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The Travels of Protean Biologies

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We live in an era in which our anxieties are kept well stoked by the media. The effects of climate change are becoming increasingly apparent as fire and water rage out of control in numerous places and food production has dropped catastrophically. In June 2017 in the Antarctic the Larson C ice shelf cracked, creating an independent iceberg with a size equivalent to Wales, or to Prince Edward Island, Canada. This imminent major planetary event had been carefully monitored for over a decade with some trepidation, and sadly, further even more such events are in store.

As of September 2016, we have been living in the Anthropocene. Designation of this new epoch was initiated in the 1980s by the ecologist Eugene Stoermer, and taken up again in 2000 by the atmospheric chemist and Nobel Laureate, Paul Crutzen at a meeting in Mexico. By 2013 over 200 peer-reviewed articles had been published about the looming, epochal transition, and Elsevier had launched a journal titled *Anthropocene,* followed by an e-journal *Elementa: Science of the Anthropocene.* The historian Dipesh Chakrabarty points out the peculiarity of this new epoch: "the Anthropocene spells the collapse of the Kantian distinction between natural history and human history". Thus we are now in the first geological epoch in which the force transforming the globe – human initiated activity – is supposedly self-conscious about what it is doing, with profound implications for politics and the allocation of responsibility (2009: 3).

For a decade or more arguments have taken place as to whether the Neolithic revolution, or possibly even earlier changes brought about by humankind, evinced the beginning of the Anthropocene. The position of ecologist Erle Ellis (2015) and his colleagues is that the transition commenced 10,000 years ago when land clearance for agriculture and irrigation began to have a global effect on vast swaths of land. In recent centuries colonization has further reduced the biodiversity of the planet to a fraction of what it was formerly. Others argue that the industrial revolution that commenced in the late 1700s, epitomized by the steam engine, was *the* singular moment (Jórgensen and Jórgensen 2016). Humans have manufactured numerous mineral compounds, including more than 500 million metric tons of pure aluminium since World War 2, much of which has sedimented into earth's layers. Even more striking are "mineraloids" – glass and plastics – 300 million tons of which are made annually and are present everywhere on the earth's crust and in all the oceans. Since the 1950s nine billion tons of plastic have been created. Concrete, a rock of our own making, encases much of the globe today. Human detritus is ubiquitous, principally in the form of CO2, nitrogen fertilizer, pesticides, diesel fuel, and electronic trash and mineraloids that have accumulated as toxic waste around the globe.

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The environment – nature – is exhibiting all the signs of trauma, toxicity, and abuse usually associated with suffering human bodies. "Capitalistic ruins," as Anna Tsing puts it (2015), are all too evident in vast swaths of the globe. Joseph Masco argues that stress is "literally a planetary condition" and a state of human "uncalm" is normal (2015: 65). But geologists need hard evidence of an *irreversible* transition to identify a new epoch. Their decisions are pegged to a so-called 'golden spike' – a marker that appears in ice-cores, the oceans, lake sediments, and soils, where recognizable fossilized strata appear that can be hammered, sampled, and/or dug up. Such changes are known as a "time-rock unit."

Following three years of heated exchanges the notoriously conservative International Union of Geological Sciences convened a group of scholars in 2013 to determine if the Anthropocene should be officially recognized. In a recommendation presented to a Congress in Cape Town in 2016 they declared that this was indeed the case. Geologists had showed little opposition to the position that humans have replaced 'nature' as the dominant environmental force on earth, but as to when, *exactly*, this indelible event took place in order for it to be recognized as a valid geological turning point, caused dispute. The IGS eventually agreed that July 1945, the day when the first nuclear device was exploded, leaving rare isotopes of plutonium distributed all over the globe, including Antarctica and Greenland, constituted such a spike.

For more than a decade we have been living with another fundamental shift, one in the biological sciences known as the 'postgenomic' era. The human genome is no longer recognized as the origin of life but, rather, as 'reactive' to environments external and internal to the body. Moreover, the genome is inherently unstable. In other words, the very 'nature' of what it is to be human is being revised on the basis of accumulating knowledge brought to light while mapping the human genome, with enormous consequences for reflecting upon and understanding ourselves.

In what follows, I first discuss the bourgeoning field of molecular biology known as epigenetics. Research findings in this specialty permit certain insights into the impact of Anthropocenic environments on human health and illness. Rapidly expanding knowledge about the microbiome is then considered. It is widely acknowledged that bacteria and other microbial forms have had a greater influence on all living entities over the millennia than any other stimuli. My focus in this paper is on the protean biologies of the human microbiome composed primarily of bacterial genomes in abundance, in addition to the human genome. This microbiota, the ecological community of commensal, symbiotic and pathogenic microorganisms found in and on all multi-cellular organisms, supplement and complement other types of environmental stimuli that impact ceaselessly on human bodies. Recognition of environments as the driving force of human life, to which the activities of ubiquitous microbes are central, makes it abundantly evident that concepts of an individualized self and of clearly bounded human bodies are no longer tenable.

The implications of these findings for anthropological research as a whole will be summarized in conclusion.

