Part I - Parasites, Human Hosts, and the Environment

4. The Dispersal of Homo sapiens and the Peopling of the Continents

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The Dispersal of *Homo sapiens* and the Peopling of the Continents

Sheila Mendonça de Souza

A look at ancient human history shows that we were a wandering species. Now pandemic, our species differs from others due to our enormous potential to explore and our capacity to develop adaptive strategies over thousands of years that allowed us to disperse and colonize a wide range of environments.

Homo habilis may possibly have engaged in migratory behavior, but such behavior was definitely present among the first archaic humans, and it intensified in *Homo sapiens*, whose mobility led the species to span greater and greater distances, often following known paths. Such behavior itself posed frequent challenges, forcing the human species to deal with changes in environmental pressures and interactions. At each stage in human history, such changes produced new life situations and contact with different parasite species, and thus with different health conditions due to the appearance and disappearance of diseases.

Cultural constructions, whether adaptive or not, have brought relief from and compensation for challenges from the environment and health risks, whenever and wherever humans lived. Human responses of adaptation and adaptability have emerged from millenary interaction with other species and environments, whether natural or modified (Moran, 1982). In some periods and places, diseases were selected because they favored adaptive success; genes were modulated to interact with the environment, causing or repressing diseases (Moalem & Prince, 2007); microorganisms turned into parasites that were more or less aggressive or successful. New diseases emerged, while others disappeared and later reemerged (Cockburn, 1967; Sournia & Ruffié, 1984; Verano & Ubelaker, 1992; Föllner & Hansson, 1996).

A significant part of the history of health problems that have affected human populations can be understood by the ways our species has either followed or swayed from paths over hundreds of thousands of years. In the process of interrelating with different environments, in survival strategies, in ways of life, and in interactions with other life forms, the human species both incorporated and expunged diseases, differentiated itself from other more phylogenetically proximate species, and harbored species inside itself that were undergoing evolution themselves. Humans developed strategic polymorphisms, retained ancestral parasites, eradicated old parasites, and saw others

emerge. In our more recent journey, we have even created modified organisms capable of producing diseases. While following paths and going astray, along the way humankind has inscribed the risks, benefits, and harms that this journey has produced for the health of our restless, creative, and wayfaring species.

In the human species, as in any other, the health-disease condition is the result of a history. It should be interpreted on the basis of some organizing dimensions: time, space, changes in human culture and behavior, and changes in the natural environment. A view across the timeline or time's arrow sheds light on the sequences of changes in the conditions leading to health and disease. Over time, we can perceive and seek explanations for various forms of transition and permanence.

Paleopathology focuses on the timeline and health and disease conditions in human populations. Considering the other dimensions, but always looking across time, paleopathology seeks archaeological and historical data that allow understanding how human populations fall ill and die.

Paleopathology has developed for more than two centuries, beginning with the work of Esper in the 17th century (Aufderheide & Rodriguez-Martin, 1998). It now has a strong basis in anthropology (Buikstra & Cook, 1980). Based on paleopathological studies, we demystify the notion that healthy living results simply from living in the natural environment. Combined with genetics, studies of human evolution, and more recently ecology, paleopathology has helped unveil the history of human health.

By going backwards in time in human evolution, or by studying other primates, we can formulate the physiological, anatomic, genetic, phylogenetic, or even behavioral models needed to understand human health today and in the past.

Physiological and pathological conditions found in other species can provide important clues to our species' inheritance. Such studies shed light on host-parasite relations based on ecological and phylogenetic principles and processes of coevolution and other mechanisms. Our species' evolutionary history and its relationship to other species with which we share phylogenetic proximity or with which we simply live contain the essential explanations to many of our health-disease processes. Since parasitism and adaptability are inseparable, in some situations anemia can mean the possibility to survive. Much of what has been defined as normal by modern scientific medicine (Canguilhem, 1966) is explained by evolutionary or adaptive processes that we have only recently begun to understand in greater depth. Understanding each step of this process also helps us define health.

When we have achieved a better understanding of the history of human diseases, we may also be able to understand their impact on our evolution. We are currently taking our first looks at our wayfaring species' ancient past and the paths and shortcuts in history of which diseases are an inseparable part (Barnes, 2005; Cavalli-Sforza, 2005; Moalem & Prince, 2007; Stearns & Koella, 2008; Trevathan, Smith & McKeena, 2008).

OUR PRIMATE HERITAGE IN A WORLD OF MICROBES

Our origin is that of primates. We belong to the family of monkeys, apes, lemurs, and other animals with which we share an extraordinarily interesting set of characteristics (Foley, 1987, 1995). Although most studies in paleopathology and paleoparasitology discuss the more recent periods of human evolution, i.e., anatomically modern humans, others have already reported on our archaic ancestors.

Although the study of our evolutionary past is fragmented and imprecise, theoretical formulations based on paleontological studies, morphology, and genetics, for example, propose models that are currently under discussion.

Other studies (zoological and behavioral) of free or captive primates (Goodall, 1990; Fouts, 1997) shed greater light on their behavior and health, providing evolutionary, phylogenetic, ecological, and epidemiological models. Studies on ancient and current DNA of microorganisms furnish information on evolutionary processes in viruses, bacteria, protozoa, helminthes, and others, helping explain current or past epidemiological conditions, contributing to our understanding of the parasite-host-environment and evolutionary processes (Araújo et al., 2003; Nozais, 2003; Iniguez et al., 2003; Ebert & Bull, 2008; Woolhouse & Antia, 2008; Koella & Turner, 2008). The scientific data accumulated in these and other types of studies allow discussing our species' health-disease processes from a temporal and evolutionary perspective.

