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Life and death: Toward a human biology of water

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> "We were root and berry owners, not water owners. We were owners of thirst and owners of hunger. We travelled to places with water roots. You dig and dig in the hard ground for water. You follow the vine down, when you reach the roots, many are bitter … The babies sucked their mothers dry … When thirst was destroying us, we visited our relatives at a place called G/am where there was always water … My father wanted me to marry for water, to marry a girl whose family were owners of G/am waterhole."
> ≠Oma, a member of Ju'hoansi. Quote from the John Marshall archive video from the Smithsonian's Human Studies Film Archives: https://www.smithsonianmag.com/videos/category/arts-culture/the-juhoansi-tribe-in-action/ and https://www.der.org/kalfam/part-1-transcript.html

1 | TOWARD A HUMAN BIOLOGY OF WATER

Water is an essential nutrient for life (Jequier & Constant, 2010). Given that the human body is ~60% water and can survive only a few days without it, this seems an obvious point. The basic story of human evolution itself is told as one of humans adapting to drier conditions and water insecurity (Finlayson, 2014; Potts, 1998; Scholz et al., 2007). Changes in body form between *Australopithecus* and *Homo erectus*, for example, increased body surface area to allow for greater heat dissipation and reducing solar radiation thereby reducing water needs by 15%-18% (Wheeler, 1993). Anatomically modern humans display many adaptations to water scarcity genetically through phenotypic changes to skin color, hair form, external nose shape, body shape and behaviorally through diets, activity pattern shifting to minimize heat loss or maximize heat loss and conserve water (Hanna & Brown, 1983; Jablonski, 2004; Lieberman, 2015; Moran, 2018). To give but one example, humans have also solved the problem of dirty water repeatedly innovating cultural practices to render it safe through fermentation (Arthur, 2014; Harner, 1984; Mcclatchey & Reedy, 2010). When the human body is dehydrated, liquids with low percentages of alcohol (1%-2% alcohol) can be as hydrating as nonalcoholic fluid—demonstrating how humans adapt physiologically to reach body water homeostasis (Hobson & Maughan, 2010; Shirreffs & Maughan, 1997).

The question of how humans can and do continue to adapt to water problems—or fail to do so—is extremely timely. Climate change means rainfall unpredictability, increased frequency of droughts, more flooding that brings contaminated water, and hotter temperatures that increase water needs and raise risks of dehydration, heat stroke, and other illnesses (Kenney, Craighead, & Alexander, 2014; Rosinger, 2015; Steffen et al., 2018). The rising commodification of safe water also means that it is increasingly scarce and costly for consumers (Pacheco-Vega, 2019). Aging infrastructures globally and domestically are adding to the challenge. Nowhere has this constellation of such factors been more evident than in the recent megacity water crises of Cape Town, South Africa in 2017-2018 and Chennai, India in 2019.

Water insecurity is an emerging analytic construct that human biologists are deploying to capture this experience at the local level, defined as insufficient and uncertain access to adequate safe water for an active and healthy lifestyle (Jepson, Wutich, Collins, Boateng, & Young, 2017; Young et al., 2019). Prior studies (by biocultural anthropologists in particular) suggest direct connections between water insecurity measures and many aspects of human biology, including elevated diarrhea (Hadley & Freeman, 2016), dehydration (Rosinger, 2018), blood pressure (Brewis, Choudhary, & Wutich, 2019), physical trauma (Geere, Cortobius, Geere, Hammer, & Hunter, 2018), hunger (Wutich & Brewis, 2014), and mental health-related stress (Brewis et al., 2019; Stevenson et al., 2012; Wutich & Ragsdale, 2008).

The field of human biology, however, has been generally quiet on a *central* role of water in the explanation of health and human variation. Classic studies provide insights into human adaptation to different thermic and water environments (Adolph, 1947; Hanna & Brown, 1983; Jablonski, 2004; Wyndham et al., 1964,b), and field research on reproductive ecology provide insights on the implications of human adaptability in arid and highly seasonal subsistence communities (Bailey et al., 1992; Ellison & Valeggia, 2005; Leslie & Fry, 1989; Panter-Brick, Lotstein, & Ellison, 1993). But, as yet, there has been no unifying effort to bring the study of water to human biology. This special issue is a step in that direction.

