CATALYST
feminism, theory, technoscience

Mitochondrial Memory: Transgenerational Trauma, Functional Medicine, and Quantum Physics

Rosalynn A. Vega
University of Texas Rio Grande Valley
rosalynn.vega@utrgv.edu

Abstract

Building from Karen Barad's "diffractive methodological approach" (2007, 71), this article combines Mariella Pandolfi's notion of the female body as a transgenerational "physiological memoir" (1990, 255) with functional medicine perspectives on mitochondria and advances in quantum physics around "entanglement" to explore a new concept—"mitochondrial memory." Recent findings in biological research depict a communicating collective of mitochondria distributed across different "human" organs and describe how this collective controls many aspects of human health through epigenetic mechanisms. Since exact copies of mitochondria are inherited through the maternal line, I draw from anthropological theory, functional medicine research, and recent discoveries in physics to offer a speculative and poetic interpretation of mitochondria as vessels containing a multilevel sense of self, allowing for connections within the same maternal line of descent across time and space. I offer autoethnographic anecdotes highlighting the struggles of immigrant women of color—women Donna Haraway might refer to as "cyborg entities" (1991, 149)—thereby framing mitochondrial memory as formed through "naturecultural" and intersectional "intra-actions" (see Barad 2007, 97; Crenshaw 1989; and Haraway 2007, 249).

Keywords

female body, transgenerational trauma, mitochondria, quantum physics, entanglement, self, ethnography, autoethnography

Vega, Rosalynn A. 2024. "Mitochondrial Memory: Transgenerational Trauma, Functional Medicine, and Quantum Physics." *Catalyst: Feminism, Theory, Technoscience* 10 (2): 1–26.

http://www.catalystjournal.org | ISSN: 2380-3312

© Rosalynn A. Vega, 2024 | Licensed to the Catalyst Project under a Creative Commons Attribution Non-Commercial No Derivatives license

My Bokbok (maternal great-grandmother) was married shortly before her husband emigrated from China to work on the Central Pacific Railroad. His boot got caught in the tracks and he was killed by an oncoming train. Bokbok was widowed at twenty-nine and my Popo (maternal grandmother) grew up fatherless.

Popo immigrated with her husband and four children to the United States in March 1956. They had "six people and seven dollars" upon arrival. Those first few decades in the US were marked by extreme poverty. Popo and her children, including my mother, picked crops during the day, and my Popo worked at Hunt-Wesson cannery at night. Popo also tended to her vegetable garden—the family's primary food source. To worsen matters, Popo's arranged marriage was filled with discord. Her husband, my Gonggong, took no active role in parenting—except to unleash harsh corporal punishment (now deemed physical abuse) on his children. Thus, my mother grew up without a close relationship to either parent. Nonetheless, as a young adult, she supported Popo's decision to go against Chinese societal expectations and divorce Gonggong by promising, along with her siblings, to take care of Popo, financially and otherwise.

Fortunately, my mother did have one family member who offered her unconditional love and support—her Popo (my Bokbok). In 1963 Bokbok finally joined her children and grandchildren in the United States. As a child, Mother had lots of fun with Bokbok, passing her off as her mother at school open houses and even teaching her how to dance the twist. Bokbok was quick to defend Mother whenever anyone commented on her skinny frame, saying, "What do you want her to be so fat for, anyway?" When my mom was studying at UC Berkeley, Bokbok's memory began diminishing. Mom regularly commuted to her hometown, an hour and a half each way, to visit Bokbok.

For as long as I can remember, my parents have been divorced. My mother, managing attorney of her office, worked long hours, often billing 115 hours per week. Like my mother, my closest relationship as a child was with my Popo. She called me her "shleem gohn bahng"—"the core of her heart." Similarly, I've always known she is inextricably embedded inside my being. Our bond made me who I am. While in my twenties, Popo started losing her memory to dementia. I was attending Brown on the other side of the country and conducting ethnographic research in Spain, but we Skyped every day. On summer breaks, I drove to her house in the early morning hours and crawled in her bed to spend a few moments with her before scrubbing in on surgeries at Sutter Medical Center and UC Davis Children's Hospital. Popo's mind was the most lucid first thing in the morning, so those moments every day were my opportunity to encounter all of her.

Introduction

This article combines Mariella Pandolfi's notion of the female body as a transgenerational "physiological memoir" (1990, 255) with functional medicine

perspectives on mitochondria and advances in quantum physics around "entanglement" to propose a new concept—"mitochondrial memory." In essence, I draw from anthropological theory, functional medicine discourse, and recent discoveries in physics to offer a poetic and speculative (re)imagining of mitochondria as vessels containing a multilevel sense of self, allowing for intergenerational connections across space and time. I offer autoethnographic anecdotes highlighting the struggles of immigrant women of color—women Donna Haraway might refer to as "cyborg entities" who posess "a potent subjectivity synthesized from fusions of outsider identities and in the complex political-historical layers of her 'biomythography'" (1991, 174), thereby framing mitochondrial memory as formed through "naturecultural" and intersectional "intra-actions" (see Barad 2007, 97; Crenshaw 1989; and Haraway 2007, 249). In so doing, I aim to follow Laura Forlano (2017) by weaving together autoethnographic descriptions of illness and feminist technoscience literature.

Functional medicine discourse—deriving its perspective from mitochondrial research—essentializes the categories of "woman" and "mother." This discourse runs the risk of "sexing" and "gendering" mitochondria, thus reinscribing the androcentric, patriarchal, and sexist biases in biological theories of sexual difference (see Cipolla and Gupta 2016; Fausto-Sterling 2000)—a path well worn by prior debates regarding "Mitochondrial Eve" (see Oikkonen 2015, 747; also see Richardson 2012, 909, on the "sexing" of the X chromosome). It is premised on sexual science's problematic grounding in a binary sex and gender system (see Butler 2004; Fausto-Sterling 2000; Kessler 1998; Salamon 2010; and Van Anders 2015).

I acknowledge debates regarding essentialism and anti-essentialism of "the female" (see Haraway 1991; Withers 2010, 231) and recent work reframing sex and gender as non-binary, continuous variables (see Fausto-Sterling 2012; Jordan-Young 2010; Subramaniam and Willey 2016). However, I also ask how mitochondrial research may be framed using feminist science studies perspectives as a productive site for theorizing embodiment and (non)human connection. The question emerges: "How do we engage the molecular with queer feminist desires for new biocultural stories and forms?" (Willey 2016, 554–55).

Racializing and gendering processes also matter to my argument, and while I acknowledge the politics of scientific discourse, I focus attention on the conditions of possibility for (non)human connection. I introduce the following narratives "not to unpack the historical and cultural baggage contained in their logics but rather to gesture to it while highlighting the stakes of how we understand our nature" at the molecular level (Willey 2016, 553). I heartily agree with Banu Subramaniam and Angela Willey, who write, "While we are all for mediating the violence of traditional bioscientific productions of difference, we also want to hold open the imaginative spaces for what else feminist engagements with the sciences can do"

(2016, 514). In so doing, I hope to "go beyond [simply] showing bias in science," as Haraway (1988, 578) urges, to begin "queering" the concepts of agency and identity.

This article, grounded in the epistemological interventions of feminist science studies, is a curious, creative, and speculative exploration of the materiality of embodiment. Feminist theories have been reluctant to engage with biological data. As Elizabeth Wilson asserts, "They retain, and encourage, the fierce anti-biologism that marked the emergence of second wave feminism" (2004, 13). Wilson has dubbed this feminism's "distaste for biological detail," which persists "despite an avowed interest in the body" (1998, 14–15). Responding to this critique, I resist "anti-biologism" and instead engage emerging mitochondrial biology data.

