

CHAPTER 12

Evolutionary Mismatch: A Framework for Understanding Health and Disease in the Modern World— “Better Living Through Evolution”

Aaron P. Blaisdell

UCLA Department of Psychology

Despite their reputation as slimy, slithery creatures that litter sidewalks and driveways after a rainstorm, earthworms are amazing creatures. They chemically alter the soil in which they live and feed, resulting in a fitness benefit not only to themselves, but also for the plants and even microbes that live in the soil (Odling-Smee, 2009).

Ants, too, alter their world in amazing ways. On a trip to Colombia in 2015, I had the good fortune to witness firsthand a trail of leafcutter ants. These ants make cuttings from plant leaves which they carry back to their underground nests. Leaf matter then serves as a food source for fungus that the ants harvest for food. Other ants tend and protect aphids that feed on certain plants, milking the aphids for a nutritive secretion that feeds the ants.

Beavers build incredible domes to live in and dams to create ponds that protect them from predators. Environmental modifications created by beaver dams have profound effects on the ecosystem, ultimately enriching biodiversity. Thus, beavers are ecological engineers and are seen as a keystone species (Rosell, Bozsér, Collen, & Parker, 2005).

These are but three of many examples of what biologists call *niche construction*. Niche construction is the process by which an organism alters its environment, typically resulting in increased fitness. While many vertebrate and invertebrate species provide examples of niche construction, humans have taken

the process to an extreme that goes far beyond the capacities of nonhuman animals (Stutz, 2014). As a result of taming fire, making tools of stone, wood, bone, and leaves, the invention of clothing and housing that protects against the elements, and ultimately the invention of language, humans have been able to leave their ancestral African birthplace and colonize much of the world's landmass, including extreme environments within the Arctic Circle. We have been able to hunt large game, fish, and even large whales for food.

Modern humans present the ultimate case of niche construction, with the creation of agriculture, cities, large-scale, stratified societies, scientific and technological feats such as lasers, particle accelerators, and gene editing, and ultimately by transporting a breathable earth atmosphere into the depths of the ocean and into space.

Despite producing amazing advancements and achievements, human niche construction is a double-edged sword. It certainly has enriched the human condition in incredible and wondrous ways: art, music, stories, dance, science, math, and philosophy—all providing a deeply enriched human experience. At the same time, however, human niche construction is also the primary contributor to the majority of human disease and suffering worldwide, especially since the Industrial Revolution and the changes it has wrought on modern human society. Human ingenuity is remarkable at the individual level, but it has become incredibly powerful with the cultural accumulation of knowledge, skills, and technology. This has allowed human societies to make advances and changes in lifestyle and habitat faster than the pace of biological evolution can keep up with. As a result, we've created a living environment that is often far different from that to which our bodies and minds are adapted. Thus, many modern-day ills and diseases can be viewed as cases of *evolutionary mismatch*. Like the foolish painter who unwittingly paints himself into a corner, so too has humankind placed itself and the world we inhabit in a precarious condition.

Before turning to the various maladies brought on by evolutionary mismatch, let's first compare in very general terms the prototypical ancestral environment to the typical modern environment as experienced by people living in the modern age. The ancestral environment in which humans existed for over 99% of the time since the origin of *Homo sapiens* (including *H. sapiens neanderthalensis*) around 500,000 years ago consisted of living primarily in outside environments. Such environments are characterized as being nonlinear, with lots of fluctuations in light, temperature, elevation, activity, and sensory input; daily interactions with a small number of familiar individuals ranging in age from infancy to elderly; a large portion of the day spent procuring and preparing food, shelter, and other necessities of daily life; consumption of foods that provide all of the necessary macro- and micronutrients and that typically prevent nutrient deficiencies;

knowledge derived largely from one's own accumulated experiences and from direct conversation with members of a small community; and sleep patterns that are fairly consistent and that adequately if not optimally meet sleep requirements. Despite a tight integration within the social ecology, there is a great deal of freedom and personal autonomy in how daily activities are arranged and choices are made. And there is no clear separation of the self from the group or the environment.

