familiar realms to describe realms that are less familiar, which will change how we think of both entities being compared. Arguing that an analogy is more than a "teaching aid or dispensable illustration" (50), Daniela Bailer-Jones cites James Clerk Maxwell, who explains that "the recognition of the formal analogy between the two systems of ideas leads to a knowledge of both, more profound than could be obtained by studying each system separately" (ibid). I suggest that something like this is happening in the following analogy that Margulis et al. offer:

> Inside [Lake Ciso's] limits, cells interact both cooperatively and antagonistically. They lower the local hydrogen sulfide concentration for one another; they provide necessary organic compounds to one another; they shade one another, compete for resources and excrete toxic waste. Each of the stratified planktonic phototropic communities reproduces only at a given position in its vertical distribution…The only reproduction by cell division of [the photosynthetic bacteria] *Chromatium* and *Chlorobium* that occurs in the lake occurs in these layers; thus, we can compare these layers to reproductive tissue in multicellular organisms. The products of reproduction slowly sediment to the bottom; their bodies provide organic carbon for the sulfate-reducing bacteria, which then excrete the hydrogen sulfide to replenish the cycle…the same energy sources and environmental restraints that have led to the grouping of animals and plants into functional aquatic, marine, and forest communities led much earlier to the evolution of complex microbial associations like those we describe here. (*ibid*)

It's one thing to call the human body an ecosystem, and another to compare the layers of a lake to reproductive, digestive, and excretory systems of multicellular organisms. The comparison is mere analogy until the authors explain the similar cellular processes that occur in each ecosystem, at which point the analogy gains a new timbre, as though the authors suddenly began playing a different instrument. The comparison pushes us to see the "humanness" of the lake, and the "lakeness" of the human, and if we follow the comparison the two distinct concepts begin to dissolve, or possibly merge. The human body is just one interface of the microcosm and macrocosm, but it is an interface that creates, revises, and abides by the heuristic of a distinct and separate "self"—a shifting assemblage of stories and countless biological entities. In the following sections I discuss Margulis and Sagan's attempts to grapple with the concept of self, which they see as a fiction.

3.3 The Consciousness Feedback Loop: Bacteria, Brains, and Biosphere

> …words, like crystals, have facets and axes of rotation with different properties, and light is refracted differently according to how these word crystals are placed, and how these polarizing surfaces are cut and superimposed…Science is faced with problems not too dissimilar from those of literature. It makes patterns of the world that are immediately called in question, it swings between the inductive and the deductive methods, and it must always be on its guard lest it mistake its own linguistic conventions for objective laws. We will not have a culture equal to the challenge until we compare against one another the basic problematics of science, philosophy, and literature, in order to call them all into question…
>
> —Italo Calvino, The Uses of Literature

Margulis and Sagan are forthcoming about their attempts to place biology, philosophy, and literature into productive tension with one another, in order to provoke wonder-induced inquiry. Margulis admired Emily Dickinson, and titled *Dazzle Gradually* after a line in Dickinson's "Tell all the truth" poem, which also serves as the book's epigraph:

Tell all the truth but tell it slant—

Success in Circuit lies

Too bright for our infirm Delight

The Truth's superb surprise

As Lightning to the Children

eased With explanation kind

The Truth must dazzle gradually

Or every man be blind—

This epigraph both invites and cautions: without delight, truth might blind. And truth all-at-once could open the door to the terrible sublime lurking in between Dickinson's lines. The sublime also lurks within the pages of *Dazzle Gradually,* and it seems to originate with the idea of self.

The book's first section *Mnemosyne* is named for the goddess of memory because in the first two essays Margulis and Sagan each introduce themselves "in a scary and personal way" (2). They begin the book with their respective stories of both their inner and public selves, then transition into "The Uncut Self," the third and final essay of the first section, *Mnemosyne*; Margulis and Sagan say this essay begins the transition to the second section's "concept of chimera—the real, biological self that combines multiple beings. The self is never the Platonic ideal implied by the word" (*Dazzle*, 2). By using the chimera to convey the self as an inherent multiplicity, they also obliquely assert that the concept of self is itself a myth. Margulis and Sagan begin "The Uncut Self" with a gesture of openness—in mid-sentence: "full circle, not based on the rectilinear frame of reference of a painting, mirror, house, or book, and with neither 'inside' nor 'outside' but according to the single surface of a Mobius strip" (*Dazzle*, 16). They end the essay with the missing first half of that sentence: "Topologically the self has no homuncular inner self but comes" (Dazzle, 26). This formal and temporal disjuncture resists representational depiction and creates a circular lack of closure between inside and outside, thus mirroring their central argument: the self is an open system, provisional rather than stable and enduring.

Though this stylistic and formal move is quite postmodern, it is also quite pre-modern, typically associated with epic poems that begin at a crucial midpoint in a series of events; this "both initiates a subsequent chain of incidents and at the same time follows as the result of preceding ones" (Hardison and Hornsby). Beginning "in medias res" allows authors "to work forward and backward in time to narrate the story or action […] to arouse the reader's interest quickly" (ibid). This move resists linear causality, even if only momentarily, and for the sake of immersing the audience in what feels like an active process. In *Ars Poetica* Horace states that the epic poet "hastens to the outcome and plunges his hearer into the midst of events as though they were familiar;" Aristotle used the *Odyssey* to argue that "a plot is a specific arrangement of incidents unified by probability and necessity, not by sequence" (*ibid*). Beginning this way Margulis and Sagan position readers in a biological and temporal tumult, yet also in a familiar place where they can gain traction: within the rectilinear frame of the book, even though they use it as a reference against which to distinguish what the self is *not*. Ending/beginning the split sentence with the homunculus creates both alchemical and neuroscientific allusions that undermine modern, western notions of self. Before continuing on to Margulis and Sagan's next sentence, I will address this "homunculus"—the alchemical origins and Daniel Dennett's placement of it inside the Cartesian Theater.

3.4 The Homunculus in Medias Res

Figure 3-7 Solutio Perfecta (homunculus), 17th Century, Public Domain.

Like literary authors, Margulis and Sagan do not take pains to over-explain the allusions they make. I suggest that their "homunculus in medias res" move frames not only this essay, but also the book's conceptual schema, and Margulis' philosophy of biology. Claiming that "the self has no homuncular inner self" may seem obvious to us moderns, but it's an idea that has persisted through the centuries. In *Dazzle Gradually*, Margulis and Sagan continuously put the self in the middle of things: they disperse the self into larger earth systems and condense it into countless sub-visible cellular selves. In this way they redistribute the self, disturbing our notions of discrete biological agency. Margulis and Sagan deny the "homuncular inner self" within the context of resisting representationalism with the essay's open and "uncut" form. The homunculus figure is associated with metaphor and representation in the alchemical tradition, current philosophy of mind, and the field of artificial intelligence.

When burgeoning scientific discourses sought out modes of literal representation, they attempted to eliminate the use of metaphor. In "Artificial Men: Alchemy, Transubstantiation, and the Homunculus," Mary Baine Campbell explains that the homunculus first appeared right before the seventeenth century's "grand eschewal of metaphor," and she argues that the homunculus figures into deep-seated feelings about resemblance and figuration. She condenses Paracelsus' infamous recipe for a "chymicall homunculus" (from *De rerum Naturae*, 1537): his "man-made-man is formed alchemically—in a test tube—from human sperm, heated by horse dung for the forty weeks of normal human pregnancy" (5). Campbell argues that "the extreme of metaphor is transmutation," and that during the late Middle Ages and the Renaissance

> the homunculus of Paracelsus [acquires] a literalism that does not reduce or abandon metaphor, but monstrously completes it […] We take it for granted now that metaphor is just a mysterious way of indicating something mysterious […] I have begun to wonder whether all this talk of "mere" metaphor was not at a profound level a defensive way of reducing metaphor's powers to those of a simple rhetorical figure among figures […] Could that abiding sense of poets as magicians, and grammar as magic, attest to an equally abiding sense that metaphorical predications can institute reality? (14)

Today it seems quite odd for scientists to create analogies between lakes and multicellular organisms (even if attending to details at the cellular level) as this can blur the boundaries between entities that science tends to study as distinct (even if interacting) entities. The seeming oddness of this analogy may be understood in terms of Feyerabend's account of science education, which "simplifies 'science' by simplifying its participants:"

> first, a domain of research is defined. The domain is separated from the rest of history (physics, for example, is separated from metaphysics and from theology) and given a

> ‘logic’ of its own [which makes the actions of those working in the domain] more uniform [and freezes] large parts of the *historical process* as well. Stable ‘facts’ arise and persevere despite the vicissitudes of history. An essential part of the training that makes such facts appear consists in the attempt to inhibit intuitions that light lead to the blurring of boundaries. (3)

In creating conceptual similarities analogies tend to blur conceptual boundaries. Scientists debate terms (such as “selfish genes” and “Gaia”) (at least partly) due to a fear that language can institute reality. Donna Haraway seems to use the title of her first book—*Crystals, Fabrics, and Fields: Metaphors that Shape Embryos*—to make this point.

Margulis’s attempts to institute a new geo-biological reality have also been battles over terminology. Though she and Sagan deride the notion of a “homuncular inner self,” they nevertheless invoke the homunculus in the sense of magical, enchanting language to institute new realities. In a broader sense, they invoke the homunculus to undermine the sense of self as a solid, enduring entity. To flesh out what Margulis and Sagan mean by a “homuncular inner self,” I turn to Daniel Dennett’s *Consciousness Explained* (1991), published the same year that Margulis and Sagan penned “The Uncut Self.”

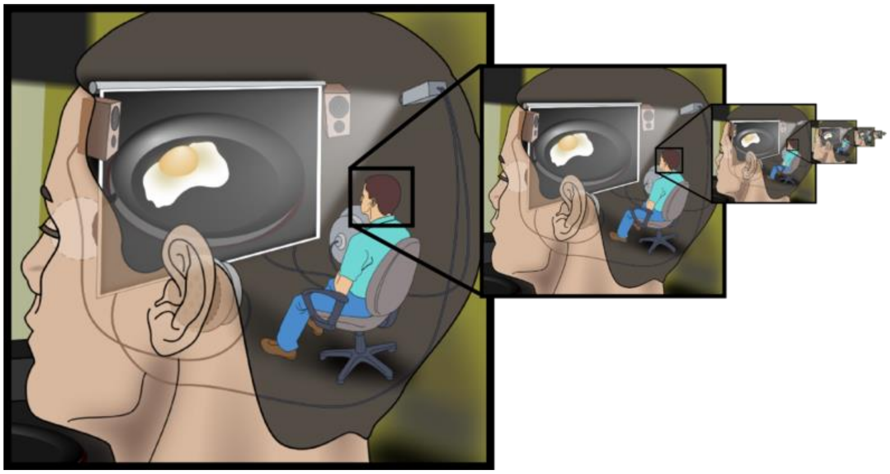

Figure 3-8 Cartesian Theater/Infinite Regress of Homunculus, J. Garcia, 2012, CC BY SA 2.5.

Dennett uses the figure of the homunculus to explain what he derisively refers to as the Cartesian Theater, which he describes as "a metaphorical picture of how conscious experience must sit in the brain" [31] (107). Dennett borrows the concept of the homunculus not from alchemy, but from theorists of artificial intelligence, and he builds upon it. "Homunculi—demons, agents—are the coin of the realm in Artificial Intelligence" (*ibid,* 261); he then calls the homunculus "the little man in the brain," the Boss, the Central Meaner," etc.[32] However, he insists that there "is no single, definitive 'stream of consciousness,' because there is no central Headquarters, no Cartesian Theater where 'it all comes together' for the perusal of a Central Meaner" (*ibid,* 253). Dennett explains that even though many theorists "would insist that they have explicitly rejected such an

31. Margulis and Sagan make several attacks upon Cartesian dualism both in this essay and throughout Dazzle Gradually, though I do not address that aspect of their arguments in this chapter.

32. The idea of the Boss or Central Meaner can still be taken quite seriously, as I showed in the previous chapter on Julius Adler.

obviously bad idea," this persuasive imagery "keeps coming back to haunt us—laypeople and scientists alike—even after its ghostly dualism has been denounced and exorcised" (*ibid,* 107).

While rejecting the Homunculus in the Theater, Dennett preserves the homunculus itself, but he revises it. He argues that only "a theory that explained conscious events in terms of unconscious events could explain consciousness at all […] This leads some people to insist that consciousness can never be explained" (*ibid,* 454-55). Dennett insists upon the crucial role that metaphor plays if we are to ever explain consciousness, and retains the homunculus for descriptive purposes. Instead of a single homunculus, he adds countless (relatively non-conscious) homunculi, which he uses to build a working explanation of consciousness:

> I haven't replaced a metaphorical theory, the Cartesian Theater, with a nonmetaphorical ("literal, scientific") theory. All I have done, really, is to replace one family of metaphors and images with another, trading in the Theater, the Witness, the Central Meaner, the Figment, for Software, Virtual Machines, Multiple Drafts, a Pandemonium of Homunculi. It's just a war of metaphors, you say—but metaphors are not "just" metaphors; metaphors are the tools of thought. No one can think about consciousness without them, so it is important to equip yourself with the best set of tools available. (455)

What Dennett does not say in *Consciousness Explained* (1991), but does say much later in *From Bacteria to Bach and Back* (2017), is that homunculi are microorganisms with "selfish" agendas, who have become enslaved in our brains as neurons: "Neurons—like all the rest of the cells that compose our bodies—are domesticated descendants of the free-living, single-celled eukaryotes that thrived on their own, fending for themselves as wildlife in a cruel world of unicellular organisms" (160). Dennett's homunculi are a stand-in term for neurons/micro-organisms, so here he seems to reconcile and perhaps synthesize Margulis's theory about spirochetes with Dawkins' “selfish gene” theory. Whereas Dennett emphasizes the single-cell eukaryotic (nucleated) organism, Margulis emphasizes the component prokaryotic (bacterial) spirochete that (she speculates) had merged with another type of bacteria to form the eukaryote; otherwise, Dennett’s claim sounds much like Margulis’s.[33] However, neither of them ever seems to mention each other by name, even though Dennett and Margulis were both members of the Reality Club, where Margulis first proposed the idea that our neurons are the descendants of spirochetes.

For more clarity about the homuncular self, we can begin reading in the middle of the last paragraph of “Uncut Self,” to gather what we “missed” at the essay’s beginning, and cut to what Margulis and Sagan are telling us about ourselves as ecological relationships with microorganisms:

> we—as densely packed biomineralizing complexes of eukaryotic cells—should not be too sanguine about the longevity of the modern notion of self. Already in the nineteenth century Samuel Butler clearly and successfully deconstructed personality by parasitizing Charles Darwin’s texts. Between the human ovum and the octogenarian, held Butler, lie differences greater than those between us and other species. What with the vagaries of memory and experience, it is essentially arbitrary to believe that the zygote and the eighty-year-old are the same person, whereas the father and son have different selves […] ‘we’ have provisionalized identity—not least of all by avoiding the traditional figure of the rectangle that enframes the essay, representing thoughts in an enclosed form that seems to

33. Though Dennett’s ideas about neurons sound a lot like Lynn Margulis’s speculations about spirochetes, Dawkins ridicules her ideas, whereas he praises Dennett’s (for Dawkins’ praise see the front matter in From Bacteria to Bach and Back).

> mirror the hegemony of a rigidly structured Platonic body. Topologically the self has no homuncular inner self but comes" (*Dazzle*, 26).

This is how the essay "ends." Though they haven't necessarily avoided the a rigidly structured rectangular framing, they have made a gesture in that direction by disjointing the first and last sentence. They intimate a correlation between literacy practices and our sense of self, suggesting that idealized form and idealized self might reflexively create each other, and that knowledge of our microbial inheritance may challenge that idealized self. Their phrase "we—as densely packed biomineralizing complexes of eukaryotic cells" rings another bell similar to Binet's assessment of higher animals as "nothing more than a colony of protozoans," which have "epithelial cells that secrete [nails and hair]" much like Difflugia urceolata,[34] "organisms perfected with reference to the secretion of protective parts."

Margulis and Sagan seem to pick up where Binet left off in the late nineteenth century, but with the difference of interaction. They illustrate through the use of mythical figures, which they introduce as the fire-breathing Chimera with the foreparts of a lion, the midsection of a goat, and the behind of a serpent; Hydra, "a nine-headed serpent [that] grows back two heads for each one cut off;" and Cerberus, "a three-headed dog with the tail of a serpent" (27):

> …[T]heir mixed features and strange powers are reminiscent of different kinds of bacteria that fused to form the ancestors of all visible life forms, from sea-weeds to humans to whales… our genetically blended ancestors are the real-life counterparts to the monsters of classical Greek imagination. They remain unslain. In fact, as mitochondria inside the muscles of the hero holding the sword, they are part of the slayer. The detailed way in

34. The shell-making amoeboid discussed on above on p. 25.

which all live organisms are complex with numerous interacting components is the central concept of this set of nine essays… Humans are one kind of self, but we are composed of smaller selves, and we form parts of the more inclusive selves" (ibid, 28).

Whereas Binet emphasized the colony, by the twenty-first century Margulis and Sagan emphasize the *interactions* occurring amongst members of the colony.

3.5 The Speculative Chimera

Both Margulis and Dennett were members of the Reality Club, and her essay "Speculation on Speculation" began as a presentation she gave at a club meeting. Beginning in 1981 the Reality Club met once or twice per month. At each meeting one member would present an hour-long talk, then open the floor for "lively, challenging, and often impolite discussion" (Brockman, ix). Founder John Brockman gave the club this name because speakers were tasked with representing "an idea of reality by describing their creative work, their lives, and the questions they are asking themselves," to share "the boundaries of their knowledge and experience" (*ibid*). In addition to Margulis and Dennett, other members included Richard Dawkins, Isaac Asimov, Annie Dillard, Betty Friedan, Stephen Jay Gould, Ken Kesey, Abbie Hoffman, Michael McClure, Mary Catherine Bateson, Jerome Bruner, and other renowned architects, mathematicians, physicists, computer scientists, neurophysiologists, and a shaman. Members were people who could recombine in a unique way "cultural materials from the arts, literature, and the sciences" to "create their own reality" rather than "accept an ersatz, appropriated reality;" members were "doers" (*ibid*, x) as much as they were thinkers. Brockman considers the Reality Club as "not just a group of people," but “as the constant shifting of metaphors, the advancement of ideas, the agreement on, and the invention of, a new reality” (*ibid, xi*).

After delivering “Speculation on Speculation” as a talk at the Reality Club, Margulis published it in 1988, revised and re-published it in 1997, and then again in 2007. Just before she passed away in 2011, she also wrote about this topic in a scientific article, published in an anthology for an audience of scientists. The idea that spirochetes are held captive in our brains as neurons was important to her, as her decades-long persistence attests. “Here I speculate on the spirochete origin of our sensory nervous systems. A strange idea, it is easy to resist because it seems so bizarre. But because life’s biochemistry and genetics are so conservative it is, I suspect, correct” (*Dazzle*, 48). Her open admission of what she does not know lends the beginning of the essay a que-sais-je? (what do I know?) tone reminiscent of the Montaignian essay. However, despite all of this, she also implies that her claim is not all that wild, but rather conservative, given what she does know about the way life works. Instead of direct proof, she relies upon her decades of research as a microbial ecologist, and the ethos she accrued for defending the endosymbiotic theory until the means to test it were invented.

By professing an awareness that her theory sounds bizarre, Margulis primes the audience for her imaginative leap into conceptual terrain that might feel more like science fiction than science proper. Only with background knowledge of her scientific persona can the audience read between the lines of her words: they didn’t believe me back then, and they won’t believe me now, or as she states it more obliquely—"Whereas in science theory is lauded, speculation is ridiculed” (ibid). She directly confronts the consequences of her speculative method: “A biologist accused in print of ‘speculation’ is branded for the remainder of her career. This biologist finds herself like a ballet dancer imitating a pigeon-toed hunchback: all of the intellectual training to keep my toes turned out emotionally backfires with any request to speculate freely" (*ibid*). By this fourth sentence the essay turns personal, with Margulis taking on a humbling "que sais-je" (what do I know?) tone reminiscent of the personal essay. She puts herself in the vulnerable position of admitting she does not know for sure. This kind of vulnerability, Philip Lopate argues, is a key rhetorical move of the personal essay (Lopate,1995), and sounds a different tone from the magazine interview about spirochetes in which Margulis declared "I don't consider my ideas controversial, I consider them right."

