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From heart beats to health recipes: The role of fractal physiology in the Ancestral Health movement

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From heart beats to health recipes: The role of fractal physiology in the Ancestral Health movement

Abstract
The human body—an amazing biological system that scales up fractally from its cellular building blocks—exhibits an incredible ability to self heal. Why then, are chronic diseases and degeneration on the rise in the population? Why are we sicker, more obese, and more depressed and stressed than ever before in human history? Why can't we heal? The answers to these questions may lie in our ancestry, and modern departure from the human ecological niche. The ability to heal requires proper spatio-temporal inputs—nutrition, sleep, stress, activity, and socialization—in order for cellular signaling to occur properly across semi-permeable cell membranes. We first review key steps in the evolutionary history of multicellular life, focusing on the fundamental role of cell-cell interactions. Next, we present this as an important framework by which to understand how the entrainment of physiological signals in homeostatic mechanisms reveals new insights into the processes of disease. Examples are drawn from the evolution of metabolism, nutrition, and respiration in multicellular life. We argue that disease processes result from a mismatch between the physiological inputs an individual receives and their optimal amount and fractal distribution as determined by an individual's ancestry. A comparative analysis is a useful tool by which to illuminate deep homologies that reveal a mechanistic account for disease processes. This cell-molecular approach provides a useful contrast to the traditional reductionist approach to disease exemplified by the human genome project. As an example, we describe how cell-cell communication drives the ontogeny and phylogeny of physiology, producing the tissues, organs, and organ systems that hierarchically serve human physiology on various levels. Modern society, with its disconnected and stress-riddled lifestyle, is increasingly failing to provide the proper inputs for healthy gene expression and physiological function. Thus, the answers to our modern health woes—physical, mental, and social—may lie in acknowledging the powerful roles that our past has played in shaping our bodies. Finding ways to provide the proper inputs of the human ecological niche in the modern day may lead to significant, perhaps staggering improvements in our health and wellness. The fractal mathematics underpinning these dynamics also serves as a metaphor for the Ancestral Health Movement, which is currently arising as a multi-cultural, multi-national grass-roots pluralistic phenomenon.

Keywords
Fractal, Physiology, Evolution, Ancestral Health, Phylogeny, Disease

Cover Page Footnote
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Introduction

One of us (APB) has a vivid memory of running quickly, as a young boy, across an open field to catch a butterfly: I stumbled and fell, scraping my knee on a loose stone in my path. After hugging the aching knee a few moments, dabbing the well of bright-red blood with a bit of clothing, I slowly meandered back home with a slight limp favoring the injured leg. By that evening, the bright-red wound had turned a deep, dull reddish brown as a scab quickly formed over its surface. A week later, the black scab was as rough as tree bark and no longer ached. I only felt a mild tickling sensation that urged me to scratch the skin around the scab. Within one more week the entire scab had fallen off to reveal a patch of pink new skin underneath. The new skin was lighter than the surrounding skin; a testament to the light tan I had acquired during the long summer days.

What a marvelous power to heal itself does the human body exhibit! The ability to self-heal and self-repair is a fundamental property of all living things. When DNA is transcribed into RNA and then translated into an amino-acid sequence to generate a new protein, there are mechanisms at each transition-point that check for errors so that they may be repaired before the product is completed and made ready for the next step. The immune system is on constant patrol for foreign invaders that may pose hazards to the body. The immune system does not work alone but is increasingly recognized to collaborate with the trillions upon trillions of denizens that make up the microbiota that reside in our guts and on our outer surfaces (Lathrop et al., 2011). Humans are perhaps unique in the animal kingdom in our ability to self-reflect on not only our own individual past, but on the past experiences of our neighbors and our ancestors. The accumulation of wisdom is powered by our ability to communicate and collaborate collectively as a cohesive unit to achieve long-range goals and adapt to an increasingly complex and nonlinear world. Ultimately, through the confluence of our accumulated knowledge and adaptability, we learned to tame the living world around us. It was the domestication and cultivation of plants and animals that made it possible for civilization to arise (Diamond, 1987).