Epigenetics and Canalization

Conrad Hal Waddington, characterized in the *Encyclopaedia Britannica* as an embryologist, geneticist, and philosopher of science, coined the term epigenetics. While teaching at Cambridge University he taught himself palaeontology and eventually became known as the founder of systems biology. Waddington initially argued (1940) that the new field would be limited to "the causal interactions between genes and their products which bring the phenotype into being." His position was influenced by the dawning realization of several researchers of his day that embryological development must inevitably involve networks of interactions among genes that form a complex integrated system, and that bifurcation of the subjects of genetics and embryology was a mistake. Waddington was trained in both fields; he had worked in Germany with the Nobel Laureate embryologist, Hans Spemann, and with the geneticist Thomas Hunt Morgan in California. He made 'development' central to his arguments specifically because of its double meaning: the growth of individuals and evolutionary change.

For Waddington, individual development denotes the set of conditions that enable what we now term 'multi-potent stem cells' to become differentiated to have specific functions within given tissues. Furthermore, an appreciation of what is today routinely accepted as critical developmental periods is embedded in Waddington's thinking. He also used the term development more generally to argue that genotypes and environments work together to produce phenotypes, and insisted that genes are responsible only for guiding "the mechanics of development."

In his book *Organisers and Genes* published in 1940, Waddington depicted "the epigenetic landscape" as a symbolic representation of the genetic regulation of developmental processes. The image is of a marble rolling down an undulating plateau in concert with other marbles, eventually coming to rest at the lowest points. The marble represents a developing egg and the gradual transformation of its cells into tissue types, the process of which is regulated by genes and their interactions with each other that modulate the manner in which the egg/ball is guided down the slopes with its numerous intersections (Fig. 1). Waddington's point was that development is 'canalized' – a process that 'buffers' the outcome of natural selection in order to produce replicable phenotypes regardless of

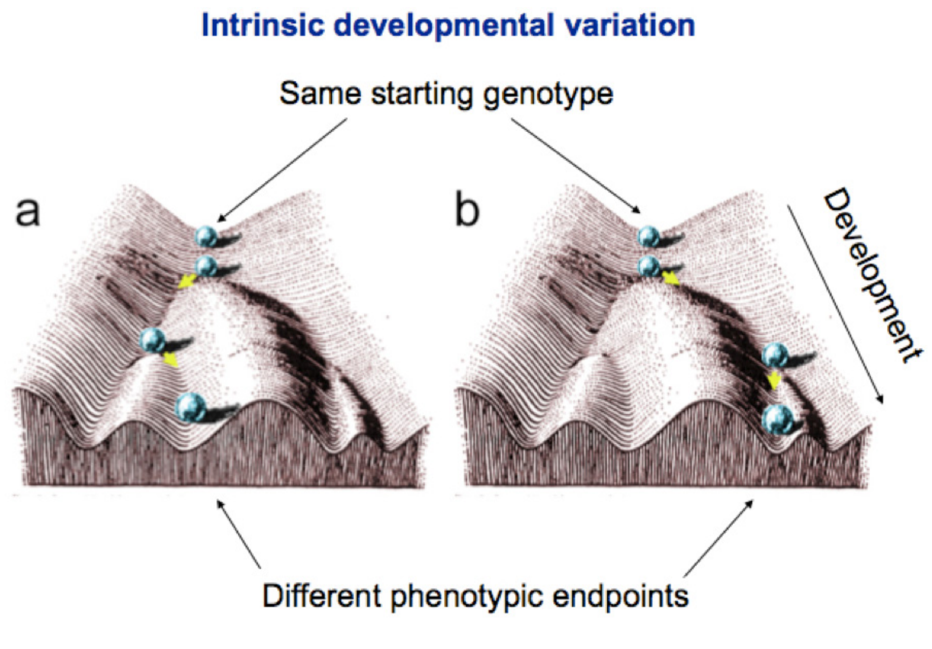

Figure 1. The Waddington Epigenetic Landscape

variability in both genotypes and the environment. He was insistent that genetic variation and phenotypic expression are not tightly coupled, thus allowing for environmental input into development. Waddington conceded that the metaphor of the epigenetic landscape had limitations (1940 92); nevertheless, this image is usually taken as the starting point for a genealogy of epigenetics.

Jablonka and Lamb note that Waddington's work essentially languished for the first three decades of its existence and one or two scientists even argued that it should be abandoned, but it survived to become molecularized in form. In the postgenomic era from the early years of the 21st century, the field has been thoroughly revitalized as one that focuses on "alternative developmental pathways, on developmental networks underlying stability and flexibility, and on the influence of environmental conditions on what happens in cells and organisms" (Jablonka and Lamb 2002: 89) – at both individual and population levels, one might add.

Epigenetics, frequently glossed as "over and above genetics," has expanded into an enormous field of inquiry that includes stem cell biology, cancer biology, investigations into genome instability, DNA repair, epigenetic epidemiology, and so on. The concept of environment, having been rendered essentially of no importance in hard line deterministic genetics, has been resuscitated in epigenetics to take on singular importance with respect to cell functioning, individual human development, and the biological embedding of individuals and their families in specific contexts.