I turn to Willey's (2016) concept of "biopossibility" to consider simultaneously the material-discursive conditions of scientific knowledge production and the materialization of bodies. At the same time, considering the biopossibilities of human connections underscores the primacy of Haraway's concept of "natureculture" (2007, 249). I do not attempt to pin down these two realms since doing so would only create a conceptual distance between them, thus lapsing into a nature/nurture debate. Like Haraway, I suggest that biology neither creates culture, nor does culture create biology. Embodiment and connection are always already naturecultural. By weaving together perspectives from feminist science studies, mitochondrial biology, physics, and anthropology, I hope to stimulate new knowledges about bodies in an entangled nature-cultural world (see Barad 2007, 30; Willey 2016, 558).

I also tease the biopossibility of mitochondrial memory. However, asking whether mitochondria are transmitters of intergenerational trauma may be the wrong question. As Willey writes, "It may be fruitful to think about the capacity to form attachments as a biopossibility that can inform our understandings of certain becomings without foreclosing as-yet-unrealized or unintelligible biopossibilities" (2016, 565). How does the biopossibility of mitochondrial memory allow for an imaginative exploration of human connection across time and space? How might we analyze the "dark matter" (drawing an analogy from the biosciences and physics) of (non)human connection?

To answer this question, I turn to both emerging findings in mitochondrial biology and Barad's queer posthumanist (re)configuration of "quantum entanglements." Barad writes, "To be entangled is not simply to be intertwined with another, as in the joining of separate entities, but to lack an independent, self-contained existence" (2007, ix). For Barad, existence is not an individual matter since individuals do not pre-exist their "intra-actions." Instead, individuals emerge *through* their "intra-action" (97): the mutual constitution of entangled agencies.

This conceptualization of entanglement interrogates pre-existing notions of subjectivity and objectivity while prompting shifts from the individual to the collective and from static objects to material-semiotic generative nodes (see Adsit-Morris and Gough 2021, 96). Following Barad (2007, 37), how might we think of realism not as representations of an independent reality, but as the creative possibilities of intra-acting within (and beyond) the world?

Mitochondrial research emphasizes maternal inheritance. Pandolfi notes indissoluble links among women in the maternal line of descent. My autoethnographic examples explore the posthum(an)ous bonds among myself, my mother, grandmother, and great-grandmother. At the same time, *I readily acknowledge that linkages unfolding beyond "maternal" and "female" realms are equally valid.* The type of limitless connection I explore, unbounded by time or space, can be similarly evoked in other types of (non)human relationships—including those appearing in this article (i.e., diamonds, buckyballs, black holes, galaxies, and quasars), romantic partnerships, friendships, sibling relationships, and parent-child relationships. Indeed, mitochondria are inherited by children regardless of sex and gender. Ultimately, I argue that connection is multiply mediated by molecular and physical (as in *physics*) means, among many others.

Methods

My first pieces of ethnographic data emerged when I was searching for answers on the internet regarding my own chronic diseases. I stumbled upon Health Means, an online platform hosting online summits and conferences on different functional medicine topics. I listened to summit after summit, conference after conference. This process exposed me to up-to-the-minute insights from dozens of functional medicine practitioners on a gamut of health-related topics—many pertaining to me. Registration for these events usually includes "free registration gifts" ranging from informational PDFs to study guides, e-books, recipes, and master classes. Resulting from my participation, I received numerous email newsletters, which included links to podcasts, blogs, webinars, and e-courses of specific functional medicine practitioners and their allies. Email newsletters occasionally promoted online docuseries in which the specific practitioner had been featured.

The question emerged: How did these practitioners engage with the public? To explore functional medicine in public digital spaces, I turned to YouTube, Facebook, and TEDMED.

To understand how functional medicine discourse circulates in print, I read books authored by functional medicine practitioners and geared toward a public audience—many of which are *New York Times* bestsellers—because, as an ethnographer, I am interested in public discourse and the social life of ideas.

Needing to directly observe how functional medicine practitioners interact with one another as colleagues, I conducted in-person participant observation while completing continuing medical education credits from the American Medical Association. This in-person participant observation provided me with opportunities to connect with numerous functional medicine practitioners in a face-to-face setting.

While I considered many more sources of ethnographic data—especially with regard to webinars, e-courses, master classes, summits, and docuseries—I stopped when I felt my data had reached saturation. I concluded my research when each additional online event no longer exposed me to new faces or ideas.

Data Source Type	**Number Included**
Hours of course work in nutrigenetics and nutrigenomics	60
Functional medicine interlocutors' newsletters	29
Continuing medical education credits	27
Books intended for a wide audience	19
Webinars, e-courses, and master classes	18
Online summits and conferences	16
Company newsletters	16
YouTube channels	11
Facebook groups (totaling 241,100+ online group members in December 2020)	9
Docuseries	6
Podcasts	6
Blogs	4
Magazine and newspaper subscriptions	3
Online health education platforms	2

Table 1. Data sources included in this ethnographic research project

Finally, I adapt Barad's "diffractive methodological approach" (2007, 71) by reading (bio)possibilities of (non)human connection through multiple areas of study, thus fostering constructive engagements across—and a reworking of—disciplinary boundaries. Diffractive methodology helps to frame science as practice rather than content (see Longino 1989, 57). That said, Barad asserts "the conceptual shifts derived from my diffractive methodology not only reconfigure our understanding of the nature of scientific and other material-discursive practices but also are significant and robust enough to actually form the basis for a new interpretation of quantum physics" (2007, 36). Diffractive methodology respects the entanglement of ideas, thus allowing for a rethinking of fundamental

concepts such as the notions of matter, causality, agency, identity, embodiment, objectivity, space, and time, as well as "mitochondria" as one of "science's proper objects" (Barad 2007, 26–29). (See existing destabilizing work on hormones [Fausto-Sterling 2000], muscles [Giordano 2013], brains [Jordan-Young 2010], and chromosomes [Richardson 2012]).

What Is Functional Medicine?

Functional medicine is a model that has shown to produce better outcomes than conventional medicine in a 2019 study published in the *Journal of the American Medical Association* (Beidelschies et al. 2019). Functional medicine is a personalized and holistic approach to treating chronic disease. It is both an alternative to, and an outgrowth of, conventional medicine (i.e., Western biomedicine). Thus, functional medicine presents a series of paradigm shifts away from conventional medicine.

One primary paradigm shift is the switch from body-as-machine model to "systems biology" approach. Instead of viewing the body as a collection of disconnected parts to be treated in isolation by various specialists, functional medicine approaches the body as one integrated system. The systems approach problematizes the notion that a specific etiology necessarily gives rise to a corresponding disease diagnosis, which, in turn, should be treated with the appropriate medications for that disease. From a functional medicine perspective, underlying imbalances in the bodily system can manifest in a range of symptoms, and the root cause must be addressed to promote healing and recovery. Since similar etiologies can give rise to distinct symptoms in different individuals, and, by the same token, similar symptoms can be traced to distinct etiologies, identifying root causes involves exploring patients' biochemical individuality, and may incorporate tools such as gut microbiome testing, genomic profiling, and assessment of mitochondrial health.

A second paradigm shift in functional medicine emphasizes the interconnectivity of all life. This paradigm shift harks back to James Lovelock's Gaia hypothesis—the idea that all life on earth collectively regulates the material conditions needed for continuance of life. This hypothesis likens the biosphere to a vast self-regulating organism. When parts of the organism are out of balance (e.g., soil depletion), other parts of the organism suffer (e.g., "humans"). From functional medicine's perspective, health of other species is of integral importance to human health. Solutions to many pressing planetary dilemmas involve "understanding the complex symbiotic interconnections between all things—from the level of microscopic microbial ecosystems that reside *within us*, to the myriad macroscale environmental ecosystems that *we reside in* and completely *depend on* for our survival" (Prescott and Logan 2017, 2). This approach to medicine emphasizes how interdependence, mutualism, and interconnectivity underpin life in all forms.

Functional medicine, as a discursive field, includes individuals from numerous professions. I have included interlocutors with diverse backgrounds to accurately represent functional medicine's heterogeneity. Many functional medicine doctors are conventionally trained. These doctors turned to functional medicine after becoming frustrated with a healthcare system that pharmaceuticalizes health problems instead of seeking to create lasting health. Other interlocutors to whom I refer have been trained in alternative medicine, and a few have not studied past the bachelor's level. Some readers may discount these alternative forms of expertise. However, more than 60 percent of functional medicine practitioners included in this study possess the type of advanced training that even the most skeptical readers will likely appreciate—out of 241 practitioners, 32 percent possess a medical doctorate and 27 percent have obtained a doctorate in science (PhD) or pharmacy (PharmD).