Though she was arguing a quite similar point there, here her stance is less aggressive, with more detail: "The process of perception, awareness, speculation, and the like evolved in the microcosm: the subvisible world of our subvisible ancestors. Movement itself is an ancestral bacterial trait, and thought, I am suggesting, is a kind of cell movement" (49). Here, she equates motility with thinking. Some microbial researchers, like J.A. Shapiro and Pamela Lyon have argued that the anthropomorphic metaphors used to describe bacterial cognition are not merely metaphors.[35] And others, like Alfred Binet and Julius Adler, have suggested that we inherited perceptual abilities from microbes. Whether wittingly or not, Margulis synthesizes these two strands of thought:

> …mind-brain processes are the nutrition, physiology, sexuality, reproduction, and community ecology of the microbes that compose us. The microbes are not just metaphors; their remnants inhabit our brain, their needs and habits, histories and health status help determine our behavior. If we feel possessed and of several minds, if we feel overwhelmed by complexity, it is because we are inhabited by and comprised of complexities. (53)

35. I discuss Shapiro's and Lyon's contributions in the following chapter on quorum sensing.

Here she may be gesturing—through double-entendre—towards complexity theory, perhaps implying that human psychological complexity and distress emerge from the complexities of cellular ecology. Or, she may simply be arguing that even organisms as simple as spirochetes/neurons are also overwhelmed by complexity. She furthers the notion that the microbes are not just metaphors for thoughts and emotions, pointing out behavioral similarities between mudflat- and brain-dwelling "spirochetes," and by extension, human affective tendencies.

And, if complexity is too abstracted as a concept, "dancing" makes their actions more visible: "It is no coincidence that salt ions and psychoactive drugs, including anesthetics, have strong effects on movement or growth of the free-living mud-bound cousin spirochetes" (55). Thus, not only similarity of morphology, but also motility and response to chemicals (i.e. chemotaxis, which Adler so astutely studied) led Margulis to see a relationship between spirochetes and neurons. Though she does not say it directly, she notes the similarity, thereby encouraging her readers to merge mudflat and mind—to see mind ecologically. "When they are starved, cramped, or stimulated we have inchoate feelings. Perhaps we should get to know ourselves better. We might then recognize our speculations as the dance networks of ancient, restless, tiny beings that connect our parts" (ibid). If we can imagine thoughts "dancing," we might also imagine spirochetes dancing and perhaps, through suggestion, imagine that the metaphorical dancing of our thoughts is derived from the metaphorical dancing of bacteria. Though the actions of the parts do not necessarily predict the behavior of the whole, Margulis nevertheless believes it necessary to understand the parts if we want to understand the whole.

Whereas Adler's research was fairly reductionist but with a holist interest in higher organisms, Margulis's approach was holist but with an interest in how the parts relate and lead to emergence of the whole organism. She draws upon the familiar analogue to the human brain, the computer, whose component parts have precedents, and which is understood as miraculous for the way these precedent parts are assembled (49). However, she argues that "biologists, psychologists, philosophers…have failed to identify even the analogues of electricity, electronic circuits, silica semiconductors, screws, nuts, and bolts," and if we don't understand "the parts and their meanings, we can never know the human mind-brain" (*ibid*) (which she also refers to as the "mind-body-brain"). Her stance values the perspective of both reductionist and holist frameworks, as well as the ability of non-scientists to address relationality. Later, she explains that the more intricate details of her theory (though published in a scientific journal) "do not belong in a popular essay about speculation…Yet, I ask that the formerly unmentionable become widely discussable by specialist scientists and inquisitive philosophers so that the consequences of the hypothesis may be explored" (53). Margulis expresses interest in the philosophical implications of a theory which may or may not be true and calls upon humanities scholars to contribute to this conversation. Margulis's fraught theory about the spirochete-neuron relationship (and Dennett's uncontested version of it) both suggest that pre-existing cells joined in new combinations to create evolutionary complexity. Their similar theories suggest that what's inside of our heads is not a substance or process altogether distinct and alienated from the world outside of heads.

Anthropologist Tim Ingold distinguishes Western alienation from nature against indigenous ecologies, which "see no essential difference between the way one relates to humans and to non-human constituents of the environment" (75). His work offers a perspective similar to Margulis's, but with a more humanistic lens. Ingold argues that "the transition from hunting to pastoralism led to the emergence [instead of egalitarian relations of sharing] of relations of domination and subordination between herding leaders and their assistants" (76). This transition from trust to domination, he says, "affects relations not only between humans and nonhuman animals, but also, and equally, among human beings themselves" (ibid). Ingold suggests that metaphor is more than metaphor, that what we assume as metaphor is perhaps knowledge we have acquired from the landscapes we arise from. He alleges that anthropology attempts to curtail threats to "Western dichotomies between animals and society, or nature and humanity" by "relativising the indigenous view," and telling us, for example, that when hunter-gatherers "use terms drawn from the domain of human interaction to describe their relations with animals," they are "indulging in metaphor" (ibid). "[N]ature, we say, does not *really* share with man," and when "hunters assert the contrary it is because the image of sharing is so deeply ingrained in their thought that they can no longer tell the metaphor from reality. But *we* can, and we insist—on these grounds—that the hunters have got it wrong" (ibid). Ingold argues that this arrogant view upholds "the Western metaphysics of the alienation of humanity from nature" and uses "*our* disengagement as the standard against which to judge *their* engagement" (ibid). He declares that the roots of our ecological crisis "lie in this disengagement, in the separation of human agency and social responsibility from the sphere of our direct involvement with the nonhuman environment" (ibid). To reverse the metaphysical alienation that feeds this ecological crisis, Ingold suggests that by appreciating the indigenous, hunter-gatherer perspective, we can "rewrite the history of human-animal relations, taking this condition of active engagement, of being-in-the-world as our starting point" (ibid). Rewriting the history of human-animal relations is but one aspect of reimagining our being-in-the-world.

I turn to Ingold because as a scholar of rhetoric I am interested the not only the language use, but also the practices that led to the institutionalized hierarchies of modern, alienated human cultures. I turn to Margulis because I am interested in the way she reimagines what might arise from relational conflict between biological entities, aside from aversion, dismissal, or domination. She hypothesizes that all "phenomena of mind, from perception to consciousness, originated from an unholy microscopic alliance between hungry swimming killer bacteria and their potential archaebacterial victims…" (51). The way Margulis phrases it, there is no way to sugarcoat the realities of consuming other beings: "…the wily and fast movement, the hunger, and the sensory ability of the survivor's enemies were all put to good use by the evolving partnership…" (ibid).

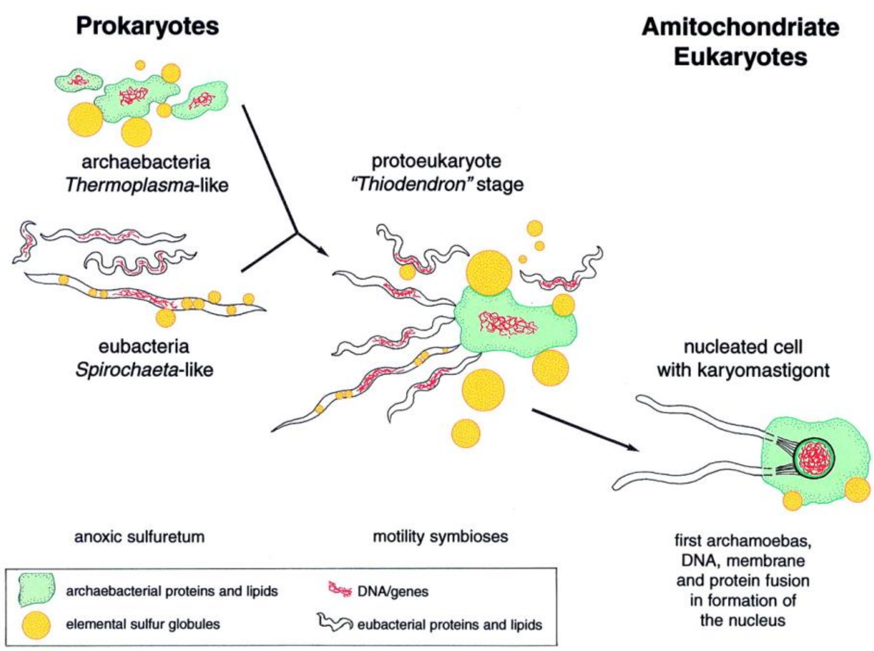

Figure 3-9 Origin of the chimeric eukaryote with karyomastigonts from a motile sulfur-bacteria consortium. Image by Kathryn Delisle, from "The chimeric eukaryote: Origin of the nucleus from the karyomastigont in amitochondriate protists." Margulis, Dolan and Guer.

Whether this happens literally, metaphorically, or somewhere in between—as is common in Western labor and consumer relations, we at least ought to be aware that it is happening, and acknowledge the damage it can wreak upon cultural and ecological relations. As humans, we have the capacity to imagine and act our way into novel experiential conditions, both at the level of individual and groups. "'Synapse,'" if I am correct, is the neurophysiologist's term for the well-developed spirochetal remnant site of interaction" (54). Our own days are full of well-developed sites of micro-interactions, from which emerge the cultural whole—which is not exactly the same as the trillions of micro-interactions that comprise it, but which is nevertheless made from them. And our own seemingly benign micro-interactions acquire a different texture when we zoom out and see the larger cultural whole that emerges from them.

In Margulis's estimation, micro-interactions make human thought—and the evolutionary analogues to it—possible: "My speculations, two thousand million years later, may be the creative outcome of an ancient uneasy peace…the spirochetal remnants may be struggling to exist in our brains, attempting to swim, grow, feed, connect with their fellows, and reproduce" (52). There is a kind of poetry in the idea that thought is a biologically relational, though at times antagonistic, process. "Speculation, I claim, is the legacy of the itching enmities of unsteady truce…the mutual stimulation of the restrained microbial inhabitants…our nerve cells are the outcome of an ancient, nearly immortal marriage of two arch-enemies who have managed to coexist…" (52). This biological process, as Margulis describes it, is but one example of the conditions which rhetoric (traditionally conceived) attempts to rectify. We will never be aware of the infinite individual interactions that lead to our own thoughts. Margulis suspects we may be "as entirely unaware of the microbial inhabitants that comprise us as a huge ship tossing in the waves is unaware that her responses are determined by the hunger, thirst, and eyesight of the captain at the helm and his communications with the crew" (53). Even if we don't understand the accumulations of cellular processes out of which our consciousness flowers, Margulis' comparison of the human mind with a non-living, non-conscious ship is an exaggeration—though one which prompts us to appreciate how much we *do not know* about our own minds. While this autopilot metaphor captures the beauty involved in such a process, it also highlights the ingrained affective patterns required to sustain enduring antagonisms that seem impervious to reconciliation by linguistic means.

3.6 Concluding Thoughts

Raymond Pierotti, scholar of traditional ecological knowledge (TEK), says that Margulis' endosymbiotic theory provides the most compelling evidence of "relatedness and interconnectedness" because it shows that humans share with the rest of eukaryotic organisms (animals, plants, fungi, protists, algae) a co-evolved relationship with our own mitochondria" (226). Pierotti believes that endosymbiosis could have been "predicted and readily understood by Indigenous people," but "required a highly technologically driven" Western science to "document its reality." Endosymbiosis is "based on relationships and co-evolution" as is "much of Indigenous philosophy, belief, and TEK," though he suggests that it "requires input from both Indigenous and Western traditions to be recognized, accepted, and fully understood" (227) [36]. Whether wittingly

36. Pierotti and Wildcat (2000) offer various other helpful descriptors of TEK as: 1) "based on close observation of…natural phenomena [though] combined with a concept of community membership that differs from that of Western political and social thought;" 2) "tied to specific localities…all aspects of the physical space [animals, plants, landforms, etc.] can be considered part of the community…native peoples look around them [rather than backward and forward in time] to get a sense of their place in history;" 3) converging "closely upon the Western science of ecology;" 4) resisting the "Western dichotomies of natural vs. supernatural, physical vs. metaphysical, sacred and profane, nature vs. nurture," so that "by placing TEK-based worldviews into abroad-based system of knowledge [we can access] a large amount of information and experience that has been previously ignored, or treated as mysticism" (p. 1333-1339).

or not, Margulis' attempt to compare consciousness with spirochete microbial ecology resounds particularly well with this ontological position—so I place her work in the context of literacy and rhetoric scholars invested in Indigenous ontologies. She assumes the kinds of ontological entanglements that foster ecological literacy—which for Ortoleva requires an understanding of our "interconnectedness to biotic and abiotic environments," and which Rios refers to the Indigenous "ontological position that sees humans as 'the Earth being conscious of itself.'"

To extend these conversations of ecological literacy, and encourage a synthesis of Western-Indigenous approaches to knowledge and being, I turn to David Abram. He explains that alphabetic literacy—which oral cultures considered a form of powerful magic—relies heavily upon imagination and ambiguity. For Abram, reading is a kind of animistic activity

> not that different from an indigenous Hopi woman…having her eyes grabbed by a small bush wherein a spider is weaving its web. And, as she focuses her eyes on that spider, she suddenly feels herself addressed, or spoken to by the spider. Or, a Lakota man strolling down a path and seeing a boulder and his eyes are captured and he focuses on a patch of lichen on that boulder and suddenly finds that the boulder is speaking to him. And, he enters into a conversation with the boulder. We do just the same things, with our own scratches and scripts. We come down in the morning, open the newspaper, focus our eyes on these little bits of ink, and they start speaking to us. And, we enter into this rich, magical field of conversations happening at other times and other places. (2004)

In the previous chapter I suggested that (similar to Abrams' description) Julius Adler studied bacterial motility in a way that exhibited animistic tendencies because he paid deep attention to the motions of individual bacteria, and speculated about our evolutionary relations to them. However, Adler was a biochemist, and seemed to lack an ecological literacy because he ignored bacterial interconnectedness to environs. Though Adler's more reductionist lens certainly shed light on the mechanisms of bacterial motility, it did not provide much insight into the motivations that arise from broader contexts. Our current geo-historical circumstances ask that we investigate how we also became unable to perceive our selves in this way. Though there are various reasons this has happened, traditional scientific literacy (which has seeped into the popular consciousness) is partly responsible for this problem. It does seem, however, that some contemporary science attempts to rectify this issue.

Deep ecology theorist Joanna Macy explains that systems theorists in the natural sciences use terms like "cyclical causality," "reciprocal and mutual causality," and "interdetermination," to counter notions of a "predetermined clockwork universe," or "the blind, random play of chance" (17), which have informed the popular imagination for the past few centuries. She says social scientists describe this framework as "symbiotic, synergistic, pluralistic, mutualistic," and have used it to remedy behaviorism's "linear model of stimulus-response," and to perceive and articulate mutual causation, for example, between "schools, jobs, housing, and health" (ibid). Returning to Abram, we can see ecological literacy as a process of mutual causality—a process he claims that alphabetic literacy disrupts:

> So, there's this kind of a loop, or reciprocity, that is basic to the human organism that gets interrupted, it would seem, when writing comes into a culture and people begin to enter into this reflexive loop with their own written signs. The land is left out of account and begins to seem superfluous … a passive backdrop against which human history unfolds …

a passive set of resources for us to … mine up and use for our own purposes. It no longer has its own rich, inherent value and life…" (Abram, 2004). [37]

In Abram's telling, (phonetic) alphabetic literacy has allowed us to disassociate from the landscape. While it's difficult to see how alphabetic literacy could have directly caused the ecological crises we now face, it's easier to see how Western scientific literacy could have. However, the scientific literacy we are familiar with would not likely have been possible without alphabetic literacy. Although it's difficult to disentangle the two, and their epistemological and ontological effects on us, awareness of these possible effects is a good first step.

Macy and Margulis both make similar suggestions, that language use at the level of grammar and syntax—how we use subjects, objects, nouns, and verbs—contribute to our sense of ecological detachment. Margulis and Sagan highlight this through their attempt to define life:

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37. Abram adds that "when a phonetic alphabet arrives, only then does that culture get this odd notion that language is an exclusively human property [and] the rest of the land falls mute. You don't experience this in that way among Eastern cultures working with more ideographic, or somewhat iconic scripts. Certainly not among the Mayans, and obviously not among the Egyptians." Abram is not phonocentric; rather he points out that humans are disinclined to read land, water and animal behavior as we once did. He says the Hebrews, the first to use a phonetic writing system "did something very interesting. They became literate, in relation to the visible world, and the visual shapes of the world. And, they would say, God is not that tree. And, God is not that golden calf, is not any visible image. That is not divine. God is elsewhere." Abram contends that a phonetic writing system, "…even as we engage it *hides* itself from us…as soon as we look at the written words on the page, they trade our eyes for our ears, so that we actually don't see something. We end up *hearing something*…a kind of internal discourse" (2004). Though the question of a pagan-like divinity is outside the scope of this chapter, it seems like an unavoidable question if we are to fully address the roots of ecological collapse.

… Life’s body is a veneer of growing and self-interacting matter encasing Earth … The question ‘What is Life?’ is thus a linguistic trap. To answer according to the rules of grammar, we must supply a noun, a thing. But life on Earth is more like a verb … In spite of English grammar, life does not exist *on* Earth’s surface so much as it *is* Earth’s surface. (22, *What is Life?*)

Though their definition does not quite avoid the linguistic trap they point to, Margulis and Sagan nevertheless illustrate the trap at work as they attempt to define life. To imagine ourselves, from the inside out, as a fluid and dynamic part of this “growing and self-encasing matter,” would require a massive shift in our self-awareness, and perhaps even the way we use language. This is not a feasible solution given the urgency of the crises we face. Rather than scrap alphabetic and scientific literacy, we could look for ways that traditional ecological knowledge converges with Western ecological science and notice places where we might intervene, such as the language we use to talk about our concepts of self and agency.

As Pierotti argues, endosymbiotic theory converges with traditional ecological knowledge; Margulis and Sagan themselves placed aspects of endosymbiosis alongside the Buddhist concept of no-self to undermine western notions of the isolated individual. Macy goes further, deeply investigating the idea of no-self alongside systems theory and deep ecology, to further draw out the implications of each. “The Buddhist perception of process,” together with the “doctrines of *anatta* [not-self] *and annicata* [impermanence] dissolve all notions of enduring, isolable entities and leave no basis for a dichotomy between substance and attribute” (47).

Macy explains this with an example she draws from the ancient Buddhist[38] sutras; like Margulis and Sagan, she lands upon the question of grammar. When asked to identify "the causal agent that produces consciousness, contact, feeling," the Buddha criticized the question, and instead substituted "verb for noun, action for substance" (47). Macy says that the "very language and grammatical forms used in the teaching of [the Buddhist doctrine of dependent co-arising] imply that it entails a nonlinear kind of causality. The departure from linear assumptions, and the emphasis on relationship rather than substance, is discernable both in the choice of terms and their inflection" (51). For example, though craving and grasping are considered root causes of suffering, the Buddha was opposed to the statement, "someone craves." Macy says that the "semantics of the questions he asked himself is noteworthy: 'What now being present, is craving also present? What conditions craving?" (ibid). This statement decenters agency away from the individual and re-distributes it throughout the environment. It renders human desire similar to bacterial chemoreception and chemotaxis (as we saw in the previous chapter, Adler at times had difficulty separating perception from attraction). This rephrasing does not shirk human responsibility, but rather, refocuses it by asking us to identify the origins of our craving so that we might learn how to dampen its power over us. This framing asks us to see how we are inextricable from our environs, and to pay closer attention to our interactions with them. Macy relates the mythical Buddhist genesis story, which illustrates how craving generates the idea of self: "Feeding greedily on the fruits of the earth, beings grew more and more conscious and prideful of their individual attributes … just as craving feeds [the illusion of an enduring self], so does the illusion of self in turn feed craving" (57-58).

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38. Ancient Buddhism was born out of the Indian forest dwelling tradition.

We may need to go as far back as 2,500 hundred years to create new origin stories, but the stories needn't be purely ancient. Whether mythical, scientific, or a hybrid of the two, the act of storytelling can help reshape our perception of ourselves, from being-in to becoming-with our environs. Seeing ourselves as part of a causal loop between fruits of the earth, craving, egoic perspective, and language structure, means deepening our appreciation of the reciprocal relationship between language and materiality. We then have more agency to recursively shape our relationships with "fruits of the earth" so that we can begin to see them too as processes. Scientifically-oriented work like that of Margulis and Macy, which also acknowledges other ontologies and worldviews could help Western people learn to see the material and processual correspondence between all organisms. As educators and theorists of literacy and rhetoric, I suggest we can put our talents and efforts to use in locating the ways our language use and theories drive our worldviews and habits, and vice versa.

