The Great Mismatch

PAUL R. EHRLICH AND DANIEL T. BLUMSTEIN

We live in an extraordinary time where many of our behavioral, morphological, physiological traits and developmental pathways—honed by many generations of natural selection—are suddenly no longer beneficial. Indeed, these adaptations may be deleterious in our current, highly industrialized and human-modified environments. A foundational insight from evolutionary medicine is that "modern epidemics are most likely to arise from the mismatch between physiological design of our bodies and novel aspects of our environment" (Nesse and Williams 1998: 93). In the present article, we suggest that. although there have been vast increases for humanity in the usual metrics of health since hunter–gatherer days in the form of, for example, longer life expectancy and lower child mortality, not all trends are in the same direction. Mismatches are hiding in plain sight, creating epidemics that cause immense human suffering and expense; a more holistic functional perspective can help us identify them and, in doing so, improve individual and public health.

Scientists interested in evolutionary medicine have examined the problems related to bringing hunter–gatherer genomes into a McDonald's environment. Initial efforts, quite naturally, were focused on changes in the chemical constitutions of human diets (Leonard 2008). But the environmental changes we have made go far beyond the agricultural revolution to urbanization, subsequent industrialization, and the widespread creation of novel chemicals and pollutants. Together, these changes not only have decimated Earth's biota but have entrained a multidimensional human health epidemic whose causes and serious consequences have yet to be properly recognized, because to recognize it, we must adopt a broad, integrative view. Such a holistic approach contrasts with the culture of extreme specialization that has led to some of our recent biomedical advances. Without stepping back and asking questions about the historical function of traits, we fear that, in future, some such advances will be stifled.

Consider the jaw. Jaws have been largely isolated from physicians' concerns with the rest of the body and are thought to be the preserve of an entirely different type of caregiver—dentists, who have their own schools, traditions, and techniques. The hunter–gatherer–industrial mismatch in the nutritional content in food have been thoroughly studied by medical scientists and brought to the public's attention in endless debates and books about sugars, fats, gluten, obesity, diabetes, Paleo diets, and on and on. But nary a word about the mismatch of jaws with the consistency or "chewability" of foods (e.g., Nesse et al. 2010, Stearns 2012, Grunspan et al. 2018). We're urged to exercise virtually every skeletal muscle in our body—use it or lose it—except our jaw muscles and tongues. A lack of exercise of our jaw muscles, a result of diminished nursing and weaning to a softer, more liquid diet, has contributed to a shrinkage of human jaws (Lieberman et al. 2004, Lieberman 2013) and the resultant plague of malocclusion (crooked teeth) and braces (Kahn and Ehrlich 2018).

The difference in chewing environment is only one factor in this now well-documented trend of declining jaw size, primarily in developed countries (e.g., Mohlin et al. 1978). Another is moving indoors, where allergens are concentrated, leading to children (especially those in communal child care) to have stuffy noses, which, in turn, result in mouth-breathing and poor oral posture (Kahn and Wong 2016), which disrupts proper jaw development (Harvold et al. 1981) and often generates a narrowed airway and sleep apnea (Harari et al. 2010). The latter, frequently exacerbated by orthodontic cosmetic treatment, is the most serious aspect of the jaws epidemic and is increasingly treated with CPAP machines. Sleep deprivation is an important chronic stressor (Sapolsky 2004), and being regularly awakened in the middle of the night choking (as happens with sleep apnea) presumably also is. Stress makes us much more susceptible to disease, although details of degree and mechanisms remain debatable (Cohen et al. 2007). As was stated in one review, "Stress is a critical crosscutting process that . . . represents modifiable variance in the etiology of disease, affects nearly every behavior that contributes to good or bad health outcomes, and has direct effects on all or most bodily systems and can thereby contribute to developing health problems as well" (Dougall and Baum 2011: 69). In 2012, for the first time, research showed that the effects of psychological stress on the body's ability to regulate inflammation can promote the development and progression of disease (Cohen et al. 2012).

Other mismatches are causing obvious health epidemics that, like the jaws epidemic, have not been given enough joint attention by evolutionary biologists and physicians, and at least one mismatch threatens life as we know it.

It has been estimated that half the people in developed nations are sleep deprived, and the World Health Organization has declared a sleep loss epidemic (Walker 2017). We sleep in situations very different from the circumstances under which we evolved—artificial lighting is nearly ubiquitous—and, as was described above, sleep apnea interferes with quality sleep. Sleep loss contributes to health

problems—from cardiovascular disease, diabetes, immune-system damage, obesity, mental health, and memory loss to death on the highway (Max 2010). Sleep deprivation's influence on your immune system can more than double your risk of developing cancer (Walker 2017).