The Western industrial society, on the other hand, is characterized as being highly linear—living in carpentered environments, with much less range of motion when sitting, standing, or walking; with a majority of time spent indoors protected from fluctuations in temperature, light, activity, and sensory input (resulting in a large degree of homogeneity in these stimuli); with a large portion of the day spent in proscribed activity, either school (children and adolescents) or work (adults); long periods of stasis (e.g., sitting at a desk job or at school); and daily connections to a much smaller social group, often of a restricted age range, while at the same time encountering brief, superficial connections to a much wider number of individuals. Furthermore, in modern households, parents are burdened with arranging schedules, feeding, entertainment, and even social activities for their pre-adult children—which poses tight time constraints that curtail the freedom of parents to engage in autonomous and social activities, such as cultivating meaningful relationships with same-sex friends. Thus, unlike the ancestral state (as evidenced from contemporary hunter-gatherer societies) fathers rarely have the freedom to spend time with their male friends, and mothers are rarely connected throughout the day to a peer group of other female friends that would offer social support and share in daily living tasks, including childcare.

What follows is a discussion of the various ways that contemporary humans live in evolutionary mismatch, and its consequences for physical and mental health (Blaisdell, Pottenger, & Torday, 2013). In discussing these cases of mismatch, I try to identify solutions that might allow us to thrive in modern society without giving up our modern-day advances and comforts.

1. Food

We diverged from the African ape niche about 6-7 million years ago when hominids moved out of dense jungle and into open woodland and savannah environments (Klein, 2009). About 2.5 million years ago, we began making and using tools to open up new feeding niches centered on carnivory. In the past 1 million years, the taming of fire allowed us to include tough, starchy tubers (underground storage organs) into our diet through cooking (Wrangham, 2009). These

developments have shaped our physiology, including our digestive system and brains (Aiello & Wheeler, 1995).

Beginning about 10,000 years ago, human societies in some areas began domesticating plants and animals for use as dependable sources of food. The most important domesticated food sources were the cereal grains, which became the staples of ever larger societies. The dawn of agriculture also brought about changes in our health, but these changes tended to be for the worse (Cordain, 1999). Wherever grain-based agriculture was adopted, a number of diseases related to nutrient deficiencies arose (Cohen & Crane-Kramer, 2007).

The Industrial Revolution introduced food-processing techniques that were an economic boon for a stable modern society. Rather than having to rely on perishable goods that needed large quantities of salt or fermentation for their preservation, refining processes allowed for the development of white sugar, white flour, and seed oils that were shelf stable at room temperature for months, if not years. This resulted in an increased storage capacity and transportability that allowed these new commodities to be transported to all corners of the globe. Nevertheless, such advancements also incurred health costs. Wherever these refined foods were introduced, developmental, infectious, and chronic diseases flourished (Price, 1939).

The Western diet, high in refined sugar, flour, and oils, and often containing chemical preservatives and artificial flavors and colors, has become synonymous with an unhealthy diet. It is the standard diet against which to compare the health value of other diets, such as vegetarianism, Mediterranean, or Paleo. Consumption of a refined diet is linked to obesity, diabetes, Alzheimer's disease, cardiovascular disease, cancer, and other degenerative diseases (Lindeberg, 2010). More recently, studies using nonhuman animals have revealed the causal role of a refined or Western diet in poor mental health (Andre, Dinel, Ferreira, Laye, & Castanon, 2014) and cognitive impairments (Blaisdell et al., 2017).

Implementing diets that mimic our ancestral eating patterns holds promise for the prevention and treatment of many modern chronic diseases, often labeled as diseases of civilization (Kuipers, Joordens, & Muskiet, 2012). Following a Paleolithic style of eating that removes grains, legumes, sugar, dairy, and seed oils from the diet has been gaining traction due to its many health benefits. The good news is that the science is becoming increasingly consistent in determining what kinds of foods most people thrive on versus what kinds of foods may be problematic for sensitive individuals or even for most people. As a rule of thumb, most people seem to do well on whole foods-based diets that minimize the amount of industrial processing (e.g., refining, using chemical solvents, using ingredients produced in a laboratory, etc.), on the one hand, and poorly on highly processed and refined flour, sugar, and seed oils, on the other.

As an aside, it is interesting to consider that the convention of comparing the health effects of an experimental lifestyle intervention, such as nutritional, exercise, or sleep, against a control group that does not receive the treatment, could be reframed as the no-treatment control group actually reflecting the modern experimental condition of evolutionary mismatch! Viewed in this light, the experimental group actually corrects for the mismatch, returning one facet of modern lifestyle back to the ancestral control condition.