Compared to the evolution of life on earth, human evolution is a very recent event. Vertebrates have already evolved for 500 million years, having undergone great extinctions and catastrophic climatic transitions. Even if one considers the overall evolution of mammals since the Triassic, some 250 million years ago, we have existed for very little time. Primates were among the last families to appear in the evolutionary sequence, dating to the early Paleocene, some 65 million years ago (Martin, 2005). During that period, the expansion of subtropical and tropical forests favored tree-dwelling adaptations and the emergence of primates and other taxa.

Human evolutionary processes rely on some peculiar characteristics, notably the genetic variability expressed in multiple polymorphisms, great mobility, intense genetic drift, and a strong component of invented, taught, and learned behaviors that increases the species' adaptability. Paleontological evidence suggests that this is a tendency of hominids, due to their morphological variability, which is interpreted as speciation but could also express major intra- and inter-group genetic and phenotypic variability (Foley, 1995). The concept of speciation in human paleontology is still based on bone morphology. Thus, the variety of hominids tends to increase through progress in research, maintaining a polemical field with a multiplicity of names and concepts.

In evolutionary terms, humans are close to the so-called anthropomorphous monkeys or great apes. The group is represented by the orangutans in Asia and the gorillas and chimpanzees in Africa. We share some 98% of our genetic material with the latter, in addition to great morphological and behavioral identity (Fouts, 1997). The process of speciation during which humans separated from our primate ancestors is represented by numerous extinct branches. Since the availability of fossils varies, with some species represented by only a few fragments of bones or teeth, we have only an approximate model of the position of these ancestors in the human lineage. The morphology and chronology of primates in the Miocene and Pleistocene provide the basis for the proposed stages of hominization (Foley, 1987).

When considering human evolution, some still imagine life in nature as a guarantee of health, and the primordial stages of life as a state of equilibrium in which all survivors were strong and healthy. Thus, studies of current primates help reflect on the health of our ancestors. A comparative study of skeletons of great apes (Lovell, 1990) found 14% of chimpanzees in nature with caries, a higher prevalence than in gorillas and orangutans. Intense tooth wear appears to contribute to tooth loss before death, bone resorption, and abscesses. Dental calculus is also common. According to the same author, traumatic bone lesions, mostly fractures, occur in some 70% of individuals. In chimpanzees, injuries are mostly related to fights and aggression, while in orangutans they are accidental, which can certainly be explained by the social structure of the former, more gregarious and bellicose, and by the form of locomotion in the latter, virtually all by swinging from tree to tree.

Infections are a fascinating subject, since humans and other primates share numerous infectious diseases. The same study by Lovell (1990) describes signs of bone infection in 10% of individuals, while calling attention to signs of infection consistent with treponematoses. The finding of this type of lesion in the bones of great apes is consistent

with proposals by Cockburn (1963) and other authors. According to them, the existence of treponematoses in large primates is indicative of the antiquity of this disease, inherited by the phylogenetic route from common hominid ancestors. Another category of lesions was that of arthroses, found in 20% of the skeletons. Osteophytes, or 'bone spurs', calluses, erosions, and collapses of joint surfaces are well-known in human rheumatism and are also shared. Finding them in hominid bones confirms that they predate the emergence of the human species, as do congenital anomalies and tumors (Krause, 2004; Martín, 2005; Barnes, 2005).

Findings indicate that both primates and hominid ancestors already had their health affected by different processes. The latter were related to ways of life, environmental risks, diet, weaknesses in physical build, and congenital factors, among others.

We definitely share some of our health problems with our ancestors. But which aspects of human evolution can help understand our current health condition?

Isolation of the savannahs in the Rift Valley in Africa was crucial to the process of speciation that preceded the emergence of genus *Homo*. Type of diet, sexual selection, and thermal regulation, as well as regulation of ultraviolet exposure must have been factors that pressured selection and favored life in that savannah. Other aspects, such as the capacity to manipulate objects and explore the environment, the capacity to move and carry materials, and structuring of stable family groups were also determinant factors in our evolution. All these changes produced impacts on our physiology and morphology, but they must also have brought various health problems. These are also among the most highly valued factors for explaining the selection of adaptive characteristics linked to biped walking and later hominization. Over the course of this process, these factors would also have modulated host-parasite interactions, redefining the natural path of human health across evolution.

Species from genus *Proconsul*, fossils from catarrhines, and the first in the human lineage are found in Africa and Europe, beginning in the Oligocene. They begin to occur in paleontological sites just over 20 million years ago. *Proconsul* specimens have no tail, but they already have proportionally large brains for primates of the period, and their frontally positioned eyes would have given them stereoscopic sight, similar to ours.

Kenyapithecus, successors in the same lineage, made their expansion 15 million years ago, and two Asian forms are known: *Ramapithecus*, considered the ancestors of genus *Pongo* (orangutans), and *Sivapithecus*, purportedly related to our lineage. A European form of these primates received the name *Oreopithecus* (Simons, 1979).