The lost path

Textbooks on human history document the array of advancements and inventions that marked our steady progress from the first cultivation of wild grasses in the Fertile Crescent and other early hotspots of a nascent agriculture, through the increasing sophistication of our art, science, and technology, to the modern space-age era of genetic manipulation and mass communication. Further reflection, however, reveals a modern global society currently facing many crises, from environmental degradation and poisoning, to the obesity and chronic disease epidemics, to societal woes of extreme poverty and unrelenting stress. All of these woes share the common feature of stemming from a loss of the collective wisdom of our ancestors (Masterjohn, 2011). Contemporary hunter-gatherer and traditionalist forager groups, a dwindling breed indeed, are generally in excellent health, bear robust physiologies, live long, vibrant lives absent of chronic disease and suffer little physical degeneration with age (Lindeberg, 2010; O'Dea, 1991). Modern civilized populations, on the other hand, are afflicted with chronic diseases, including cancer, heart-disease, diabetes, autoimmune diseases, neuropsychopathologies and developmental psychopathologies, and show advanced physical degeneration with age (Lindeberg, 2010).

What differs between these dichotomous extremes that may account for these differences in health and well-being? Some key apparent factors that are worth considering include the following:

1. Nutritional knowledge borne by hunter-gatherers is all but lost in the modern age, or has been replaced with an overly-reductionist and arrogant nutritional science, informed more by untested "innovation" than by ancestral wisdom.

2. Hunter-gatherers live lifestyles that are generally in synch with the world around them. Modern citizens, on the other hand, live lives out of balance. Our lives are increasingly socially-disconnected, chronically-stressful, surrounded by a toxic environment and increasing uncertainty and insecurity. The result has been a body of knowledge unhinged from the context of first principles of physiology, creating an increasingly linear world and a reactive approach in clinical practice.

To summarize, the fractal stimulus inputs experienced by our ancestors regulate gene expression to optimize health and well-being. We argue that civilized individuals, especially in industrialized settings, generally receive suboptimal and linear stimulus inputs, thereby adversely affecting gene expression. Too often, attempts to deal with the results of deranged gene expression resort to tricks or shortcuts based more on uninformed hunches or blatant falsehoods (Steen, 2011), instead of on evolutionary logic. For example, counting and limiting calories has failed thousands of times over as an effective weight loss strategy (Mann et al., 2007), while eating a nutrient-dense, toxin-poor whole foods diet, especially of foods to which our physiologies and biochemistries are best adapted, leads not only to drastically improved weight management but also to better body composition (e.g., increases in lean muscle mass), elevated and normalized mood and energy, improved immunity, reduction in chronic systemic inflammation, and an overall feeling of well-being and satisfaction with life (Frassetto et al., 2009; Lindeberg, 2010). Removal of sources of chronic stress results in many of the

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same improvements, and furthermore obviates the need to ingest a suite of pharmaceuticals, taken by millions daily, such as antidepressants and anxiolytics, analgesics, proton-pump inhibitors, and sleep-enhancing drugs, to name a few (Grossman et al., 2004; Rosenkranz et al., 2013). Not only can life be lived longer when the underlying causes of degeneration and disease are removed, but that life will also be healthier, more vibrant, and serene (Epel et al., 2004, 2006).

Ancestral physiology reveals deep homologies

How can an understanding of ancestral wisdom rebalance life and at the same time inform progress in the science of human physiology? The answer is through an understanding of the human ecological niche in which we evolved and how our bodies respond, through gene expression, cell-cell communication, and physiological regulation, to the signals provided by the ancestral environment. We must seek the signals our genes and physiologies "expect" to encounter for optimal expression and function; and, we must find solutions to the modern ills of society by bringing our bodies into contact with these proper signals, most notably at the semi-permeable cell-membrane/environment interface, in order to influence genetic and epigenetic expression positively. At the root of this approach is an appreciation for the fractal nature of physiology. The self-similarity of physiology at different scales is important because it demonstrates the universality of the underlying organizing principle involved. In the remainder of this essay, we outline an approach that weds an understanding of fractal physiology to a modern cultural movement seeking health solutions through its application. What is the historical process that reveals the fractal pattern of physiology?