2. Activity

Similar to diet and nutrition, activity patterns of modern humans in Westernized societies have departed dramatically from the ancestral template. There has been an increase in sedentary behavior (e.g., sitting), especially with the advent of the Industrial Revolution, which produced machines that can do a majority of former human labor. Attempts to remedy the health ravages of sedentary behavior have often introduced problems of their own. Repetitive movement exercises, such as jogging or those involving fixed-movement machines (e.g., rowing, elliptical, cycling) may be the source of many chronic use injuries and enhanced tissue degeneration. For example, endurance athletes are at a greater risk than the general population for developing atrial fibrillations (Abdulla & Nielsen, 2009), whereas older adults who engage in light exercise are at reduced risk (Mozaffarian, Furberg, Psaty, & Siscovick, 2008). Marathon runners also have been found to have more calcified plaque in their arteries compared to a sedentary control group (Kröger et al., 2011). Furthermore, endurance training induces oxidative stress (Duca et al., 2006) and increases the stress hormone cortisol (Skoluda, Dettenborn, Stalder, & Kirschbaum, 2012). Moreover, when adults do exercise in groups, such as in a pickup game of basketball or soccer, they can experience a high rate of injury because the long periods of sedentary behavior induced by the modern lifestyle does not allow a sufficient baseline level of physical fitness and physiological robustness to protect the body from the large peak forces involved.

While high-volume endurance exercise does provide some health benefits, low-volume but high-intensity exercises such as sprinting and high-intensity interval training (HIIT) offer the same benefits at a fraction of the time investment and risk of injury and tissue degeneration (Gillen et al., 2016). Contemporary hunter-gatherers engage in a much higher volume of low-level movement, such as walking (often over uneven surfaces in bare feet), bending, squatting, climbing, and carrying, interspersed by infrequent bouts of high-intensity activity, such as sprinting, jumping, throwing, and heavy lifting (O'Keefe, Vogel, Lavie, & Cordain, 2011). This pattern of non-linearly distributed activity entrains a high level of

cardiovascular fitness and a body that is robust and resilient to a wide range of forces encountered in a heterogeneous natural environment. Mimicking more ancestral types of movement patterns appears to be conducive to greater health and fitness without the costs of novel repetitive movement exercises (Gillen et al., 2014). Thus, an ideal ancestral pattern of exercise for a modern person should include a lot of low-volume, slow-paced movement such as walking, gardening, house work, etc. on an almost daily basis, and short-duration, intermittent bursts of high-intensity movements, such as sprinting, weight-bearing movements, climbing, jumping, etc., once or twice per week. This pattern, which is close to that observed among contemporary hunter-gatherer and foraging societies, may be more sustainable for a wider segment of modern society, including the frail and elderly.

3. Surroundings

In the ancestral environment, individuals spent a vast majority of their time outside, embedded in nature. Only with the development of carpentered home environments, and especially with the advent of glass windows and air-conditioning systems, have individuals started to spend a majority of their time indoors, isolated from the outside environment. What are the consequences of this dramatic change?

Inside air quality is often poor due to off-gassing of chemicals in furniture, paint, carpeting, etc. (Jones, 1999). Likewise, spending long hours indoors incurs a dramatic reduction in exposure to sunlight. As a result, we are not exposed to the intense bright light or full spectrum of light that we receive outside. Sunlight provides a stimulus for many important functions, including the production of calcitriol (active Vitamin D), nitric oxide (which regulates blood pressure and heart health (Feelisch et al., 2010)), and other key nutrients (Mead, 2008), as well as regulating circadian rhythms (van der Horst et al., 1999). Spending a majority of our time indoors has also dramatically reduced exposure to fluctuations in temperature and air movement. The drop in temperature after dusk plays as much of a role (or an even greater role) in entraining sleep onset as does the drop in illumination intensity (especially in the blue range) (Van Someren, 2000). Furthermore, indoors, we experience a reduced exposure to ambient sounds and odors typical of outside settings.