This emerging framework of the "*human biology of water*" we present here recognizes that access and use of water extends into every domain of human biology and health—nutrition, stress, development, reproduction, lactation, growth, infectious and chronic disease morbidity, mortality, life history, adaptation, physiology, and behavior. That is, the quantity and quality of our water are woven into the intersections between human health, culture, and human biology, just as they are for food (Wutich & Brewis, 2014). As the papers in this special issue show, there are many different theoretical entry points, and many different levels of analysis that can be engaged to ask the same basic question: *How does variation in access to clean water affect health and human biology, and in turn, how do humans adapt to these conditions, further affecting health?*

To understand who is most at risk of water scarcity, global figures give us some indications. In 2015, 11% of the world's population had no access to even the most basic drinking water services, defined as improved water within 30 minutes round-trip of the household (WHO and UNICEF, 2017). Those without services are those already vulnerable politically and socioeconomically. And more than a billion people living in urban areas globally face the challenges of intermittency and contamination of water supplies (Adane, Mengistie, Medhin, Kloos, & Mulat, 2017; Cinner et al., 2018; Elliott et al., 2017; McDonald et al., 2011; McDonald et al., 2014). A recent modeling analysis indicates that by 2050 up to 4.5 billion people globally will face water pollution and water shortages, with the worst impacts in Africa and South Asia (Chaplin-Kramer et al., 2019). Fundamentally, because water insecurity intersects so acutely with poverty, the goal of access to sufficient safe water for all is not just viewed as a practical challenge to meet, but fundamental to basic human rights and sustainable development goal SDG 6.2.

A key point that emerges in this special issue is that the challenges of coping with water are certainly—but not only—relevant to lower and middle-income countries, however. Within advanced economies, household water insecurity is a mostly hidden and rapidly growing challenge, intersecting with low income and/or minority status in ways that can significantly worsen health and well-being (Doyle, Kindness, Realbird, Eggers, & Camper, 2018; Kruger et al., 2017). For example, adults living in mobile home units often have less reliable access to water services (Pierce & Gonzalez, 2016), which can shift consumption of tap to bottled water (Rosinger, Herrick, Wutich, Yoder, & Ogden, 2018), lead to restriction of plain intake, or consumption of worse, sugary beverages (Javidi & Pierce, 2018; Rosinger, Bethancourt, & Francis, 2019).

In this special issue, we step off from this very basic understanding that water insecurity worsens health, to open into a more dynamic, wider view of water in human biology. We begin with some basic questions that must set the basis for understanding how humans manage water insecurity: How much water do humans actually need? For example, do the recommendations of 50 L a day per person (Gleick, 1996) as a basic minimum amount for all water needs make biocultural sense? We open with Swanson and Pontzer's (2020, this issue) review which examines a key aspect of human water needs—those of water turnover physiology, or the amount of water used on a daily basis. In their review, they demonstrate that water turnover across Western and small-scale populations is driven largely by environmental and lifestyle differences. Ultimately, humans are flexible in their ability to deal with these different environmental conditions, but they highlight how climate change may have drastic consequences in this domain.

This key point is expanded by Rosinger (2020, this issue) in his analysis of human variation in water intake as he demonstrates that water intake is quite variable even in a water secure location like the United States. He posits that this may be driven by early-life experiences as well as life course changes in diseases and health behaviors. Early-life experiences like water restriction may shape water needs as well as homeostatic set points related to thirst. The take-home message being that to understand variation in water needs, we must examine these questions from an evolutionary, developmental origins of health and disease, and life course perspectives because these experiences may have important health consequences related to body size and cardiovascular health.

Water security is not just about adequacy of water, but also its safety. Schell (2020, this issue) charts how water moves industrial contamination to human consumption on the United States-Canada border, in a manner that focuses environmental injustice on Akwesasne Mohawk Nation lands. The issue of how water and pollutants in water become embodied is an issue of increasing public health concern. And then what is culturally appropriate to eat, like fish recommendations, may be modifiable to an extent that is allowed within communities. What damages is not just bad water chemistry, but also what people *believe* is in water. As Huock et al. (2020, this issue) show, building a new water treatment plant on the Galapagos can improve access to cleaner water and decrease the risk of urinary and gastrointestinal infections. However, shifting from a culture of drinking bottled water to relying on tap water is hard to reverse without addressing perceptions of tap water safety.