The period between 15 million and 7 million years ago represents a major paleontological silence. With the exception of genus *Pongo*, whose ancestry in Asian sites can be traced until some 12 million years ago, we know nothing about the immediate ancestors of the great apes. However, molecular models based on the comparison of genetic diversity and frequency of mutations help build hypotheses for this evolutionary period, estimating the antiquity of the Oligocene primates. Based on these models, the emergence of the first hominids is estimated at the transition from the Miocene to the Paleocene, some 7 million years ago (Martin, 2005). In fact, starting 7 million years ago, when the fossil record again began to provide information on human evolution, much more complex and larger primates already inhabited Africa.

The ancestors of gorillas, chimpanzees, and humans also lived in hot and wet tropical environments like woods and gallery forests, as well as in savannahs. Paleoenvironmental reconstitution until the late Miocene shows that their environment was subject to intense tectonic and volcanic activity. There would also have been episodes of temperature drops and the formation of drier regions, with the modification of geographic barriers. Thus, our species' ancestors, although tropical, were also exposed to drier and colder environments, under successive and sudden climatic and

ecological changes. These alternating climatic cycles coincide with the emergence of the first hominids, suggesting that our lineage emerged under drastic adaptive pressures and challenges.

Judging by the predominantly accepted classification of hominids, East Africa, east of the Rift, was stage to an important species diversification. Another hominid called *Ardipithecus ramidus* was found in this same region of Ethiopia, as published recently (White et al., 2009), drawing great interest. The discovery has changed the interpretation of our evolution and its relationship to the African great apes, confirming that the evolutionary trends that distinguish the human species were already under way long before, e.g., patterns in locomotion, skull structure, etc.

The largest known hominoid in the region belongs to genus *Gigantopithecus*, whose bones are found in layers dated 9.5 million to 7 million years ago. This genus was followed by *Australopithecus*, whose oldest fossils date 5 million to 4.5 million years ago, distributed east and north of Lake Victoria in Kenya and around Lake Turkana in Ethiopia (Foley, 1995). Although the genus is described for Africa, the current literature also records findings of examples of *Gigantopithecus* in Asia, thus indicating a wider dispersal than proposed by the conventional models (Wang, 2009).

Australopithecus have been the icons of hominization, as bipeds with heads similar to modern-day chimpanzees and bodies similar to humans. These hominids are characterized by their erect gait, greater stature and robustness than their other contemporary primates, increased relative brain size, and a reduction in the masticatory system. The most famous *Australopithecus* is 'Lucy', a well-preserved skeleton that allowed the first detailed study of the lower limbs of this genus, helping confirm the morphological and functional similarity of its skeleton to that of genus *Homo*.

The hypothesis that bipedalism preceded genus *Homo* was later confirmed by the finding of *Australopithecus* tracks in Laëtolí, Tanzania. The tracks, left by different individuals in a dated layer of volcanic ash, confirmed what the bones suggested. Bipedalism appears to have represented an adaptive advantage, as a more energy-sparing form of locomotion and also by reducing the body area exposed to the sun, thus minimizing body heat in the savannah. Freeing the forelimbs would also have allowed the development of grasping and handling, care for offspring, and physical struggles, substantial evolutionary advantages in combination with the social and cultural development provided by encephalization (Napier, 1979).

Australopithecus, known for their distribution and variety, had a skull capacity of 400 to 500 cm³. They are classified as robust versus graceful, based on their larger or smaller physical build, and they display varied morphology, including their foot bone anatomy, with some variants more adapted to bipedalism. Their teeth vary in shape, with different patterns of wear, suggesting the consumption of distinct foods. This may indicate varied occupation of ecological niches as an adaptive strategy. The principal variants known today and which most paleoanthropologists consider species are: *A. ramidus*, *A. anamensis*, *A. afarensis*, *A. africanus*, *A. aethiopicus*, *A. boisei*, *A. crassidens*, and *A. robustus*.

According to the current paleontological record, the Australopithecines occupied the savannahs of East Africa for some 4 million years before they reached Southern Africa. The Rift Valley Barrier appears to have prevented their expansion northward and westward. Even so, they dispersed across a considerable geographic area and lived in diverse environments. There is now relatively wide agreement with the hypothesis that *A. afarensis*, the species to which "Lucy" belongs, was the most likely predecessor to genus *Homo* (Foley, 1995).

Some 3 million years, a new cycle of warming of the Earth led to a new forest expansion, even reaching regions where only tundra now exists. The sea reached 30 meters above the current level, and the African and Asian deserts were greatly reduced.

The emergence of genus *Homo* some 2.5 million years ago coincided with this new climatic cycle. It is assumed that the first representative of this genus had a face with little forward projection and a lighter skull than *Australopithecus*, without the bony abutments that supported the latter's powerful masticatory muscles. The dentition was delicate, the brain proportionally larger, and the lower limbs fully adapted to walking erect. Findings of their bones were associated with rudimentary chipped stone tools such as choppers and chopping tools and animal bones with marks suggesting intentional cuts or breaks, confirming a differentiated skillful behavior and the regular use of handmade tools.