The discovery of deep homologies in the physiological systems of widely disparate taxa underscores the fractal nature of physiological processes. To start, a fractal is a mathematical pattern—it is the math that underlies the dynamics of natural systems—and it drives the evolution of phenomena via a simple function that repeats itself across all scales of time and space, producing self-similarity on all levels of inspection. We are not claiming that the similarity of ontogeny and phylogeny are the result of selection acting independently on different processes (development of a trait versus the evolution of traits). Rather, we are making the much stronger claim that the processes of ontogeny and phylogeny are one and the same, but operate at different time scales. Upon close examination of molecular traits, ontogenetically (within an individual across time) and phylogenetically (across generations of individuals), they appear in a specific sequence over time on both time scales. The genes expressed earliest in ontogeny (i.e., immediately following conception) are those that are phylogenetically most ancient. Genes expressed late in development are those that are evolved more recently and have a much narrower phylogenetic distribution (Roux & Robinson-Rechavi, 2008). When molecular traits are 'stressed' they follow the same trajectory in the reverse direction of ontogeny/phylogeny, suggesting that there is a common origin for all traits going back to the unicellular state. For the human organism, this means that the dynamics playing out at the molecular level are self-similar in nature to the actions at the cellular level, which scale up to produce both the organ and the organ system level interactions that culminate in a person's physiology. These fractal interrelationships may reflect the mechanism for the evolution of the internal environment, or physiology, in adaptation to the external environment (Torday and Rehan, 2012). The external environment was formed by the Big Bang (Singh, 2004), which we now know because the Universe refers to that event through phenomena like the Redshift. In contrast to this, physiology mimicked the external Universe to form its own internal 'Universe', homeostasis being its iterative self-referential framework, an emerging concept in evolution theory (Torday and Rehan, 2011, 2012).

Humans are not unique with regard to fractal physiologies; they share this pattern of being with all living things. For example, Brad Davidson at the University of Arizona has shown that, developmentally, the stem cells for the heart in the tunicate *Ciona intestinalis* are derived from the tail, suggesting that the beating of the tail for locomotion has been exapted for heart beat (Davidson, 2007). Unicellular organisms don't require a heart or a circulatory system, suggesting that the heart evolved in support of fundamental biologic traits like respiration, metabolism, and locomotion in multicellular organisms. That is, the heart is derivative. Exaptations, such as the evolution of the middle ear bones in vertebrates from the jaw bones of early fishes, have generally provided powerful clues to the ancestry of structures, and reveal the repeating process of evolution through innovation from preexisting conditions (Tucker et al, 2004; Shubin, 2008). Similarly, the brain may have a history in response to the demand for central control of the evolving viscera (organ systems for respiration, digestion, barrier function, and movement; see Bronner and LeDouarin, 2012; Obermayr, Hotta, Enomoto, Young, 2013).

Reaching further into the past, the evolution of semi-permeable cell membranes provides an informative example of how fractal processes influence human beings' nutritional needs in the modern day. The following thoughts may be helpful in thinking about fractal physiology and nutrition. Biology entrained energy via semi-permeable membranes, promoting the reduction in entropy that is the 'metabolic driver' for evolution as a way of perpetuating that mechanism (see Torday and Rehan, 2012, for elaboration). For example, the entraining of cholesterol in the plasma membrane facilitated both endocytosis and exocytosis by eukaryotes, and aerobic respiration by thinning out the membrane, making it more permeable for gas exchange. Another process in this context is chemiosmosis, the theory that forming semi-permeable membranes allowed for the creation of ionic gradients that are fundamental to generating the 'vital force' of life. The entropy and chemiosmosis mechanisms are complementary in their mutual dependence on the existence of a semi-permeable membrane. As these processes evolved, they had to cope with thermodynamics in a hierarchical manner. Cholesterol subsequently was exapted to facilitate the formation of lipid rafts, which are the structural basis for cell-cell signaling, ultimately culminating in the synthesis of steroid hormones to form the endocrine system. Putting this evolutionary story back into the context of the co-evolution of nutrition (endocytosis) and respiration, that interrelationship has been serially reiterated in evolution, particularly as vertebrates emerged from water to land (Bridgham et al, 2006; Torday and Rehan, 2011). Such serial homologies may offer powerful and effective insights into ancestral nutrition. A similar story of how the biologic imperative was accommodated by nutrients is told of how the most recent thrust of encephalization in anatomically modern humans may have been critically dependent on marine and freshwater environments (Cunnane & Stewart, 2010). In particular, aquatic plant and animal foods are typically much more concentrated (compared to terrestrially-derived foods) sources of nutrients critical to human brain and reproductive development. Key nutrients include iodine, selenium, zinc, sodium chloride, vitamins A, D3, and K2, and the preformed long-chain n3 fatty acids (e.g., Docosahexaenoic acid or DHA), among others.