In a very different set of conditions but speaking to the same point, Adams et al. (2020, this issue) work on water in urban West African cities demonstrates that these are “built deserts” for many living in them. Water is often far from dwellings, is heavy, and must be carried far over uneven and slippery surfaces. For those millions globally who must fetch their water from off-plot sources, this work shows the dreadful risks this poses to girls and women in particular. This clarifies that a human biology of water must—at its core—recognize that many of the physical and psychological vulnerabilities water creates are often highly gendered, to the disadvantage of women.

Water contamination itself leads to some ~2 million premature deaths each year (Landrigan et al., 2017). But, biological effects of water can extend far beyond this to many areas that we don't yet fully understand, like reshaping our microbiome. Piperata et al. (2020, this issue) herein examine the water quality of water insecure households in Nicaragua. They find that households that have water with a high pathogenic load leads to increased risk of infections. However, what is striking and novel is that they are able to link those households with a high pathogenic load in their water supply to significantly different microbiome compositions with lower biodiversity of gut microbiota of children. The implications of gut microbiome changes are still being understood but are likely crucial to many mechanisms related to growth, health, and disease risk.

Using the case of Ecuador, Thompson et al. (2020, this issue) then use a syndemic (or synergistic epidemic) approach to test how water access and quality alongside food security are associated with a dual burden of overweight and chronic disease alongside underweight and infectious disease risk. This frame helps conceptualize a nonlinear epidemiological transition as populations get access to market foods and some access to improved water, but both over- and undernutrition coexist alongside infectious and chronic disease. The role of water in the dual burden of disease has rarely been examined and while not significant on its own in predicting the dual burden it was jointly associated when examining it with food insecurity. Clearly, to understand the dual burden of disease, both food and water must be examined jointly as studying only one variable misses critical information.

This reminds us that water and food are intimately linked, but one key immediate challenge and point of entry for a human biology of water is its constant intersection with poverty and other forms of low power. Brewis et al. (2020, this issue) using data from 27 low- and middle-income countries clearly show that food and water insecurities often—perhaps always—co-occur. The mechanisms linking the two need to be understood to be able to address either adequately. They propose that it is more likely that water insecurity leads to food insecurity than the other way around. Perhaps for no one is this relationship more important than for mothers and infants. Schuster et al. (2020, this issue) drill into mother's words from the same cross-cultural data set to explicate just one such mechanism, the role of low quality water in shaping—and particularly limiting—infant and childhood feeding practices. Water is critical to human growth and infant and childhood feeding practices, yet we have relatively little data examining how water insecurity may drive the decisions that women and caregivers make regarding how to feed their babies and infants. And moreover, it is critical to understand how water's entanglement in feeding practices is affecting their risk of dehydration and growth.

Finally, Dinkel et al. (2020, this issue) examine alternate pathways, between water insecurity and sanitation insecurity—another correlate of living with low resources. Using biomarker data from Tsimane' horticulturalists in Bolivia, they show that provision of safe water (by boiling) is *not* necessarily the primary factor in reducing infectious disease risk (measured via white blood and eosinophil counts). Rather, the key factor is open vs latrine based defecation. There is certainly much work to do yet to unpack all these interconnections between