The Reactive Genome

Richard Lewontin made clear more than a decade ago: "DNA is a dead molecule, among the most nonreactive, chemically inert molecules in the living world" and "DNA has no power to reproduce itself" (2001: 141). He points out: "an egg, before fertilization, contains a complete apparatus of production deposited there in the course of its cellular development" (ibid: 143). In order for genes to function they must be activated (switched on) and, when appropriate, deactivated (switched off) by means of complex processes bringing about differentiation that takes place at the cellular level throughout the life cycle, the process that Waddington depicted as 'canalization.'

Ramirez-Golgoechea (2013: 66) explains: "cellular differentiation is governed by the epigenetic landscape, a complex panorama of networks and feed-forward loops that determine whether or not stem cells go into a lineage. As a developmental process, epigenesis is highly context-specific, following a chronological and topological logic."

The epigenetic mechanism best researched to date is methylation, a process initiated by enzymes in which DNA sequences as such are not altered but one nucleotide alone, cytosine, is transformed, changing the nucleotide base thus rendering a portion of DNA inactive. Animal research has shown definitively that methylation modifications can be transmitted inter-generationally, and some findings strongly suggests that this is also the case among humans (Pembrey 2014), although certain researchers argue that this has not been absolutely established. It has been demonstrated recently that the epigenetic regulation of chromatin structure is of crucial importance in these processes (Lappé and Landecker 2015).This emerging knowledge makes clear that the task of the genome is to *respond* to environments from the moment of conception and throughout life. Genes no longer initiate and sustain life itself; on the contrary, we live with a 'reactive genome' (Gilbert 2003).

Genomic Hubris Laid Bare

Following the announcements in 2001 that the human genome had been mapped (which was not, strictly speaking, true; the human genome has never been completely sequenced (Aragon 2017), one journalist reported that it was like completing God's own jigsaw puzzle. Other journalists, however, were more sceptical. Some insisted that the map resembled a list of parts for a Boeing 747, but with no idea as to how the parts go together, and no knowledge of the principles of aeronautics. Furthermore, many surprises came to light, some of which scientists had already predicted prior to embarking on the HGP, but which hitherto had been ignored.

Mapping made it apparent that humans have approximately 20,000 genes, and not 100,000 as had been predicted. Numerous plants have many more genes than do humans, and the diminutive worm *C. elegans* has about the same number as ourselves. The size of a genome bears no relationship to its complexity, and the genome is not a template for the organism as a whole. Only approximately 1.2% of DNA segments or less code for proteins, and the remaining 98.8% was initially labelled disparagingly as "junk" (Carey 2015).

Although non-coding sections of the genome appeared to have no obvious function, and are frequently remnants of bacterial and viral genomes, they separate out the coding parts of the genome, thus inhibiting unwanted mutational changes during DNA transmission between generations. Moreover, numerous non-coding DNA sequences are highly conserved, implying that they have been present in genomes for hundreds of millions of years, suggesting that they influence evolutionary change. Furthermore, it is well established that the activities of non-coding RNA (ncRNA) comprise a comprehensive regulatory system that functions to create the "architecture" of organisms, without which chaos would reign. To this end, ncRNA profoundly affects the timing of processes that occur during development, including stem cell maintenance, cell proliferation, apoptosis (programmed cell death), the occurrence of cancer and other complex ailments (Mattick 2004).

These findings relate to the structure and function of the genome itself; over the past decade, the research of molecular epigeneticists has added further insights to this already complex picture. Scientists in the expanding subfield of behavioural epigenetics claim that they have tracked the molecular links that travel between 'nature and nurture,' thus providing sound evidence that nature/nurture is not divisible (Lutz and Tureki 2014). This assertion was based on research demonstrating how environmental stimuli and stressors originating both externally and internally to the body initiate trains of molecular activity that modify how DNA functions, often with lasting effects on human behaviour and wellbeing including, at times, increased mental illness and suicide rates (Labonté et al. 2012).

Environmental Epigenetics and Miniaturized Environments

Of direct interest to anthropologists is the sub-field of environmental epigenetics, a term used to cover investigations into topics as wide ranging as toxic exposures, malnutrition, and abuse. Disagreements among practitioners of this sub-discipline are evident, and the presumption that one or more teams of researchers represent the entire field is in error (Landecker and Panofsky 2013; Lock 2015).

Several researchers have described arguments made by environmental epigeneticists as "neo-Lamarckian." Although the belief was abandoned years ago that use or disuse of body parts brings about evolutionary change, certain investigators have proposed continually from

Lamarck's time that forces internal and external to the body, in addition to genes, contribute to the phenotype of the next generation, and possibly ensuing generations, a position supported by Waddington and, today, by a large number of environmental epigeneticists. Work with single celled organisms, nematodes, rodents, and primates has substantiated the inter-generational transmission of epigenetic marks, but some researchers remain less than confident about the evidence among humans, although others are convinced that this is indeed the case (Champagne 2008).