The effects of such dietary changes on the evolution of the human brain may have been further advanced by the practice of cooking food, which increases the efficiency of nutrient absorption from the gut (Holtz & Gibson, 2007). These incremental steps in human brain evolution may, in the aggregate, have given rise to agrarian societies, which ‘unconsciously’ fostered the contemporary brain. As humans evolved from hunter-gatherers to farmers some 7000–12,000 years ago, access to food resources changed from a punctuated, episodic distribution of foods of high nutrient density and low toxicity (wild animals; starchy tubers and roots, and nuts and seeds, fruits and vegetables) to a steady, unvarying access to foods of low nutrient density and higher toxicity (cereals and legumes) (Cohen & Crane-Kramer, 2007; Diamond, 1987). This, in turn, led to a marked increase in acute infectious disease (Cohen & Crane-Kramer, 2007), and increased body fat deposits, resulting in sustained, elevated production of circulating leptin (Torday & Rehan, 2012), the hormonal product of fat and a master metabolic regulator. The advent of the first and second industrial ages, followed by the modern and postindustrial eras, freed humans from much of their need for physical exertion for food gathering, mobility, warmth, and other basic necessities. The creation of industrially-engineered processed foods (initially flour, sugar, vegetable oils; more recently chemical additives, flavorants, and preservatives) that replaced more traditional whole foods embodies a dramatic shift in the modern nutritional landscape. It is hard to imagine what selective pressures these radical departures from our evolutionary/ancestral template have created on modernized populations. Increases in obesity (Rohner-Jeanrenaud & Jeanrenaud, 1996) and chronic stress (Furukawa et al., 2004), in particular, are linked to dysregulation of leptin, resulting in elevated circulating leptin. Leptin has been shown to affect serotonin production in the brain, which stimulates brain development (Bonnin & Levitt, 2011). One of the most rapidly evolving genes in human societies is SNTG1 (Voight et al, 2006), which regulates serotonin synthesis in the hypothalamus, and is stimulated by leptin (Dozio et al, 2009). This demonstrates just one of a myriad ways that the recent radical shifts in physiological inputs may compromise human health on a global scale.

A related big-picture issue is the entraining of xenobiotics in biology; that is, how the utilization of such otherwise toxic substances as oxygen, nitrogen, iodine, and iron facilitated vertebrate evolution rather than poisoning it, literally (but see Berking et al., 2005 for iodine's deeper roots). These substances are toxic to biological systems in their nascent form, but they have been harnessed in their bioactive forms to play important nutritive functions in the fundamental physiological processes of multicellular life—respiration, metabolism, and movement. The iodine scenario is interesting because the physiological utilization of iodine appears to have co-evolved in invertebrates as a way of coping with the increased bacterial load generated by the endostyle while feeding. The endostyle in lampreys evolved to become the thyroid gland, as it does when the lamprey develops during its life cycle (Dumont, Corvilain, & Maenhaut, 2002). This highlights the counterintuitive nature of exaptational processes in turning a poison into a metabolic nutrient. This recurring evolutionary process is not counterintuitive, however, when viewed from the perspective of cell-cell communication as a starting principle for the existence of multicellular life and for the coevolution of symbiotic relationships—or collaborations—between eukaryotic organisms and their microbiotic (prokaryotic) residents.