Although the capacity to make and use tools is common to many animals (Bonner, 1983), it is generally associated with occasional and opportunistic intuitive behaviors, without characterizing technological patterns or chains transmitted and improved across generations. Meanwhile, some rare examples, mainly in primates like chimpanzees, point to the potential of these animals to develop creative solutions to problems they encounter in their natural environment. Since the principal adaptive characteristic of these animals appears to have been their exploratory potential, they have proven capable of learning, teaching, and modifying their behavior and environment as a function of their experiences and needs, even in free-living conditions (Goodall, 1990). This potential was certainly an important adaptive factor in the large primates and developed in the evolution of the human species.

The specimens from Olduvai and Lake Turkana were called *Homo habilis*, exactly because they systematically manufactured tools. Their emergence, as well as that of other mammals, coincides with the beginning of the great glaciations, or Pleistocene, and from this period on there is a reduction in the fossil record of *Australopithecus*, suggesting that the latter became progressively less adapted or competitive until extinction (Foley, 1995).

This is a period for which there are no findings of human fossils anywhere else in the world, leading one to suppose that the representatives of genus *Homo* remained limited to Africa for more than 1 million years. Archaeological sites without skeletons, but with chipped stone artifacts from the Olduvai tradition, indicate that *Homo* expanded to occupy Northern as well as Sub-Saharan Africa (Foley, 1995). Two species, *H. habilis* and *H. rudolfensis*, even shared the savannah with species of *Australopithecus* before the latter disappeared.

Some 2 million years ago another archaic species also emerged in Africa, called *Homo ergaster*. The existence of this new species, with a very heavy skull and more robust bone structure, with an evolutionary tendency towards larger bodies and brains, would only have been feasible due to an increase in the availability of energy-rich foods, i.e., the regular use of high-calorie foods. According to most current authors, this condition would have been provided by the regular consumption of bone marrow, animal fat, and game. According to some, these skills would have been associated initially with the exploitation of an available food source in the savannahs, namely animal carcasses. Even after consuming all the flesh and viscera from a carcass, the marrow inside the long bones is a rich source of potential energy, and it is extremely rare for animals to access it. Hyenas, for example, with extraordinarily strong jaws and teeth, are able to break the long bones to eat the marrow. But the stone tools already made and handled by our ancestors allowed breaking and opening the long bones.

Paleontological findings in African sites suggest that this activity was indeed performed by those members of *Homo*. A higher proportion of animal fat in the diet would have brought nutritional and metabolic advantages, as a concentrated energy source.

However, feeding on the carcasses of other animals would also have introduced new health risks and adaptive pressures, especially from parasitic infections (Reinhard & Urban, 2003; Sianto et al., 2005). Thus, the increasing consumption of meat and fat, based on the establishment first of carrion scavenging and then a hunter diet, would have produced the epidemiological conditions for the emergence of new infectious diseases and thus resulting in adaptive pressures.

H. erectus, like other hominids, showed morphological variants that have led paleoanthropologists to propose their speciation. According to some authors, this tendency towards variability, observed in Africa but also on other continents, is the expression of the polymorphic and polytypical potential that was present since the beginning of human evolution and that is maintained in modern humans. According to other authors, this variety represents different species that emerged as a result of the processes of dispersal and adaptation. Increased stature, greater skull capacity, a more robust build, and technological progress in manufacturing stone tools by bifacial flaking, known as the Acheulean Industry, are characteristic of this human evolutionary stage.

These archaic humans were armed with greater cultural accumulation and considerably expanded their territories, reaching the Middle East, Europe, and Asia (Cervera et al., 2001; Foley, 1995; White et al., 2009). They colonized a diversity of environments and crossed relatively important geographic barriers. They occupied both rainy tropical areas and high, cold lands, becoming practically pandemic. In this process, they were exposed to new adaptive cycles and biodiversity conditions in completely different climates from the savannah. The transitions and different selective pressures experienced by archaic humans in their evolutionary process certainly contributed to their genetic diversity. Without ever becoming extremely specialized, they probably also maintained the potential to deal with varied exposures to different health problems, undergoing an extremely wide range of selective pressures.

From the genetic point of view, the question for the present is the apparent absence of any contribution by archaic humans to the constitution of modern humankind. All evidence indicates that all these groups that left Africa in the first Great Diaspora of *H. erectus* and their variants disappeared and were replaced by modern humans slightly more than 100,000 years ago.

Thus, two great Diasporas or dispersals of genus *Homo* occurred, repeating the adventure of a wandering genus. One consisted of archaic humans whose classifications are multiplying today, and another of modern humans, physically and culturally different from their predecessors, a single species despite their many cultural and biological differences. Related only in their remote African ancestry, these two species traveled similar paths and probably shared health risks and conditions, parasites of similar phylogenetic origin.

The entire adaptive process accumulated over the course of hundreds of thousands of years of existence of archaic humans, except for those who remained in Africa, was lost by the complete replacement of populations with a new genetic stock.

Modern humans are believed to have evolved from archaic humans that stayed in Africa, and that already had their current physical shape when they left the African continent to occupy new lands (Guégan, Prognolle & Thomas, 2008). The new travelers, now *H. sapiens*, or modern humans, retraced many of their ancestors' steps, were exposed to similar environments, and faced different health-disease conditions. Armed with more sophisticated technologies, they also had a greater advantage in adaptively overcoming the challenges raised by the colonization of planet Earth.