TABLE 1 Potential questions to explore for a human biology of water

Emerging domains to consider	Examples of questions	Suggestive references
Water, adaptation, life history, and development	What are the later life consequences of water restriction during early life? Does early life water restriction change thirst set points for detecting dehydration?	Ross & Desai, 2005; Rosinger, 2020, this issue
	How does dehydration affect breast-milk composition in humans? Does this pattern into child development? Do infants compensate in any way with changes in milk composition, such as by changing feeding styles?	Bentley, 1998; Ballard & Morrow, 2013; Quinn, Largado, Power, & Kuzawa, 2012
	Are *minimum* water intake allocations, for example, 50 L/person/day, bioculturally adequate? What about recommendations for *optimal* hydration across different environments?	Gleick, 1996; Institute of Medicine, 2004; Swanson & Pontzer, 2020, this issue; Rosinger, 2020, this issue
	What mechanisms connect the experience of water insecurity to infant and child feeding, nutrition, and growth?	Collins et al., 2019; Schuster et al., 2020, this issue
	How do water practices and water quality affect the gut microbiome?	Piperata et al., 2020, this issue
	How are exposures to water-borne plastics (and microplastics) and other contaminants affecting basic human physiology in ways that reshape menarcheal age, conception risk, obesity, or inflammation?	Schell, 2020, this issue
Water and chronic disease risk	How are the physical risks associated with household exposures to water insecurity reflecting broader injustices, environmental or otherwise?	Balazs & Ray, 2014; Cooper-Vince et al., 2018; Adams et al., 2020, this issue
	What biocultural mechanisms link household water insecurity to elevated risks of overnutrition/obesity as well as other chronic diseases, like cardiovascular disease, diabetes, and chronic kidney disease?	Thompson et al., 2020, this issue; Rosinger et al., 2019; Rosinger, 2020, this issue
	How does water worry in itself lead to chronic disease? How do power relations shape who is most affected?	Wutich & Ragsdale, 2008; Brewis et al., 2019; Wutich, 2020, this issue
Managing household water insecurity	How do culturally-shaped hydration strategies and water restriction practices shape infectious disease risk (eg, child diarrhea)?	Rosinger & Tanner, 2015; Nichter, 1985, 1988; Huock et al., 2020, this issue
	How are the cognitive, social, and physical drains of water-fetching or other daily demands of water insecurity embodied?	Gomez, Perdiguero, & Sanz, 2019; Geere et al., 2018; Adams et al., 2020, this issue
	Do local (eg, interhousehold) water sharing systems worsen or improve mental/physical health?	Wutich et al., 2020, this issue; Brewis et al., 2019; Stoler et al., 2019
Biocultural contributions to improve water interventions	What are the implications of co-occurring household water insecurity with other resource insecurities? When do they act syndemically? Which trade-offs seem to help people manage best? Does this suggest leverage points for successful interventions?	Wutich & Brewis, 2014; Brewis et al., 2019; Brewis et al., 2020, this issue; Dinkel et al., 2020, this issue; Thompson et al., 2020, this issue
	Under what conditions do improvements in water (fail to) improve objective biomarkers of health and disease?	Pickering et al., 2019; Dinkel et al., 2020, this issue; Huock et al., 2020, this issue; Wutich, 2020, this issue
	How might water insecurity interventions also alleviate trauma risk for women, including intimate partner violence?	Kevany & Huisingh, 2013; Stevenson et al., 2012; Adams et al., 2020, this issue

human biology and water, food, sanitation and other forms of material poverty. This line of research has considerable implications for the translation of our human biology to improving health around the globe. This is one more basic reason a fully-formed human biology of water is important to our field.

Wutich's Pearl lecture (2020, this issue) from the 2019 Plenary at the Human Biology Association meetings makes the compelling case for why it *needs* to be human biologists who take the lead in this crucial work. As she points out, humans employ an array of technological and social (eg, sharing) strategies at an institutional level to deal with water scarcity. As many of the factors leading to disparities in health and access to water are structural in nature, the work that human biologists do can help inform policies that can address these social determinants of health. For example, understanding how maternal hydration practices are linked (potentially) to birth outcomes similar to food, may lead to increased access to clean water for women and children who live in areas dealing with water quality problems. As water issues worsen in both the global north and south, the time for human biologists to engage with one of the most immediate and stressful aspects in many people's lives—sufficient, safe water—is right now.

2 | LOOKING FORWARD: KEY QUESTIONS, NEW METHODS

So what can a more fully formed human biology of water look like, moving ahead? Here we share a set of questions to move that conversation forward (Table 1). These are suggested by the offerings in this volume, from conversations we had during and after the 2019 Human Biology Association plenary session that this special issue draws on, and our own readings of the wider literature. The list is necessarily incomplete and biased to our preferences. But, we hope it provides a starting point for a growing dialogue about how human biologists are particularly well-positioned to speak to how water, health, and human biology intersect, and in myriad ways.

Of course, we need the right tools to answer all these questions, particularly with regard to measuring or otherwise describing water in ways that are valid and reliable and hence comparable. To that end, an up-to-date and comprehensive "toolkit" by Wutich et al. (2020, this issue) helps address this gap. Drawing from an array of different fields and disciplines, including physiology, nutrition, social science, and environmental science, we hope this final piece provides the means for all human biologists to engage water in their research—whether as a central concern or as a corollary to other foci in their work.

We hope the thought and work reflected in this special issue in its entirety, along with these ideas for future directions, and the toolkit outlining many ways that water can be measured or tested, opens the door for water to be embraced as central to human biology's agenda. Water is both life and death, and almost any aspect of human biological research will benefit from considering it.

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