The humanities might be more curious about what the sciences and other worldviews could offer us in our attempts to reframe what language is and does, and to theorize the possibilities of communication, linguistic or otherwise. To feel true empathy for and interest in my adversary requires transformation of my concept of self, perhaps even to the extent that I believe my enemy exists within me, or not at all. Far too often, people with opposing opinions communicate as though they are not having the same conversation, if they communicate at all. As the polemical political climate pushes us further into the comfort of echo chambers, we have cordoned ourselves off from supposed enemies, who have the ability to transform us. Instead, political and ethical opponents might engage in a way that is transformative. How could the way we respond to others reflect our attitudes towards the environs? In the remaining two chapters I discuss quorum sensing research and microbiome studies which respectively understand bacteria and humans as ecological organisms.

4.0 Metaphoric Consensus: How "Quorum Sensing" Caught Fire

4.1 Introduction: How Scientists Came to See Bacteria as Social

> …anthropomorphism rests on the prior assumption that thought, value, and experience are essentially, or exclusively, human to begin with…our own value activities arose out of, and still remain in continuity with, nonhuman ones…the best we can do is create metaphors and similes…aesthetic semblances—that allude in some way to chiropteran or canine existence.
>
> —Steven Shaviro (2014)

> The term "quorum sensing" quickly caught on, and the floodgates opened. Now there are hundreds of articles on quorum sensing published every year.
>
> —Peter Greenberg (2010)

Soil microbiologists began studying bacterial group behavior in the early twentieth century [39] but they would remain alone in their interest until the late 1960s, when marine bacteriologists discovered that bacteria produced certain kinds of bioluminescence. They explained that numerous individual *Vibrio fischeri* bacteria residing inside the light organs of marine creatures would behave as one multicellular organism to "auto-induce" luminescence, though *V. fischeri* would

39. For a brief review of early soil microbiology see J.A. Shapiro 1988, p. 82

only do this at a very high cell density—upon sensing their population was dense enough to collectively produce visible light (Miller & Bassler, 2001, 167). The host organism supplies the nutrient rich environment and *V. fischeri* provides the light, given the appropriate environmental conditions. Scientists would later explain that this "autoinduction" of luminescence was made possible through quorum sensing, which they defined as a cell-to-cell communication process through which bacteria produce and detect "extracellular chemicals called autoinducers to monitor cell population density" thereby allowing bacteria "to synchronize the gene expression of the group, and thus, act in unison" (Ng and Bassler, 2009).[40]

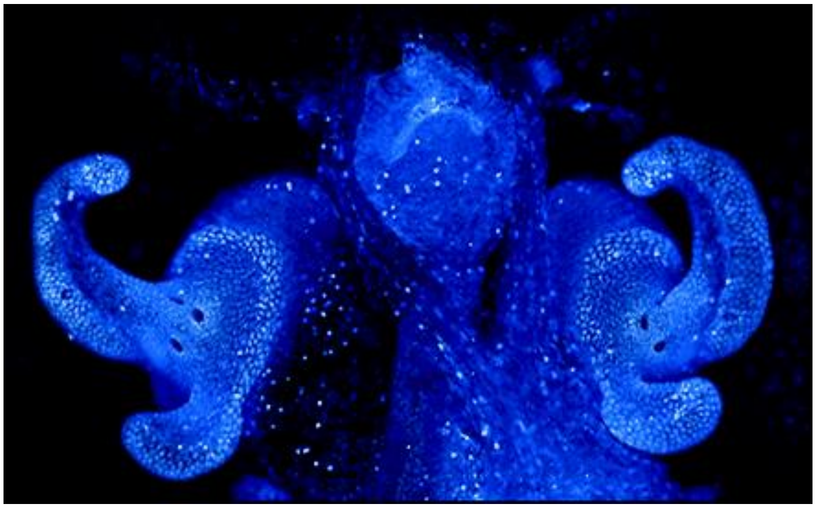

Figure 4-1 Bioluminescence, newly hatched squid, Fogel et al. 1972. CC BY-SA 3.0.

40. It is important to consider this fairly current definition of quorum sensing because quorum sensing replaced the term autoinduction, even though autoinducers and autoinduction are still being used in the scientific literature about quorum sensing.

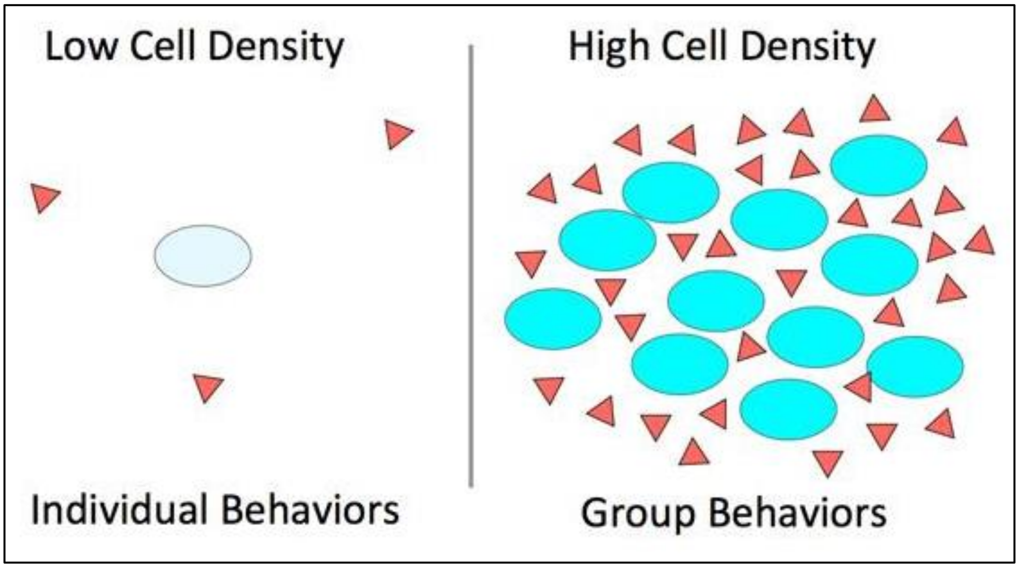

Figure 4-2 Bacterial Quorum Sensing, Bassler Lab, Princeton University.

According to this definition it would seem as though a bacterial quorum equals what we might call "consensus." However, later researchers learned that just because bio-luminescing bacteria sense a quorum, they do not necessarily "act in unison," but rather, "even at high cell densities only 69% of the cells of the population produced bioluminescence, 25% remained dark and 6% were dead" (Anetzberger et al. 2009). To follow the metaphor of quorum sensing further, we could say that a bacterial quorum does not lead to or force "decisions"— bioluminescence (or any other bacterial group action dependent upon quorum sensing) does not require a high degree of "consensus." Apparently, this difference in "votes" cannot be explained by genetic or environmental differences, because as the researchers put it, "a clonal [genetically indistinguishable] high dense population forms two major subpopulations, a bright and a dark one, in a homogeneous environment. Moreover, light intensity varied considerably from cell to cell" (ibid). Though they did not have answers about why these differences would occur amidst genetic and environmental homogeneity, they could affirm that "[h]eterogeneous behaviour was found under all tested cultivation conditions [so] it appears unlikely that the observed heterogeneity is attributed to specific laboratory conditions" (ibid). Even though bioluminescence requires a high population density, it is neither necessary that each individual bacterium light up, nor that they do so with the same vigor as their cohorts. Since not all bacteria will luminesce, something like "choice" seems to exist, though the extent, cause, or degree of such choice still remains unclear.[41]

The idea of choice becomes murkier once we take host organisms into consideration. The symbiotic complexity found in phenomena such as bioluminescence, together with scientists' efforts to name and describe such behaviors, are beginning to challenge our assumptions about anthropomorphism and anthropocentrism. Quorum sensing occurs in certain species of squid capable of counterillumination, an anti-predation strategy that "enables the squid to avoid casting a shadow beneath it on bright clear nights when the light from the moon and stars penetrates the seawater" (Miller & Bassler 2001, 167). One extraordinary example of counter-illumination occurs in the Hawaiian bobtail squid, which dons the brilliant speckles of a starry sky, a celestial camouflage from predators and prey beneath. The bobtail squid's bioluminescence demonstrates a nonhuman intelligence within the community of *V. fischeri* bacteria, which collectively determine when and where to turn on their lights. Quorum sensing also demonstrates an environmental intelligence: bacteria and squid working in concert with ocean and starlight. The bobtail squid demonstrates sophisticated responses to environment, occurring outside of spoken language and possibly even conscious intent. Though the squid cannot directly regulate its bioluminesce-ing inhabitants, it can detect the light they produce and control how much it will open its light organ.

41. I recently asked Bonnie Bassler about the 25 percent of bacteria that do not bioluminesce; she replied that heterogeneity and stochastic decision making are still hot topics under discussion, and that her lab is currently working on an article about heterogeneity.

The bobtail squid's bioluminescence exhibits a complex decision-making process which one individual creature alone cannot control, and which challenges our ability to clearly distinguish between "intelligent choice" and automatic response.

Figure 4-3 Hawaiian bobtail squid. © Ludovic, 2014.

I suggest that the phrase quorum sensing (and others that could be labeled anthropomorphic) invited bacteriologists to make imaginative leaps in ways that autoinduction could not, and opened avenues of research that are now destabilizing notions of humans as discrete entities that make fully autonomous and conscious decisions. Instead, scientists are advancing theories of human-microbial assemblages and in doing so, they simultaneously challenge anthropocentric ideals. In challenging our ideals about what decisions are, and what kinds of creatures are able to make them, bacteriologists also challenge our ideals about conscious, rational, and intentional human decision-making capacities. For example, bacterial geneticist J.A. Shapiro says his decades-long research on E. coli bacteria pattern formations has convinced him that quorum sensing dismantles Cartesian dualism because bacteria display cognition by making decisions using only their bodies (2007). Later in this chapter I engage scientists' claims that terms like quorum sensing and cognition are not just metaphors, and I track how metaphors reminiscent of human behaviors help some scientists to understand and write about bacterial behavior.

Like the *V. fischeri* inside of marine creatures, bacteria do not waste energy performing pointless tasks; rather, they wait for prime conditions and the critical mass required to produce results that are most beneficial to the population as a whole. Scientists point to mounting evidence that quorum sensing even elicits specific responses from "higher" plant and animal hosts, including responses that meet the needs of bacteria, conferring upon bacteria qualities typically attributed to higher organisms (Miller and Bassler, 2001; Shapiro, 207). Indeed, the evolution of quorum sensing systems may have been "one of the early steps in the development of multicellularity" (Miller and Bassler, 2001). I devote an entire chapter to quorum sensing because the phenomenon it names may be the earliest form of suasive biological behavior. Understood as such the term depends upon an important gap: quorum sensing subtly connotes a correlation between how bacteria make group decisions and how humans make group decisions. I suggest that the term appeals to some part of us that (perhaps unconsciously) understands our own decision-making as more intuitive and automatic rather than deliberat-ive and intentional. The term quorum sensing plays upon vague and unstated assumptions, attitudes, and feelings about human decision-making, and circuitously prompted later researchers to inquire into human as well as bacterial decision-making. The story of quorum sensing illustrates how metaphors can do more than decorate or explain, but also propel scientific discourse and concepts.

Though it's unclear whether the term's creators intended it, this metaphor may have eventually transformed into something like an implicit scientific model, as it seems to have nudged scientists into reconceiving human ontology after studying the communicative behaviors of our bacterial inhabitants. In her extensive discussion of the relationship between analogy and scientific models, Daniela Bailer-Jones says scientific models are oftentimes based on analogies, and are sometimes said to be analogies, but only in cases when the model is not physical, but rather, conceptual or abstract (2009, p. 46). “Very roughly”, she says, “an analogy is a relationship, whereas a model is a (interpretive) description of a phenomenon, whereby this description may or may not exploit an analogy” (ibid, 56). She points out that models in science typically develop “beyond the boundaries of the analogy from which they originated” (ibid). Quorum sensing is not used in the scientific literature about human/bacterial communication process, although analogous faculties in humans are currently being suggested. Bailer-Jones’ work is particularly useful for considering how quorum sensing may have developed aspects of the scientific model after certain discoveries about human-bacteria symbiosis—which led to the holobiont theory of the human5 bacteria assemblage. Bailer-Jones argues that an analogy is more than a “teaching aid or dispensable illustration,” citing Maxwell’s statement that “the recognition of the formal analogy between the two systems of ideas *leads to a knowledge of both, more profound than could be obtained by studying each system separately*” (ibid, p. 50, italics mine).[42]

In the previous chapter I discussed Lynn Margulis’s hypothesis that the neurons in our brains are the descendants of spirochete bacteria. And neuroscience, though not specifically suggesting from whence our neurons evolved, points to the importance of single-celled organisms

42. While outside the scope of this chapter, it could be fruitful to discuss quorum sensing as either an accidental or retrospective scientific model, especially as the science of human-bacteria assemblages develops further. Especially pertinent is Bailer-Jones’ development of Mary Hesse’s “positive,” “neutral,” and “negative” analogies: “The positive analogy refers to those things that two analogues are known to have in common; known differences are referred to as negative analogy; all those properties for which commonality or difference is yet to be established are referred to as neutral analogies” (ibid, 54).

for understanding how individual brain cells work, so in this case, the single free-living cell does act as a kind of model for the neuron. In a review article, Kendal and Squire state that "cells of the nervous system are understood to be governed by variations on universal biological themes" and that "even bacteria…express remarkably similar ion channels" making "neuronal signaling" a "capability inherent in most cells (2000). Similarly, Antonio Damasio states that

> All living organisms from the humble amoeba to the human are born with devices designed tonsolve automatically, no proper reasoning required, the basic problems of life. Those problems are: finding sources of energy; incorporating and transforming energy; maintaining a chemical balance of the interior compatible with the life process; maintaining the organism's structure by repairing its wear and tear; and fending off external agents of disease and physical injury. (2003, p. 30)

Kendal and Squire recognize that whereas "studies of single cells have been enormously informative, the functioning brain consists of multiple brain systems and many neurons operating in concert" (2000). I do not yet see evidence of bacterial group behavior being used as a model for "neurons acting in concert," but the science around this phenomenon is still relatively new.

Although I seem to be the first in rhetorical studies take an active interest in what scientists call bacterial decision-making, I am not the first in the humanities to do so. In his introduction to *Cognition and Decision in Nonhuman Biological Organisms*, editor Steven Shaviro pays particular attention to the chapters dedicated to bacterial, slime-mold, and plant decision-making, perhaps because the word *decision* is most likely to be considered outlandish in reference to brainless organisms, as mind is widely believed to be housed neatly within the brain. Regardless of whether we agree that bacteria (or any other brainless creature) can actually make non-determined decisions, scientists and philosophers are already taking seriously the idea that they do, and I suggest that rhetorical studies is well-suited to join this conversation.[43] One need not believe that bacteria make decisions in order to entertain the idea and its consequences. Keats' notion of negative capability, the ability to remain in "uncertainties, mysteries, doubts, without any irritable reaching after fact and reason" seems appropriate in this context. "The only means of strengthening

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43. In their extensive review of cellular decision making "from viruses, bacteria, yeast, lower metazoans, and mammals," Gábor Balázsi et al. define this term as "the process whereby cells assume different, functionally important and heritable fates without an associated genetic or environmental difference […] Such stochastic (randomly determined, not predictable) cell fate decisions generate nongenetic cellular diversity, which may be critical for metazoan [animal] development as well as optimized microbial resource utilization and survival in a fluctuating, frequently stressful environment." They add that "cellular decision making is one of at least three key processes underlying development at various scales of biological organization" and that "bacteria are masters of cellular decision making, which enables them to hedge bets in a fluctuating, often stressful environment. This may explain their presence in the most extreme and unpredictable environments […] genetically identical bacteria can select their fates randomly from a spectrum of multiple options. Fates with lowest direct fitness (such as the spore state) are entered gradually, with a delay, while a variety of alternative options are explored […] bacteria can combine cellular decision making with other mechanisms (such as cell-cell communication) to achieve more complex population-level behaviors. Cellular decision making appears suppressed when cell-cell communication becomes prominent (as in quorum sensing), suggesting that microbial individuality is undesired when genetically identical bacteria assume multicellular behaviors" (2011). As this excerpt shows, the conversation about cellular decision making is contingent on various related terms and metaphors, and though this conversation is related to cellular communication it is also distinct from it. As such, it could use its own chapter. Whether cellular decision making is deterministic or not is still a matter of debate. Whereas Balasazi et al. call the term an "oxymoron" because they believe the decision making power lies in the cells' genetic material, Shapiro (2011) and Margulis (2008) would object to this statement as reductionist, because they assert the agency resides in the entire organism.

one's intellect," he argues, "is to make up ones [sic] mind about nothing—to let the mind be a thoroughfare for all thoughts. Not a select party" (as quoted in Rohrbach).

Research on the varieties of bacterial decision-making is still in the formative stages, and so is the language that scientist use to describe it. We do not have to trust that bacteria can "make decisions" to be able to entertain the idea. Our responses to these terms can at the very least help us to clarify and distill our own conceptions of the human decision-making process as traditionally understood, prior to any understanding of the bacterial interface with the human body. I do not offer here the ultimate truth about whether or not bacteria make non-determined decisions, as individuals or as groups. The point of this chapter is not to decide the question of free will once and for all, but to further open up inquiry into the phenomenon called bacterial decision-making. It may feel foreign to say that bacteria make decisions, and much more comfortable to say that molecules trigger in bacteria pre-determined reactions. But if we do not like the idea that bacteria might make something like decisions, this dislike may teach us something about our own trigger mechanisms—regardless of whether they originate in cultural tradition, chemically induced reactions deep inside of us, or some combination of the two.

Though these unsettled and perhaps unsettling questions are not irrelevant to this chapter, neither can they be finally answered here. My first goal in this chapter is to show how multicellularity came to be understood as a ubiquitous bacterial behavioral. I first examine the parallel switch in terms from <u>autoinduction</u> to <u>quorum sensing</u> (which bacteriologists hazily attribute to an outsider, a literary-type). I then consider the term <u>quorum sensing</u> via Burke's discussion of the four master tropes (metaphor, metonymy, synecdoche, and irony), each of which helps to understand how the term works. I suggest that <u>quorum sensing</u> taken as irony created a dramatic reversal that ushered in an important conceptual switch: from bacteria as antagonist (a pathological lens) to bacteria as incorporate with the human body (the communication lens). I then consider how the term quorum sensing behaves like an enthymeme, eliciting a kind of silent epideictic rhetoric from those who use it. I end by offering some preliminary implications for rhetorical theory, which I develop further in chapter four, when I propose that quorum sensing, a term that takes for granted the distributed nature of bacterial intelligence, enabled current scientists to theorize a distributed, embodied cognition in humans.

4.2 Conceptual Re-genesis: Multicellularity

Multicellularity is one of the most important conceptual developments of twentieth century bacteriology; it is very much intertwined with quorum sensing, and both phenomena gained popularity in the field around the same time.[44] Essentially, the communicative process of quorum sensing enables bacteria to behave multicellularly, though scientists acknowledged that multicellularity existed before the term quorum sensing was invented. As scientists began to recognize that multicellularity was a general bacterial behavior trait, they also became interested in researching and explaining the chemical processes that enabled multicellular behavior. The

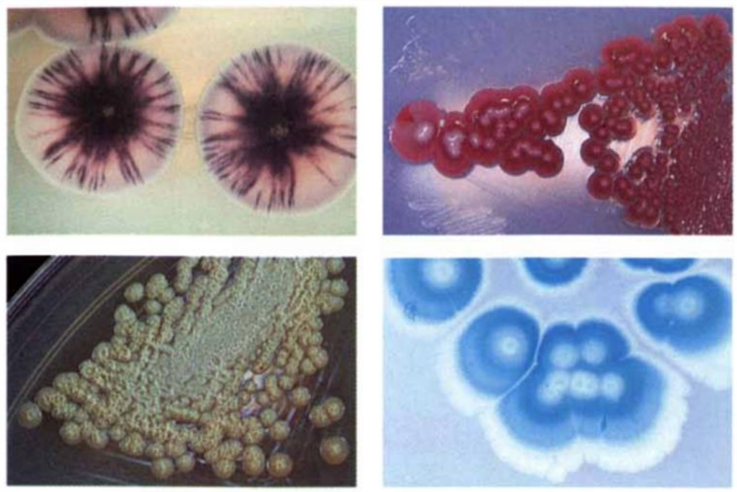
44. Horizontal gene transfer (which Fred Griffiths discovered in 1928) is an equally important conceptual development. However, quorum sensing enables both multicellularity and horizontal gene transfer. Specifically, quorum sensing allows for DNA release, and for recipient cells to be in a state called "competence," a prerequisite for DNA uptake (see Shapiro's "Physiology of the Read-Write Genome," 2014, and Evolution: a View from the 21st Century). So, perhaps quorum sensing is the most important conceptual development of twentieth century bacteriology because it helps to explain a variety of bacterial behaviors of crucial interest to human society.

acceptance of multicellularity as a widespread phenomenon seems to have triggered the invention of the term quorum sensing several years later to facilitate discussions about multicellularity. In this section, I will first briefly sketch how multicellularity came to be seen as a ubiquitous bacterial trait, and in the following section I will relate the origin story of the term quorum sensing. I focus primarily on the stories that bacteriologists have told (to themselves and the public) about how their discourse community came to accept the concepts of multicellularity and quorum sensing.