But the unhappy health consequences of moving indoors in the industrialized world extend beyond shrinking jaws and sleep deprivation. It has also had negative effects on human eyes. People in some parts of the world have been becoming more and more myopic (Grosvenor 2003). It has long been unclear (Morgan et al. 1975) whether this epidemic of nearsightedness (Park and Congdon 2004) is caused by light differences between indoors and outdoors or by kids inside having less chance to focus their eyes on distant vistas. What *is* clear is that the cause is largely environmental, a part of the great mismatch (Dolgin 2015).

The massive and rapid environmental change from hunting and gathering to industrialization created mismatches that can seriously threaten the persistence of civilization. Industrial society has soaked the entire Earth in toxic chemicals, many of which are hormone mimics (e.g., Beyer and Biziuk 2009), as well as radiation and electromagnetic fields. Bringing our hunter–gatherer genomes into this new industrial environment seems to be causing a rapid decline in human sperm counts (Horan et al. 2017) and may be involved in increasing certain cancers (Irigaray et al. 2007, Pellegriti et al. 2013)—not just in human beings but in wildlife as well (Giraudeau et al. 2018). The new environment also contains trillions of microscopic plastic fragments that become coated with persistent organic pollutants (Andrady 2011) that enter aquatic food chains and can pass through the human blood–brain barrier (Hollman et al. 2013). In short, there is evidence that a direct consequence of industrialization is the dumbing down humanity (Muir and Zegarac 2001, Zeeman 1996, Stein et al. 2002, Williams 2005).

Therefore, Paleolithic genomes interacting with today's industrial environment produces not so bright people, who are often sleep derived and who live in exceptionally large groups with exceptionally potent weapons. Human culture largely evolved in small societies of 50–150 individuals (Dunbar 1993, Ehrlich 2000, Kristensen et al. 2017). The cultural evolution of those small-group animals as they began to live in groups of millions and billions was very slow in areas such as how to treat other members of their species, creating an extremely dangerous mismatch with the cultural evolution of weapon technologies. Modern military weapons are designed to be weapons of mass destruction. Industrialization therefore produced the capability of primates to take their Stone Age aggressive activities far beyond what was possible in a hunter–gatherer group, hugely expanding the number of potential targets, and to enable decision-makers to accidentally (or deliberately) destroy civilization itself (Kristensen et al. 2017).

However, all is not dark. The great mismatch offers unprecedented opportunities, because these mismatches are lying around in plain sight, waiting to be properly identified and addressed. Addressing them requires interdisciplinary collaborations of ecologists and evolutionary biologists, physicians and public health experts, and social psychologists and political scientists. And, importantly, the very same cultural evolution that created these problems will be required to solve them. Against that grim background, the good news is that people can, to a degree, directly protect themselves and especially their children from some of the serious impacts. Only social action is likely to reduce the threats of climate change, the sixth mass extinction, or nuclear war. But we can have some control over the chewability of our children's diets, the amount of time they spend outdoors as opposed to inside playing computer games, their sleep hours, and the like. Cultural evolution can start at home.

Acknowledgments

We thank Joan Diamond, Barbara Natterson-Horowitz, and Kirk Smith for helpful comments.

References cited

Andrady AL. 2009. Microplastics in the marine environment. Marine Pollution Bulletin 62: 1596–1605.

Beyer A, Biziuk M. 2009. Environmental fate and global distribution of polychlorinated biphenyls. Pages 137–158 in Reviews of Environmental Contamination and Toxicology, vol. 201. Springer.

Cohen S, Janicki-Deverts D, Doyle WJ, Miller GE, Frank E, Rabin BS, Turner RB. 2012. Chronic stress, glucocorticoid receptor resistance, inflammation, and disease risk. Proceedings of the National Academy of Sciences 109: 5995–5999.

Cohen S, Janicki-Deverts D, Miller GE. 2007. Psychological stress and disease. Journal of the American Medical Association 298: 1685–1687.

Dolgin E. 2015. The myopia boom. Nature 519: 276.

Dougall AL, Baum A. 2011. Stress, health, and illness. Pages 53–78 in Baum A, Revenson TA, and Singer J (eds). Handbook of Health Psychology, vol. 2. Psychology Press

Dunbar RIM. 1993. Coevolution of neocortical size, group size and language in humans. Behavioral and Brain Science 16: 681–735.

Ehrlich PR. 2000. Human Natures: Genes, Cultures, and the Human Prospect. Island Press.

Giraudeau M, Sepp T, Ujvari B, Ewald PW, Thomas F. 2018. Human activities might influence oncogenic processes in wild animal populations. Nature Ecology and Evolution 2: 1065–1070.

Grosvenor T. 2003. Why is there an epidemic of myopia? Clinical and Experimental Optometry 86: 273–275.