Even deeper functional similarities across different kingdoms of life reveal fascinating clues to factors that may contribute to increasing rates of many chronic diseases, such as obesity and metabolic syndrome. Lim et al. (2009) found a commonly used herbicide, atrazine, to dysregulate mitochondrial function in rats through chronic exposure in drinking water. Downstream effects of mitochondrial dysfunction included decreased metabolic rate, and increased body weight, intra-abdominal fat and insulin resistance. These effects were seen in the

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absence of any measurable change in food intake or physical activity level. Atrazine, an electron transport inhibitor, is an effective herbicide that dysregulates the metabolic system of plants by acting on photosystem II of the thylakoid membrane of chloroplasts. It turns out that these membranes have a functional structure similar to mitochondria, the cellular energy production system found in all eukaryotes. In particular, mitochondria have electron transfer chain complexes with binding sites similar to those found in plant chloroplast membranes. As an unintended consequence, areas in the United States where atrazine use is particularly high also show the greatest rates of obesity (BMI > 30) (Lim et al., 2009). Such broad biological similarities across phylogenetically distant taxa, whether due to deep homologies or homoplasies, serve as a cautionary statement about the effects of anthropogenic environmental toxins—such as persistent organic pollutants—on human and nonhuman animal health. Dr. Daniel Blumstein has noted increased adiposity among his study groups of the Colorado marmot population in the absence of any noted dietary changes (personal communication, March, 2012).

On the mechanism of fractal physiology

Imagine the enabling power in knowing our biologic origins from molecules to man? Such as the revelation of how the trade-off between selection of cytosolic calcium and membrane lipids resulted in homeostasis. This process has iteratively fostered ontogeny and phylogeny at each and every stage of vertebrate evolution, as Haeckel had declared in his Biogenetic Law (1866).

We now have experimental evidence that unicellular organisms are the universal unit of life. For example, unicellular organisms bear the complete metazoan toolkit (King, Hittinger, & Carroll, 2003). Life evolved by entraining energy (entropy) using evolved lipid-containing cell membranes. Lipids then facilitated cell signaling via lipid rafts, forming regulatory calcium channels, culminating in organismal endocrine homeostasis. For example, environmental stress caused endoplasmic reticulum calcium stress (The de Duve Hypothesis) in unicellular organisms (De Duve, 1969), thus disrupting homeostatic control, giving rise to peroxisomes, which metabolically counter-balanced disrupted calcium homeostasis through lipid homeostasis (Rehan & Torday, 2012); now fast-forward to mammals, in which stimulation of the lipogenic nuclear transcription factor Peroxisome Proliferator Activated Receptor gamma (PPARγ) restores homeostasis in a wide variety of tissues and organs, even extending the life-span of mice, aging being the aggregate of calcium/lipid dyshomeostasis (Rehan & Torday,, 2012). Such fundamental knowledge forms the basis for understanding the first principles of health and disease.

The Human Genome Project (HGP) was funded to search for first principles of health and disease, having provided us with tools to make such fundamental discoveries. Yet the promised solutions to such complex clinical problems as obesity, heart attack, stroke, and hypertension are unsolved a decade and a half after publication of the HGP. Why? Because we are constrained by the traditional top-down, descriptive, non-mechanistic paradigm of pathophysiology. The consensus is that there is no paradigm to 'shift to'. Alternatively, we should adopt a cellular/molecular approach to ontogeny and phylogeny as an evolutionary continuum (Torday & Rehan, 2007) that is causal, refutable, and predictive. This approach has revealed that the First Principles of Physiology (FPPs) are knowable, and can be exploited to deconvolute pathology based on its biologic origins (Torday & Rehan, 2012). This transformative concept offers the opportunity to move away from treating clinical symptoms, the default mode of the old paradigm, towards predictive and preventive medicine at long last.

Exploiting the cell-cell communication mechanisms that have driven the phylogeny of the mammalian lung from the swim bladder of fish has enabled us to deconvolute the phylogenetic histories of other key physiologic traits (skin, bone, adrenals, kidney, liver, brain). Founded on the self-same cell-cell communication principles, Torday and Rehan (2012) have used lung ontogeny and phylogeny as 'reference points' to deconvolute these mechanisms. This systematic, reductionist approach, suggests that ontogeny and phylogeny are actually diachronic, that is, self-similar processes occurring on different time-scales, both having evolved from a common unicellular eukaryote. This view leads to the insight that the cell membrane of unicellular organisms is the common homolog for all the metazoan visceral organs- the skin, lung, kidney, heart, adrenals, bone, brain. Although it is challenging to empirically demonstrate this principle due to the prevailing descriptive paradigm (a 'chicken and egg problem'), one proof of principle is that ontogeny is the process whereby the zygote gives rise to all of the viscera.