Individuals who spend more time outdoors, and especially in nature, report improvements in mental health and cognition (Mantler & Logan, 2015; Pearson & Craig, 2014). Kids choose to play in natural settings more than in more artificial, carpentered, planned settings when access to each is equally available (Lucas

& Dymont, 2010), and more natural play spaces have higher play value than do more rigidly constructed play spaces with fewer manipulable features (Woolley & Lowe, 2012). This suggests that we should prioritize more exposure to the outside throughout the day to receive important health benefits for adults, in addition to benefits to children's health and physical, cognitive, and mental development (Kemple, Oh, Kenney, & Smith-Bonahue, 2016).

4. Light Exposure

Related to the change in exposure to sunlight is the change in the type and distribution of indoor and artificial light to which we are exposed. Indoor lighting is typically much less intense than sunlight. Fluorescent lighting contains blue light, which is dramatically reduced in morning and evening sun, and thus evening and nighttime exposure to fluorescent lighting and the lighting from TV, computer, tablet, and phone screens can dysregulate circadian rhythms (Chang, Aeschbach, Duffy, & Czeisler, 2014). Dysregulated circadian rhythms are linked to increased probability and length of illness, dysregulated sleep, depressed mood, and so on. (Roenneberg & Merrow, 2016).

Some methods to reduce or prevent the disturbances of blue light include programs and settings on computer and phone screens, such as *f.lux*, and wearing blue-light blocking glasses after sunset. Light bulbs are now available on the market that do not give off blue light and thus can be used at nighttime for indoor lighting.

5. Education

Children are adapted to learn and shape intelligence naturally through play and exploration (Blaisdell, 2015). Yet 13% to 20% of children living in the United States experience a mental disorder in a given year, and these trends have been increasing over the past couple of decades (Centers for Disease Control and Prevention, 2013). This illustrates another case of evolutionary mismatch. A typical preschool and kindergarten setting, for example, is highly scheduled and structured, with many of the activities directed by the teacher rather than motivated by the children's own interests. The entire classroom of children spends proscribed periods of time on specific activities arranged by the teacher, and the children are moved from one scheduled activity to the next according to an external cue, such as clock time. Throughout their entire career in prekindergarten through twelfth-grade education, children rarely have the freedom to engage in

playful exploration of whichever topic or activity they would want, for the amount of time that they want, and at their own pace. Instead, the modern educational setting requires and places value on the child sitting still for long periods of time, listening to directed instruction or performing instructed operations (e.g., reading, writing, calculations). This system is at odds with children's disposition to move, laugh, play, daydream, and socialize.

This contrasts dramatically with the way children learn and develop in hunter-gatherer societies, where kids move about freely in mixed-age groups, sometimes working together with others and other times on their own (Gray, 2015). The mismatch between modern work-based educational settings on the one hand, and the play- and freedom-based ancestral context of child cognitive, emotional, and social development on the other, may be a leading contributor to the chronic mental, psychological, and perhaps physical health issues that face children in modern society (Gray, 2011). The increase in the number of progressive schools, such as Montessori and unconventional charter schools, home schooling, and unschooling in modern American society is a symptom of a malfunctioning educational system. Unfortunately, most lower- and middle-class families do not have the time and/or financial resources to commit to such alternatives. What is really needed is an overhaul of the modern educational system to align it closely to the biological needs of child development, incorporating freedom, play and humor, cooperation, and democracy as core tenets.

6. Social Life

For most of our evolutionary history, humans lived in small band societies, consisting of on average 40 to 60 individuals in the primary social group. There were occasional gatherings among networks of bands, but these were likely rare and seasonal events. As a result, people directly knew everyone in their society, and developed close, lifelong friendships within this small community. In such a society, everyone assists with and contributes to different activities that serve the group, ranging from foraging, building shelter, constructing and mending tools and clothing, to early childcare, storytelling, and maintaining and participating in cultural activities (Sober & Wilson, 1999). Despite some division of labor—women tended more toward early childcare, while men tended toward exploration and hunting (and in some societies warfare)—band society is egalitarian, with everyone sharing in the same freedoms and autonomy on the one hand, and contributing significantly to the group and community on the other. Perhaps most important of all, belief systems, decision-making structures, and community relations were handled with a playful approach and attitude (Gray, 2009).