Profession/Role	**Number of Individuals**
Medical doctors (MD)	77
Health and science doctorates (PhD)	63
Entrepreneurs, health advocates, and consultants	39
Patients	28
Nutrition experts (PhD, CCN, CN, FACN, DACBN, MS)	26
Health coaches and educators	18
Chiropractors (DC)	15
Naturopathic doctors (ND)	13
Filmmakers and show hosts	10
Health science journalists, editors, and authors	9
Administrators of functional and integrative medicine clinics and organizations	6
Osteopaths (DO)	6
Nurses (RN, CNS)	6
Acupuncturists	6
Politicians	5
Oriental medicine practitioners (DOM, MSOM/MSAOM)	4
Dieticians (RD, RDN)	3
Pharmacists (PharmD and Registered Pharmacists)	3
Food activists	2
Ayurvedic doctor (AD)	1
Institute for Functional Medicine Certified Practitioner (IFMCP)	1
Other allied health professionals	6

Table 2. Number of individuals included in this ethnographic research project by profession

The Materiality of Mitochondria

Recent advances in biological research have revealed widespread characterizations of mitochondria as "the powerhouses of the cell" to be insufficient. Picard, Wallace, and Burelle write, "Mitochondria are now recognized to perform multiple essential functions beyond energy production, impacting most areas of cell biology and medicine" (2016, 5). As a guest *on The Energy Blueprint* podcast, Dr. Martin Picard explained while the "powerhouse" analogy portrays mitochondria as little machines, "mitochondria actually have this beautiful, complex life where they interact with each other" (Whitten and Picard 2019). Focusing on mitochondria-microbiota crosstalk during his interview for *The Human Longevity Project* docuseries, Dr. Marvin Edeas emphasized that mitochondria and microbiota share the same structure and mechanics. While biologists and functional medicine researchers describe how mitochondria are micro-entities of bacterial origin that continue to behave like bacteria, a feminist materialist science studies reading of their "intra-action" points to the mutual constitution of their entangled agencies (Barad 2007, 97).

Functional medicine descriptions of "our" estimated 14 quadrillion mitochondria destabilize binary understandings of "us" ("humans") and "them" ("bacteria"), thus deconstructing anthropocentric thought in a similar way to posthumanist scholarship (see Badmington 2003; Herbrechter 2013; Wolfe 2010). Functional medicine interlocutors consider the human as an assemblage of different microbial species, and describe personhood as emerging from the unison of microbial and human cells. In so doing, functional medicine discourse reframes the "humananimal" (see Bergthaller 2010, 728; also Nayar 2018) as the "humicrobe" (see Vega 2023a, 58). Similarly, following Haraway, functional medicine interlocutors signal that evolution and human development is less about Being and more about "becoming-with" the microbes on and within us (2007, 27).

This perspective is supported by mounting evidence regarding communal behavior among mitochondria and mitochondrial communication with other substances and microorganisms in "our" bodies. Dr. Zach Bush (2020) indicated during "The Virome: A Template for a Regenerative Future" webinar, "We see this beautiful communication or cooperation between the microbiome outside the cell and the mitochondrial microbiome within the cells." On *The Energy Blueprint* podcast, Dr. Picard elaborated, "What we are finding is that mitochondria can actually respond to different hormones, or to different metabolic signals, and that's fairly well documented." (See, e.g., Goglia, Moreno, and Lanni [1999] on the regulation of mitochondrial activity thyroid hormones; Campbell and Febbraio [2001] on the effect of ovarian hormones on mitochondrial enzyme activity in the fat oxidation pathway of skeletal muscle; Fernández-Vizarra et al. [2008] on how mitochondrial gene expression is regulated in the heart and liver by thyroid

hormones; and Álvarez-Delgado [2022] on the role of mitochondrial hormone receptors on the bioenergentic adaptations to lactation.)

In turn, mitochondria provide instructions to "our" "human" genes. Michael McEvoy, describing the process of cell methylation in *The Human Longevity Project* docuseries, noted, "There is a lot of crosstalk between our nuclear DNA and our mitochondrial functionality." At the Advances in Mitochondrial Medicine symposium, Dr. Andrew Heyman compared this new epigenetic paradigm to what he called "old school genetics." He described gene sequences in mitochondria as "at the crossroads" of epigenetic activity, thus making mitochondria prime targets for therapeutic intervention. Speaking to *The Energy Blueprint* audiences, Dr. Picard explained how mitochondria release biochemical signals that determine what happens throughout the body: "These can be transmitted among mitochondria; between mitochondria and other parts of the cell, including the nucleus, where the nuclear genome rests and waits for signals and information to know what genes to turn on and which genes to turn off through epigenetics; and then ultimately to the rest of the cell and the rest of the body. So, mitochondria can send signals, including their own genome—they can release their DNA into the cell cytoplasm, the internal part of the cell, or even into the bloodstream." These mechanisms support the functional medicine view of a communicating collective of mitochondria distributed across different "human" organs. Ultimately, mitochondrial metabolism is responsible for regulation of innate immunity, calcium homeostasis, programmed cell death, and stem cell regulation, among other roles (see Eisner, Picard, and Hajnóczky 2018).

While nuclear DNA are "human" genes inherited from both parents, mitochondrial DNA—abbreviated to mtDNA—have an ancient bacterial origin and are only passed down from mothers. The most accredited hypothesis traces the origin of mitochondria to a bacterial "infection" of an ancient eukaryotic cell (Atlante and Valenti 2023, 4451). A eukaryote is an organism containing a nucleus. Plants, fungi, protists, algae, and many unicellular organisms are all eukaryotes. Millions of years ago an aerobic bacterium (i.e., a bacterium that used oxygen to produce energy) was subsumed by the ancestral eukaryotic cell, thus establishing a symbiotic relationship of mutual benefit. In humans, mtDNA is inherited by the next generation through the cytoplasm of the mother's fertilized cell. Since sperm provide virtually no cytoplasm to the fertilized egg, mtDNA is maternally inherited.

Functional medicine descriptions of mitochondria, which emphasize connection to foremothers, signal an "affective politics" of human ancestry (see Oikkonen 2015, 747). These portrayals offer an opportunity to build on feminist philosophies on subjectivity and theories of embodiment by turning to the actual molecular matters of mitochondrial biology and microbial inheritance more generally—thus

shifting from uncertainty to materiality (see Roy 2008, 134, on "asking different questions" when conducting a feminist analysis of the natural sciences).

From the perspective of functional medicine, mitochondrial inheritance is a direct, supra-genomic mechanism by which the well-being of our foremothers determines our own health. As Andrea Nakayama (2017) explained during the Interpreting Your Genetics Summit, "We cannot deny that our children's health is reliant on…particularly the health of the mother going into the place of conception and pregnancy." The effects of genetic transmission of maternal mitochondria is often discussed alongside inheritance of the maternal microbiome via birth and lactation. Nakayama continued, "I don't think we can remove the child and their health from the mother and the father, but particularly the mother and her health in her life, and her ancestry." Nakayama's focus on the mother's ancestry was reiterated by Beth Lambert, who noted during *The Human Longevity Project* docuseries how vulnerability can be transmitted multigenerationally via microbial inheritance: "If grandma took lots of rounds of antibiotics, that vulnerability in the immune system will be transferred down to the mother, which will then be transferred down to their grandchild." Given that mitochondria are descendants of bacteria, functional medicine interlocutors emphasize that mitochondria are affected by antibiotics. These comments thread together a larger tapestry regarding how environmental factors shape maternal microbiomes, including mitochondria, which in turn plays a determining role in future generations' health.