In 1998 James Shapiro published a retrospective account of scientists' acceptance of multicellularity, "Thinking About Bacterial Populations as Multicellular Organisms" *in Annual Review of Microbiology*. Though this technical article addresses a specialist audience, Shapiro begins with a narrative about the initial difficulty he experienced when he attempted to generate interest in multi-cellularity in his article "Bacteria as Multicellular Organisms" (1988), which he had published in *Scientific American* just ten years prior. He explains that he based this earlier article

> largely on the observation of pattern and organized cellular differentiation in the colonies of many bacterial species, including E. coli. While stimulating interest in the idea that bacteria may be more interactive than generally realized, that 1988 article did not convince most microbiologists that multi-cellularity should be considered a basic tenet in our thinking about how bacteria operate. (82)

Shapiro's goal in 1988 was not to persuade peers that multicellularity existed, but rather, that it was a phenomenon more prevalent than they had previously assumed. He wanted them to believe that, generally speaking, “an individual bacterium is more analogous to a component cell of a multicellular organism than it is to a free-living, autonomous organism” (ibid). To convince them of this he included various spectacular images of colony pattern formations, occurring across species.



FLOWERLIKE COLONIES can be produced by streaking bacterial cultures over an agar plate. Each colony (when it is not crowded) assumes a pattern characteristic of its strain. *Chromobacterium violaceum* (*top left*) naturally produces the pigment violacein and forms purple colonies. *Serratia marcescens* (*top right*) synthesizes prodigiosin; it forms bright red colonies once thought to be drops of blood. *Pseudomonas cepacia* (*bottom left*) is yellow and has a unique surface texture, the result of cell aggregation at the surface. An *Escherichia coli* colony (*bottom right*) carries genetically engineered DNA sequences encoding the enzyme beta-galactosidase; where the enzyme is expressed the colony turns blue. The colonies are at various magnifications.

Figure 4-4 Flowering bacterial colonies, James Shapiro, June 1988, Scientific American.

Publishing this first article on multicellularity in *Scientific American* would allow Shapiro to cast a wider net and attract a broader scientific audience. The *Scientific American* would likely afford him the opportunity to make claims that the editors of a specialist journal might have dismissed, due to ingrained disciplinary assumptions about bacterial behavior. Whereas his 1998 *Annual Review of Microbiology* article includes zero images and relies on elaborate chemical formulas, his 1988 *Scientific American* article narrates laboratory techniques, offers glosses on chemical diffusion, and discusses early twentieth-century research about soil bacteria's communal behavior. Shapiro retrospectively hypothesizes that microbiologists did not take active an interest in multicellularity in 1988 because

> [it] was still widely considered a specialized adaptive strategy of particular groups, such as the Myxobacteria[45] or Actinomycetes.[46] The historical tradition of single-cell, pure-culture microbiology derived from Koch's postulates[47] 9 and medical bacteriology still held sway, despite an old and well-established alternative interactive, multicellular tradition based on environmental microbiology. (1998)

Shapiro wanted to inform his peers that multicellularity was a pre-existing framework for thinking about bacteria that had fallen into disuse, circa Pasteur, when scientists trained their attention

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45. Myxobacteria are a type of soil bacteria known for their extreme sociality, and have been particularly important in producing antibiotics. One research team explains that although microbes in general display diverse cooperative strategies, "particularly sophisticated forms of sociality have arisen in the myxobacteria, including group motility and multicellular fruiting body development. Myxobacterial cooperation has succeeded against socially destructive cheaters and can readily re-evolve from some socially defective genotypes. However, social harmony does not extend far. Spatially structured natural populations of the model species Myxococcus xanthus have fragmented into a large number of socially incompatible genotypes that exclude, exploit, and/or antagonize one another, including genetically similar neighbors" (Vellicer and Voz, 2009).

46. Actinomycetes are also a type of soil bacteria, with a long filamentous structure visually similar to fungal mycelia. They are important to humans because of their antibiotic properties and their composting and nitrogen-fixing abilities (Goodfellow andWilliams, 1983).

47. Koch first introduced his postulates in 1877 and they soon became a basic tenet of bacteriology and the germ theory of disease. The postulates require laboratory preparation of pure bacterial cultures, kept in isolation. Koch's postulates "are used to prove that specific microorganisms cause specific diseases which can reproduce and spread form animal to animal." ("Contagion," Harvard)

toward developing laboratory cultures to address urgent medical concerns. He makes the case for studying multicellularity by pointing to Myxobacteria and Actinomycetes, soil bacteria that were studied within an ecological framework—not as isolated individuals, but as integral agents in a bustling, complex network of relations. Shapiro had highlighted multicellularity's wide potential for application in fields such as biotechnology, biochemistry, environmental bioremediation, and medical technology, though he says he failed to pique medical bacteriologists' interest in the phenomenon.

While he had addressed that colonies are able to form antibiotic resistance and asserted a "clear correlation between the tendency of cells to aggregate and their ability to establish an infection" (89), he did not explain that bacterial communications enable them to congregate. When he does discuss bacterial communication at the end of the article, it is to make the open-ended, somewhat philosophical suggestion (similar to Adler and Binet before him),[48] that bacterial cognition and communication might help us to better understand "higher organisms":

> If, as I have proposed here, bacteria possess elaborate developmental and behavioral capabilities typical of higher organisms, then it is likely that detailed explanations of how these small cells communicate will influence views of information processing in all organisms […] they display biochemical, structural and behavioral complexities that *outstrip scientific description* (89, italics mine).

It was not the promise of better understanding how higher organisms process information that would eventually spur widespread interest in bacterial multicellularity. First, scientists would need

48. In chapter one I discuss similar claims made by Julius Adler ("Chemotaxis in Bacteria," 1975) and Alfred Binet ("Psychic Life of Micro-organisms," 1889).

to understand that bacterial communication enabled the multicellular behavior that in turn enabled virulence attacks; only then would multicellularity become a useful framework for studying bacteria in a way that could benefit humans in concrete, practical ways. But the terminology to adequately discuss these behaviors would have to be invented.

The term quorum sensing was not available when Shapiro wrote his 1988 *Scientific American* article; the term would only be coined six years later, to afford bacteriologists a more palpable way of understanding the processes underlying bacterial multicellularity. The concepts of multicellularity and bacterial communication would have to emerge in tandem. Before they could become curious about the ways bacteria communicated with each other, scientists would first have to entertain the proposition[49] that bacteria were inherently social creatures, and that this sociality creates what (for humans) amounts to pathogenesis. I suggest that Shapiro was unable to spark interest in multicellularity because he did not adequately discuss multicellularity's potential for medical bacteriology. Specifically, once scientists accepted quorum sensing as a widespread bacterial behavior, they could then research what they now call "quorum quenching,"[50] an alternative to antibiotics to circumvent the looming threat of antibiotic resistance.

49. I use the term "proposition" in Whitehead's sense of a "lure for feeling," for entertaining an idea. I discuss the proposition in chapter two, and will discuss it further at the end of this chapter.

50. Quorum quenching involves inhibiting the quorum sensing process: "Decoding the language taking place between plants and bacteria will be a major challenge for future research due to the numerous and different associations and/or interactions taking place in nature."—From a recent review article about quorum quenching, "Shoot the Message, Not the Messenger—Combating Pathogenic Virulence in Plants by Inhibiting Quorum Sensing Mediated Signaling Molecules"(Alagarasan et al., 2017).

4.3 The Birth of a Term: From Autoinduction to Quorum Sensing

For the most part, the term quorum sensing seems to have replaced the term autoinduction, though the two terms are at times used in tandem. In their now classic review article on quorum sensing, Miller and Bassler state, "Quorum sensing bacteria produce and release chemical signal molecules called autoinducers that increase in concentration as a function of cell density. The detection of a minimal threshold stimulatory concentration of an autoinducer leads to an alteration in gene expression"(2001, p.165). In this case, autoinduction helps to explain what quorum sensing is; autoinduction is the chemical process behind the curtain, if you will. Miller and Bassler's article was published seven years after quorum sensing first appeared in print, and much as Shapiro did with multicellularity in 1988, they were attempting to introduce the term to their audience and to persuade them that it was a nearly ubiquitous bacterial behavior. They argue that at this point it had become clear "that the ability to communicate both within and between species is critical for bacterial survival and interaction in natural habitats"(166). It is clear that by this time multicellularity had become a popular term because they hypothesize that "the evolution of quorum sensing systems in bacteria [could have been] one of the early steps in the development of multicellularity"(165).

The first mention of quorum sensing came from Fuqua, Winans, and Greenberg in their 1994 review article "Quorum Sensing in Bacteria: the LuxR-LuxI Family of Cell Density-Responsive Transcriptional Regulators." It is interesting to note that aside from the title, they do not use the term quorum sensing directly in the body of their text. Only after reviewing the existing literature on cooperative behavioral patterns and multicellularity (in respect to bioluminescence in *V. fischeri* bacteria) do they conclude that,

> ...certain bacterial behaviors can be performed efficiently only by a sufficiently large population of bacteria. We describe this minimum behavioral unit as a quorum of bacteria. LuxR-LuxI type systems provide an effective though not unique way for bacteria to take a census of their numbers. The LuxR and LuxI homologs so far discovered play roles in cell-density-responsive regulation during interactions between bacteria and plant or animal hosts. It will be interesting to determine whether new examples will follow this trend (273).

At this point it would have made sense to place the word "sensing" next to the word quorum, but they did not. Instead, they use the governmental, bureaucratically-loaded term "census." "Sensing" implies a bodily kind of intelligence, while "quorum" suggests collective decision-making, and together they connote the collective, bodily intelligence of bacteria. Though Fuqua et al. borrow from terminology that describes human behavior in order to name bacterial behavior, they do not go as far as Binet, Shapiro, Margulis, and Adler before them, who each separately suggest that bacteria can teach us about the behavior of higher organisms. They published this article five years after Shapiro first suggested that bacteria generally behave multicellularly, but remain more conservative in their suggestion, simply asking whether this bacterial behavior will be found to occur between other bacteria and their host organisms. They do not discuss how they landed on the term quorum sensing, but other bacteriologists do so elsewhere.

Thirteen years after the Fuqua et al. article, Turovskiy et al (2007) tell the story of the term's origins in their paper "Quorum Sensing: Fact, Fiction, and Everything in Between." Hoping to clarify the term, they offer a concise gloss of the Fuqua et al. review article, and briefly discuss the term <u>autoinduction</u>, which quorum sensing had largely replaced. They attribute the invention of the term quorum sensing to Fuqua's coauthor Dr. Steve Winans:

> Somehow, the word "autoinducer," a term used to describe the small diffusible molecules involved in the process, just did not seem right to the young professor. Part of that dislike was due to common confusion of the term "autoinduction" with "autoregulation" (Fuqua et al., 1994). Also, the cross-species induction of the bioluminescence had been reported by Greenberg et al. (1979) so by 1994, the term autoinduction became somewhat inaccurate. (Turovskiy et al., 1)

Turovskiy et al. do explain that Winan disliked the term autoinduction because scientists conflated it with another process called autoregulation, but they do not discuss the different nuances of these terms, nor the different nuances between autoinduction and quorum sensing. They wrote the article in an attempt to point out what they see as ambiguities in the term quorum sensing, but they do not make a case for using autoinduction, or for creating a new term altogether. The way I read it, the term autoinduction bespeaks a kind of automaticity, whereas the term quorum sensing lends more agency to bacteria.[51] Turovskiy et al. do not delve deeply into the key differences between the terms, and how the terms distinctly shape the way bacteriologists see the process of bacterial decision-making. However, the part that follows does begin to show how subjective, cultural forces shape scientific knowledge and worldviews. The passage reads somewhat like bacteriological lore or legend because they do not include citations to inform the audience about the source of the following quorum sensing origin story:

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51. The problem of automaticity vs. agency in microorganisms is also of central concern to Alfred Binet's Psychic Life of Microorgansisms, as I discussed in chapter one. Binet argued that microorganisms actively make decisions in response to environmental cues, and are not behaving automatically.

> Winans was determined to come up with a new name that was innovative, descriptive, and most importantly, catchy. Assisted by his literary-minded brother-in-law, Dr. Winans generated dozens of possible terms, including "gridlockins," "communiolins," and "quoromones."[52] None of the terms themselves became popular, but the notion of a quorum was accepted by Winans' colleagues and eventually made it into the title of the chapter. The term "quorum sensing" spread like wildfire, making its way into virtually every paper involving autoinduction written afterward (1).

A better unpacking of the term <u>autoinduction</u> would allow for a more thorough appreciation of its successor term, <u>quorum sensing</u>, but Turovskiy et al. do not offer this analysis.

However, in a 2014 video recording, J. Woodland Hastings tells of his personal role in this discovery of autoinduction during the late 1960s and offers some insight into what may be the difference between the two terms.

> I want to tell a remarkable story about the discovery of quorum sensing, how it came from our experiments[...]in what we called autoinduction at the time. It's a more proper word perhaps, but quorum sensing also describes it..." The way Hastings describes it, it seems as though the two terms describe different processes, because "the discovery of quorum sensing...came from our experiments in...autoinduction. ("Autoinduction," 2014)

Yet, he also suggests that the two terms are interchangeable, because he says the term <u>autoinduction</u> is more proper. He never explains why autoinduction is a more proper term, but

52. It is interesting to note that one of the suggested terms, "quoromones," is reminiscent of pheromones, which does make it seem as though the originators of the term quorum sensing were at least thinking about analogues to human sensing behaviors.

neither does he explicitly criticize the term quorum sensing. Instead, he focuses on the chemical specifics of the process, and how the bacteriological community came to know it. "I [had] no idea that it would ever lead to anything important...it was just a question of why do cells grow exponentially and have certain processes, bioluminescence for one, that uh, don't turn on for three hours, then turn on very, very fast?" Hastings was at Harvard, and he received a call from Kenneth Nealson, a graduate student at University of Chicago, who was working on the genetics of bioluminescence in bacteria and having difficulty getting cells to produce luciferase, the enzyme that produces bioluminescence. Hastings reports that he and Nealson collaborated on this problem and concluded that the first three hours was "the time at which the cells were producing a substance which was then responsible for...the synthesis of messenger RNA for luciferase, that that substance was an inducer, and we said well this is autoinduction, it's doing it all by itself, you don't have to add anything." According to Hastings' summary of the what autoinduction is, the term quorum sensing begins to look like one part of the process. First, a quorum must be sensed (or scientists must chemically suggest to the bacteria that their population is dense enough), then the cells produce the luciferase that induces bioluminescence.[53] Either term on its own (quorum sensing or

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53. Gábor Balázsi et al's. review article illustrates the dilemma of using the term "decision" for cells:" If we, humans, want to control living cells, two strategies are typically available: modifying their genome or changing the environment in which they reside. Does this mean that cells with identical genomes exposed to the same (possibly time-dependent) environment will necessarily have identical phenotypes [gene expression]? Not at all, for reasons that are still not entirely clear. When cells assume different, functionally important and heritable fates without an associated genetic or environmental difference, cellular decision making occurs. This includes asymmetric cell divisions as well as spontaneous differentiation of isogenic cells [cell the same or very similar genotypes] exposed to the same environment. Specific environmental or genetic cues may bias the process, causing certain cellular fates to be more

auto- induction) seems to leave out the full story of the bacterial decision-making process (especially because scientists later learned that a quorum does not *compel* each individual bacterium to luminesce).

Hastings says that once Peter Greenberg learned how to synthesize the *Vibrio fischeri* autoinducer, Kenneth Nealson was then able to add the autoinducer to bacteria cultures that he specifically kept at a low cell density. Hastings explains that when Nealson did this, "the cells responded by immediately synthesizing luciferase, even though they were very few in number. There was no quorum there, I can assure you!" This then, was luminescence that Hastings externally-induced, to demonstrate how autoinduction happened in the phenomenon of bioluminescence (at least in a laboratory setting, as Turovskiy et al. remind us). Hasting adds that by 1981, it was very clearly established that "the bioluminescent bacteria luciferase was stimulated by virtue of a substance in the medium produced by the cells themselves," even though many colleagues "did not really agree with this conclusion [and] thought it was some quirky phenomenon associated with luminous bacteria," and that it didn't apply to "bacteria in general." This tendency in the bacteriological community at the time is also expressed in Shapiro's 1988 article on bacterial multicellularity. That Shapiro was still arguing for multicellularity as a general bacterial behavior trait in 1988, verifies Hastings's assessment of bacteriologists' skepticism towards autoinduction/quorum sensing as a general bacterial behavior, even though it had been "very clearly demonstrated by 1981." Hastings says that it would not be until 1990 that Bonnie Bassler

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frequently chosen (as when tossing identically biased coins). Still, the outcome of cellular decision making for individual cells is a priori unknown" (2011). Balasazi et al's use of the terms "cellular fate" and "tossing coins" to refer to cellular decisions (which cannot be predicted) suggests some confusion as to exactly when, where, and how the decision is made.

and colleagues would demonstrate that many species of bacteria carry out autoinduction/quorum sensing. He concludes by offering his version of how the term quorum sensing replaced autoinduction.

Hastings does not attribute credit for the term to Dr. Steve Winan's literary-minded brother-in-law, as Turovskiy et al. do, but rather to Peter Greenberg (one of Winans' coauthors of the original 1994 quorum sensing article), a dinner party, and an unnamed lawyer:

> It is described by Pete Greenberg as occurring at a dinner where he and several colleagues were discussing the phenomenon with other non-scientists, and one of the nonscientists [who] happened to be a lawyer, of course, said "aha, that phenomenon is really a quorum sensing." Now only when the bacteria get to a certain level in the culture is enough autoinducer produced to cause the phenomenon, which is called a quorum sensing. [Greenberg] introduced the term and from then on the rest is history. (Hastings, 2014)

Previously, Hastings' explanation made it seem as though a quorum sensing led to autoinduction, but here, Hastings does not speak of autoinduction as a phenomenon, but rather, of an auto-inducer that causes the phenomenon of quorum sensing. Given Hastings' murky explanations of autoinduction, autoinducers, and quorum sensing, delivered in a video produced for a scientific audience, it is understandable why Turovskiy et al. would want to clarify the usage of the term quorum sensing. Though both Turovskiy et al. and Hastings' origin stories differ in their specifics, they do share a common theme: an interested nonscientist, adept with language in considerations of human behavior, helps a bacteriologist to conjure the phrase that will capture the spirit of bacterial communication, and therefore direct more attention to the phenomenon as something worthy of broad attention. At its root, quorum sensing is a cross-disciplinary term. The study of bacterial multicellularity may never have taken off to the extent that it did were it not for the influence of the non-scientist(s) involved in naming it. A non-scientist may have been better able to view bacterial sociality and name it in this way because a non-scientist would not be as limited by what Kenneth Burke calls (borrowing from Dewey, Veblen, and Robert Merton) "occupational psychosis" or "trained incapacity" (*Permanence and Change*).

There is a remarkable confluence between the name quorum sensing itself, and the shift in perspective it enabled, the extent of which the bacteriological community still seems to be attempting to understand, as is evidenced by the retrospective pieces I have analyzed here. Peter Greenberg says that even though "the terminology 'colonial' or 'colony growth' implies some sort of social interactions," by and large "the eyes of microbiology did not see social interactions among individual bacteria," and that this would continue to be the case until the 1990s ushered in "rapid developments in quorum sensing and biofilm research" (New Science, p. 213). But this inability to see and/or believe in bacterial sociality is only one side of the story. If bacteria behave like higher organisms, then higher organisms also behave more like bacteria than had previously been understood. Waters and Bassler says that "[m]ost quorum-sensing-controlled processes are unproductive when undertaken by an individual bacterium acting alone but become beneficial when carried out simultaneously by a large number of cells"(2005. P. 319). This kind of behavior can be seen in many plants, animals, and fungi, and is not limited to intra-species cooperation. "Thus," they say, "quorum sensing confuses the distinction between prokaryotes [unicellular organisms] and eukaryotes [multi-cellular organisms, plants, animals] because it enables bacteria to act as multicellular organisms" (ibid).