In contrast, modern society consists of millions of individuals, organized into multiple, partly overlapping social groups that are connected via incredibly complex networks, and enforced through coercion and policing. We are a citizen of a neighborhood, city, state, and nation. Most individuals work for a company or other organization. We are members of political parties, book clubs, parent-teacher groups, sports teams, gyms, social media groups, and so forth. A typical modern day is organized around a fairly restrictive schedule of commuting to and from work at proscribed times set by the standard work day, chauffeuring kids to and from school, preparing (or ordering) meals at specified times of breakfast, lunch, and dinner, and going to bed often much later than our ancestors in small band societies typically did. Moreover, at the end of the work or school day, we may spend a little while in extracurricular activities with friends and acquaintances, but most of our remaining time is spent in our homes with our nuclear family, but not with our friends. This restrictive and regimented daily schedule, with so little time spent socializing with a large network of close friends, significantly injures our mental health and psychological well-being. Spending time among friends helps reduce stress and improves physiological health (Uchino, Cacioppo, & Kiecolt-Glaser, 1996). Restricted access to friends, especially on a daily basis, leaves us disconnected from the support group that would naturally surround us in band society. As a result, we suffer a greater degree of anxiety, which adversely affects our mental and even physical health. Social disconnection is associated with increased systemic inflammation, a major contributor to chronic disease (Steptoe, Owen, Kunz-Ebrecht, & Brydon, 2004) and cognitive decline (Cacioppo & Hawkey, 2009).

7. Parenting

We've already mentioned how the role parents play in a contemporary nuclear family in a middle-class, dual-income household contrasts drastically with parenting roles in traditional, ancestral communities. As parents, we must feed, bathe, and clothe our children, and provide them with safety and shelter. Moreover, we must wash their clothing and chauffeur them to and from school, extracurricular activities, and "play dates." And beyond this, we are their primary source of both entertainment and socialization. Thus, contemporary parenting is highly restrictive of the parents' freedom and is laborious and tedious.

In ancestral communities, by contrast, parenting roles can be quite different. While the mother is heavily invested in childcare during her child's infancy, other adults and older children provide plenty of alloparenting. Furthermore, the ability to carry and feed the infant wherever she goes means that the mother is not as

restricted in movement or daily schedules as is a mother in Western society. There is no separation of a new mother from her peer group and social network. Fathers also play a strong, supporting role in ancestral communities, but are not burdened by the labors of maintaining a household. Thus, fathers, too, have similar freedom after the birth of a child as they enjoyed beforehand. Children rapidly gain independence in the first few years of life. In fact, by the time a child is 5 or 6 years old, he or she typically spends very little time around the nuclear family and instead spends most of his or her time with the other children in the band. In most contemporary hunter-gatherer groups, children from ages 5 to 18 typically form their own separate, somewhat independent camp adjacent to the adult's camp (Gray, 2015).

It is difficult to underestimate the stress level induced by the burdens of child rearing in modern society, and it is likely to become increasingly recognized as an important evolutionary mismatch that needs to be addressed. In fact, the rise in home schooling and even unschooling movements across the United States and other modern societies reflects this growing awareness and is an attempt to restore balance to both the child and parental sides of the equation.

8. Social Structure and Governance

Hunter-gatherer band society is largely democratic and egalitarian. Cognitive biases evolved to adapt individuals to band society (Haselton & Nettle, 2006). Human behavior is naturally both altruistic and greedy (cooperative and competitive), but in hunter-gatherer society there are social constraints, and especially severe consequences for antisocial behaviors (Boehm, 1999). Antisocial and selfish individuals can be ostracized or even ejected from a group. Cultural practices also evolved to prevent individuals from mistreating or abusing others (especially women and children), from hoarding resources, and from curtailing the freedom of other individuals. Such individuals would lose out on mating opportunities, would suffer a loss of reputation, group status, and reciprocity, and might ultimately be shunned and cast out from the group.

In modern society, anonymity, population size, and the economic systems of the modern world insulate individuals from the effects of their greed or other antisocial behaviors. Unconstrained greed is now actually glorified (large mansions, conspicuous consumption, purposeful waste, etc.). In the United States, the wealthiest 160,000 families own as much wealth as the poorest 145 million families (Saez & Zucman, 2016). Anonymity in such a large society allows for behaviors that normally would be kept in check in a small band society, such as mistreatment of women, child abuse, unequal distribution of resources, and so on.