Dr. Picard and a team of researchers are turning their attention to how emotions impact mitochondrial health, which in turn affects overall physical health. In an article published in *Biological Psychiatry*, they document how caregiving induces recalibrations in the mitochondria and lead to changes in both mitochondria quality and quantity (Picard, Prather, et al. 2018). In another peer-reviewed study, Bersani et al. (2016) discovered that mitochondrial DNA copy number is reduced in male combat veterans who suffer from PTSD.[1]

Dr. Picard and his colleagues have shown how experimentally manipulating mitochondrial functions alters physiological and behavioral responses to stress, leading them to characterize mitochondria as endocrine organelles that direct stress adaptation. In *Frontiers in Neuroendocrinology*, Picard, McEwen, et al. (2018) observe that neural circuits regulating social behavior are influenced by mitochondrial energetics. In a study of individuals with major depressive disorder, Lindqvist et al. (2018) found that mitochondria release higher-than-normal amounts of their DNA into the blood stream.[2] Findings such as these led Fernström et al. (2021) to conclude that mitochondrial dysfunction is implicated in major depressive disorder.[3]

Emerging acknowledgment among biologists and functional medicine interlocutors of "psychobiotics"— bacteria, including mitochondria, that biochemically shape emotions by prompting and producing neurotransmitters—introduces space for speculation regarding transmission of intergenerational trauma. Dr. Bradley Nelson applied the concept of emotional inheritance to humans when he said, "It's possible to inherit trapped emotional energy…[If] the mother is feeling an intense emotion and her whole being is resonating and vibrating at that frequency and the babies inside her are resonating at that frequency too." Dr. Jolene Brighten, naturopathic doctor, explained, "If mama's under stress, [that stress is] going to make baby run the [mitochondrial] stress response. Baby is going to get the signal the environment is not safe." These assertions by functional medicine interlocutors, spoken in layperson's terms, are garnering support from published research. In *Journal of Genetics and Genomics*, Zhang and Tian identify "maternal provision" as a potential mechanism for transgenerational inheritance of stress memory resulting from "ancestral environmental cues" (2022, 89). They specifically point to "mitochondrial perturbations" as a molecular mechanism whereby maternal experience can affect future generations (89).

Imbuing "mitochondrial memory" with meaning at the cellular level, Amin Cheikhi et al. (2019) explain that mitochondria are a substrate of cellular memory, which, in turn, underlies cellular identity (see also Burrill and Silver 2011a, 2011b; Burrill et al. 2012; Inniss and Silver 2013; and Hinge et al. 2020). Furthermore, stress can invoke enduring physiochemical changes of mitochondrial networks, leading to transgenerational persistence of epigenetically scripted cellular behavior. In essence, "mitochondria provide mnemonic information that underlie the transmission, storage, and retrieval of cellular memory across generations after removal of an environmental stress" (Cheikhi et al. 2019, 538). Cheikhi et al. were not only able to demonstrate that stress memory is stored within a self-renewing subpopulation of daughter cells in a mitochondrial-dependent fashion; they were also able to administer targeted electron scavengers to reset key epigenetic marks of cellular memory and redirect the identity of daughter cells to a non-stress-like state (532).

Cheikhi et al. call the physiochemical change of mitochondrial networks that transmit transgenerational epigenetic cellular behavior a "mitoengram"—in so doing, they are building on the engram theory, which posits that neuronal memory is stored as a specific connectivity pattern among synaptic networks and is associated with enduring cellular alterations of a specific subpopulation of neurons (2019, 528). In a subsequent commentary published in the *HSOA Journal of Gerontology & Geriatric Medicine*, Cheikhi (2020) writes, "This discovery of mitoengram is important not only because it reveals a previously undescribed mechanism underlying the cellular memory dependence on mitochondria, but also because it defines mitochondria as a universal unit of cognitive information,

beyond the brain cell engram." Flavia Messina et al. add further nuance to the discussion of mitochondrial memory by signaling how mitochondria are key regulators of the brain's activity and how impaired mitochondria can lead to the loss of proper neuronal interaction or even of neurons themselves (2020, 2; see also Grimm and Eckert 2017; Sun et al. 2016).

Cheikhi et al. further posit that the discovery of "mitoengrams" may unlock effective mitochondrial-targeted therapeutics that erase maladaptive cellular memories (2019, 540). They write, "In some circumstances, it may be advantageous for the stem cell to 'learn to forget'" (539). By the same token, Messina et al. (2020) ask, "Should we imagine a similar role for mitochondria in the neuron? Could we imagine to, somehow, interfere with these processes in order to sustain, recall, or restore memory in the elders?" Ultimately, Cheikhi et al. (2019) and Messina et al. (2020) signal therapeutic potential of erasing particular mitoengrams (i.e., those perpetuating environmental stress memories at the cellular level) for individuals.

Meanwhile, more research is required to illuminate the role of "mitochondrial memory" in transmitting transgenerational stress in "humans" (aka "humicrobes"; see Vega 2023a, 58). Researchers have already identified specific transgenerational epigenetic signals for mitochondrial stress adaptation in animals (see Ma et al. 2019). Herein I explore this "biopossibility" (Willey 2016) through the "diffractive" (Barad 2007, 71) lenses of anthropology, quantum physics, astrophysics, and feminist science studies.

Links in a Chain

Over the course of my mother's early thirties, multiple, overlapping chronic diseases took hold of her life, causing her severe pain and fatigue. When I was growing up, she didn't share her "private" information with me regarding her health diagnoses. She didn't want to cause me worry. Now that I am in my mid-thirties and have also struggled with chronic disease, she sometimes shares her health woes, however, usually after the worst symptoms have already passed. I will not describe her health issues with the same detail as I have described my own (Vega 2023b). Suffice it to say many of the health issues I have struggled with—hypothyroidism, autoimmunity, viral infections, etc.—my mother has and continues to experience. It makes sense we would share similar diagnoses given the influence of genetic inheritance on health. However, I have always sensed our commonalities are rooted in something even more pervasive than the fifty-percent of my genome that I inherited from her.

My mother and I share mitochondrial memories of suffering and loss. Our multigenerational story unfolds continuously, like links in a chain. At least three generations have suffered the effects of truncated marriages, and absent or uninvolved fathers. At the same time, from one generation to the next, the unconditional love of maternal grandmothers has been the sustaining force.

Over thirty years ago, medical anthropologist Mariella Pandolfi described how the secret, emotional world of women is fundamentally experienced through the body. In her 1990 article, "Boundaries Inside the Body: Women's Suffering in Southern Peasant Italy," Pandolfi described a symbolic anatomy, pathology, and physiology that bridges inner and outer experiences and distinguishes male and female worlds. Her work documented how the female body feels and absorbs external events. Women experience a continuum between social catastrophe and bodily catastrophe. While Pandolfi offers wars, earthquakes, and disintegration of traditional social roles as examples of "social catastrophe," *our* bodily experience (mutually embodied by my Bokbok, Popo, mother, and me) is marked by immigration, poverty, anti-Asian racism, and mothering alone. This example extends Kimberlé Crenshaw's 1989 theory of intersectionality by demonstrating how multiple forms of discrimination (e.g., racism, sexism, and classism) overlap and manifest in the *bodily experiences* of marginalized individuals.

Using ethnographic evidence, Pandolfi argued this process allows the past to become inscribed on future generations of female bodies. The stories she collected during fieldwork clearly linked a multigenerational history to individual women. She wrote, "The ancestral discourse indissolubly links the women in the maternal line of descent by way of a metaphorical string of symptoms and illnesses that petrify any possibility of social redemption or recovery" (1990, 264). The "traces" women absorb convert the female body into a physiological memoir, thus opening up new interpretations of distress, illness, and disease. In essence, Pandolfi signals how the experiences of foremothers in one's maternal line produce new identities, characterized by a polysemic and multilevel sense of self, for subsequent generations of women.