We cannot definitively explain why most bacteriologists did not previously see bacterial multicellularity, though we might say that they were more prone to seeing multicellularity once practical medical applications began to arise from the concept. For example, when quorum quenching began to look like a viable alternative to antibiotics, the good associated with seeing multicellularity became readily apparent. The term quorum sensing enabled not only a shift in how bacteriologists see bacterial behavior differently, but also a subsequent shift in how emergent subfields began to see human and animal behavior differently. Even if it is difficult to determine the values of the bacteriologists who invented the term, we may nevertheless begin to recognize the kind of values that the term quorum sensing appeals to *and* evokes. In the following sections I use Burke's four master tropes to investigate the epideictic rhetoric at play in quorum sensing and consider how it has affected the bacteriological imagination during the past few decades.

4.4 Quorum Sensing and Burke's Master Tropes: Metaphor, Metonym, Synecdoche, Irony

In this section I will consider the various rhetorical functions of quorum sensing. Because the origin story of the term involves literary- and rhetorically-minded outsiders to the scientific community, I will use the lens of Burke's four master tropes, which he says have not only figurative usage, but also a corresponding "literal" or "real" usage that aids in "the discovery and description of 'the truth.'" He identifies the four figurative/literal pairings as: *metaphor/perspective*, *metonymy/reduction,* *synecdoche/representation*, and *irony/dialectic* (503, Grammar). I find Burke's discussion of the master tropes particularly helpful with quorum sensing because Burke does not confine their function to the literary, but extends it to the scientific and systems of thought, emphasizing the feedback between these two seemingly disparate functions. Burke describes the interactions between the four tropes as evanescent, with "the dividing line between the figurative and literal usages" shifting and shading "into one another" (ibid).

Accordingly, I will discuss quorum sensing in terms of each distinct trope, while also showing how quorum sensing productively oscillates between and across these four tropes.

4.4.1 Metaphor/Perspective

Burke calls metaphor,

> a device for seeing something in terms of something else. It brings out the thisness of a that, or the thatness of a this. If we employ the word ‘character’ as a general term for whatever can be thought of as distinct (any thing, pattern, situation, structure, nature, person, object, act, rôle, process, event, etc.,) then we could say that metaphor tells us something about one character as considered from the point of view of another character. And to consider A from the point of view of B is, of course, to use B as a perspective upon A. (504, Grammar)

If we wish to follow Burke in this case, we could either turn bacteria (the creatures) into a character, or turn quorum sensing (the process or event) into a character. That is, either we can see bacteria *in terms of* humans because we usually think of humans when we think of reaching quorums. Or, we can think of the process of quorum sensing *in terms of* the human process of reaching a quorum, so that we can then deliberate. The trouble is, when we think about how humans then deliberate, we usually think about language, talk, chatter, and not wordless, brainless chemical signaling.

Though we are all quite responsive to pathos, we generally believe that well-reasoned logos should bring us to our deliberative conclusions; we consider human collectives who reach decisions without this well-reasoned logos as less rational. If we turn the process of quorum sensing into a character with agency, then we might also have to say that the process (as a character) has a mind, will, or motive of its own, that this process-as-character is somehow antagonistic to the human(s) as character(s) who should otherwise make a well-reasoned decision. Reaching a decision without reasoning well, without discussion, somehow makes another group of humans seem less than human: the decision is making them—they are not quite making the decision. Either way, a less-reasoned deliberation is typically something that other groups of people seem to do, never what we do. Groups of people usually believe their reasons are good, but others outside that group may not be able to understand those reasons in the same light, or even at all. Tactics for self-preservation vary across groups, but at bottom, group decisions tend to strive for preservation of the group.

Perhaps this explains why bacteriologists found the term <u>quorum sensing</u> acceptable, despite its anthropomorphic spirit. The term might be understood as only quasi-anthropomorphic since humans (ideally) do not participate in <u>quorum sensing</u>, but instead reach a quorum though well-reasoned language use, which somehow circumvents the anthropomorphic danger inherent in <u>quorum sensing</u>. What's more, <u>quorum sensing</u> may even cause human deliberation to appear that much more reasonable through this metaphoric juxtaposition. The term quorum sensing extends bacteria enough agency to then proceed into the decision-making process, though not extensive agency because sensing is not deliberative in the way we typically understand deliberation—as rational, intentional, and conscious. Burke addresses the fear that metaphoric juxtapositions might interfere with locating the truth when he adds, "[i]t is customary to think that objective reality is dissolved by such relativity of terms as we get through the shifting of perspectives (the perception of one character in terms of many diverse characters). But on the contrary, it is by the approach through a variety of perspectives that we establish a character's reality…" (ibid). In Burke's estimation comparing characters—be it bacteria to humans, or bacterial decision-making to human decision-making—does not interfere with truth-finding, but rather, accentuates scientists' ability to arrive at a more objective reality.

However, there is always the possibility that bacteriologists in general (at the time the term quorum sensing was invented) simply harbored fewer qualms about anthropomorphizing than do other kinds of biologists. Perhaps because the category of life they study seems so drastically different from human life, the danger of anthropomorphizing seemed to them less consequential than it would to zoologists, botanists, or entomologists, for example. And, the less similar a creature is to humans, the less we may be able to understand its behavior. Burke says that when we do not understand what an object is

> we deliberately try to consider it in as many different terms as its nature permits: lifting, smelling, tasting, tapping, holding in different lights, subjecting to different pressures, dividing, matching, contrasting, etc. […] in keeping with the older theory of realism (what we might call 'poetic realism,' in contrast with modern 'scientific realism') we could say that characters possess degrees of being in proportion to the variety of perspectives from which they can with justice be perceived" (ibid).

Let's pause to sample "the variety of perspective from which" bacteria can "with justice be perceived." First, we might ask the extent to which we can justly perceive bacteria or their decision-making if we, by necessity, have microscopes between us? We cannot physically interact with bacteria in the ways Burke lists, as we can with most other kinds of living creatures. As I discussed in chapter two on Julius Adler, the tracking microscope did allow us to view individual bacterial movements, though at the cost of simultaneously viewing their collective behaviors; additionally, scientists can perceive bacteria from a different angle through biochemistry, a much different technological interface, though still a discourse of human design. More recently, scientists have attempted to add to the variety of perspectives by genetically engineering bacteria to achieve various computational goals. For example, Levskaya et al. designed a bacterial system that could "'photograph' a light pattern as a high definition chemical image" (2005); Baumgardner et al. designed a bacterial computer to perform the Hamiltonian path problem, and display their success by fluorescing both red and green to create yellow colonies—effectively solving a type of problem that silicon computing systems are not well-suited to solve (2009); and this year, in an effort to develop bacteria into biological hard drives, Shipman et al. used CRISPR gene-editing technology to encode a five-frame GIF of Muybridge's running horse into *E. coli* (2017).

The variety of perspectives through which scientists attempt to justly perceive bacteria continues to unfold and multiply, but these attempts rely upon—and are now even on the cusp of modifying—human technologies. Scientists are not on the ground, at bacterial level, and are likely missing many possible varieties of perspectives due to the necessary reliance on technological interface, which is nevertheless remarkable in its capacity to make the invisible visible. Language is one of the human technologies that scientists might use to justly perceive bacteria, one that perhaps seems relatively innocuous in the case of bacteria, if we continue following Burke's train of thought: "Thus we could say that plants have 'more being' than minerals, animals have more being than plants, and men have more being than animals, because each higher order admits and requires a new dimension of terms not literally relevant to the lower orders"(ibid). Perhaps this apparent lack of literalness led quorum sensing to flourish as a replacement term for autoinduction. It is not clear whether these scientists selected a metaphor with a rhetorical slant due to some pedagogical aim, but Burke suggests that poets and scientists alike use extended metaphors to train audience perspectives:

> By deliberate coaching and criticism of the perspective process, characters can be considered tentatively, in terms of other characters, for experimental or heuristic purposes. Examples may be offered at random: for instance, human motivation may […] be considered in terms of conditioned reflexes, or chemicals, or the class struggles, or the love of God, or neurosis, or pilgrimage, or power, or movements of the planets, or geography, or sun spots, etc. Various kinds of scientific specialists now carry out the implications of one or another of such perspectives with much more perseverance than that with which a 17th century poet might in one poem pursue the exploitation of a 'conceit'" (ibid).

We do not know whether bacteriologists adopted quorum sensing as a heuristic, as a literal/real perspective, or as some hybrid of the two. However, we do know they chose a term that, at the very least, played with the idea of bacterial motivation in terms of human motivation and deliberative rhetoric. And we know that their colleagues continued to play with this term until it quickly became orthodox, generating widespread interest in a previously ignored phenomenon.

Regardless of its inventors' intentions, this tiny metaphor would eventually make possible new research areas and projects that might not have unfolded otherwise. The blatant anthropomorphizing we see in this case might raise eyebrows when considered in light of Burke's assertion that seeing something "in terms of something else involves the 'carrying-over' of a term from one realm into another" and with this, "varying degrees of incongruity in that the two realms are never identical" (ibid). However, incongruence makes metaphor a useful heuristic in the search for and discovery of scientific "truth," or any attempt to think otherwise than we already do. Humans and bacteria need not be identical for scientists to create semantic associations between these two categories of beings. In fact, the seeming absurdity of the quorum sensing conceit may be the very thing that allowed it to thrive. A surprising incongruence is required to create a productive tension for more fully considering each distinct kind of being; and, being (vs. process) will factor into the next pairing: metonymy/reduction. Though I have given the metaphor/perspective pair extensive treatment, the three that follow should be considered an extension of this discussion, "[f]or since the four pairs overlap upon one another, we shall be carrying the first pair with us as we proceed" (505, ibid).

4.4.2 Metonymy/Reduction

To highlight the distinction between his metonymy/reduction pairing, Burke creates the dichotomy of poetic realism and scientific realism, so that continuing to use his master tropes allows us to walk around inside his categories of science and poetry. However, I suggest that whereas a firm distinction between scientific realism and poetic realism makes sense in many cases, for my purposes it might make more sense to imagine scientific realism and poetic realism on a spectrum with ends that bend toward one another in a semi-circle. However, Burke's dichotomy between science and poetry relies upon a third, auxiliary dichotomy: science's concern with process, versus poetry's concern with substance, or being—which means that science "need not be concerned with motivation. All it need know is correlation. The limits of science, *qua* science, do not go beyond the statement that, when certain conditions are met, certain new conditions may be expected to follow" (Grammar, 505). So, to get at the metonymy/ reduction distinction, we need to consider process and being. According to Burke's dichotomy, quorum sensing (qua science) does not require scientists to know or even deliberate about bacterial motivations, intentions, or consciousness. These sticky problems can be dutifully ignored in service of objectively observing the *process* of quorum sensing. Deliberating about bacterial ontology might even be construed as un-scientific. However, quorum sensing can politely and passively evoke allusions to motivation, intent, and consciousness without needing to address metaphysical conundrums—even though it may not be possible for humans to imagine any decision-making process without also imagining the deciding beings as desiring a certain outcome over some other outcome. And, it is difficult to imagine desiring beings without simultaneously imagining that they share some kind of value system—even if those values only pertain to basic survival.

However, the kinds of imaginative leaps that quorum sensing induces may not be altogether bad if they allow for novel and dynamic associations. All-in-all, the term was merely a rebranding of its stale predecessor, autoinduction. Nothing really happened aside from a semantic shift prompted either by a writer or a lawyer, some shadowy figure from the humanities. The term did not force, but rather seems to have merely encouraged other scientists to acknowledge bacterial sociality. To use the term would be to implicitly acknowledge that bacterial sociality exists. The term did not directly cause later scientists to begin researching something like human-microbial endocrinology (for example), but it did encourage scientists to interpret bacterial behavior in a new light. Historically, says Burke, science's discovery of correlations has been directed by now discredited "philosophies of causation" and by "ideational forms developed through theology and governmental law. Such 'impurities' will always be detectable behind science as the act of given scientists; but science *qua* science is abstracted from them" (ibid). It is difficult to determine the values that midwifed quorum sensing into existence, but the scientific research that happened in the wake of its conception seems to be much more open to the idea of bacteria as creatures with some kind of agency. Quorum sensing might suggest that we inductively assume that bacteria deliberate in some fashion, but the science behind the term suggests that this kind of deliberation happens through sheer molecular exchange. Regardless of whether we consider the world as "mind," or "matter," or "both," or "several," Burke argues that the *procedure* for striking a match does not change—science, "*qua* science," abides operations (process) rather than substances (being)—even if all the inventions leading to the chemistry of a matchstick originate in "very explicit beliefs about substances and motivations of nature [and] the supernatural" (ibid).

The key difference for my purpose is that humans did not invent quorum sensing (the phenomenon), but only the term to describe that phenomenon. However, if no one had invented the term we may not have experienced a shift in the way we see bacteria, which would render the phenomenon largely nonexistent anyway, save for the small cadre of scientists who had already been studying autoinduction. A small group of scientists who were able to see that phenomenon had to invent a term that could enable others to see it as well. The way we see bacteria now may depend as much on language choices as it does on microscopes and genome sequencing. Indeed, the first person to see bacteria at all, Antony van Leeuwenhoek, compared them to flocks of sheep.[54] However, natural scientists during the 1670s were not sufficiently primed to heed this observation, given they were simply trying to make sense of bacteria's existence, and so multicellularity would go largely unnoticed for the next three hundred years.

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54. In a 1677 letter to Henry Oldenburg, secretary of the Royal Society (and creator of scientific peer review), Leeuwenhoek explains: "My counting is always as uncertain as that of folks who, when they see a big flock of sheep being driven, say, by merely casting their eye upon them, how many sheep there be in the whole flock. In order to do this with the greatest exactness, you have to imagine that the sheep are running alongside one another, so that the flock has a breadth of a certain number: then you multiply this by the number which you likewise imagine to make up the length, and so you estimate the size of the whole flock of sheep" (quoted in C. Dobell, 1932, pg. 170).

Leeuwenhoek was comparing something supposedly less complex (bacteria) to behavior that was more complex (sheep). Thus, looking back to the earliest attempt at creating analogies for bacterial group behavior, we see the opposite of what Burke describes as reductionism: "[A]ttempts to "deal with human relationships after the analogy of naturalistic correlations becomes necessarily the reduction of some higher or more complex realm of being to the terms of a lower or less complex realm of being" (505). If we think of reduction the way Burke does, then quorum sensing may very well be reductionist, though inversely so: it compares what we consider to be a less complex form of decision making (bacterial) to a more complex form of decision making (human). And, because the behavior under question is not visible without microscopes, we might wonder how threatening this kind of (inverted) reductionism could be. It is easy to get lost in the metaphysical thickets when debating whose behavior resembles whose, but we can remain grounded in the physical. Burke reminds us that the "basic 'strategy' in metonymy" is "to convey some incorporeal or intangible state in terms of the corporeal or tangible. E.g., to speak of 'the heart' rather than 'the emotions.'" It might be difficult for us to think about bacterial decision making as tangible and corporeal because certain particulars of the process remain invisible and unknown, and because the bodies doing it are so small that it's difficult to think of them as bodies at all. Calling it quorum sensing helps to visualize the exchange of chemicals as actual happenings. Burke argues that concepts we tend to conceive as immaterial have their linguistic origins in physical states: "If you trail language back far enough…all our terms for 'spiritual' states were metonymic in origin. We think of 'the emotions,' for instance, as applying solely to the realm of consciousness, yet obviously the word is rooted in the most 'materialistic' form of all, 'motion' (a key strategy in Western materialism has been the reduction of 'consciousness' to 'motion')" (506).

We need not reduce our own consciousness to motion to appreciate the material roots of consciousness. The term quorum sensing retains its ties with motion: the movement and exchange of molecules is a key part of the bacterial decision-making process. Quorum sensing may very well remind us of the corporeal roots of our own deliberations and, by extension, our language. Echoing Nietzsche's "Truth and Lies in the Nonmoral Sense," Burke argues that,

> Language develops by metaphorical extension, in borrowing words from the realm of the corporeal, visible, tangible and applying them by analogy to the realm of the incorporeal, invisible, intangible; then in the course of time, the original corporeal reference is forgotten, and only the incorporeal, metaphorical extension survives (often because the very conditions of living that reminded one of the corporeal reference have so altered that the cross reference no longer exists with near the same degree of apparentness in the 'objective situation' itself); (ibid).

We might do well to recall that before we speak our deliberations, we are bodies that congregate and sense environmental cues, a fact we have put aside while the centuries pearled accretions around our most elaborate invention, rational discourse. It is beyond the scope of this chapter to parse how and why we tend to forget the corporeal roots of our distinct style of decision making—though it may be easier to recall the corporeal now, as the intricate weave of rational discourse becomes threadbare in a quite public way, while our environments rapidly alter around us.

But we are linguistic as well as physical beings. Burke explains that although language takes us away from the physical, language also brings us back to it.

> [A]nd finally, poets regain the original relation, in reverse, by a 'metaphorical extension' back from the intangible into a tangible equivalent (the first 'carrying-over' from the material to the spiritual being compensated by a second 'carrying-over' from the spiritual back into the material); and this 'archaicizing' device we call 'metonymy.' Metonymy is a

> device of 'poetic realism'—but its partner, 'reduction,' is a device of 'scientific realism.' Here 'poetry' and 'behaviorism' meet. (ibid).

It may be the poet's work to remind us that we are physical beings, but the scientists who commissioned the term <u>quorum sensing</u> accomplished the same thing for bacteria. In doing so, they blurred the distinction between science and poetry at their deepest levels. Whereas "poetry" has a positive connotation, "behaviorism" rings negatively. Though Burke explains reduction as metonymy's evil behaviorist twin, I suggest that <u>quorum sensing</u> bucks this distinction. Born of a scientist and either a poet or lawyer (depending on whose story we abide), the phrase is at once a device of both poetic realism (metonymy) and scientific realism (reduction), resisting Burke's dichotomy. Metonymy, as 'archaicizing' device, might be the most appropriate kind of trope for considering <u>quorum sensing,</u> which was a tangible translation from the intangible predecessor, <u>autoinduction</u>.

This archaicizing function of metonymy/reduction adds nuance to Julius Adler's suggestion: "From the earliest studies of bacterial behavior […] people have hoped that this relatively simple system could tell us something about the mechanisms of behavior of animals and man. Certainly, striking similarities exist between sensory reception in bacteria and in higher organisms" (Adler, p. 354, 1975). Adler's word choice, "mechanism," reveals the commonplace reductionist sentiment of his time. I suggest that <u>quorum sensing</u> marks microbiology's shift away from dogmatic reductionism. Recall that <u>quorum sensing</u> research has its roots in bacteriologists' quest to understand how marine creatures bioluminesce, and place this next to Burke's observation of the poet's attention to the bodily markers of mood. The poet,

> knows that 'shame,' for instance, is not merely a 'state,' but a movement of the eye, a color of the cheek, a certain quality of voice and set of the muscles; he knows this as

> 'behavioristically' as the formal scientific behaviorist who would 'reduce' the state itself to these corresponding bodily equivalents. He also knows, however, that these bodily equivalents are but part of the *idiom of expression* involved in the act. They are 'figures.' They are hardly other than 'symbolizations.' Hence, for all his 'archaicizing' usage here, he is not offering his metonymy as a *substantial* reduction. For in 'poetic realism,' states of mind as the motives of action are not reducible to materialistic terms. Thus, though there is a sense in which both the poetic behaviorist and the scientific behaviorist are exemplifying the strategy of metonymy […] the first is using metonymy as a *terminological* reduction whereas the scientific behaviorist offers his reduction as a 'real' reduction (506-507).

It might be coincidence that bioluminescence—a visual, nonhuman expression—ultimately made quorum sensing matter to bacteriologists; a more human non-human expression might have been seen as too reductionist. It may also be that the term may never have been invented if it not for the fact that it gives rise to such a visual expression as bioluminescence; and this particular expression is not possible without the bacterial, bodily equivalent. Indeed, quorum sensing feels as much like metonymy as it feels like reduction.