Connecting the fractal dots of an evolutionary history from theory to practice

These converging layers of historical (phylogenetic) and developmental (ontogenetic and epigenetic) evidence suggest that by looking at the fractal evolution of physiologic systems, from single-celled organisms to complex structures and functions, in tandem with sources of nutrients, the historic interrelationships can be seen. This emerging evidence does much more than provide a unifying framework for an historical biological process; it provides critical insights into best medical practices. After all, the social philosopher

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Santayana (1905) warns us not to forget our past; conversely, by understanding our past, we can use it to our advantage.

The coevolution of respiration and lipid metabolism (Torday & Rehan, 2012) provides insights to the role of fractal physiology in human evolution, and how evolution feeds back to culture. Both the lung and skin are primary physical barriers against environmental factors, which prevent loss of bodily fluids and their contents, and which mediate gas exchange and selective nutrient uptake. By focusing on the historic nature of these molecular barriers, one can visualize how and why these structures have coevolved. The molecular barrier of the most primitive gas-exchanger, the swim bladder of fish, is cholesterol, which is synthesized and secreted by the epithelial-lining cells to prevent the sticking together of the walls of the bladder as it expands and contracts to accommodate buoyancy; the stratum corneum of the skin similarly secretes lipid to protect it,. and in both cases, the epithelial cells produce antimicrobial peptides to prevent bacterial infection (i.e., colonization by pathogenic agents) (Torday & Rehan, 2012). The significance of these commonalities is exemplified by the occurrence of asthma in man and dog alike. In dogs, a specific antimicrobial protein in their skin determines its fur color, and also causes asthma (Torday & Rehan, 2012). Similarly, in man, asthma is associated with atopic dermatitis, a skin rash, which is also due to a dermal antimicrobial protein mutation. The evolutionary tradeoff between coat pigment, which determines both mate selection and protective coloration, and asthma points to the primacy for the role of evolution in optimizing reproductive success.

The functional interrelationship between cholesterol in the lung and skin likely refers back to the evolutionary strategy of single-celled eukaryotes by introducing cholesterol into their plasma membranes, facilitating endo- and exocytosis, as well as gas exchange by thinning out the membrane. Moving forward in biologic time, Torday and Rehan (2012) describe how this same molecular strategy has been exapted to thin out the alveolar wall, increasing the surface area of the lung for efficient gas exchange, driving vertebrate evolution. Oxidant and mechanical stress on the alveolar wall were co-opted to literally increase the cell-cell interactions that generate lung surfactant. By promoting the evolution of progressively more efficient surfactant production, facilitating the developmental/phylogenetic decrease in alveolar diameter increased the surface area-to-blood volume ratio. In turn, the homeostatic control of the surfactant in the alveolus was exapted for glomerular control of water and electrolyte balance by the kidney. It is such insight to the deep and ancient homologies that have facilitated fractal physiology from single cells to Man that will ultimately elucidate the physiologic first principles of vertebrate evolution. Is it any wonder, when these dots are connected between evolution, homology, and function, that individuals adopting a whole-foods ancestral diet report a pleiotropic reduction or elimination of a seemingly disconnected array of health problems, such as asthma, skin problems, kidney stones, cognition and mood, fatigue, etc. (Jaminet & Jaminet, 2012; Kuipers, Joordens, & Muskiet, 2012; Lindeberg, 2010)?

As a working example of how a physiological signal can inform a cultural phenomenon, up until 1985 the majority of infants born prematurely died of surfactant deficiency, or Respiratory Distress Syndrome. With the scientific development of antenatal corticosteroid treatment, in combination with exogenous surfactant treatment, today, all of these infants survive. Hundreds of millions of dollars were spent to rescue these preterm infants in Neonatal Intensive Care Units world-wide, yet in the big picture, it is well known that women will not practice birth control without such efforts on the part of society to provide health safety nets for infant survival (Matthews, Ribar, & Wilhelm, 1997).