The assertion that multiple mechanisms of inheritance exist, and that variation in genomic sequences alone cannot account for phenotypic differences (Ramirez-Golcoechea 2013: 66-67) inevitably raises ontological concerns similar to those apparent in the days of Lamarck, regardless of the question of inter-generational inheritance. If the gene is no longer understood as the fundamental force of human life and is not "part physicist's atom and part Platonic soul," as the philosopher of science Evelyn Fox Keller put it (2000: 47), then assumptions about the relationship of nature with nurture and of genes with environment have to be confronted head on. Barry Barnes and John Dupré in their 2008 book *Genomes and What to Make of Them* use the term 'astrological genetics' to describe what they insist has been a fetishization of DNA that must now be overcome. Central to this new understanding is recognition, partly as a result of findings made while carrying out the human genome project, that genes, in and of themselves, although essential in the creation of the form and structure of life, determine very little indeed of their functioning (Lock in press).

Epigenetic researchers are usually careful to point out that the identification of mechanisms that transmit signals from social environments resulting in changes in DNA methylation have yet to be fully worked out, but it is agreed that epigenetic mechanisms including methylation refer to heritable changes in gene expression that do not involve changes to the underlying DNA sequence. It has been indubitably demonstrated that methylation (a highly conserved process found widely in both animal and plant worlds) functions so that any given genome is able to code for diversely stable phenotypes, as Waddington suggested. In other words, although every cell is 'multi-potential,' methylation brings about cell differentiation among, for example, what will become liver as opposed to neuronal cells. Methylation also determines whether an embryo bee will become a drone or a queen bee. Furthermore, methylation changes do not take place only *in utero* and early postpartum years, as was formerly believed, but continue throughout the life span (Meaney 2010).

An additional hypothesis that attracts environmental epigeneticists posits that DNA methylation and other related mechanisms have a second very important function, namely, that these processes are not solely the result of endogenous stimuli, but are also direct responses to environmental signals external to the body that modulate patterns of cellular activity. A substantial body of research of this kind can be found to be in existence (Cortessis et al. 2012, Feil and Fraga 2012). Three examples must suffice.

Intergenerational Transmission of Toxins

Based on many years of fieldwork that commenced in 2003 in Hanoi, Vietnam, the Danish anthropologist Tine Gammeltoft has documented the devastating effects on reproduction that persist more than 40 years after the war caused by the chemical defoliant Agent Orange (Gammeltoft 2014). The Vietnam War lasted from 1962 until 1971, during which time the

US military conducted an aerial defoliation program that was part of a 'forced urbanization' strategy designed to force peasants to leave the countryside, where they helped sustain the guerrillas, and move to the cities dominated by US forces. Nearly 20 million gallons of chemical herbicides and defoliants was sprayed onto Vietnam, eastern Laos, and parts of Cambodia, destroying all plant material in two days. In some areas, toxic concentrations in soil and water became hundreds of times greater than the levels considered safe in the United States.

Agent Orange contains the highly toxic chemical dioxin, known to have long-lasting effects on the environment and human tissue. Gammeltoft documents a widespread fear about the so-called 'dioxin gene,' widely believed by many people living in Vietnam today to be increasing in the population over time. It is estimated that at least three million citizens in Vietnam suffer from serious health problems due to exposure to defoliants, and the rate of severe congenital abnormalities in herbicide-exposed people is reckoned at 2.95 per cent higher than unexposed individuals (Gammeltoft 2014: 46). The mass media coverage has reported cases of third-generation Agent Orange victims, in which individuals exposed during the war have produced apparently healthy children whose grandchildren are born severely disabled. Animal research has shown that, following foetal exposure, dioxin re-programs epigenetic developmental processes, the effects of which may become manifest throughout life.

Vietnam was given membership in the World Trade Organization in 2007. One result of this was the heightened concern by the Vietnamese government about the international visibility of the health of the population as a whole. It was at this juncture that extensive use of ultrasonography was introduced – a political tool designed to ensure the birth of healthy children. One result has been that ultrasound is now used repeatedly during pregnancy as part of antenatal care, even though the Vietnam Ministry of Health does not recommend this practice (Gammeltoft 2014: 10-12). Making the decision to have an abortion if a deformity is detected by ultrasound is not easy. Many affected families think that abortion is an evil act. Furthermore, everyone involved knows that it can be difficult to assess the extent of the deformity from ultrasound images, although it is also the case that frequently it is all too evident. Some families, who were reluctant about abortion, but longing for a healthy child, are raising three or four children with deformities, the most common of which is hydrocephalus ('water on the brain') that causes severe retardation. A few women discover very late in a pregnancy that their foetus is not normal, and some opt for a late termination, making their doctors very perturbed (Gammeltoft 2014: 111-113).

Gammeltoft's moving interviews with affected families make it clear that many people choose not to entertain the idea that an anomalous foetus detected by ultrasound, or the birth of a horribly deformed child, is due to Agent Orange (Gammeltoft 2014: 77). They are all too well aware that the stigma attached to Agent Orange families ensures that finding marriage partners for healthy members of the family would be virtually impossible. They feel that it is better to claim publicly that the anomaly resulted from a cold that the mother had or the heavy work that she did while pregnant.