THE FIRST GREAT DISPERSAL: ARCHAIC HUMANS AND THEIR RISKS

The impact of the use of tools certainly changed access to some high-energy food sources such as bone marrow, serving as a differential milestone for the dispersal of human groups across greater distances. It is believed, therefore, that it was no coincidence that the first great human expansion, with *H. erectus* as the protagonist, only occurred after the development of more advantageous nutritional patterns.

According to Leonard & Robertson (1994), the availability of high-energy foods also allowed the development of larger brains, the voracious consumers of 20 to 25% of daily energy demand. The brains of other mammals consume

only 3 to 5% of the energy produced in a normal diet. In other primates, this consumption ranges from 8 to 10%. According to calculations by Leonard (2008), for a resting *Australopithecus*, 11% of the energy would have been consumed by the brain, increasing to 16% in *H. erectus*. This means that at least 250 Kcal per day were necessary for the proper functioning of the brain in the first representatives of genus *Homo*. The association between brains with higher energy demand and the change in diet is consistent with the rapid expansion of *H. erectus* within and outside of Africa. The demand for more meat and animal fat and the development of meat-eating habits, as carrion scavengers or hunters, would have increased the pressure for larger territories, while also allowing greater adaptive flexibility, since the consumption of meat or carcasses would make the diet more universal: bison, gnus, horses, mammoths, wolves, bears, and so many other large, mediums-sized, or small mammals became just blood, flesh, fat, viscera, and bones to be consumed.

The ingestion of other animal parts, especially those not processed by cooking, would have increased the exposure to microorganisms, larvae, eggs, and even adult helminths, saprophytes, and decomposers present in carcasses.

Depending on the respective life cycles, these organisms could persist in the mucosa, skin, digestive tract, blood, and other body parts of the consumers before being eliminated or digested.

There are some 1,400 known species of microorganisms that are potentially pathogenic to humans. Of these, humans share approximately 800 with other animal species. In the last 30 years alone, some 50 new parasites of humans, including viruses, bacteria, prions, and others have been identified and combated. Most infectious human diseases are shared with other animals, and genetic studies have shown that few human parasites have their diversity associated with human evolution. This means that most of the diversity in these microorganisms was acquired before adapting to the human species, and that such diversity is shared with different animal host species. Some of the resulting interactions, such as shared feeding, manipulation, use of common spaces, physical contacts, and other forms of contagion certainly allowed the occurrence of co-evolutionary processes and provided (and continue to provide) for the emergence of new health-disease conditions.

We know, for example, that a high proportion of parasites in domestic animals do not affect our species, protected by the species barrier, which certainly means that over the course of all this evolutionary contact, part of this exposure was neutralized by natural inter-specific barriers (Woolhouse & Antia, 2008).

Situations of false parasitism, or the presence of parasite forms (including their reproduction) inside organisms that would not normally be their hosts, have been described as the result of exotic food practices and have posed health problems, including in recent prehistoric peoples, as demonstrated by Araújo et al. (2003), Sianto et al. (2005), and others. Therefore, the increase in animal protein in the hominid diet would have been both an adaptive advantage and a new type of risk. The evolutionary success of genus *Homo* certainly showed that the overall gains outweighed the losses. Humans evolved as omnivores, with the consumption of other animal species as an important dietary source.

Many current studies on human health can be elucidated from an evolutionary perspective. Infections, different forms of symbiosis and commensalism, parasitic diseases, endemic or epidemic infections, and other disease processes that have been studied (e.g., AIDS, Ebola, and SARS, among others) reflect recent situations in which animal infections have become epidemic in humans (Woolhouse & Antia, 2008), reminding us that this is an on-going process.

Although hominid data are limited by the lack of complete findings, some paleopathological models based on the study of peoples whose life could be compared to Paleolithic peoples, as well as models obtained from the study of natural primate populations, confirm that mechanical injuries threatened their health more seriously than infections (Lovell, 1990; DeGusta & Milton, 1998).

Development of the frontal and temporal brain is characteristic of human evolution. The brain of an *Australopithecus* was similar in size and shape to that of a modern chimpanzee (Holloway, 1979) and capable of performing a series of sophisticated functions, just as the brain of the gorilla or orangutan. The more sophisticated functions include recognizing the individual's own image, awareness of individuality, distinguishing oneself from the group, formulating thoughts, articulating ideas, developing empathy, performing inter-subjective communication with sound or mime (gestural or facial), planning actions, problem-solving, and learning and teaching in general (Fouts, 1997). The organization of social and family units and the adoption of behaviors including political strategies and skills and other characteristics also result from this development. Serving as a model for understanding hominization processes, primates offer good examples of how social behavior, group and family culture, feelings, political alliances, and social support among individuals affect the possibilities for survival (Goodall, 1990).

Thus, hominid expansion, in which the greatest challenge was survival in new and changing environments, was directly related to the complexification of behavior. According to Foley (1995), two important characteristics established during our species' dispersal were the maintenance of male kinship ties and greater investment in the offspring. The literature refers to this behavior as the "costly offspring" strategy. Strong political ties between males, social organization in bands, reinforcement of kinship ties, the existence of stable families, and special care to ensure the survival of small, frail, and physically dependent offspring bore a direct relationship to progressive encephalization.