Grunspan DZ, Nesse RM, Barnes ME, Brownell S. 2018. Core principles of evolutionary medicine: A Delphi study. Evolution, Medicine and Public Health 1: 13–33

Harari D, Redlich M, Miri S, Hamud T, Gross M. 2010. The effect of mouth breathing versus nasal breathing on dentofacial and craniofacial development in orthodontic patients. Laryngoscope 120: 2089–2093.

Harvold EP, Tomer BS, Vargervik K, Chierici G. 1981. Primate experiments on oral respiration. American Journal of Orthodotics 79: 159–172.

Hollman PC, Bouwmeester H, Peters RJB. 2013. Microplastics in Aquatic Food Chain: Sources, Measurement, Occurrence and Potential health risks. Rikilt-Institute of Food Safety. Report no. 2013.003.

Horan TS, Marre A, Hassold T, Lawson C, Hunt PA. 2017. Germline and reproductive tract effects intensify in male mice with successive

generations of estrogenic exposure. PLOS Genetics 13 (art. e1006885).

Irigaray P, Newby J, Clapp R, Hardell L, Howard V, Montagnier L, Epstein S, Belpomme D. 2007. Lifestyle-related factors and environmental agents causing cancer: an overview. Biomedical Pharmacotherapy 61:640–658.

Kahn S, Ehrlich PR. 2018. Jaws: The Story of a Hidden Epidemic. Stanford University Press.

Kahn S, Wong S. 2016. GOPex: Good Oral Posture Exercises. Self.

Kristensen HM, McKinzie M, Postol TA. 2017. How US nuclear force modernization is undermining strategic stability: The burst-height compensating super-fuze. Bulletin of Atomic Scientists https://thebulletin.org/2017/03/how-us-nuclear-force-modernization-is-undermining-strategic-stability-the-burst-height-compensating-super-fuze/.

Leonard WR. 2008. Lifestyle, diet, and disease: comparative perspectives on the determinants of chronic health risks. Pages 265–276 in Stearns SC, Koella JC (eds.), Evolution in Health and Disease, 2nd ed. Oxford University Press.

Lieberman D. 2013. The Story of the Human Body: Evolution, Health and Disease. Penguin.

Lieberman DE, Krovitz GE, Yates FW, Devlin M, Claire MS. 2004. Effects of food processing on masticatory strain and craniofacial growth in a retrognathic face. Journal of Human Evolution 46: 655–677.

Mohlin B, Sagne S, Thilander B. 1978. The frequency of malocclusion and the craniofacial morphology in a medieval population in Southern Sweden. Ossa 5: 57–84.

Morgan R, Speakman J, Grimshaw S. Inuit myopia: An environmentally induced "epidemic"? Canadian Medical Association Journal 112: 575.

Muir T, Zegarac M. 2011. Societal costs of exposure to toxic substances: economic and health costs of four case studies that are candidates for environmental causation. Environmental Health Perspectives 109: 885.

Nesse RM, Bergstrom CT, Ellison PT, Flier JS, Gluckman P, Govindaraju DR, Niethammer D, Omenn GS, Perlman RL, Schwartz MD. 2010. Making evolutionary biology a basic science for medicine. Proceedings of the National Academy of Sciences 107: 1800–1807.

Nesse RM, Williams GC. 1998. Evolution and the origins of disease. Scientific American 279: 86–93.

Max DT. 2010. The secrets of sleep. National Geographic, https://www.nationalgeographic.com/magazine/2010/05/sleep/

Park D, Congdon N. 2004. Evidence for an "epidemic" of myopia. Annals of the Academy of Medicine Singapore 33:21–26.

Pellegriti G, Frasca F, Regalbuto C, Squatrito S, Vigneri R. 2013. Worldwide increasing incidence of thyroid cancer: Update on epidemiology and risk factors. Journal of Cancer Epidemiology 2013:965212

Sapolsky RM. 2004. Why Zebras Don't Get Ulcers, 3rd ed. Holt.

Stearns SC. 2012. Evolutionary medicine: Its scope, interest and potential. Proceedings of the Royal Society B 279: 4305–4321.

Stein J, Schettler T, Wallinga D, Valenti M. 2002. In harm's way: Toxic threats to child development. Journal of Developental Behavioral Pediatrics 23: S13–S22.

Walker M. 2017. Why We Sleep: Unlocking the Power of Sleep and Dreams. Scribner.

Williams F. 2005. Toxic breast milk. New York Times. Available: http://www.nytimes.com/2005/01/09/magazine/09TOXIC

Zeeman M. 1996. Our stolen future: Are we threatening our fertility, intelligence, and survival? A scientific detective story. BioScience 46:542–546.

Paul R. Ehrlich (pre@stanford.edu) is affiliated with the Department of Biology at Stanford University, in California. Daniel T. Blumstein (marmots@ucla.edu) is affiliated with the Department of Ecology and Evolutionary Biology at the University of California, Los Angeles.

doi:10.1093/biosci/biy110