A range of severe illnesses are associated with dioxin exposure, including deadly cancers, Parkinson's disease, and Spina bifida, in addition to those associated specifically with pregnancy (Gammeltoft 2014: 55). Vietnamese researchers have reported these findings, but the official US position is that there is no conclusive evidence that herbicide spraying caused health problems among exposed civilians and their children. However, following extensive lobbying over many years, in 2014 the US Congress passed a five-year aid package of $21 million that amounted to a modest sum for each Vietnam veteran. These cases were settled out of court and no legal liability has ever been admitted (Gammeltoft 2014: 46-47). The official position to this day is that the government was in effect prodded into settling these legal suits and that there is no evidence whatsoever that Agent Orange caused harm, a position supported by its principle makers, Monsanto and Dow Chemical companies. Vietnam war-veterans whose children were born with severe birth defects, including hydrocephalus and spina bifida, have received no compensation (Gammeltoft 2014: 49).

In Vietnam, officials were reluctant to press complaints about Agent Orange because uppermost were concerns about the economy as a whole, notably a desire not to damage the marketing of numerous agricultural and aquacultural products made in Vietnam. In the mid-1990s, Vietnamese writers and artists finally began to express concern about Agent Orange, and eventually Vietnamese citizens filed a class action suit in the US District Court in New York that was abruptly dismissed. But demands for responsibility are increasingly being heard, spearheaded by nongovernmental organizations (Gammeltoft 2014: 44-46).

Malnutrition and Migration

Globally, nearly 2 million children die from malnutrition each year. Recent research has revealed remarkably interesting findings about biological differences between infants who suffer from marasmus (severe malnourishment) as opposed to kwashiorkor (severed protein-energy malnutrition with oedema (Forrester et al. 2012).This impressive study was carried out in Jamaica, commencing in 1962 and continued for 30 years; during this time over 1,100 infants with severe acute malnutrition were admitted to University Hospital, Kingston. It was found that those infants diagnosed with kwashiorkor had considerably higher birth weights than did infants diagnosed with marasmus. The authors concluded that mechanisms associated with physiological "plasticity" are operative in utero and that these children have distinctively different types of metabolism.

Of the two conditions, children more often die from kwashiorkor, associated with oedema, although less wasting takes place as compared to marasmus. Children diagnosed with marasmus do not become oedematous but endure much greater wasting of their flesh, although their survival rates are better than those of children with kwashiorkor. Researchers characterize marasmus as "metabolically thrifty" and kwashiorkor as "metabolically profligate." They propose that in the case of children with marasmus, when the maternal diet is low in nutrition, foetal metabolism in utero in effect anticipates a postnatal environment of scarcity, and low birth weights are assumed to be evidence of this process designed for survival. The authors argue that this finding provides the first direct evidence in humans in support of the fitness-enhancing effects in childhood of "anticipatory responses" in utero. Hence, the distinctly different phenotypes of children with kwashiorkor and marasmus are understood as the endpoints of epigenetic activity in utero on genotypes.

Nutritional epigenetics is a field attracting a great deal of attention in part because it is hoped that it will throw light on the so-called obesity epidemic currently affecting many countries, whether affluent or not. The same team that carried out the research reported above argues that growing evidence exists of "developmentally plastic processes" (Forrester et al. 2012) that, in addition to lifestyle and individual genotypes, contribute significantly to obesity. No claim is being made that such developmental pathways, in which methylation processes are involved, cause obesity directly, but that the risk of genetically predisposed individuals for developing obesity in later life is increased. Based on a hypothesis known as the "mismatch pathway," it is posited that "evolved adaptive responses of a developing organism to anticipate future adverse environments" can have maladaptive consequences if the environment is not what has been "biologically anticipated" (Gluckman and Hanson 2008: 124). In other words, if foetuses and young infants are exposed to nutritionally deprived diets, their bodies may be epigenetically prepared to deal with deprivation as they mature, as the marasmus study suggests, a situation that can cause havoc in energy-rich environments. In addition, maternal diabetes, maternal obesity, and infant overfeeding are associated with increased risk of obesity in adult life (Gluckman and Hanson 2008).

Clearly this account resembles the thrifty gene hypothesis put forward in 1962 by James Neel, an argument now outmoded in the postgenomic era. The discussion about thrifty phenotypes has superseded it (Watve and Yajnick 2007). Animal research into epigenetics, and recent findings with humans, is showing how "evolution has equipped organisms with mechanisms to respond specifically and efficiently to certain critical novel experiences [...] and to transmit this information effectively to their offspring without the need for the typically slow process of natural selection" (Szyf 2014: 4).

Given the inordinate rate of global change currently being brought about by human activities, environmental and social, much of it involving extraordinary violence and dislocation of one kind or another, mismatches are likely to exist commonly between environments to which human populations are reasonably well adapted biologically, and the lived environments in which millions of people are forced to exist. It is of note that UNHCR, The United Nations Refugee Agency, reported that 65.6 million people had been forcibly displaced worldwide by 2016.