One beam of my diffractive methodology reads recent discoveries in mitochondrial medicine through Pandolfi's perspective of female bodies as physiological memoirs containing a multilevel sense of self. This reading bridges the discursive gap between what Pandolfi refers to as "symbolic anatomy, pathology, and physiology" (1990, 255) and what some may call "real biological changes." Functional medicine interlocutors, referring to mitochondrial biology research, critique how "psychosomatic" illness is often dismissed in biomedicine. They describe how emotional suffering is symbolically and somatically inscribed on female bodies in intertwining ways. I propose the concept of mitochondrial memory to signal how the symbolic and the somatic are knotted together in women's biologies.

Embodied Loss: A Tripartite Model of Risk

At the October 2019 Advances in Mitochondrial Medicine symposium, Dr. Heyman explained that all his patients, seeking his expertise because their complex illnesses are rooted in mitochondrial dysfunction, became ill after being exposed to a tripartite

model of risk. They had been exposed to pathogens and environmental toxins, suffered a traumatic brain injury, and experienced emotional trauma approximately two years before the onset of mitochondrial dysfunction symptoms. Suddenly I felt singled out—as if he were speaking to his colleagues about me. I created a timeline in my mind. While completing my epidemiology master's in public health and PhD in medical anthropology, I struggled through a concussion for six months March to September 2015. My Popo died July 2015. Two years later, while at my worst, my lab results were positive for heavy metal poisoning, BPA poisoning, and multiple viral infections. Just as Dr. Heyman indicated, my mitochondrial dysfunction resulted from "the perfect storm"—a trifecta of exposures affecting hypothalamic-pituitary-adrenal (HPA) axis dysfunction and leading to cellular damage.

I reflected on what my—our—bod(ies) already knew. In my family, when maternal grandmothers pass on, they are mourned through our bodies. Mom and I lost our Popos at twenty-nine and twenty-seven, respectively. We acknowledge how fortunate we are to have had our Popos for as long as we did—although the time we had will never be enough. The mitochondria in every cell of my mother's body are exact copies of the mitochondria in her Popo's body. Likewise, the mitochondria in every cell of my body are exact copies of each of my foremothers' mitochondria, and they hold the stories of our maternal line. When our Popos died, it was as if our mitochondria knew that millions of themselves, copies from another link in the chain, departed.

Using the concept of mitochondrial memory, I am not only suggesting that emotional, psychological, and physical experiences of women are recorded by their mitochondria and passed down to subsequent generations, but furthermore opening up a speculative space for "mutual recognition" among mitochondria from the same maternal origin. What if the mitochondria of women in the same maternal line can directly influence one another—even when they are located in different bodies and separated by distance? For elucidation, I turn to physics and the theory of quantum entanglement—the phenomenon Albert Einstein referred to as "spooky action at a distance."

Einstein, along with Boris Podolsky and Nathan Rosen, first described quantum entanglement in the 1935 paper "Can Quantum-Mechanical Description of Physical Reality Be Considered Complete?" Quantum entanglement occurs when a pair or group of particles interact in such a way the quantum state of each particle cannot be described independent of its pair or group, even when the particles are separated by great distances. Writing for *Live Science,* Tim Childers (2020) explains, "Quantum entanglement is the ethereal connection between two or more particles such that any action performed on one instantaneously affects the others, regardless of how far apart they are." These findings lie at the heart of the disparity between classical and quantum physics since, according to classical physics, particles will respond to their immediate physical surroundings.

I will provide a simple analogy to place these concepts into layman's terms. Water is a liquid at room temperature. If exposed to temperatures below 0°C (32°F), water will freeze into a solid. At temperatures above 100°C (212°F), water will boil, create steam, and evaporate. In either case, the physical state of water is determined by its immediate surrounding.

Quantum entanglement defies these general physical principles. In experiments with different types of particles—ranging from photons to molecules as large as buckyballs (Arndt et al. 1999; Nairz, Arndt, and Zeilinger 2003), and even small diamonds (K.C. Lee et al. 2011)—scientists have observed phenomena that violate local realism's approach of causality. Entangled particles were taken to two separate locations as far as 746 miles apart (Billings 2017). In these experiments, certain features of the entangled particles—for example, polarization or spin—were measured. When the particle at the first location was manipulated, this shifted the outcome of the particle at the second location. These studies show that entanglement produces a correlation between the measurements of particles, and that these particles share an instantaneous form of communication or "mutual information."

"Called Home"

When Bokbok died, my mother was studying in the student lounge at UC Berkeley. She knew the exact moment Bokbok died—she was flooded by overwhelming grief, and she cradled her head on the table and wept. When Mom arrived back at her apartment, she immediately called home and learned the news.

When my Popo passed away, I, too, was on campus at UC Berkeley. Mom called me on my cell so I could tell Popo I love her one last time. My phone was set to "do not disturb" because I was in a biostatistics exam. Knowing how important it was for me to say goodbye, Mom made repeated calls to me, without break, over the course of ten minutes. After the exam I noticed my missed calls. I immediately called Mom back. Fortunately, I was able to briefly say goodbye. Those few minutes were much too short, and I regret not having connected with Mom sooner. At the same time, Popo already knew what I felt in my heart—after all, I am her "shleem gohn bahng."

Over twenty years prior, Popo asked me to sing her favorite hymns—"Blessed Assurance" and "Jesus Loves Me." Not wanting to bring bad luck by directly stating her request, Popo asked me to sing these songs "the day I am no longer here." Knowing what she meant, I never forgot. Members of my extended family and church community approached me at Popo's funeral, weeping and offering me their hugs and condolences. An older cousin, knowing how close our relationship was, asked me, "How are you keeping your composure?" The pain I felt that day—and the pain I've been feeling since—is not a pain one can wear on the outside. That would be

unbearable. It's a pain one carries, in every fiber of one's being, every moment of the day, and throughout the night.

Some nights I have moments of relief, because Popo visits me in my dreams. Other nights she is not where I expect her to be, and I am consumed by despair.

Recent findings in astrophysics suggest a degree of galactical connectedness that scientists had not formerly anticipated and, thus, share commonalities with quantum discoveries. In 2014 Damien Hutsemékers and his team noted unexplained alignments, stretching across billions of light years, of supermassive black holes at the cores of nineteen quasars (European Southern Observatory 2014). Since black holes are actually ancient ultra-luminous galaxies—galaxies that have metaphorically "died"—these alignments beg the question of how interconnectedness persists, even after death.

Subsequently a study by Joon Hyeop Lee et al. (2019) examined the rotations of 445 galaxies within 400 million light years of earth. That is, Lee et al. have observed a "mysterious coherence" in galaxy rotation, operating against the predictions of cosmological models, thus suggesting that galaxies are tied together by enormous, invisible structures (2019, 104). Like quantum entangled particles, distant galaxies are moving in unison. These "entangled" galaxies demonstrate interconnectedness across distances that are too great to be explained by the direct interaction of their gravitational fields.

In her article "There's Growing Evidence That the Universe Is Connected by Giant Structures," Becky Ferreira (2022) writes,

> Galaxies within a few million light years of each other can gravitationally affect each other in predictable ways, but scientists have observed mysterious patterns between distant galaxies that transcend those local interactions.
>
> These discoveries hint at the enigmatic influence of so-called "large-scale structures" which…are the biggest known objects in the universe. These dim structures are made of hydrogen gas and dark matter, and take the form of filaments, sheets, and knots that link galaxies in a vast network called the cosmic web.

It may be these findings from quantum- and astrophysics are simply confirming, at much smaller and larger scales, Pandolfi's observations of multilevel identities and functional medicine's application of the holobiont theory of interconnectedness. Different types of scientists are discovering, using their unique tools, skill sets, and perspectives, an astonishing degree of connectedness at different scales, ranging from particles, to humans, to ecosystems, to galaxies. Stated differently, these diffractive beams, stemming from different disciplinary

perspectives, are all shedding light on modes of connection across time and space.

Coming for a Visit

On Christmas Eve 2021, my mom opened her cedar chest to search for baby items she had purchased several years before. At the time she made these purchases, she was not yet a Popo, but she had hope. Any grandchild would be a blessing but she longed for a girl, as evinced by the pink color or detailing of her hidden treasures. So in September 2021, when Madelena was born, it was Mom's time to step into a role she had spent generations preparing for.