4.4.3 Synecdoche/Representation

In a way, quorum sensing has come to represent bioluminescence and vice versa. Curiosity about bioluminescence generated research into quorum sensing and in turn, quorum sensing is commonly explained with the visual aid, bioluminescence. Burke refers to synecdoche "in the usual range of dictionary sense […] part for the whole, whole for the part, container for the thing contained, sign for the thing signified, material for the thing made […] cause for effect, effect for cause […] All such conversions imply an integral relationship [of convertibility], between the two terms" (507-08). A swirling mass of bacteria becomes palpable and relevant when it is contained within a creature's light organ and visually translated into bioluminescence. However, discerning which is the whole and which the part—quorum sensing or bioluminescence—is tricky, at least as far as the human understanding of it goes. Though quorum sensing had been studied by soil scientists for decades (before acquiring that name), it remained quite literally in the dark and largely irrelevant to other scientists. A visible phenomenon like bioluminescence may have been necessary if scientists and the public alike were going to pay any attention to it.[55]

Bioluminescence exhibits one decision-making body housed within another decision-making body, whereas soil microbiology studies decisions occurring within (seemingly) lifeless soil. Bioluminescence now incorporates an added air of magic because the decisions that lead to it are diffused across various bodies and their environs. "The 'noblest synecdoche,'" says Burke, "is found in metaphysical doctrines proclaiming the identity of 'microcosm' and 'macrocosm'"—in this case microbes and host, though Burke gives us an example in the opposing optical direction:

> [W]here the individual is treated as a replica of the universe, and vice versa, we have the ideal synecdoche, since microcosm is related to macrocosm as part to whole, and either the whole can represent the part or the part can represent the whole […] One could thus look through the remotest astronomical distances to the 'truth within,' or could look within to learn the 'truth in all the universe without'. (508)

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55. In her scientific article, "Quorum Sensing in Bacteria," (2001), and her Ted Talk "How Bacteria 'Talk'" (2009), Bassler uses bioluminescence to explain how quorum sensing works, and to make the phenomenon visible.

Part of the research appeal that quorum sensing held for scientists might have been this awe-inspiring relationship between microcosm and macrocosm, a relationship which was not as readily apparent in soil microbiology and was not featured (or perhaps even obscured) with the term autoinduction.

The flatness of the term autoinduction perhaps led Hastings to refer to it as "more appropriate" than quorum sensing. Latour explains that rationalists deride the pre-moderns for “making too many connections between what they called the micro- and the macrocosm” and for believing “in a world animated by all sorts of entities and forces instead of believing, like any rational person, in an inanimate matter producing its effects only through the power of its causes” (480, C.M.). Though the world may very well be animated by all sorts of invisible entities after all, autoinduction does not encourage anyone to imagine connections between the microcosm and macrocosm, and so seems the safer term. Latour argues that the charge of “anthropomorphism is so strong that it paralyzes all the efforts of many scientists in many fields—but especially biology—to go beyond the narrow constraints of what is believed to be “materialism” or “reductionism” (ibid). Quorum sensing, taken as synecdoche, does encourage connections between microcosm and macrocosm and risks (though somehow avoids) the charge of animism. Specifically, quorum sensing nudges into our imaginations the suggestion that our own decision-making is steered by nonlinguistic and nonconscious factors. Quorum sensing (the phenomenon) may even be synecdochic, at least if we continue to follow Burke’s rendering of synecdoche: “Sensory representation is, of course, synecdochic in that the senses abstract certain qualities from some bundle of electro-chemical activities we call, say, a tree, and these qualities (such as size, shape, color, texture, weight, etc.) can be said to ‘truly to represent’ a tree” (508-509). If we do choose to understand quorum sensing as synecdochic, then it would be more direct, accurate, "true," and less abstracted than our own sensory representation. However, I'm more interested in how quorum sensing as a synecdochic term seems to work (at least in part) through the (nearly) unconscious suggestion that our own decision-making may be more sensory-driven and less conscious and intentional than we thus far have led ourselves to believe.

4.4.4 Irony/Dialectic

More so than the previous tropes I've discussed, quorum sensing as irony frames bacteria as complex characters. The discovery of the bacterial role in human death and disease led us to view bacteria primarily in antagonistic terms, but current bacteriology probes philosophical questions that unsettle this simple characterization. Burke suggests that by extending the synecdochic pattern we can "include such reversible pairs as disease-cure, hero-villain, active-passive [and] 'ironically' note the function of the disease in 'perfecting' the cure, or the function of the cure in 'perpetuating' the influence of the disease" (512). The story of antibiotics—from their development as miracle drug to their part in cultivating "superbugs"—shows us that bacteria's role is more complex than this. Vuillemin first used the term "antibiosis" (against life) in 1877 to explain Pasteur and Koch's observation that the troublesome *Bacillus anthracis* was inhibited by a different airborne bacillus (Saxena, 2015). Bacteria play a reversible two-sided role quite well, and an ironic frame encourages us to see this character development unfold in the story of microbiology. Noticing the antagonism between varieties of "good" and "bad" bacilli eventually led scientists to develop penicillin from fungal molds that burst asunder their bacterial competitors, also leading to the idea that fungi and bacteria are antagonists. However, as environmental microbiologist Lukas Wick asserts in an NPR report, "this is certainly part of the story, but it's a really complex story" because bacteria also transport themselves along fungal hyphae, which he describes as "a logistic network…a type of supply chain" ("The Cheese Does Not Stand Alone," 2018). Scientists are telling new stories about bacteria, so that statements like the following from the Human Microbiome Project are becoming commonplace:

> they produce some vitamins that we do not have the genes to make, break down our food to extract nutrients we need to survive, teach our immune systems how to recognize dangerous invaders and even produce helpful anti-inflammatory compounds that fight off other disease-causing microbes […] changes in the composition of our microbiomes correlate with numerous disease states, raising the possibility that manipulation of these communities could be used to treat disease (NIH Human Microbiome website).

Just as we cannot reduce the bacteria-fungi relationship to sheer antagonism, neither can we do this with the human-bacteria relationship.

As with any seeming foe, we cannot extricate bacteria from ourselves, nor can we consider what we might be without their presence. Burke claims that "true irony" justifies "the attribute of 'humility,' is not 'superior' to the enemy [but] is based upon a sense of fundamental kinship with the enemy, as one *needs* him, is *indebted* to him, is not merely outside him as an observer but contains him *within*, being consubstantial with him. This is the irony of Flaubert, when he recognizes that Madame Bovary is himself" (514). A compelling and complex antagonist insists that we see ourselves differently. Bacteria are undergoing a transformation, not in biotic makeup, but in our understanding of their consubstantiality with us. Burke's "over-all ironic formula" proposes a certain "inevitability": that "what goes forth as A returns as non-A," highlighting "the strategic moment of reversal" (517). I argue that the term <u>quorum sensing</u> (whether consciously or subconsciously) acted as alchemical irony, shifting scientists away from the pathological lens and towards a communicative lens through which to view bacteria. Though scientists do use the communicative lens to work on pathogenic problems, the communicative lens has also pushed them to re-imagine the human-bacteria interface, ultimately highlighting a fundamental kinship of sorts.

4.5 Concluding Thoughts: Inherent Values of “Mere” Metaphors

This chapter contributes to rhetorical theory’s conversation about “mere metaphors” in relation to science and animal studies. For example, Ken Baake demonstrates how complexity theorists use “colorful terms” such as "spin glass," “emergent design,” and "sand pile catastrophes" to “conjure up rich visual images and prompt recurring discussion among scientists over meaning. Some of these terms may be metaphors, while others may not"(3). These concrete terms he explains, “generate harmonics that transport meaning across terms,” “forc[ing] scientists to either modify or reject the original theory so as to accommodate the harmonics” (218). Similarly, I argue that quorum sensing may have “forced” the bacteriologists who used it to accommodate its implications about persuasion and agency. The high stakes of metaphor usage are evident in the term holobiont which an interdisciplinary team of scientists invented to describe the complex entity of a human host plus all of its symbiotic microbes. The team continues to haggle with peers about the appropriateness of the term and concept, which they have continued to revise in a series of publications (Theis et al., 2016). On the other hand, Pamela Lyon notes that “for the past several decades, microbial researchers increasingly have helped themselves to cognitive terminology (i.e., ‘decide,’ ‘talk,’ ‘listen,’ ‘cheat,’ ‘eavesdrop,’ ‘lure,’ ‘vote’) to describe complex bacterial behavior, often without caveat.” Lyon believes that “such linguistic usage is not wholly metaphorical” and that “there is something going on at the microscopic level that doesn’t just 'look' cognitive, it is cognitive, or, more accurately, it is typically considered cognitive when studied in animals more like us" (Lyon, 3). In her work on nonhuman animals in the history of rhetoric, Hawhee reminds us that "what seems merely metaphorical or even decorative usually harks back to a persistent, transactional, material relation. Indeed, as Nietzsche formulates it, the transference of metaphor begins with sense perception, an observation that potentially deactivates the adjective 'mere' when it comes to metaphor" ("Tooth and Claw,"169). She suggests that nonhumans can offer rhetorical theory "phantasic suggestiveness, their ability to enliven the imagination" (ibid).

Even if we adhere to the idea of "merely," metaphor's power in theory-building is quite evident. Following John Angus Campbell, Nathan Crick objects to the term "merely," when he argues that Darwin's guiding metaphor of natural selection "is not *merely* a metaphor. It is also the concept that drives Darwin's entire theory" (38). Crick goes further, however, categorizing natural selection as a thought experiment. He establishes a kinship between the enthymeme and the thought experiment, given that "both lack the necessary premises to create formal syllogisms" (23), though he also builds upon the sophistic interpretation of the enthymeme as more than "simply a syllogism with a suppressed premise" (24). Following this, Crick argues that "thought experiments are enthymemes that "rely on the active cooperation of speaker and audience to effect rhetorical persuasion through an appeal to the creative imagination of the hearers" (25). Similarly, I argue that quorum sensing invited peers to fill an imaginative gap in a way that autoinduction did not. By using the term in their own publications, colleagues forwarded the idea that bacteria perform some kind of rhetoric. Over years of usage, the term made bacteriologists comfortable with the idea that bacteria make group decisions, which perhaps led to the idea that bacteria adapt to and engineer their environments, even when that environment is the human body.

This story of quorum sensing illustrates how the core scientific value of falsifiability may be circumvented through a switch in terms. This can create an enthymematic gap for others to fill with other values (seemingly contra science's core value of falsifiability), ushering in changes perhaps more profound than those made through discrete, falsifiable (syllogistic) claims. The shift to quorum sensing was a kind of soft argument which might have been more easily disputed if Fuqua, Winans, and Greenberg had explicitly argued for the term's viability over autoinduction. However, given that interest in quorum sensing "spread like wildfire" once the term appeared, the bacteriological community was perhaps primed for it in some way. Perhaps autoinduction was appropriate during the late 1960s, when Hastings, Nealson, and Greenberg were simply trying to persuade colleagues that intracellular bacterial communication was more than a curious anomaly. Autoinduction, a flat and actively dis-imaginative term, could not create the imaginative space necessary to imagine bacteria as characters or agents. Twenty-five years would pass before the scientific community would be open to a term like quorum sensing, which offered newer bacteriologists the scaffolding to see bacteria as social. Once the community's values had shifted enough to accommodate the idea of that bacteria communicate to make group decisions, further conceptual possibilities would open up regarding bacterial communications with other creatures.

In his work on aesthetic theory via Whitehead (and Deleuze), Steven Shaviro states that the orchid "is not beautiful in itself: but something *happens to* the wasp, or to the gardener, who encounters the orchid and feels it to be beautiful" (Without Criteria, 3). Similarly, bioluminescent beauty *happened to* the scientists who sought to understand the causes of such beauty, evoking a sense of wonder that would lead to twenty-first research on human-bacteria symbiosis. Shaviro equates the "beauty of the orchid" to Whitehead's (re-)definition of a "proposition" as "a lure for feeling"[56]: "Whitehead insists [that] 'at some point' in the entertainment of a proposition 'judgment is eclipsed by aesthetic delight'" (ibid). Bioluminescent beauty and the term quorum sensing together acted as a kind of "lure for feeling." The truth or falsity of propositions becomes less important; rather, propositions are "'the tales that might be told about particular actualities,' from a given perspective […] The 'primary role' of a proposition, Whitehead says, is to 'pave the way along which the world advances into novelty… A proposition is an element in the objective lure *proposed for feeling,* and when admitted into feeling [the proposition] constitutes *what is felt'*" (ibid). Bioluminescence and quorum sensing together transfigured bacterial behavior into something beautiful in its own right, rather than just a threat to human health. Working with and through this aesthetic enjoyment helped enable bacteriology's "advance into novelty"—an advance into human nervous and sensory systems.

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56. Another useful translation of Whitehead's definition of proposition comes from Anthony Steinbock: "Indeed, common parlance has acclimated us to propositions as declarative (usually true) statements of fact; if they are anything but this, they are useless […] propositions [according to Whitehead] are not primarily given for a judging subject. The existence of imaginative literature, e.g., Shakespeare's Hamlet, claims Whitehead, should have cautioned logicians that their 'narrow doctrine is absurd […] It is difficult to believe that all logicians as they read Hamlet's speech, 'To be or not to be . . .' commence by judging . . . and keep up the task of judgment throughout the whole 35 lines.' Certainly, [Whitehead] continues, 'at some point judgment is eclipsed by aesthetic delight'—revealing that propositions in their simplest and most fundamental form are entertaining and for entertainment" (Steinbock, 1989).

5.0 Human Boundary Seepage, Bacterial Rhetorics

5.1 Introduction: Microbes and Rhetoric?

> Who, out of the theory of the earth and of his or her body understands
> by subtle analogies all other theories,
> The theory of a city, a poem, and of the large politics of these States
>
> —Walt Whitman, "Kosmos"

The general public understands bacterial communication through scientist's translations for the public, like Lynn Margulis's work which I discussed in chapter two, or the work of science writers like Ed Yong, whose book *I Contain Multitudes* shares overlapping concerns with this chapter. However, research suggests that we can also feel with our bodies the effects of bacterial communication, and that we act upon these feelings to make the most basic decisions in our daily lives. This creates a bit of a paradox: we must choose whether we will believe what science tells us about our bodies' innate intelligence and decision-making processes, though we may not be able to consciously affirm these processes as they unfold inside our bodies. Our unfolding knowledge of bacteria's reach into human emotion and cognition is blurring any neat distinctions between the two. Regardless of how the public or the humanities define "cognition" or "decision," scientists already freely use these and many other slippery terms to discuss the way bacteria respond to their environments, both as individuals and as groups. Research on phenomena like bacterial quorum sensing may one day help us to better understand what and how human bodies decide—both prior to and in tandem with the brain—as well as the decision-making capacities we have in common with other animals, and the relationship between spoken language, body, and sensation. In this chapter I analyze research that may help us expand our definition of rhetoric to further include the non-rational and non-verbal, the body and sensation. I do not suggest that we directly apply bacteriological theories to cultural phenomena but rather that we investigate our commonalities in communication and the potential feedback between microscopic and macroscopic, biological and cultural phenomenon.

George Kennedy initiated rhetorical studies' conversation on animal rhetorics when he reframed rhetoric not as a human art or science, but as the emotional energy that exists prior to speech and conscious intent. He suggests that humans and animals share a "'deep' universal rhetoric," (6) and that "speech would not have evolved among human beings unless rhetoric already existed" (4). In doing so, Kennedy extended the potential for rhetoric to any life form that can give signals. Diane Davis engaged Kennedy's long-ignored argument by addressing what Freud called the Darwinian revelation— "that man shares a common ancestor with apes, which indicates that he is not inherently 'a being different from animals or superior to them'" (Creaturely, 88). She argues that the "panicked deflection" of this revelation "continues to ground contemporary theories of rhetoric," manifesting as rhetoric's requisite "engagement with the symbolic" (ibid). Davis challenges the (Burkean) notion of humans as symbol-using animals, as well as contemporary rhetoricians who have been hesitant or unable to see engagement with the symbolic in non-human creatures; meanwhile, some bacteriologists seem to be on a quest to find something like symbolic behavior in quorum sensing bacteria, who have no brain, and are not even categorized as animals.

Combinatorial communication—a phenomenon believed to occur only among humans and select primates—was recently found to occur in bacterial quorum sensing. I will argue that this research pushes us to reconsider our definitions of the symbolic, and with it, nonsymbolic motion/symbolic action. This research also implicitly corresponds with Davis's suggestion that animal studies offers rhetorical studies the chance "to reopen the question of the language relation, to reconsider not only what it involves but who or what engages it" (92). At the level of human-bacteria communication, the field of microbial endocrinology investigates the biological circuitry of the microbiota-gut-brain (MGB) axis—the vagus nerve route through which bidirectional signals travel between the gastrointestinal tract and the brain, allowing bacteria to affect digestion, emotion, cognition, sociality, gregariousness, visceral perception, and sexual behavior (Montiel-Castro et al, 2013). The holobiont and hologenome theories create a new micro-biological framework that challenges the idea of animals as autonomous entities, and instead posits the notion of animals as biomolecular networks, comprised of the host creature and its associated symbiotic microbes (Bordenstein and Theis, 2015). Additionally, work on bacterial pheromone production may encourage us to elaborate upon theories of the transmission of affect.

Taken together, this emerging research offers a new lens for questioning human exceptionalism, mind-body dualism, and the myth of the self-contained individual that makes autonomous, intentional, brain-based decisions. We do not classify bacteria as animals, but the complex bodies that we do classify as animals are not possible without the bacteria that inhabit them. Interested bacteriologists are beginning to ask rhetorically-oriented questions, and to invent a corresponding vocabulary. I hope that my reading of this literature will help rhetorical studies to continue to push against the boundaries of human communication—the boundaries between bodies and their environs—while opening an interdisciplinary exchange that enlivens both rhetorical studies and bacteriology.

5.2 Combinatorial Communication in Bacteria: Non-Symbolic Motion? Symbolic Action?

One laboratory research team comprised of microbiologists, bio-informaticians, and cognitive and evolutionary anthropologists, seems to have set out with the goal of unsettling human exceptionalism. In their publication, "Combinatorial Communication in Bacteria: Implications for the Origins of Linguistic Generativity," Scott-Phillips *et al*. detail a famous study on primate communication, and how they replicated it with bacterial quorum sensing. Combinatorial communication, ubiquitous in human language, exists when two signals combined create an effect different from the sum of component parts. Elsewhere, Thom Scott-Phillips, the cognitive and evolutionary anthropologist who took part in this research, explains the combinatorial power of spoken language by showing how we can extend any existing sentence simply by adding the expression "Pinker wrote that." This addition creates a new sentence, the meaning of which is not simply the combination of the two individual sentences, but rather, depends upon how they are combined. He offers the following example: if the existing sentence is 'I didn't know that,' then "the meaning of the new sentence would depend on the order in which this was combined with the additional expression 'Pinker wrote that.'" (Scott-Phillips, 2014). The research team that Scott-Philips leads notes that this combinatorial quality "gives language its expressive power," and that outside of language, the most famous example of combinatorial communication is "the alarm call system of putty-nosed monkeys" which includes "a distinct call for each of two predators" (glossed as "pyow" for leopards— climb up; and "hack" for eagles— climb down); however, when the two distinct calls are produced together, the call sequence effect "is not simply the composite effect of the two component parts, but something different, namely group travel in non-alarm situations… [e.g. to forage]." (Scott-Phillips et al, 2014). When they replicated the study with bacteria, they encountered similar results.

The putty-nose monkey call system, considered alongside Burke's notion of human as *symbol-using animal*, prompts the question: what counts as a symbol? General, non-disciplinary definitions suggest that a symbol is a material object, sound, gesture, or idea that represents another idea, abstraction, action or material entity. If putty-nose monkeys call "pyow" to signify leopards and climbing up, and "hack" for eagles and climbing down, then this behavior seems already symbolic because "pyow" means leopards, but automatically translates into the command "climb up." Furthermore, if combining these two symbolic calls (pyow and hack) for opposing actions (*alarm* calls to climb up and climb down) results in an opposing meaning and response (*non-alarm* group travel to forage), then we can say that these symbols both produce abstraction, and lead to action. Debra Hawhee says that essentially, "nonsymbolic motion names strictly physical movement, human and nonhuman, while symbolic action names the interpretive, communicative activity of language, the story-ing of motion" (Hawhee, 2009, p. 156). According to these parameters, putty-nose monkey communication is symbolic action, because they tailor their calls to the environment; they create and respond to two distinct, combined signals as an altogether different signal—action that in humans would be deemed interpretive.