Toxic Water Supplies

Persistent contamination of the Grassy Narrows' Wabigoon River system in Ontario, Canada graphically illustrates the health effects of irresponsible government behaviour in the provision of one of the basic rights of human health – clean water. The Ontario government claims that defilement of the river stopped forty years ago when the paper mill run by Domtar, the largest producer of uncoated free-sheet paper in North America that had been in operation for decades in Dryden, upstream from Grassy Narrows, was forcibly shut down. This was done after it had dumped approximately 9,000 kilograms of mercury into the downstream Wabigoon River. Today, mercury levels in the fish near Grassy Narrows are fifteen times the safe consumption limit and forty times the limit for children, pregnant women, and women of child-bearing age (Mosa and Duffin 2016).

There are many parallels between the present disaster in Grassy Narrows with the situation in Japan where mercury poisoning was officially recognized in the 1950s. In Minamata, a fishing village, the local cats appeared to go crazy, and some were described as "committing suicide" by "falling into the sea". Thereafter, humans began to report numbness in their extremities, accompanied by tremors, difficulty in walking and, in some cases, signs of mental illness. By 1959 it was definitively established that mercury poisoning was implicated. A large petrochemical plant active in Minamata, Chisso Corporation, was immediately suspect. Chisso denied involvement, even when it was shown that an estimated

27 tons of mercury compounds was present in Minamata Bay. Protests began in 1959, but it was 1968 before the company finally stopped dumping effluents into the river. Close to 3,000 people contracted what came to be designated as Minamata disease (*Minamata-byô*), and more than half of them have died (Mosa and Duffin 2016). Japanese experts who were summoned to Grassy Narrows reported that up to 90% of the people living there today show signs of mercury poisoning that is being inter-generationally transmitted (Mosa and Duffin 2016).

The people in Grassy Narrows fought for fifty years for a cleanup of the river. In a confrontation with the Ontario Minister of Environment, it appeared at first as though the government was attentive, but then the Minister stated in May 2016 that a cleanup was not necessary despite an expert report stating that the river was extremely contaminated with mercury (Mosa and Duffin 2016). Today, two generations of people from Grassy Narrows and Wabaseemoong First Nations exhibit symptoms of mercury poisoning, including loss of muscle coordination, numbness in the hands and feet, hearing loss, speech damage, and tunnel vision. Foetuses are particularly vulnerable to cognitive damage. Extreme cases result in paralysis, insanity, coma, and death.

In May 2017 the government demanded that Domtar run tests to find out the source of what is clearly an ongoing leak of mercury into the river. Domtar vows to fight this demand in court ensuring that no investigation of changes will take place for some time to come. In June 2017 the Ontario government announced that it had dedicated $85 million to the remediation of the contaminated river system and demands have been made and that this money has been put into a trust that is accountable to the inhabitants of Grassy Narrows. The hope is that this will ensure a thorough cleanup of the toxic mill site, contribute to health care for the effects of mercury poisoning, and also be used to install a permanent environment monitoring system. But many observers are sceptical and believe that remediation of the river may well be set aside by future governments.

From Local to Situated Biologies

The above examples are illustrative of environmental epigenetic effects, the full social and political import of which can be interpreted by introducing the concept of "situated biologies" (Niewöhner and Lock 2018). Epigenetic research is an objective science and, when collecting data, the subjective, lived experience of embodied experience, as recounted by informants is not taken into account by researchers. The concept of local biologies, in contrast, explicitly pays close attention to subjective accounts on the assumption that human bodies are not universal and that local variation is at times significant and should be taken into account in analyses. However, local biologies, now well established in medical anthropological literature (Lock and Nguyen 2017), is perhaps best understood today as a sub-category of an over-arching concept of "situated biologies" – that are mobile and widely distributed.

Examples of local biologies are ubiquitous, of course; two are present in the Ukraine and Japan, where administrators managed massive nuclear fallout in these countries significantly differently, resulting in varying short and long-term consequences (Petryna 2002; Avenell 2015). Similarly, local responses to war and abduction – notably to the effects of violent and sadistic rape – are best interpreted as bringing about local biologies of affiliation and/or disaffection, in which the telling of events and memories are deeply implicated (Lambert and

Kirkup 2017; Macdonald 2017; Theidon 2013). The specific inter-generational debilitating effects of colonialism, notably in connection with mental health, is another example in which the varied objectives of colonial forces with respect to what kinds of wealth they sought to extract and how, have brought about lasting impacts on indigenous peoples that should be situated in local contexts for the purposes of analysis (Daschuk 2013; Lock 2015; Lea 2012). The case of Agent Orange cited above is another example of local biologies, as is cannibalism and kuru (Lock and Nguyen 2017) and, more recently, Iraqibacter (Dewachi 2017: 179-180). Repeated reports of unremitting racism resulting in violent death are also such examples (Stevenson 2017).