As evolution favored larger brains, skull size also increased. Meanwhile, standing upright led to the evolution of a horizontal and straight pelvis, making the birth canal a veritable evolutionary tunnel. In humans, labor is more difficult, more prolonged, and riskier than in other primate species, because the child passes through a bony ring narrowed by evolution. The inherent contradiction in the evolutionary tendency towards larger head size and a smaller pelvic ring is believed to have led to the birth of increasingly premature (and immature) infants from the neuromotor point of view (Campbell, 1974).

Dependent on adults to move, feed, and keep warm, human offspring required increased attention and protection, as well as more time to learn. In the evolutionary sense, this would have favored families that were better structured and more stable with their offspring, while conferring greater adaptive flexibility to members of the species, increasingly dependent on learned rather than inborn behaviors.

Thus, armed with a set of biological, sociocultural, and cognitive attributes, archaic humans occupied all the lands on Earth except for the subarctic areas, Oceania (including Australia), and America. Each new environment brought contact with new vectors and pathogens, predators, toxins, and foods that helped maintain polymorphisms and modulate the potential for phenotypic adaptability.

However, not everything in the course of human evolution accumulated in the form of genes. An important part of our adaptive process comes from memories and cultural experiences. The control of fire and its use for cooking, for example, were among the oldest and most useful techniques developed by humankind. Fire was used not only to keep warm and ward off predators, but also to allow the preservation and increase the use of foods. Even tougher vegetables like tubers can be digested and absorbed better after softening by fire.

Cooking must have contributed progressively to the reduction of food contamination, impacting the ingestion of viable eggs, larvae, and microorganisms. Although only confirmed archaeologically for more recent periods (200,000 years in Europe), evidence suggests that the use of fire is much older, having accompanied the Asian expansion of *H. erectus*.

Some authors have raised the hypothesis of cannibalism among archaic hominids, defending this evidence for sites up to 780,000 years old. Examples include *H. ancestor* of Atapuerca, Spain (Cervera et al., 2001); *H. neanderthalensis*

of Krapina and Vindija, Croatia, and Moula-Guercy, France (White, 1992). Different studies suggest that consumption of bodies from the same species also occurs in other primates (Goodall, 1990), and among human groups it became a routine procedure in various cultures. Archaeological and ethnographic references for *H. sapiens* describe forms of ritual cannibalism (funerary or not) all over the world (Arens, 1940; White, 1992; Torres, 2006). Such practices are characteristic of the South American lowlands (Métraux, 1947), including in Brazil (Vilaça, 1992). Cannibalism may have accompanied human evolution on a scale as yet unknown, and its consequences for health would bear a relationship to some diseases caused by retroviruses, which have only recently begun to be studied in the human species (Lindenbaum, 1979).

Some 700,000 years ago, the first changes in the skeletal pattern of archaic hominids began to appear in Africa (Rightnure, 2009). About 300,000 years ago, the brain volume of archaic humans was already more than a thousand cubic centimeters. The development of variant forms of archaic humans in different parts of the world points to a slow process of evolution to modern man, apparently from *H. rhodesiensis* and *H. heidelbergensis* (Balter, 2009).

Some 250,000 years ago, the most well-known species of archaic humans emerged: Neanderthal. He colonized Europe, North Africa, and the Middle East and was the most specialized of the hominids, physically adapted to living in the glacial Old World environment. This species received the scientific name of *Homo neanderthalensis*, with an average brain size of some 1,520 cm³, reaching 1,750 cm³. This was the largest absolute and relative brain size ever reached by genus *Homo*. As could be expected, reaching the extreme in the human evolutionary tendency of encephalization, this species also became noteworthy for its cultural advances in the so-called Mousterian culture (Krause, 2004), only surpassed eventually by modern humans.

In addition to unique chipped stone technology, the Neanderthals developed polished bone, horn, and wooden artifacts, as well as adapted rock shelters. The fact that some burials were performed, even including ritual depositing of flowers, suggests that Neanderthals experienced thoughts and feelings related to magical and spiritual conceptions. The skull base conformation, hyoid bone, and development of Broca's area in the brain attest to the anatomical potential for a spoken language similar to ours.

The survival of seriously injured and mutilated individuals, as demonstrated by bioarchaeological studies, indicates a well-developed social structure, even capable of supplying for the less fit (Krause, 2004).

All evidence suggests that the Neanderthals had a huge energy demand, which would have been supplied by a diet based heavily on hunting the Pleistocene fauna. An approximation to this pattern can be obtained by observing the human groups now inhabiting the Arctic (Moran, 1982). This adaptation is a highly interesting evolutionary fact and also suggests a peculiar pathocenosis, about which we know very little, mainly due to the small number of well-preserved skeletons.

A more recent hypothesis suggests the species' great brain development also led to the need for a diet that provided a large energy supply, easily obtained by hunting the megafauna, but which must have become more difficult as climate changes from the thaw made their main food sources disappear.

According to some, the Neanderthals' large brains and their bodies adapted to the cold required a much higher calorie supply as compared to modern humans, and this may have contributed to their extinction when the climate changed and the megafauna, their staple diet, died out, forcing them to turn to alternative diets with fewer calories (Leonard, 2008).

Of the known problems that affected fitness and health during this period, the most prevalent were certainly injuries resulting from the inherent risks in daily activities, especially hunting the megafauna. Other specimens such

as those from Shanidar also show signs of violent injuries that may have resulted from intra-species interaction or social tension with other members of genus *Homo*. In some regions such as the Near East there are archaeological sites suggestive of contact between modern and archaic humans (Bosinski, 2004).