While we retain built-in biases that adapted us to the ancestral world, such as mistaking a stick for a snake (Johnson, Blumstein, Fowler, & Haselton, 2013), there has not been sufficient evolutionary time to acquire biases for evolutionarily novel immediate threats, such as cars or drugs, or for long-term dangers, such as failure to plan for retirement or to make choices that benefit our environment and address climate change (Kahneman, 2011). What are the implications of the lack of biases for dealing with long-term problems? Their absence can lead to greater disparity between the diminishing wealthy and the growing poor, increased stagnation at the level of governments and organizations in addressing global issues such as overpopulation, food production, climate change, pollution, health care, and the burden of chronic disease, to name a few (Diggs, 2017). We need to apply evolutionary thinking to re-engineer our society, governance, policy, infrastructure, and resource management and allocation, and to realign our ancestral psychology with our modern technology and systems, in order to promote a healthy population and environment (Wilson, 2011).

9. Cognitive Grounding

Humankind has been defined by its technology, from the origin of *Homo habilis* or “handy man” and associated Oldowan tool assemblages, to the more sophisticated Acheulean stone tools and control of fire evidenced at *Homo erectus* archaeological sites, to the progression of ever more advanced tools constructed by *Homo sapiens* from the stone age to the bronze age to the iron age; from the steam engine to the combustion engine to the airplane to the rocket ship; from the control of electricity to the microprocessor to the wireless Internet of a globally connected world.

This last technological revolution of a continuously connected Internet that links devices such as smart phones, computers, and tablets distributed across all corners of the globe has happened so swiftly (over the past 15 or so years), and transformed our daily lives so dramatically that it is surprising how little we have noticed these changes. While this recent advancement is the true birth of the information age, and all of the wonderful advantages it brings, there is also a dark side to this new technology. It is difficult to step out of one’s door these days and not observe a large segment of the population engaged with their smartphones—while walking, sitting in a café or restaurant, or even while driving a car. Aside from potential accidents due to distracted walking or driving, the ubiquitous overuse of smartphones may dysregulate normal neurofunctional connectivity and end up lowering productivity (Gazzaley & Rosen, 2016). Even ten years ago, Internet overuse and cell phone overuse were being recognized as emerging

behavioral addictions (Jenaro, Flores, Gómez-Vela, González-Gil, & Caballo, 2007). The compulsive usage of smartphones and related types of “technostress” (excessive use of technology) positively correlate with negative psychological effects, such as lower perceived locus of control, increased social interaction anxiety, exaggerated materialism, and an excessive need for touch (Lee, Chang, Lin, & Cheng, 2014).

The ramifications of this major technology-driven cultural shift are clear. If left unchecked, technostress-induced distraction, disconnection from the physical, emotional, tangible world, loss of boredom and daydreaming, and the dysregulation of sleep circadian rhythms, in combination can overwhelm our coping mechanisms and induce clinical levels of anxiety, stress, and depression, as well as contribute to systemic inflammation and dysregulation of the HPA axis, and catalyze the development of chronic illness.

At the same time, the incredible flexibility and rapid development and evolution of information technology could help us to find answers to these emerging problems. When combined with evolutionary thinking, technology can be shaped to optimize human performance and health. Despite the pessimistic view presented in this chapter, there is actually much to be optimistic about. Already, there is a growing wave of new apps, devices, and programs that harness technology for human betterment. Now one can wear a daily step counter, connect to a sleep tracker at night, and download a nutrition app on the smart phone, all to optimize these health variables. The open source, embed nature of the emerging sharing economy holds promise for support from social groups and community, and even a new ecology of choices of increasing efficiency and convenience distributed across the globe. Airbnb and Uber are two examples of information-technology-driven companies that have integrated themselves into the fabric of local and international travel. Academic organizations such as the Ancestral Health Society and the Evolution Institute, academic journals such as the *Journal of Evolution and Health* and *Evolution, Medicine, and Public Health*, and the plethora of personal and commercial websites devoted to topics grounded in evolutionary mismatch (often identified by the words “Ancestral,” “Paleo,” or “Primal”) are all testaments to the growing use of information technology and social institutions to leverage health and wellness.

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