However, these detectable biological differences are not necessarily limited to one place – they travel. Agent Orange was sprayed on US service men who returned to the US with the potential to create deformed foetuses and newborns – an outcome reluctantly compensated by the US government following numerous law suits. And Iraqibacter has spread throughout conflict zones in the Middle East. Furthermore, local biologies may dissipate as dietary habits change, although research has shown that Japanese Americans living in Hawaii report a similar low rate of hot flashes, as do women in Japan (Sievert et al. 2007). In other words, biology is everywhere situated in time and space, but is equally subject to change over time and through space, and, given the ever-increasing mobility of people today their biologies too change increasingly rapidly. The International Displacement Monitoring Centre predicts that, since 2008, an average of 26.4 million people have been displaced from their homes by natural disasters. In addition, UN figures show that 232 million people were on the move globally in 2013 and that in 2015, 65.3 million people migrated internally or externally as a result of conflict or persecution (Weinberg 2017). The Middle East and Sub-Saharan Africa are particularly affected, and every indication is that displacement is on the increase. The epigenetic effects of such ongoing environmental displacement, whether due primarily to climate change or to conflict, is, as the media makes clear daily, without doubt affecting the health and wellbeing of involved individuals. Such changes are not necessarily all negative, but until such time as they are carefully investigated, the long-term effects of these movements (that Homo sapiens has undertaken ceaselessly, we should keep in mind) remain unknown.

The Microbiome

In what follows, I consider the entity that affects human health and illness to a greater extent than any other aspect of the material world. Ed Yong argues that we live in the Microbiocene that started at the dawn of life itself, and will continue to its extinction (2016). This emerging knowledge provides a lens that exposes the inexhaustible extent of the mutability and permeability of human bodies. In addition to the human genome, those of bacteria, viruses, and plasmids are present in the human body and purportedly outnumber human DNA in an approximately 10 to 1 ratio, although the latest estimates now suggest a roughly even split between the number of human cells and microbial cells in human bodies. The majority of these residents live in the intestine, but they are also present in the mouth, scalp, on the skin, in all the crevices and orifices of the body, and envelop us externally in clouds. The commensal bacteria that work on our behalf, but equally work to their own benefit, have approximately 3 million genes. The resultant 'metagenome' is exquisitely sensitive, and can change rapidly – within two or three days (Barnes and Dupré 2008). The microbiome of each individual is unique. Even identical twins do not share the same microbial inhabitants.

Given that the microbial ecosystem plays an indispensable role in the functioning of the immune system, and hence serves to distinguish self from non-self, and further, produces beneficial compounds that we cannot make for ourselves, we are not merely host to our microbiomes, rather, these commensals are integral to 'us'; the relationship of humans and their genomes is not one to one, and the genome of an organism is not equivalent to the organism itself. A tightly bounded, autonomous, human simply does not exist.

The microbiome – me, self, and us – weighing in at about one kilogram, is perhaps best thought of as a human organ, albeit a rather odd one (Barnes and Dupré 136). Our permeable skin-bound selves comprise a collection of ecosystems, of miniaturized-communities that are products of our evolutionary past, more recent historical events, and of social and political contingencies of many kinds. The microbial mix at work today in North America and Europe copes primarily with the digestion of sugars, fats, and proteins. In contrast, children living in countries such as Malawi, Bangladesh, and the Yanomami in Venezuela, Hadza in Tanzania, and Matsés in Peru, have microbes in their digestive tracts that 'fit' with their local diets and environments (Yong 2016: 131). It is possible that our early ancestors harboured even greater variety of microorganisms. The microbiome has powerful effects throughout our bodies including the neurological system in addition to the immunological system (Heijtz et al. 2011). This complex ecosystem is tuned to continuously adapt to the vagaries of human life, but given the environmental havoc we are currently wreaking, it may be in a losing battle.

The Human Ecosystem

A foetus is exposed to bacteria in its mother's womb that may ultimately be beneficial to it. It is further exposed as it passes through the birth canal, becoming coated with some of its mother's commensal cells that begin to multiply rapidly. It has been shown that infants born by Caesarean section, on the increase worldwide, are at higher risk for allergies and asthma as they mature. Breast-feeding, being handled by the family, contact with pets, bed linen, and so on, add to the microbial load, so that the human body by late infancy has become a unique, microbially-packed ecosystem, and by about aged 3 a child's microbiome is similar to that of an adult. Prior to that age, when the microbiome is developing, is also the time when a baby's metabolism and immune system develop, and major cognitive steps take place. These first years are a highly significant time in the developmental processes of both the young child, and its microbiome (Yong 2016).

The human genome cannot be thought of as the fount of human life and wellbeing. Our permeable skin-bound selves comprise a collection of ecosystems, of miniaturized-communities that are products of our evolutionary past; more recent historical events, and of social and political contingencies of many kinds. This emerging knowledge transforms the nurture/nature debate entirely – these entities are no longer confined to what humans are, or to what they do. Numerous genomes, microbial and the human genome, constitute every human life, but no one genome determines who we are and what we become.

Microbiomes are not haphazard, and the bacteria that compose the human microbiome are divided into four distinct phyla, each of which has a different repertoire of capabilities. But the daily activities of the microbiome vary according to the microenvironments in which they exist. The microbiome is exquisitely sensitive, and can change rapidly – within two or three days – in response to dietary changes relating to food availability. Part of this shift involves changes in the genes that the microbiome expresses that can be beneficial to the body. The human genome is not a passive bystander to these activities, and contributes to the composition of the microbiome of persons, thus influencing individual phenotypes, including proclivities for certain illnesses. This complex ecosystem is meticulously tuned to adapt continuously to the vagaries of human life.