While searching in her cedar chest, she came across a plastic bag. She brought it to my house on Christmas Day. I recognized the plastic bag immediately—it was from the Chinese corner store near my Popo's house. Opening the bag, my heart fluttering with anticipation, I found an intricately hand-crocheted baby blanket. I knew immediately what this meant. Twenty years prior, when Popo began losing her eyesight, she wanted to leave me something for her great-grandchild but didn't want to jinx my future fertility by mentioning it to anyone. I held the blanket and wept. Popo had come to visit me on Christmas Day with a beautiful present for my baby girl.

Several months later, my mom opened the cedar chest again to look for the baptismal gown I wore as a baby. I was baptized on Easter Sunday and Madelena would also have an Easter baptism. While searching for the gown, Mom came across a Woolworths bag. The next time Madelena and I visited her, she handed it to me. Inside were two pink crocheted baby sweaters. Again, I began crying. My husband looked at my quizzically, asking, "What happened?" I responded, "My Popo came for another visit." I held up the sweaters to show him Popo's handiwork. He asked, "How did she know Madelena would be a girl?"

This final autoethnographic anecdote invites an intersectional reading. My Popo's Christmas and Easter "visits" unfold within a context of both gratitude to the United Methodist Church and cultural mores related to ancestor worship. Our family practiced Confucianism up until fleeing China during Mao Zedong's purge. The Chinese United Methodist Church in Sacramento, California, sponsored my Popo, Gonggong, and their four children as refugees in 1956. Although my mother and I were both raised Methodist, we continue to practice ancestor worship—rituals based on the belief that deceased family members have a continued existence. Seen through this dual lens, my Popo belongs to the Christian "cloud of witnesses" (Hebrews 12:1) and is also a Chinese ancestor who participates in world affairs by looking after her family and bestowing gifts. Her double positionality as a "witness" and as an "ancestor" can be traced back to an intersectional history of political persecution, immigration, and an impoverished life in the "Gold Mountain." These details hint at how power, difference, and situated knowledge

shape maternal inheritance both biologically and physically. The categories of "woman" and "mother" always emerge at the intersection of race, class, nation, age, religion, etc.

At the same time, a feminist science studies reading of this anecdote points to details (e.g., pink baby blanket and pink knitted sweaters) that essentialize "females" while simultaneously emphasizing how "women" are "naturecultural" beings (Haraway 2007, 249). I agree with these critiques and signal that *our* existence (the life force binding my Popo, my mother, and me) is mutually constituted by our "intra-action" (Barad 2007, 97)—a phenomenon that stretches far beyond the limits of mitochondrial inheritance and existing notions of sex and gender.

Conclusion

While I recognize there are many layers to (non)human connection, herein I adapt Barad's "diffractive" methodological approach to (re)configure the ontological role of mitochondria. Specifically, I open a space for mitochondrial memory, combining the theory of entanglement from quantum physics with recent advances in mitochondrial medicine, thereby embracing the murky waters between the literal and the figurative.

As part of their study design, Yong Yu and colleagues (2020) developed "quantum memories"—devices that store quantum information. Using frequency-manipulated photons, these physicists successfully achieved entanglement between different quantum memories. My interpretation of the term *quantum memories* is twofold: a "memory" references a technological device used to store information, and, at the same time, memories are, in and of themselves, the information being stored—the information that consolidates communicative, entangled bonds.

Mitochondrial memory furthermore brings Pandolfi's "physiological memoirs" to bear on functional medicine's understandings of maternal-inherited mitochondria and quantum physics perspectives of memories as the loci of entanglement. By pointing to mitochondrial memory, I explore how women may experience a multilevel sense of self because their mitochondria are, to use the language of quantum physics, inextricably *entangled* (see Barad 2007). Since women inherit exact copies of the mitochondria in their maternal line, how might we think of mitochondria as *memories that contain memories*? That is, might mitochondria store the felt experiences of women linked by what Pandolfi calls "maternal lineage" and entangled by shared intersectional histories? I argue that women's intersectional experiences of racism, sexism, and classism are manifested intergenerationally through the body, and offer mitochondrial memory as a poetic, speculative, and hermeneutic response to emerging research in functional medicine. This (re)imagining of mitochondria allows mitochondrial memories to

exist in unison with the mitochondrial memories in foremothers' bodies. That is, the notion of mitochondrial memories offers a potential mechanism for how "individual" women carry the pain and suffering they never experienced but are inscribed on their bodies nonetheless by first establishing that individuals only exist in relation to their mutual entanglement (see Barad 2007, 33). Could it be that when a mitochondrial memory is linked to the mitochondrial memory of a subsequent generation, it provides the code for being, loving, and loss?

Notes

[1] Picard is fifth author.

[2] Picard is third author.

[3] Picard is fourth author.

References

Álvarez-Delgado, Carolina. 2022. "The Role of Mitochondria and Mitochondrial Hormone Receptors on the Bioenergetic Adaptations to Lactation." *Molecular Cell Endocrinology* 551 (July): 111661. https://doi.org/10.1016/j.mce.2022.111661.

Arndt, Markus, Olaf Nairz, Julian Vos-Andreae, Claudia Keller, Gerbrand van der Zouw, and Anton Zeilinger. 1999. "Wave–Particle Duality of C_{60} Molecules." *Nature* 401 (October): 680–82. https://doi.org/10.1038/44348.

Atlante, Anna, and Daniela Valenti. 2023. "Mitochondria Have Made a Long Evolutionary Path from Ancient Bacteria Immigrants within Eukaryotic Cells to Essential Cellular Hosts and Key Players in Human Health and Disease." *Current Issues in Molecular Biology* 45 (5): 4451–79. https://doi.org/10.3390/cimb45050283.

Badmington, Neil. 2003. "Theorizing Posthumanism." *Cultural Critique* 53 (Winter): 10–27. https://www.jstor.org/stable/1354622.

Barad, Karen. 2007. *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning.* Durham, NC: Duke University Press.

Beidelschies, Michelle, Marilyn Alejandro-Rodriguez, Xinge Ji, Brittany Lapin, Patrick Hanaway, and Michael B. Rothberg. 2019. "Association of the Functional Medicine Model of Care with Patient-Reported Health-Related Quality-of-Life Outcomes." *JAMA Network Open* 2 (10): e1914017. https://doi.org/10.1001/jamanetworkopen.2019.14017.

Bergthaller, Hannes. 2010. "Housebreaking the Human Animal: Humanism and the Problem of Sustainability in Margaret Atwood's *Oryx and Crake* and *The Year of the Flood*." *English Studies* 91 (7): 728–43. https://doi.org/10.1080/0013838X.2010.518042.

Bersani, Francesco Saverio, Claire Morley, Daniel Lindqvist, Elissa S. Epel, Martin Picard, Rachel Yehuda, Janine Flory, et al. 2016. "Mitochondrial DNA Copy Number Is Reduced in Male Combat Veterans with PTSD." *Progress in Neuro-*

Psychopharmacology & Biological Psychiatry 64 (January): 10–17. https://doi.org/10.1016/j.pnpbp.2015.06.012.

Billings, Lee. 2017. "China Shatters 'Spooky Action at a Distance' Record, Preps for Quantum Internet." *Scientific American*, June 15, 2017. https://www.scientificamerican.com/article/china-shatters-ldquo-spooky-action-at-a-distance-rdquo-record-preps-for-quantum-internet/.

Burrill, Devin, and Pamela Silver. 2011a. "Recording Cellular Experiences of DNA Damage." *Cell Cycle* 10 (15): 2410–11. https://www.tandfonline.com/doi/abs/10.4161/cc.10.15.16384.

Burrill, Devin, and Pamela Silver. 2011b. "Synthetic Circuit Identifies Subpopulations with Sustained Memory of DNA Damage." *Genes & Development* 25 (5): 434–39. https://genesdev.cshlp.org/content/25/5/434.