Forward the Ancestral Health Movement

So, then, how does a global social movement scale up through spontaneous order via these first principles that emerge from evolutionary logic applied to the modern human ecological niche? If Ancestral Health is defined as an umbrella conceptual framework for viewing human health through the context of our unique ancestral histories, as well as those histories we share with the rest of life on Earth, then the underlying interactions between the people involved in the Ancestral Health movement provide ample opportunity to observe how social and physiological phenomena cross-link on many different scales across space and time. In 2011, two of the authors (APB and BCP) co-organized the first annual Ancestral Health Symposium (AncestralHealth.org) at the University of California, Los Angeles. This historic event united physicians, research scientists, and laypeople from all walks of life who are passionate about finding ways to improve health in the present by respecting how we got here in the first place. This fractal perspective blossomed into a social movement thanks to several early entrepreneurs who applied fractal mathematical models to human health. In particular, Arthur DeVany (author of *The New Evolution* Diet, 2011, and *Hollywood Economics: How Extreme Uncertainty Shapes the Movie Industry*, 2003) of the University of California, Irvine, studied fractals in the movie industry, building mathematical models that showed how success in the movie industry is a dance with nonlinear chance, resulting in unpredictable exponential payoffs. In the late 1990s, Professor DeVany began sharing his ideas about *Evolutionary Fitness* and its fractal underpinnings on his Web site, including essays about how heart cells evolved the ability to convey complex information within the body through multifractal neuron firing and subsequent muscle

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contraction patterns (Goldberger et al., 2002); and, about how human movement patterns should be fractal, just as animals and hunter-gatherers move naturally in the wild (as demonstrated by numerous foraging and predator-prey models), in order to feedback and strengthen the underlying fractal physiological signaling in mammalian nervous systems (Takase, 2010). From these humble beginnings, a social movement started coalescing as more and more people saw value in applying an evolutionary framework to the modern human ecological niche and all of its health challenges. Spontaneously, this exponential growth snowballed throughout professional and lay communities, morphing into the momentum that made the first Ancestral Health Symposium a reality, as well as spawning the Ancestral Health Society and its fledgling *Journal of Evolution and Health* (JEvoHealth.com).

Interestingly, as people started self-experimenting with evolutionary health and medicine precepts, they also contributed to the nonlinear social contagion of the Ancestral Health movement, rapidly creating a large population of people interested in fractal physiology. In turn, as these people experienced positive health adaptations, they responded by shaping their social systems in ways that would further foster these underlying evolved health pathways (by forming exercise training groups that moved about in fractal ways, for instance). As a result, the Ancestral Health movement demonstrates that physiological considerations do shape how we structure our environments, our schedules, our lifestyles; and, that these choices then feedback to influence the physical signaling that drives our body systems, creating a cross-level phenomenon in which we cannot distinguish the inputs and outputs of the various levels. This dynamic is what makes the Ancestral Health movement so intriguing to study, not only physiologically but also psychologically and sociologically, because it provides valuable insights into how emergent phenomena manifest at various levels, interlinked from the simple origins up to the fractal complexity of their final destinies. That is, while heart beats may inform health recipes, health recipes can also shape heart beats: synergy.

The global manifestations of this emerging Ancestral Health movement are not ideas of an impractical utopia; instead, they are practical and applicable to all aspects of medicine, research, and daily living. For example, currently, the Ancestral Health Society (AHS) is taking shape and functioning to support efforts to investigate the science of modern human health through the lens of evolution. AHS achieves its goals by hosting the annual Ancestral Health Symposium and publishing the peer-reviewed *Journal of Evolution and Health*. These projects are practical because they are translating into real-world institutions and cultural products that human beings from across the planet can interact with and use to shape their daily choices about how to live and how to interact with their local environments. These projects are also founded on fractal physiological underpinnings. Consequently, we see tremendous potential for more and more *fractical* (fractal merged with practical) phenomena arising serendipitously from the platforms that AHS builds for folks from all walks of life. In some ways, the Ancestral Health movement is like the new skin emerging from the depths of a scabbed knee: people (though perhaps not society, Schwartz & Stapell, under review) have reached a tipping point with social and health challenges, have responded by searching for alternative solutions, and have embraced a new direction in physiology that respects our unique histories as human beings as a source of wisdom and healing, emerging with a freshness akin to new skin.

Colophon

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