The last Neanderthals were found in the extreme south of the Iberian Peninsula, in the Gibraltar area, just less than 30,000 years ago. They lived in milder climates, but in marginal conditions, and their diet included marine life (Krause, 2004). As different species, they would have competed; the extinction of Neanderthal, more specialized biologically and technologically, may also have been accelerated by inter-species tensions with modern humans.

An on-going question concerns the possibility (and extent) of interbreeding between Neanderthal and *H. sapiens* during the more recent period. According to a study by Pennisi (2009), no evidence had been obtained that current human DNA contains contributions from Neanderthal DNA. However, a first draft of the Neanderthal genome published in May 2010 (Green et al., 2010) indicates that interbreeding may indeed have occurred. According to co-author David Reich, "The proportion of Neanderthal-inherited genetic material is about 1 to 4 percent. It is a small but very real proportion of ancestry in non-Africans today." New developments in this area clearly demonstrate the challenges and potential of paleogenetics.

The rapid transition from a dry, cold glacial climate to a hotter and more humid environment would have been accompanied by an increase in biodiversity, particularly insects and numerous forms of potentially pathogenic invertebrates and microorganisms. This change alone exposed the Neanderthals to a third important pathological factor in the new environments they inhabited. But it is also possible that even discontinuous contact between modern and archaic humans led to a new epidemiological situation. By living for the first time in the same region, *H. sapiens* and *H. neanderthalensis* would have faced different pathocenoses. Bearers of different evolutionary histories and different genetic stocks, and hosting different macro and microorganisms, their bodies underwent separate adaptations for hundreds of thousands of years.

H. sapiens had recently emerged from tropical Africa, where all its ancestry was located. The species was not as physically specialized and could thus carry more polymorphisms. It was also better adapted to dealing with the pathogenic biodiversity of tropical and temperate environments as compared to humans of the glaciations, adapted to sterile frozen environments. This contact would certainly have posed a health risk, due to the approximation of different genotypic potentialities, immunological experiences, and parasite stocks. Entering with tropical parasites into an environment sterilized by glacial decades, modern humans probably helped spread new vectors, parasites, and pathogens across Europe. Climate warming and new conditions of humidity would have favored the invasion of new species, exposing both the fauna and the Neanderthals to new health risks.

THE SECOND GREAT DISPERSAL: MODERN HUMANS AND THEIR RISKS

Some 150,000 years ago, a new African Diaspora began: that of anatomically modern hominids. This dispersal of modern humans was more rapid than that of their archaic forerunners. Although we lack demographic data for archaic humans, the geographic amplitude and amount of existing archaeological sites from just a few tens of thousands of years confirms that modern population expansion was demographically overwhelming, changing the species' demographic scenario.

Principally beginning 30,000 years ago, when great land expanses in Europe and Asia were already free of ice, the multiplication of Cro-Magnon sites shows a sophisticated culture, including expressions of rock art like the Levantine. Cro-Magnon painted caves are located in well-known sites such as Altamira, in Spain, and Lascaux, in France.

From Europe and Asia, modern humans reached the other continents, although more recently. Thus, only *H. sapiens* dispersed worldwide as a pandemic *Homo* species. Based on current archaeological evidence, the crossing of the major geographic barriers like the oceans only occurred in the last 60,000 years. Before the end of the last great Ice Age and the European domain of the Cro-Magnons, other modern humans, armed with technological resources that already included navigation, reached places like Australia, and shortly afterwards America. Commanding increasingly sophisticated technologies, humans became capable of exploring and manipulating plants and animals, storing goods, building shelters adapted to different climates, and manufacturing tools and instruments that greatly expanded their adaptive capacity. With an increasingly complex social organization and elaborate language, they dominated diverse environments, foraging, hunting, and fishing. They explored diverse economic possibilities and occupied various lands, limited only by their own capacity to obtain natural foods (Bocquet-Appel & Najji, 2006).

Modern humans diversified even more than their archaic ancestors, since they dispersed and settled ecologically diverse regions. Their polymorphous nature provided the flexibility they needed to adapt. As they adapted, becoming extremely polytypical, they established phenotypes with favorable characteristics for diverse living conditions. These characteristics include some conditions corresponding to phenotypic expressions now classified as “diseases”. Even so, some of these phenotypic expressions would not have emerged if the cultural and environmental changes of recent decades had not turned successful millenary adjustment mechanisms into difficulties in adapting to our current diets and lifestyles.

Biochemical, physiological, or morphological variations that favored human evolution became pathological or less adaptively favorable conditions as new environments and ways of life were adopted (Dobzanski, 1966; Comas 1967; Moalen & Prince, 2007; Stearns & Koella, 2008; Trevathan, Smith & McKeena, 2008).

Some geographic areas became important foci of genetic diversity or dispersal of characteristics that emerged from mutations, concentrated through founding effects or genetic drift, or through pressure from natural selection. Important haplotypic variants of the human species represent evolutionary or microevolutionary health-related conditions, such as thalassemia, sickle cell anemia, cystic fibrosis, lactase deficiency, and others. The geography of current health thus also contains part of the human species' evolutionary history.