Burrill, Devin, Mara Inniss, Patrick Boyle, and Pamela Silver. 2012. "Synthetic Memory Circuits for Tracking Human Cell Fate." *Genes & Development* 26 (13): 1486–97. https://pmc.ncbi.nlm.nih.gov/articles/PMC3403016/.

Bush, Zach. 2020. "The Virome: A Template for a Regenerative Future." Zach Bush MD, September 8. https://www.youtube.com/watch?v=pJxjdGtuEs4&t=2s.

Butler, Judith. 2004. *Undoing Gender.* New York: Routledge.

Campbell, S.E., and M.A. Febbraio. 2001. "Effect of Ovarian Hormones on Mitochondrial Enzyme Activity in the Fat Oxidation Pathway of Skeletal Muscle." *American Journal of Physiology, Endocrinology, and Metabolism* 281 (4): E803–E808. https://doi.org/10.1152/ajpendo.2001.281.4.E803.

Cheikhi, Amin. 2020. "On the Substrate of Memory: Engram and Mitoengram." *HSOA Journal of Gerontology & Geriatric Medicine*, no. 6, 050. https://doi.org/10.24966/GGM-8662/100050.

Cheikhi, Amin, Callen Wallace, Claudette St Croix, Charles Cohen, Wan-Yee Tang, Peter Wipf, Panagiotis V. Benos, Fabrisia Ambrosio, and Aaron Barchowsky. 2019. "Mitochondria Are a Substrate of Cellular Memory." *Free Radical Biology and Medicine* (January)130: 528–41. https://doi.org/10.1016/j.freeradbiomed.2018.11.028.

Chessa, Adsit-Morris, and Noel Gough. 2021. "Queering Evolution: The Socio-political Entanglements of Natural and Cultural Evolutionary Mechanisms." In *Queer Ecopedagogies: Explorations in Nature, Sexuality, and Education*, edited by Joshua Russell, 95–121. New York: Springer. https://doi.org/10.1007/978-3-030-65368-2_6.

Childers, Tim. 2020. "Physicists Link Quantum Memories across the Longest Distance Ever." *LiveScience*, March 5, 2020. https://www.livescience.com/quantum-memory-entangled-far.html.

Cipolla, Cyd, and Kristina Gupta. 2016. "Neurogenderings and Neuroethics." In *The Routledge Handbook of Neuroethics*, edited by L. Syd M. Johnson and Karen S. Rommelfanger, 381–93. New York: Routledge.

Crenshaw, Kimberlé. 1989. "Demarginalizing the Intersection of Race And Sex: A Black Feminist Critique of Antidiscrimination Doctrine, Feminist Theory and Antiracist Politics." *University of Chicago Legal Forum*, no. 140, 139–67. https://philarchive.org/rec/CREDTI.

Einstein, A., B. Podolsky, and N. Rosen. 1935. "Can Quantum-Mechanical Description of Physical Reality Be Considered Complete?" *Physical Review* 47 (10): 777–80. https://doi.org/10.1103/physrev.47.777.

Eisner, Verónica, Martin Picard, and György Hajnóczky. 2018. "Mitochondrial Dynamics in Adaptive and Maladaptive Cellular Stress Responses." *Nature Cell Biology* 20 (June): 755–65. https://doi.org/10.1038/s41556-018-0133-0.

European Southern Observatory - ESO. 2014. "Spooky Alignment of Quasars across Billions of Light-Years." *ScienceDaily*, November 19, 2014. https://www.sciencedaily.com/releases/2014/11/141119084506.htm.

Fausto-Sterling, Anne. 2000. *Sexing the Body: Gender Politics and the Construction of Sexuality.* New York: Basic Books.

Fausto-Sterling, Anne. 2012. *Sex/Gender: Biology in a Social World.* New York: Routledge.

Fernández-Vizarra, Erika, José A. Enriquez, Acisclo Pérez-Martos, Julio Montoya, and Patricio Fernández-Silva. 2008. "Mitochondrial Gene Expression Is Regulated at Multiple Levels and Differentially in the Heart and Liver by Thyroid Hormones." *Current Genetics* 54 (May): 13–22. https://doi.org/10.1007/s00294-008-0194-x.

Fernström, Johan, Synthia H. Mellon, Marlon A. Gill, Martin Picard, Victor I. Reus, Christina M. Hough, Jue Lin, Elissa S. Epel, Owen M. Wolkowitz, and Daniel Lindqvist. 2021. "Blood-Based Mitochondrial Respiratory Chain Function in Major Depression." *Translational Psychiatry*, no. 11, art. 593. https://doi.org/10.1038/s41398-021-01723-x.

Ferreira, Becky. 2022. "There's Growing Evidence That the Universe Is Connected by Giant Structures." *VICE*, March 10, 2022. https://www.vice.com/en/article/zmj7pw/theres-growing-evidence-that-the-universe-is-connected-by-giant-structures.

Forlano, Laura. 2017. "Data Rituals in Intimate Infrastructures: Crip Time and the Disabled Cyborg Body as an Epistemic Site of Feminist Science." *Catalyst* 3 (2): 1–28. https://doi.org/10.28968/cftt.v3i2.28843.

Giordano, Sara. 2013. "What's Political about Plantarflexion Muscles? A Feminist Investigation into the Boundaries of Muscles." Paper presented at the Thirty-Fourth Annual Conference of the National Women's Studies Association, Cincinnati, November 9, 2013.

Goglia, Fernando, Maria Moreno, and Antonia Lanni. 1999. "Action of Thyroid Hormones at the Cellular Level: The Mitochondrial Target." *FEBS Letters* 452 (3): 115–20. https://doi.org/10.1016/S0014-5793(99)00642-0.

Grimm, Amandine, and Anne Eckert. 2017. "Brain Aging and Neurodegeneration: From a Mitochondrial Point of View." *Journal of Neurochemistry* 143 (4): 418–31. https://pmc.ncbi.nlm.nih.gov/articles/PMC5724505/.

Haraway, Donna Jeanne. 1991. "A Cyborg Manifesto: Science, Technology, and Socialist-Feminism in the Late Twentieth Century." In *Simians, Cyborgs, and Women: The Reinvention of Nature*, 149–81. New York: Routledge.

Haraway, Donna. 1988. "Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective." *Feminist Studies* 14 (3): 575–99. https://doi.org/10.2307/3178066.

Haraway, Donna. 2007. *When Species Meet.* Minneapolis: University of Minnesota Press.

Herbrechter, Stefan. 2013. *Posthumanism: A Critical Analysis.* New York: Bloomsbury.

Heyman, Andrew. 2019. Advances in Mitochondrial Medicine symposium, Dallas, TX, October 2019. https://oimh.smhs.gwu.edu/events/symposium-advances-mitochondrial-medicine-new-model-treating-chronic-disease.

Hinge, Ashwini, Jingyi He, James Bartram, Jose Javier, Juying Xu, Ellen Fjellman, Hiromi Sesaki, et al. 2020. "Asymmetrically Segregated Mitochondria Provide Cellular Memory of Hematopoietic Stem Cell Replicative History and Drive HSC Attrition." *Cell Stem Cell* 26 (3): 420–30. https://pmc.ncbi.nlm.nih.gov/articles/PMC7212526/.

Hutsemékers, D., L. Braibant, V. Pelgrims, and D. Sluse. 2014. "Alignment of Quasar Polarizations with Large-Scale Structures." *Astronomy & Astrophysics* 572 (December): A18. https://doi.org/10.1051/0004-6361/201424631.

Inniss, Mara, and Pamela Silver. 2013. "Building Synthetic Memory." *Current Biology* 23 (17): R812–R816. https://pmc.ncbi.nlm.nih.gov/articles/PMC3821973/.

Jordan-Young, Rebecca M. 2010. *Brain Storm: The Flaws in the Science of Sex Differences.* Cambridge, MA: Harvard University Press.

Kessler, Suzanne J. 1998. *Lessons from the Intersexed.* New Brunswick, NJ: Rutgers.