Prior to replicating the primate study with bacteria, researchers believed that combinatorial communication occurred exclusively among humans and a few nonhuman primate species (Scott-Phillips et al, 1-2). Accordingly, it was also previously assumed that "(i) these differences in the complexity of observed communication systems reflect cognitive differences between species; and (ii) that the combinations we see in non-human primates may be evolutionary precursors of human language." However, when they replicated the experiment with bacterial quorum sensing— purely chemical, material communication—researchers discovered the same pattern generally found in human communication: the "effect of the combined signal differs from the composite effect of the two individual signals" (ibid). In a related 2014 article, a team comprised of some of the same researchers further elaborate upon what the combinatorial communication experiment implies for bacteria sociality. They define quorum sensing as the process by which bacteria secrete and detect diffusible molecules to make frequent regulatory decisions based on "limited information about their external world" (Cornforth et al, 2014); they explain that bacteria are able to make these decisions because they can respond to multiple signals (with different decay rates) using what the researchers call 'heuristics' or 'rules of thumb.' They call this ability in bacteria the power to *infer* both *social* density (how many individual bacteria occupy a given space) and *asocial* "physical (mass-transfer) environment," (ibid, 4280) or, the rate at which the chemical signals diffuse or wash away in a given environment (italics mine). So, according to the researchers, an individual bacterium responds to two distinct signals differently than if it were to receive each distinct signal separately, and can also make what they call a robust estimate based on the rate at which the environment washes away those chemical signals—communicative behavior which the researchers term "inference." And, the greater the variety of molecules a given bacteria species secretes, the more information they can cull, since the environment affects each kind of molecule differently (ibid, 4283).

If we say that combinatorial communication in monkeys is symbolic action, then is combinatorial communication in bacteria also symbolic action? The researchers themselves are a bit ambiguous; they say their findings suggest that "advanced cognitive abilities and large brains do not necessarily explain why some species have combinatorial communication systems and others do not," and argue that it is "premature to conclude that the systems observed in non-human primates are evolutionarily related to language" (Scott-Phillips et al, 1). But as I will discuss later, the human neurosensory system, and thus human communication, is inextricable from bacterial communication. Even if combinatorial communication does not lead *directly* to language use (in the primate-to-human-evolution sense), human language use nevertheless relies upon bacterial communication systems. Although the researchers do not extend advanced cognitive abilities to bacteria, they nevertheless do extend to bacteria the power to infer, estimate, and communicate to each other their social and environmental conditions—behaviors that we *do* associate with advanced cognitive abilities. However, they also undermine the long-held assumption that combinatorial communication is the special purview of linguistic or proto-linguistic species. This confusion seems resolvable only by stating outright that advanced cognitive abilities either do or do not require brains.

One might argue that extending these abilities to bacteria confuses our definitions of these abilities in humans, but I suggest that recognizing the commonalities between human and nonhuman behaviors can help us ask better questions about what makes the human version of these abilities distinctly human. We may have it backwards. We see advanced cognitive abilities in humans and assume that these abilities arose only within the past 50,000 years, along with modern human behavior (abstraction, symbolic behavior, exploitation of large game, etc). William Bechtel, philosopher of cognitive science, argues that while one "can debate the scope of the term [cognitive]" when applied to bacteria,

> my strategy is to focus on activities, such as perceiving and acting, decision-making, learning and memory, which fall within the domain of cognitive science when performed by humans […] the goal is to understand the basic principles employed in the responsible mechanisms, and a focus on simpler mechanisms employed in species reflective of early ancestors can provide a basis for understanding the more complex mechanisms underlying human activities regarded as cognitive. (Bechtel, 2014)

As Bechtel suggests, it might be more productive to entertain the idea that the evolving human body adopted (and adapted) cognitive and communicative abilities from creatures that learned to adapt to their environs during the initial 3.5 billion years of life on earth. Cognitive scientists Almer *et al.* propose a generalized model of social cognition applicable to a range of entities, from the single cell to "groups of increasingly complex organisms with social, distributed cognition," that supports "the project of new cognitivism, [which] acknowledges the central role of embodiment for cognition." Almer *et al.* recognize as "cognising," information processing agents in activity as far ranging as "quorum sensing in bacteria," to "swarm intelligence" in insects, to the "full richness of human languages and other systems of communication" (Almer et al, 2015, pp 20-22).

While it is tempting to make associations across species, rhetorical theorist Alex Parrish convincingly argues that "I must be careful to use honeybee rhetorics analogically, rather than homologically, as I might do with chimpanzee gestures and the physical suasion of humans. Because we share a recent ancestor with chimps, it is quite possible we are hardwired to perform similar behaviors in response to similar situations" (Parrish, 2013, p. 47). This assessment is fair, but becomes difficult to apply when considering what I refer to as "bacterial rhetorics." Bacteria are certainly our most remote evolutionary ancestors, but should we read their communication as analogous (similarities between unrelated organisms) or homologous (similarities between related organisms)? This question may require different answers, depending upon whether they reside within us and are entangled with our own bodies. Our conscious and intentional communication relies upon an array of non-coconscious micro-decisions and communications. Rather than fear that we anthropomorphically impose a human framework upon non-humans, we might instead imagine the human body as a distinct conglomeration of cognitive abilities that previously manifested in myriad other species.

J.A. Shapiro argues that these kinds of comparisons are not so new, pointing out the long-time custom of comparing bacterial chemotaxis (movement in response to a chemical signal) with the operation of a neuro-sensory system.(Bacteria are Small but not Stupid, p. 812). Bacterial chemotaxis developed billions of years prior to neuro-sensory systems. Either scientists are using convenient operational metaphors for bacterial behavior, or they are finding in bacteria the rudiments of neuro-sensory systems. Or, perhaps they are doing some admixture of the two, muddying the issue of anthropomorphism and metaphor use. Pamela Lyon argues that although unicellular organisms are less complex than animals, their behavior is not necessarily less complex. The ability to "navigate, become familiar with, value, learn from and solve critical existential problems within its world of experience, including coordinating action with conspecifics," she says, may explain why microbial researchers have "helped themselves to cognitive terminology (i.e., 'decide,' 'talk,' 'cheat,' 'eavesdrop,' 'lure,' 'vote,) to describe complex bacterial behavior, often without caveat." Lyon argues that this language use may not be entirely metaphorical, that "there is something going on at the microscopic level that doesn't just 'look' cognitive, it *is* cognitive" and is typically considered so "when studied in animals more like us" (Lyon, 2015). Our first instinct as rhetoricians may be to question bacteriologists' metaphor choices, but given the fully entangled bacteria-human symbiosis, we might give pause to the critical impulse until we have given enough consideration to claims like those from Shapiro, Lyon, Bechtel, and Almer *et al.* Extending cognition to bacteria need not diminish the unique ways that human cognition manifests. To make better sense of human communication patterns we might entertain bacteriologists' imaginative leaps, and parenthetically treat them as more than imaginative.

For example, we could learn to see differently our human- and language-centered distinctions between nonsymbolic motion and symbolic action. Hawhee says critics obfuscate the nonsymbolic motion/symbolic action pairing when they rigidly dichotomize the two terms and ally Burke with symbolic action" (the interpretation, communication, languaging, story-ing of motion) (*Moving Bodies*, 157). If bacteriologists now extend to bacteria the power to make group inferences about social-plus-environmental conditions, then should we change the bottom-line requirement for symbolic communication? Bacterial chemotaxis is the first kind of chemotaxis, the first kind of motion and decision-making performed by life on earth (that we know of). Can we call it symbolic action if brains are not involved? For Hawhee, it is important that Burke neither advocates liberation from bodily matters, nor believes that motion is 'senseless,' even bestial," but rather, that motion is sense-full: "nonsymbolic motion names…sensory perception" and "sheer physical movement" which hovers at the edge of language, or symbolic action, neither juxtaposed nor mutually exclusive to it." (ibid), Both bacterial chemotaxis (the motion) and bacterial quorum sensing (the group's chemical communication process) require inference— interpretation of social and/or environmental conditions. In this instance, nonsymbolic motion (strictly physical chemotactic movement) is also symbolic action. Bacteria make both individual and collective decisions using material, chemical secretions; this chemical sensing is symbolic action because it is a reading of and response to environment. A chemical response at the group level is not less of a response or decision than is a gestural or verbal response, it's just a different kind of response or decision-making process. The modifier *bacterial* decision-making allows each audience to interpret that modifier as they wish, and to imagine the degree of agency appropriate (see chapter three for a discussion of the term "decision").

Our current definitions of the symbol, and therefore of nonsymbolic motion/symbolic action, break down when we analyze monkeys and bacteria. Which kinds of supposedly non-symbolic human actions might we need to reconsider as symbolic? This distinction may allow us to distinguish what we call rational or reasonable discourse, but the distinction may also prevent us from developing a more robust definition of rational discourse. To classify quorum sensing as symbolic action may upend the sensory/symbolic dichotomy, and open a floodgate of related questions: If quorum sensing never leads to or "hovers at the edge of" spoken language then what of human sensing and sensation? If bacteria comprise 90% the cells in the human body, communicate extensively inside of and with it, then what material combinatorial communications do our bodies practice, outside of spoken language and conscious intent? How does this in turn shape our conscious rhetorical practices?

I propose that it might not be possible for the human body to enact *sheer physical movement* in an inference-free, story-less vacuum. If bacteria "converse" with each other and their environs to make decisions, then we might inquire further into the wordless conversations between human bodies and their environs. The nonhuman physical movements occurring inside the human body are a kind of interpretation in their own right. The bacteria inside of us can read the environment that exists beyond the tenuous boundary between our skin and our surroundings —conveying messages between body and environs. At the cellular level our bodies interpret our environs and the other entities within it. In the next section I test the implications of this idea. I juxtapose both the holobiont theory and microbial endocrinology with various rhetorical theories: Diane Davis on suggestibility; Teresa Brennan on the transmission of affect; and Burke on group identification.

5.3 Bacterial Communications, Human Bodies

In his introduction to *Microbial Endocrinology: The Microbiota-Gut-Brain-Axis in Health and Disease*, editor Mark Lyte defines microbial endocrinology as the intersection of microbiology and neurobiology, or the study of microorganisms' ability "to both produce and recognize neurochemicals that originate either within the microorganisms themselves or within the host they inhabit" (Lyte, 2014, p. 3). The field of microbial endocrinology blurs the distinction between bacteria and host, and asks how bacteria affect hosts, complicating a host's ability for conscious intent and decision-making. Lyte says that although it is still unclear why bacteria produce neuroendocrine hormones, it is clear that many of the "*neurohormones produced by bacteria also function in mammals as part of the neurophysiological system"* and *"can impact the neurophysiological aspects of the host including cognition"* (ibid, 5). Chemical happenings inside the body do not easily translate into engagement with language and symbols (in the traditional sense), and may remain in the realm of unspoken and ineffable sensations. These sensations would be neither entirely human nor entirely nonhuman, but a synthesis of the two. Human cognition, as Lyte suggests, may not be as unique as we have believed it to be, but might be better understood as a distinct assemblage of non-human cognition: "The ubiquitous presence of neuroendocrine hormones in non-mammalian systems means that the presence of the very same neuroendocrine hormones in mammalian systems has a long evolutionary shared history" (ibid). In other words, like Shapiro and Lyon before him, Lyte attributes to bacteria cognitive capacities, but he goes even further, suggesting that human cognitive capacities originated in, and rely upon bacterial cognition. Lyte also proposes that neuroactive chemicals produced by the microbiota may interact not only with the host, but also act as a signaling mechanism between members of the microbiota, and would thus make up a kind of "primitive nervous system" reminiscent of "an organ—namely, that the cellular elements which comprise the organ can be influenced, and in turn influence, the host…" or a kind of "microbial organ" (ibid, 6). This bi-directional influence, like a conversation between host and microbiota, seems to dissolve any rigid distinction between brain and gut, human and bacteria. A newfound microbial nervous system might mean that we have been giving our brains too much credit for cognitive functions that are distributed across our bodies and our symbionts. Microbial endocrinology can open up conversations about the relationship between cognition and decision-making, between bodily sensations and beliefs.

These concerns are not altogether new. Bodily cognition has concerned humans for quite some time. Non-scientific conversations also offer perspectives on these matters. For example, Alan Watts uses metaphors of light—spotlight consciousness and floodlight consciousness—to explain the different inflections that eastern and western cultures place upon cognitive processes:

> When the teacher in class says, "Pay attention!" everybody stares, and looks right at the teacher. That is spotlight consciousness; fixing your mind on one thing at a time. . .flip, flip, flip, flip, flip. However, we also have floodlight consciousness. For example, you can drive your car for several miles with a friend sitting next to you, and your spotlight consciousness may be completely absorbed in talking to your friend. Nevertheless, your floodlight consciousness will manage the driving of the car, will notice all the stoplights…without even thinking about it…However, our culture has taught us to specialize in spotlight consciousness, and to identify ourselves with that form of consciousness alone…Although we very largely ignore it, the floodlight consciousness is working all the time, and every nerve ending that we have is its instrument…the floodlight consciousness is undervalued, we have the sensation of ourselves as being just the spotlight, just the ego that looks and attends to this and that and the other. So we ignore

> and are unaware of the vast, vast extent of our being. People, who by various methods become fully aware of their floodlight consciousness, have what is called 'a mystical experience,' or what the Buddhists call *bodhi*, an awakening. The Hindus call it *moksha*, or liberation, because they discover that the real deep, deep self, that which you really are fundamentally and forever, is the whole of being—all that there is, the works, that is you. Only that universal self that is you has a capacity to focus itself at ever so many different here-and-nows…We are brought up in a special way so that we are unaware of the connection, and unaware that each one of us is the works. (Watt, 11-12)

Floodlight consciousness, based in the body and the nerves, allows us to navigate, process, and adapt to our environs without thinking—a consciousness without intent. This mode of being and knowing could be considered antithetical to conscious deliberative processes, which would seem to rely more upon "spotlight consciousness." The body has been opposed to the intellectual as a mode of engaging with the world, partly due to its association with mysticism. For example, Freud disparages what he calls the "oceanic feeling" (a visceral sense of oneness with the world), associating it with the "primitive ego feeling" of infancy, an inability to differentiate between (subjective) self and (objective) world. (Freud, 4)

This opposition between body/sensation and mind/intellect is reminiscent of the tendency to avoid discussions of bodily sensations in academic discourse. If we want to open new avenues of inquiry into rhetorical theory, we might gravitate toward modes of being and knowing that have been repressed or disparaged as unknowable. Though it may be challenging to introduce into scholarly conversations concepts such as floodlight consciousness, we need not reject them as mystical nonsense. Massumi is not too far off from the idea of floodlight consciousness when he points out that the "vast majority of the world's sensations are certainly nonconscious" (Massumi, 14). And, Diane Davis approaches Watts' notion of *the works* when she declares, "the body is not a discrete phenomenological entity. It's unclear where it begins and ends" Davis, "Creaturely", 89). Taken together, these re-conceptions may help us to reflect on how the body factors into the way humans develop a deep sense of belonging to something greater than themselves, like a religious community, political group, or natural environment. In their own way, each of these theorists moves toward the unknown contours of bodily sensation, and the limits of knowing and reason. We can neither pin down sensations, nor explicitly understand our bodily enmeshment in the world, but this does not mean that it makes sense to ignore the messy ways that bodily phenomena factor into our deliberative and rhetorical behaviors. Perhaps the unknowns of bacteria-human symbiosis can allow us to theorize such rhetorical concepts, without slipping into biological reductionism.

The holobiont theory revises organismic boundaries and gestures toward unity between organisms but is still in its formative stages. As I discussed in chapter two, Lynn Margulis coined the term holobiont, but it would be fleshed out by later biological theorists. Bordenstein and Theis clarify the term and attempt to make it widely understood by linking it to current theories in ecology and environmental biology. They say plants and animals are no longer understood as "autonomous entities, but rather as 'holobionts,' composed of the host plus all of its symbiotic microbes." But a holobiont is still an inherently unknowable kind of entity, given the countless symbiotic microbes inhabiting a particular host. They underscore the importance of selecting the appropriate terminology to build this new conceptual framework: "the term [holobiont] importantly fills the gap in what to call such assemblages" (2015). Bordenstein and Theis acknowledge the language gap for referring to these material entities (which are perhaps un-knowable in each given situation); they also use the term assemblage, navigating terrain familiar to rhetoricians already re-theorizing the subject-object dichotomy. Additionally, the term holobiont seems particularly pertinent to the current human condition. Bordenstein and Theis say that symbiotic microbes are fundamental to "nearly every aspect of host form, function, and fitness," and to "traits that once seemed intangible to microbiology: behavior, sociality, and the origin of species" (ibid).

The holobiont theory aims to make tangible the invisible human-bacteria processes and relationships, but it is still in the formative stages. Though it is a newly emerging theory, we might experiment with the perspective shift it offers. If we view ourselves not as biologically autonomous, but rather as enmeshed and shifting assemblages, then this material condition re-distributes human desire, agency, and actions across human and nonhuman bodies and populations. We are perhaps too much in the midst of things to draw conclusions about cultural factors informing terms like *holobiont*; however, a desire to unify disparate biological parts would make sense, given heightened concerns about fractured environments and political spheres—both global and domestic. It remains to be seen whether and how re-imagining the *biological* assemblage of human communities can also help us to re-imagine the *cultural* assemblage of human communities; or, how cultural circumstances influence how scientists *see* our biological circumstances. Despite our current inabilities to answer these questions, understanding ourselves as a species-cooperative at the micro-level raises questions about the cooperation/competition dichotomy we tend towards at the macro-level.

Lynn Margulis created the term holobiont from a systems thinking standpoint which emphasizes interdependence, with all parts depending upon the others. John Feldman, who directed a documentary about Margulis, explains that the prevailing neo-Darwinian position commonly equates the word "evolution with the word competition and the symbiotic view with cooperation, but these words are so anthropocentric that Lynn advised not to use them at all when describing nature" (Feldman, 2018). Margulis warned biologists against talking "about cost-benefit or cooperation or competition because those words are proper for the banks and the basketball courts but they are not proper for the scientific explanation" (Margulis, in Feldman, 2018). Adding to this, philosopher of microbiology Jan Sapp explains that the "Darwinian theory of natural selection is nothing more than laissez-faire socioeconomic theory applied to nature. The reason we see so much struggle and conflict out there is because it's a reflection of our social world" (Sapp, in Feldman, 2018). We cannot hope for neat one-to-one explanations and metaphors that will translate across species, especially given that agonism seems like the foundation of rhetorical theory, traditionally conceived. However, we might borrow other ways of seeing the relationships between *seemingly* distinct entities.

The hologenome theory is closely related to the holobiont theory, which taken together attempt to update our current evolutionary framework of competition. The most current effort at distilling these theories comes from an interdisciplinary team of fifteen researchers and theorists who declare "the host and microbial genomes of a holobiont are collectively defined as its hologenome" (Theis, et al, 2016, p. 1). The hologenome theory looks at the holobiont in evolutionary terms, so this is an area of bacteriological research that we should tread lightly until we can feel confident about navigating it ethically. It would not make sense to replace a "survival of the fittest" mindset with another that unknowingly or implicitly sanctions other cultural maladies. Given criticism that the holobiont and hologenome theories received from the scientific community, the researchers clarify that cooperation is not the only driving force in the coevolution of the hologenome. Rather, they say that "conflicts of interest resulting from the nature of the host transmission of microbes could select for microbes that manipulate hosts to improve their own transmission" (ibid, 4). The idea that resident bacteria can manipulate host behaviors may cause discomfort for those of us concerned with biological determinism (and human exceptionalism). However, we needn't dismiss nor explain away cultural factors simply because we factor in new information and theories about human-bacteria symbiosis. The researchers add that holobionts and hologenomes are not the *primary* unit of selection, but rather "*a* unit of selection in evolution" (ibid, 4, *italics mine*). The way we communicate with each other has influenced the way we have evolved, but so have non-linguistic forms of rhetoric. We can observe that human bodies and bacteria have evolved both *cooperatively* and *antagonistically*, yet still keep in mind that these terms might be fraught at the microscopic level, as Margulis declares. But if microbes (including those within us) do not belong in the cooperative/competitive framework, we could ask where this conceptual framework should rightly end. We should be cautious of determinism and reductionism, but we cannot ignore that culture emanates from bodies, which are increasingly understood as open systems.