Ridding our bodies of bacteria has been a major goal of modern health care systems. The development of antibiotics is regarded as one of the greatest innovations of the 20th century, and millions of lives have been saved as a result. But, we have in effect acquired a 'germophobia' and make enormous efforts to stay clean in daily life. By the age of 18 the average American child has received from ten to twenty courses of antibiotics, most of which have resolved a potentially serious infection. It is becoming clear that a price must be paid for banishing bacteria from our ecosystem, the large majority of which are actively beneficial to our bodies.

At the beginning of the 20th century *H. pylori* was present in the stomach of just about everyone worldwide. This bacterium has been linked to ulcers and at times to the onset of stomach cancer, and great efforts were made to wipe it out. It is now evident that *H. pylori* also performs beneficial functions that start in infancy – normally it is commensal, and protects its human 'partner,' but in adult life in certain individuals it can cause damage (Blaser 2014). People who do not have *H. pylori* in their stomachs are far more likely to have had asthma as children than those whose guts harbour the bacterium, and an absence of *H. pylori* is associated with increased risk for obesity and hence Type 2 diabetes, because this bacteria is linked to two hormones that regulate the appetite (Finlay and Arrieta 2016). Coupled with the high intake of sugar and fat in the diets of so many people and a sedentary lifestyle, the absence of *H. pylori* is clearly troubling. What is more, antibiotics are administered in very high doses to the poultry and meat that we consume in order that they put on weight quickly, and to increase profits they are then slaughtered at a younger age. Antibiotic residues are at times passed along to humans, adding to our vulnerability.

Michael Gillings and colleagues have argued that practices associated with the Anthropocene, including agriculture, sanitation, and widespread antibiotic use, probably largely account for reduced diversity in the microbes in our gut (2015). He suggests that this commenced around 350,000 years ago when humans first started to cook their food following mastery over fire. Eating cooked food allows for the evolution of smaller digestive tracts. Gillings adds that the agricultural revolution that commenced 12,000 years ago exacerbated matters because human diets were then drastically transformed. No longer eating wild animals with huge diversity in their microbial flora, humans limited their diets mostly to farmed animals: pigs, sheep, cattle and chicken, whose microbiomes, as compared to wild animals, are not highly diverse. This loss of exposure on the part of humans to micro bio-diversity ingested from food sources has been associated with increased rates in obesity, asthma, psoriasis, irritable bowel syndrome, and even mental health conditions (Finlay and Arrieta 2016).

Rapidly accumulating knowledge about the microbiome reveals that our understanding of the relationship between outside in and inside out – environments external and internal to the body – must be radically re-conceptualized. The presence of a community of commensal, symbiotic, and, at times, pathogenic organisms that reside in each one of us makes strikingly apparent the ubiquitous difference among individual human bodies, while also revealing mutable differences dispersed among groups. Such difference has cumulated from ever changing and evolving practices of subsistence and existence present since the emergence of *Homo sapiens.*

In Summary

In *The Western Illusion of Human Nature,* Marshall Sahlins argues: “the opposition between nature and culture…is distinctive of our own folklore” (2008: 2); epigenetic and microbiome findings now challenge this folklore at the molecular level. Culture generates and relates to environments that are working on the next generation prior to conception, as it worked on *Homo sapiens* prior to our very existence. Of course, culture does not *determine* biology, but deeply informs it, as recognition of the ‘reactive genome’ responding to the human ecosystem makes clear.

These findings suggest that, for perhaps the majority of anthropological research projects, we must move beyond the problematization and explication of the culture concept whether in general or specific contexts. Moreover, the concepts of nature and nurture and nature and environment demand contextual explication – as several recent ethnographies have shown (Kohn 2013; Nading 2014; Stevenson 2014). In addition, the many urgent projects underway in connection with the physical and psychological effects of forced migration, displacement, and violence would do well to keep in mind the profound epigenetic and microbiotic effects on embodiment and well-being resultant from such perturbations and “derangements” (Ghosh 2017).

The era of the Anthropocene, or Capitalocene, as it has been named (2017), in which life in its endless forms is confronted by a ceaseless assault of human activity, much of it disruptive, does not bode well for the future. At the very least, anthropologists can no longer remain impartial; we must enter fully into the fray, and make ourselves present in what Didier Fassin has described as “The public afterlife of ethnography” and its multiple configurations (Fassin 2015). In this era of alternative facts the need to expose the brutal reality of the after effects of war and violence, of toxic environments and climate change, and of poverty and government indifference, is more than urgent; it is a genuine emergency that we work to contain with vigour. The Rockefeller Foundation posits that ‘the resilience age’ is here and “through smart planning, decisions and investments, our cities, communities and nations will be better equipped to manage the unavoidable and avoid the unmanageable.” Humans have for eons ceaselessly demonstrated resilience in response to tragedies and disasters. But equally we must act with urgency to stop the rape of the planet, and this calls for an abandonment of the current ‘Carbon Democracy’ (Mitchell 2013) and concerted moves towards use of renewal sources of energy coupled with urgent drives to reduce increasing inequality and racism.

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