Lee, Joon Hyeop, Mina Pak, Hyunmi Song, Hye-Ran Lee, Suk Kim, and Hyunjin Jeong. 2019. "Mysterious Coherence in Several-Megaparsec Scales between Galaxy Rotation and Neighbor Motion." *Astrophysical Journal* 884 (2): 104. https://doi.org/10.3847/1538-4357/ab3fa3.

Lee, K.C., M.R. Sprague, B.J. Sussman, J. Nunn, N.K. Langford, X.-M. Jin, T. Champion, et al. 2011. "Entangling Macroscopic Diamonds at Room Temperature." *Science* 334 (6060): 1253–56. https://doi.org/10.1126/science.1211914.

Lindqvist, Daniel, Owen M. Wolkowitz, Martin Picard, Lars Ohlsson, Francesco S. Bersani, Johan Fernström, Åsa Westrin, et al. 2018. "Circulating Cell-Free Mitochondrial DNA, But Not Leukocyte Mitochondrial DNA Copy Number, Is Elevated in Major Depressive Disorder." *Neuropsychopharmacology*, no. 43, 1557–64. https://doi.org/10.1038/s41386-017-0001-9.

Longino, Helen E. 1989. "Feminist Critiques of Rationality: Critiques of Science or Philosophy of Science?" *Women's Studies International Forum* 12 (3): 261–69. https://doi.org/10.1016/S0277-5395(89)80004-4.

Ma, Chengchuan, Rong Niu, Tianxiao Huang, Li-Wa Shao, Yong Peng, Wanqiu Ding, Ye Wang, Guifang Jia, Chuan He, Chuan-Yun Li, Aibin He, and Ying Liu. 2019. "N6-methyldeoxyadenine Is a Transgenerational Epigenetic Signal for Mitochondrial Stress Adaptation." *Nature Cell Biology*, no. 21, 319–27. https://doi.org/10.1038/s41556-018-0238-5.

Messina, Flavia, Francesco Cecconi, and Carlo Rodolfo. 2020. "Do You Remember Mitochondria?" *Frontiers in Physiology*, no. 11, 271. https://doi.org/10.3389/fphys.2020.00271.

Nakayama, Andrea. 2017. Interpreting Your Genetics Summit. Virtual conference, August 2017.

Nairz, Olaf, Markus Arndt, and Anton Zeilinger. 2003. "Quantum Interference Experiments with Large Molecules." *American Journal of Physics* 71 (4): 319–25. https://doi.org/10.1119/1.1531580.

Nayar, Pramod K. 2018. *Posthumanism.* Malden, MA: Polity Press.

Oikkonen, Venla. 2015. "Mitochondrial Eve and the Affective Politics of Human Ancestry" *Signs: Journal of Women in Culture and Society* 40 (3): 747–72. https://doi.org/10.1086/679527.

Pandolfi, Mariella. 1990. "Boundaries Inside the Body: Women's Sufferings in Southern Peasant Italy." *Culture, Medicine and Psychiatry* 14 (2): 255–73. https://doi:10.1007/BF00046664.

Picard, Martin, Bruce S. McEwen, Elissa S. Epel, and Carmen Sandi. 2018. "An Energetic View of Stress: Focus on Mitochondria." *Frontiers in Neuroendocrinology* 49 (April): 72–85. https://doi.org/10.1016/j.yfrne.2018.01.001.

Picard, Martin, Aric A. Prather, Eli Puterman, Alexanne Cuillerier, Michael Coccia, Kirstin Aschbacher, Yan Burelle, and Elissa S. Epel. 2018. "A Mitochondrial Health Index Sensitive to Mood and Caregiving Stress." *Biological Psychiatry* 84 (July): 9–17. https://doi.org/10.1016/j.biopsych.2018.01.012.

Picard, Martin, Douglas C. Wallace, and Yan Burelle. 2016. "The Rise of Mitochondria in Medicine." *Mitochondrion* 30 (September): 105–16. https://doi.org/10.1016/j.mito.2016.07.003.

Prall, Jason, and John Dahlgren, dirs. 2018. *The Human Longevity Project.* Encinitas, CA: Human Longevity Project.

Prescott, Susan, and Alan Logan. 2017. *The Secret Life of Your Microbiome: Why Nature and Biodiversity Are Essential to Health and Happiness*. La Vergne, TN: New Society Publishers.

Richardson, Sarah S. 2012. "Sexing the X: How the X Became the 'Female Chromosome.'" *Signs: Journal of Women in Culture and Society* 37 (4): 909–33. http://dx.doi.org/10.1086/664477.

Roy, Deboleena. 2008. "Asking Different Questions: Feminist Practices for the Natural Sciences." *Hypatia* 23 (4): 134–57. https://doi.org/10.1111/j.1527-2001.2008.tb01437.x.

Salamon, Gayle. 2010. *Assuming a Body: Transgender and Rhetorics of Materiality.* New York: Columbia University Press.

Subramaniam, Banu, and Angela Willey. 2016. "Fighting the *Derpy* Science of Sexuality." *Archives of Sexual Behavior* 45 (April): 513–15. https://doi.org/10.1007/s10508-015-0626-x.

Sun, Nuo, Richard J. Youle, and Toren Finkel. 2016. "The Mitochondrial Basis of Aging." *Molecular Cell* 61 (5): 654–66. https://pmc.ncbi.nlm.nih.gov/articles/PMC4779179/.

Van Anders, Sari M. 2015. "Beyond Sexual Orientation: Integrating Gender/Sex and Diverse Sexuality via Sexual Configurations Theory." *Archives of Sexual Behavior* 44 (March): 1177–1213. https://doi.org/10.1007/s10508-015-0490-8.

Vega, Rosalynn. 2023a. "The Holobiont, Food Justice, and Gaia 2.0: A Post-human(ist) Approach to Functional Medicine." *Interconnections: Journal of Posthumanism* 2 (2): 51–74. https://scholarworks.utrgv.edu/anthro_fac/91/.

Vega, Rosalynn. 2023b. *Nested Ecologies: A Multilayered Ethnography of Functional Medicine.* Austin: University of Texas Press.

Whitten, Ari, and Martin Picard. 2019. "Mind-Body Link Discovered?! Mitochondria in Stress & Disease – Dr. Martin Picard." *The Energy Blueprint* (podcast), August, 2019. https://theenergyblueprint.com/the-stress-mitochondria-link/?_ga=2.41167015.406354787.1719957177-189270053.1719957177

Willey, Angela. 2016. "Biopossibility: A Queer Feminist Materialist Science Studies Manifesto, with Special Reference to the Question of Monogamous Behavior." *Signs: Journal of Women in Culture and Society* 41 (3): 553–77. https://doi.org/10.1086/684238.

Wilson, Elizabeth. 1998. *Neural Geographies: Feminism and the Microstructure of Cognition.* New York: Routledge.

Wilson, Elizabeth. 2004. *Psychosomatic: Feminism and the Neurological Body.* Durham, NC: Duke University Press.

Withers, Deborah M. 2010. "What Is Your Essentialism Is My Immanent Flesh!: The Ontological Politics of Feminist Epistemology." *European Journal of Women's Studies* 17 (3): 231–47. https://doi.org/10.1177/1350506810368907.

Wolfe, Cary. 2010. *What Is Posthumanism?* Minneapolis: University of Minnesota Press.

Yu, Yong, Fei Ma, Xi-Yu Luo, Bo Jing, Peng-Fei Sun, Ren-Zhou Fang, Chao-Wei Yang, et al. 2020. "Entanglement of Two Quantum Memories via Fibres over Dozens of Kilometres." *Nature* 578 (February): 240–45. https://doi.org/10.1038/s41586-020-1976-7.

Zhang, Qian, and Ye Tian. 2022. "Molecular Insights into the Transgenerational Inheritance of Stress Memory." *Journal of Genetics and Genomics* 49 (February): 89–95. https://doi.org/10.1016/j.jgg.2021.11.015.

Author Bio

Rosalynn A. Vega is Associate Professor of Medical Humanities and Global Health at the University of Texas Rio Grande Valley. Her current research interests include global health, social justice, epigenetics, the human microbiome, mixed-methods research, and syndemics.