Joshua Gunn points out that rhetorical studies (as traditionally construed in speech communication departments) was "founded on the object of human speech" and that its "demotion of feeling over the last century has become particularly problematic" (Gunn, 191). The attempt to cleanse rhetoric of feelings that Gunn criticizes seems especially poignant now, as feelings increasingly saturate spoken rhetoric. He argues that uncontrolled speech, gendered as female, "represents a dimension of speech that we tend to repress: the bodily and affective. This dimension is repressed because it threatens masculine norms of control and order…the discipline of rhetoric concerns the disciplining of speech" (ibid, 192). It's easy to lose sight of the simple fact that conscious rhetorical practice is typically an attempt to manage sensation, affect, and bodies. Furthermore, "uncontrolled speech" now no longer seems gendered as strictly female. Conscious rhetorical practice arises from bodies that are an ever-shifting array of non-conscious processes. Bodies desire, hunger, envy, and nurture offspring, regardless of how well-educated they are, individually or collectively. Our decisions may depend upon environmental factors more than we have been able to understand or acknowledge, which feels especially pertinent during a time of environmental crises and population upheavals.

Bodily sensation may be primary, and language may be secondary; deliberation may involve verbal confirmation of group decisions which our bodies are in a constant process of sensing and creating. Gunn maintains that "although we acknowledge the centrality of affect…we no longer seem particularly invested in explaining just exactly what influence or persuasion actually is" (ibid, 191). Citing Diane Davis's "Burke and Freud on Who You Are" (2008), he says that "persuasion may be nothing more than suggestion, a form of hypnosis" (ibid, 211). Many of us might readily admit the power that pathos plays in our attempts at making well-reasoned decisions. More unsettling, however, is the suggestion that when we've been persuaded we've succumbed to a kind of hypnosis. In the following section I look more closely at Davis's essay to trace the steps she takes in claiming that suggestibility "could quite possibly be the 'ultimate' rhetorical question" (140). I synthesize Davis's suggestions on suggestibility with Theresa Brennan's theory on the transmission of affect to evaluate how microbiome-related theories might impact rhetorical theory. Bacteria make decisions using only their bodies and material surroundings, and they affect the hosts they inhabit. What we are beginning to learn about this can help us to inquire into the ways our bodily, affective decision-making processes might influence our attempts at reasoning with and persuading both ourselves and others.

5.4 Identification, Suggestibility, and Affective Transmission

In "Burke and Freud on Who You Are" Diane Davis illustrates how Burke built his theory of identification upon Freud's, while downplaying the more primitive influences. She explains that "whereas Burke insists that identification is a symbolic act that therefore remains available for conscious critique and reasoned adjustment," Freud insists on "an affective identification that precedes the distinction between 'self' and 'other'" (123). This seemingly small difference—Burke's *symbolic* identification versus Freud's *affective* identification—has vast implications for rhetorical studies and our sense of self-sovereignty. Davis recasts Freud's "primary identification," preferring the term "non-representational identification" because she says it "remains stubbornly on the motion side of the action/motion loci, impervious to symbolic intervention" (*ibid*). In the previous section I suggested that the distinction between symbolic action and nonsymbolic motion breaks down at the cellular level because bacteria actively interpret the chemical motions of their environs and other entities within it—then respond and adapt accordingly. Similarly, I suggest that a primary, non-representational identification would mean that our bodies actively interpret our environs for us.

This is another perspective from which the motion/action dichotomy begins to erode. Entertaining the idea that (nonsymbolic) motion/(symbolic) action could be a false dichotomy might better position us to theorize non-conscious identification processes. To do this we need to delve into the biological details. Burke tethered "nonsymbolic motion" to the now-shaky notion of biological individuation:

> The purely physiological aspect of the Self (its grounding in the realm of motion) is characterized by the centrality of the nervous system. Its sensations are immediately its own, not thus felt by any other organism. Like organisms presumably have similar

> pleasures and pains, but these are *immediately* experienced only within the centrality of each one particular organism's nervous system, as individuated at parturition. [(Nonsymbolic) Motion/(Symbolic) Action, 1978].

The motion/action pairing is a conceptual dichotomy which supports a culture that tends to ignore the feedback between bodily sensations and conceptual thinking—as though by ignoring the primal we might keep it at bay. Given what was known at the time Burke either could not, or did not want to imagine that our nervous systems create identifications before we can even use symbols. To acknowledge that our bodies create nonconscious identifications for us, we would also need to acknowledge that we have less control than we do.

Instead of relentlessly questing after what makes humans so different (e.g. "symbol using") from other living organisms, we could entertain the idea that we are assemblages of pre-existing nonhuman communication systems, and then look for points of similarity. We may have less control or agency than we assume; our sensations, (perhaps even our beliefs) may seep in and out through our skin, not just our eyes and ears and mouths. Our speech manifested from myriad pre-existing communication systems and may resemble them more than we've been able to see. E.P. Greenberg says that for the most part, "the eyes of microbiology" only began to see bacteria sociality in the 1990s, as quorum sensing and biofilm research rapidly developed. He says it has now become "apparent that the same selective pressures that led to the evolution of sociality in animals are forces for evolution of sociality in bacteria" (Greenberg, 2013, p. 11). Assumptions about humans' place in an imagined natural hierarchy may have prevented bacteriologists from seeing bacteria as social creatures; similar assumptions may now prevent us from entertaining the idea that human sociality and communication could somehow depend upon or originate with nonhuman entities. If bacteria help regulate humans' nonconscious bodily communication then there is no clear line where bacterial communication ends and human communication begins. Even language, seemingly so immaterial, emanates from a body affected by words as it speaks them, a body with billions of years of affective history behind it.

Davis supports Freud's "scattered insights on primary identification," and she argues that they "undercut any theory of relationality grounded in representation," and with this, "any hope of securing a crucial distance between self and other through conscious critique" (*ibid*). Given Freud's seemingly bleak outlook on discursive remedies for non-representational (aka primary) identification, it's easy to imagine why Burke wanted a theory that offered hope for symbolic intervention. I do not entirely agree with Davis's suggestion that nonrepresentational identification is "impervious to symbolic intervention," and I do think it's worthwhile to attempt symbolic representations of it, even if intervening in it is challenging. Nevertheless, I do agree with Davis's overall argument: that "Freud's theory on identification presents rhetorical studies with a distinctly unBurkean challenge: to begin exploring the sorts of rhetorical analyses that become possible only when" we no longer presume that identification is "compensatory to division" (2008, 123).

What kinds of rhetorical analyses become possible when, with Davis, we no longer presume that identification is "compensatory to division? As a preliminary answer I propose that we could pause our critiques of others' identification tendencies, and focus on our own. Only *we* can feel the sensations that arise within our bodies when we *imagine* identifying or dis-identifying with other individuals or groups. Only we can understand the *felt* difference our identifications make in our lives. Even if we are unwittingly influenced by some kind of primordial, non-representational identification process, we might use symbolic intervention to explore how it *feels* to identify or dis-identify with some person, group, or concept. However, for rhetorical studies to respond effectively to the force of a primary, non-representational identification, we first need to uproot lingering assumptions that we are truly individuated biological entities. Davis explains how Burke's belief in isolated nervous systems is tied to his belief that identification is a symbolic act: "But if you then 'bring together a number of individual nervous systems, each with its own centrality,' he says, relational impulses intervene; there will be 'vicarious sharing by empathy, by sympathy, the 'imaginative' identification with one another's states of mind'" (Davis, 129). Burke seems to take our acts of identification as proof that we are distinct nervous systems, and his proposed "relational impulses" still seem to inform our 'imaginative identification' across minds. However, even though imaginative identification is a "real" phenomenon we all experience, this does not mean that we are necessarily biologically separable from one another. Davis explains that, for Burke, we are born into "an endless dialectical struggle between 'the original biological goading [located] in the divisive centrality of the nervous system' and the inborn desire to transcend this state of nature through the mediatory ground of identification" (*ibid*). If we have been presuming (with Burke) that identification is a symbolic act because our nervous systems are divided from one another, then we may need to revise our theories about symbolic identification as we learn that our nervous systems are more connected to one another than we had previously imagined.

To better understand the processes of affective, biological identification and corresponding sensations, we can explore the microscopic connections that hold us together. Bacterial transmission across bodies can facilitate group cohesion. The most direct way this could happen is through physical touch. In their study of wild baboons (which excluded for kinship, shared diet, and environment) Jenny Tung *et al*. found that "an individual's contacts in a grooming-based social network, as well as its membership in a given social group [highly predict] its gut microbiome composition," thus implicating "direct, affiliative physical contact" as a determinant of gut microbiome…with potentially important consequences for the evolution of sociality" (Tung et al, 2015, 8). They add that physical contact in humans (hugging, kissing, holding hands) "may provide a similar route through which close social partners transmit gut bacteria" (ibid). We might find comfort in the idea that we are microbially-bonded to those with whom we share physical proximity, but given the microbiota's role in producing human neuroendocrine hormones, affective transmission is also possible without physical touch.

Though baboon studies may hint at resemblances in human behaviors, baboons don't necessarily behave like humans in daily life. Human studies are trying to get at some of the mundane ways we might transmit microbiota across bodies. Reviewing human and animal microbiome studies, Archie and Tung explain that social interaction affects microbiome composition. And in turn, they say, "microbiomes can affect host social behavior" in two ways: "by producing chemical signals used in social communication, and by directly influencing host nervous systems" (Archie and Tung, 2015). The most direct way this could happen is through physical touch. For example, Meadow and colleagues used repeated sampling to study three different rollerderby teams and found a "strong microbial fingerprint linked to each team," in part because they were from three distinctly different geographic locations." However, they also found that "members of competing roller derby teams exhibit more similar microbial communities following a 'bout' than beforehand," which means that transfer occurred "between players during the game" (ibid). Simliarly, Lax and colleagues sampled host skin surfaces and household surfaces for seven families over 6 weeks, including 3 families that moved within the sampling window. Skin microbiota on household surfaces rapidly converged to mirror the skin microbiota of their owners. Social interaction, they claim, leads to skin microbiota similarity, even through intermediate surfaces" (ibid). The Kort research team tracked the "effects of kissing on the salivary microbiome' and found that "approximately 80 million bacteria were transferred in an intimate kiss" (ibid). Archie and Theis (2011) report that many mammalian odors, which animals use to recognize members of the same species, are produced by symbiotic bacteria. They say "some of the best evidence that bacterial communities signal information about their hosts comes from human armpits," with different bacteria metabolizing different organic compounds (i.e. testosterone, sebum, sweat) to produce different odors, which humans also use as recognition cues, with each person likely having an individual "microbial signature" that reflects "genotype and/or kin relationships" (Archie and Theis, 2015, 427-28).

We may be non-consciously predisposed to others through what is beginning to look like a feedback loop in which social behavior influences microbiota composition, and microbiota composition in turn influences social behavior. Identifying through non-conscious cues can interfere with our conscious desire to create identifications along other lines, perhaps undermining our efforts at inclusion and tolerance of populations from elsewhere with different microbiome compositions. However, a lack of identification is not the only difficulty facing human populations attempting to get along with each other. Burke was driven by the issue of identification because, as Davis notes, "[t]oo much identification, too much unification, too much cooperation within any group, Burke warns, can be deadly for everyone else: he calls the 'ultimate disease of cooperation: war… [a] perversion of communion" (quoted in Davis, 126). Davis explains that Burke "pins his hopes for a survivable coexistence not so much on the act of identification, which is ontologically guaranteed, but on the human capacity to resist a little, to maintain a crucial distance through reasoned critique" (*ibid,* italics mine).

Researchers are beginning to inquire into how microbiota composition may influence belief formation in human societies. For example, Panchin *et al*. note that "[s]ome microorganisms would gain an evolutionary advantage by encouraging human hosts to perform certain rituals that favor microbial transmission"; they hypothesize that "certain aspects of religious behavior…could be influenced by microbial host control and that the transmission of some religious rituals could be regarded as the simultaneous transmission of both ideas (memes) and parasitic organisms" (Panchin et al, 2014, p. 4). They call this the "biomeme hypothesis." This (perhaps) hyperbolic imagining of how microbes influence human identification is still untestable because it would require further advances in genome sequencing. While it's fascinating to consider the implications of this hypothesis, it could also potentially degrade many cultural behaviors—not just religious ones—as irrational and mindless. However, the theory is based upon evidence about bacterial influence upon human and animal sociality. Where do we draw the line when turning to scientific research in hopes of learning more about human behavior patterns? How can we avoid ethical landmines? Does acknowledging (micro-) biological influence upon group behavior mean that we are flirting with (micro-) biological determinism? [57]

57. To argue against Burke's theory built upon the idea of individuated nervous systems, Davis appeals to research about mirror neurons. However, her reluctant framing of the topic reveals the taboo against using scientific research to build new theories in the field: "Now, it would not be my first choice to venture into the arena of neuroscience here, but I feel compelled to try to speak Burke's language…" (131). When our intellectual forebears relied on what are now outdated scientific presumptions to build their theories, we should not feel embarrassed to rely upon updated research to renovate those now-shaky rhetorical theories. Of mirror neurons Davis asks, "who can deny that sense organs and sensory neurons, which operate together not so much at, but as threshold, already indicate an excentric structure, an inside-outside similar to a Klein jar or mobius strip?...When an infant witnesses an adult open her mouth or stick out her tongue, for example, the mere observation often triggers the related neurons in the motor cortex that physically mime that action: the infant's mouth opens and the tongue comes out. Here, identification surely does not depend on shared meaning: a mimetic rapport precedes understanding, affection precedes projection…published

Teresa Brennan argues that the turn away from affect in group psychology research reflects "the turn toward the self-contained individual"; she links the belief in the "self-contained state" with the trend in social movement literature, which despite good intentions shows "the same escalating prejudice… caught up in the very process it should be analyzing…the idea of self-containment is tied to the belief that cognition, more than emotion, determines agency…as [self-containment] comes to dominate in the history of ideas, so does [cognition]" (Brennan, 2004, 62-63). Along these lines, Davis argues that Burke's *symbolic* identification versus Freud's *affective, non-representational* identification, leads rhetorical studies to the "problem of suggestibility." Just as Brennan points out how social movement theory avoids questions of affect, Davis notes that Burke wrote about hysterical rhetoric without "touching on the question of 'suggestibility,' which is both the chief feature of hysteria and what could quite possibly be the 'ultimate' rhetorical question" (140). She says that Freud, on the other hand, was "convinced that suggestibility is 'an irreducible, primitive phenomenon, a fundamental fact of the mental life of man'" (139). Davis says that Freud "ditched hypnosuggestion…not because it didn't work [but] because it worked too well, so well that it offended his humanist sensibilities…what Freud couldn't tolerate, he tells us in *Group Psychology,* was that 'suggestion, which explained everything, was itself to be exempt from explanation'" (*ibid*). We may now be at a historical crossroads where it is no longer ethical to ignore a psychological phenomenon that seems impervious to traditional analysis.

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reports on the activity of mirror neurons and resonance mechanisms can be read as elegant deconstructions of Burke's ultimate order of things, shattering the presumption of an originary biological disconnect between self and other" (ibid).

Once we begin changing our perspective about the microcosm it is difficult to not also change our perspective on the macrocosm. And, if we accept Brennan's correlation of cognition with an idealized self-containment, or self-sovereignty, then it seems to follow that refocusing on emotion (instead of cognition) would admit to a decreased sense of agency, self-sovereignty, and control. Fear of this led Burke to recast Freud's theory of affective identification as symbolic action, as if by willing it we could make it so. Unraveling the idea of self-contained individuals may help us to re-theorize human group behavior in military, religious, and educational practices. We live paradoxically, imagining ourselves as autonomous, self-contained individuals, while our institutions impart group solidarity through physical proximity. However, to avoid ethical pitfalls we need to find a way to discuss the microcosmos without directly and reductively applying it to the unknowns of human behavior. Encouraging further research into human pheromones, Archie and Theis cite a study finding that bacteria "play a causal role in invertebrate social behaviour…by producing pheromones that promote cohesion in locust swarms," though "similar research on vertebrates lags far behind" (Archie and Theis, p. 431). While we cannot expect the same results among humans, neither should we be surprised if some similarities were found.

Brennan argues that "research on entrainment by olfactory and other sensory means accounts for situations where people act as of one mind [and] points to a reevaluation of evidence for the postnatal social shaping of factors we think of as biologically given: human hormones" (Brennan, 52). What Brennan calls postnatal social shaping could be complemented by microbial endocrinology's research into human hormone production. She nominates human hormones as "the leading candidates for how affects are transmitted, as they involve the deployment of all the senses" (ibid, 53). Hormones do not act reductively, in isolation, but are integrated into the body-brain processing of information. Interested in biological factors in group cohesion, Brennan asks, “[i]f olfactory communication turns a hormone into a pheromone and changes another’s affects, does it also change their hormones in a way that (temporarily) changes their habitual affective disposition? Are such changes, in turn, communicated by additional pheromones?” She predicts that if “such cycles can be shown to hold in groups, then the contagion of affects has been explained” (ibid, 72). I hope that Brennan, together with my discussion of microbial endocrinology, make it possible to imagine something like a non-symbolic, pheromonal identification. Though Brennan is correct in suggesting the value of inquiring into how hormones become pheromones and what this means for group psychology, we must also be wary of using biology to fully explain something like the contagion of affects. Additionally, we must remember to distinguish between longer term affective dispositions, and shorter-term emotional states. Bacteriology is one avenue for interrogating the myth of the self-contained individual, and blurring the distinction between nonconscious persuadability and conscious rhetorical practice. Our biology exists in feedback with cultural factors. Microbial influence on the transmission of affect brings us to the physical nether-reaches of understanding non-conscious communication. While we should not be surprised to learn that our co-evolutionary symbionts have afforded us some of their own social capacities, they are not the only influence upon us.

5.5 Concluding Thoughts

I began chapter one with a discussion of experimental psychologist Alfred Binet, the expert hypnotist who also wrote the *Psychic Life of Micro-organisms*. In a way, I’ve come full circle to the problem of suggestibility. Recall Diane Davis’s concern with the “panicked deflection” of the Darwinian revelation, which manifests as rhetoric’s requisite “engagement with the symbolic.” If microbes do promote human group cohesion via pheromone production, then we must address the post-sensation function of language accordingly, as well as the cultural systems—ideas, philosophies, ethics, religions—that bind (and repel) human societies. Where Gunn calls for attention to instances of uncontrolled speech to parse our cultural values around self-control, I argue that we call attention to ecology (microbial or otherwise) to parse our cultural values of the self-contained individual. David Dobbs culls research on gene expression and plasticity to explain the genetic (non)difference between grasshoppers and locusts.

> [E]very locust was, and technically still is, a grasshopper — not a different species, but a sort of hopper gone mad. If faced with clues that food might be scarce, such as hunger or crowding, certain grasshopper species can transform within days or even hours from their solitudinous hopper states to become part of a maniacally social locust scourge…these phase changes…occur when crowding spurs a temporary spike in serotonin levels, which causes changes in gene expression so widespread and powerful they alter not just the hopper's behaviour but its appearance and form. Legs and wings shrink. Subtle camo colouring turns conspicuously garish. The brain grows to manage the animal's newly complicated social world, which includes the fact that, if a locust moves too slowly amid its million cousins, the cousins directly behind might eat it… Does something happen to their genes? Yes, but… they don't mutate or in any way alter the genetic sequence or DNA. Nothing gets rewritten. Instead, this bug's DNA— the genetic book with millions of letters that form the instructions for building and operating a grasshopper — gets reread so that the very same book becomes the instructions for operating a locust…Same genome, same individual, but…quite a different beast…Perhaps better then to speak not of genes but the genome—all your genes together. And not the genome as a unitary actor, but the genome

in conversation with itself, with other genomes, and with the outside environment…it's not a selfish gene or a solitary genome. It's a social genome (Dobbs, 2013).

Clearly, human do not experience changes in gene expression the way that grasshopper/locusts do. Nevertheless, nonhuman behaviors offer rhetorical studies the opportunity to reassess assumptions about individualism and agonism. The hologenome theory and microbial endocrinology, for example might help lay culture to retrace the contours of conscious rhetorical practice. Entertaining the idea that human behavior evolved so that microbes could be more easily transmitted across our bodies may humble us, but re-conceiving ourselves as biological networks could open new avenues for thinking the body and culture. This could also afford a rich material perspective on what Davis calls "an always prior rhetoricity, an affectability or persuadabilty," based upon "the *exposedness* of corporeal existence," making rhetoric not "an essence or property '*in* the speaker'…but an underivable obligation to respond that issues from an irreducible relationality" Davis, "Creaturely," 89). This irreducible relationality may be uncomfortable, as is the difficulty of addressing "communal sensation without presuming *sameness*," as Hawhee puts it. (Hawhee, "Sensorium," p. 13). Humans desire the ability to modulate and control their biological and bodily constraints in many ways. Understanding rather than ignoring those constraints that seem impossibly mysterious may help us to use them more ethically.

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