Some of the more recent changes in health conditions probably date to the period in which humans managed to cross the last great geographic barriers. When *H. sapiens* reached Australia, some Pacific islands, and America in the last tens of thousands of years, or more recently, the hundreds of South Pacific islands, including Easter Island, modern humans again had to deal with new ecosystems and environments, in some cases very different from those previously known. Many of these lands, new and subject to intense volcanic and tectonic activity, would have kept the human evolutionary scenario in constant change.

The peopling of Australia appears to have occurred between 120,000 and 60,000 years ago, by sea (Nile & Clerk, 1996). Moving from Sundaland, an area that encompassed Borneo, Indonesia, Philippines, and other lands in Southeast Asia, human groups reached the Timor region, from where they could have crossed stretches of shallow sea a few dozen kilometers long until they reached Kimberley, in what is now Australia. This continent, in turn, was connected to New Guinea, forming what is called Sahul. Another possible path for the first settlers would have been directly from Sundaland to New Guinea and from there to Australia. The existence of archaeological sites dated to some 60,000 years ago in Australia and of sites only half that old in New Guinea suggests that the first hypothesis is probably correct.

This crossing would have been possible because during the last great glacial period the sea was about 60 meters below the current level, thus posing a less formidable barrier. Even though a direct view of the lands on the horizon was not possible, coastal and seafaring peoples would have observed signs of other such lands, as they do today.

Findings of very ancient boats and human dispersal to so many islands in Asia and Oceania (Ashby, 2004) prove the existence of knowledge of the technology needed for maritime crossings. There is consensus that different groups made the crossings at different times before the Holocene. According to Nile and Clerk (1996), the cultural, linguistic, and biological diversity in Australia supports this hypothesis.

Most authors contend that Oceania and America were only peopled by *H. sapiens* (Lahr & Foley, 1987). However, physical characteristics of the Australian aborigines have led some to defend other possibilities and suggest interbreeding with archaic humans (Hawks et al., 2000).

With the end of the Pleistocene, the oceans reached their highest level again. Great expanses of sea separated the lands comprising Sahul and Sundaland, isolating the peoples that had settled in New Guinea, New Zealand, and Australia.

The peoples living in Australia, despite their simple economic system and restricted nomadism, survived and developed sophisticated belief and art systems, in addition to intense exchange. Although there are more than 500 different tribal groups and more than 200 linguistic variations on the Australian continent, records show great integration among the Aboriginal peoples, for whom a complex system of exchange and contact appears to have prevailed in recent times. As a function of their unique history in the last 10,000 years, the Aborigines are considered the set of peoples in the entire world that developed with the least outside influence, making them the oldest continuous culture with know. This condition remained uninterrupted until the 18th century, with European colonization (Nile & Clerk, 1996).

The peopling of America is believed to have occurred through different migratory waves over the course of the last 20,000 years (Lima, 2006). In addition to great differences in the fauna and flora, with an impact on the economy, the rapid transition of environments in America led to exposure to new pathogens. Although controversial, the rapid occupation of the territory, confirmed by the existence of very ancient dates in South America, suggests that the coastline was a preferential entry route. Recent studies, especially discoveries in Monte Verde, Chile (Dillehay, 1992; Dillehay et al., 2009), prove that the coastal adaptations are much older than previously assumed. Exposed to different risks, in inland or coastal areas, these populations developed diverse adaptive responses, undergoing a new cycle of parasite-host-environment interactions.

There are few archaeological data that allow linking Asia to America, and thus little is known about the human waves that migrated from one continent to the other. We do not know exactly how many migratory waves occurred or which ethnic groups or cultures were involved. Much of what has been proposed in recent decades was based on linguistic, anthropological, and genetic studies, leading to the model of the three migratory waves.

The Eskimo-Aleuts certainly entered in the last six millennia. This interpretation is supported not only by archaeological and linguistic data, but also by more recent genetic data. However, the first settlers and the date of entry into America are still controversial. Archaeological, bioanthropological, and genetic studies all point to Asia as the origin of the peoples that reached the Americas. The date of occupation of Central Asia by modern humans was around 40,000 years ago, although there is little archaeological proof of this chronology. The mitochondrial and Y chromosome genetic variations found between American and Asian groups point to a genetic separation, that is, a first entry into Beringia, about 20,000 years ago. Meanwhile, dispersal southward of the continental glaciers only occurred between 16,000 and 11,000 years ago (Goebel, Waters & O'Rourke, 2009).

Morphological variations in the human skulls in the oldest sites, such as Spirit Cave, Keneewick, and Lagoa Santa, Brazil, have led to the proposal of a differentiated and much older migration, later replaced by more recent groups, referred to as “mongoloid” (Neves et al., 2004, Lahr & Souza, 2006). However, genetic studies show a reduced haplotypic variation, suggesting that the origin of all modern and ancient Native Americans involves a single founding population. The ancient dates for South America, the existence of two cranial morphologies, and the DNA data, suggesting a precise biological clock, lead to the interpretation that despite the differences, Paleoindians and more recent prehistoric groups, although having entered America at different moments, had their origin in the same founding population (Goebel, Waters, & O'Rourke, 2009).

The emergence of mongoloid cranial morphology in Asia is proposed as a recent fact (Lahr, 1995). A group that was still not mongoloid may have entered America first. The division of Asian groups into two main dental types, sinodonts and sundadonts, appears consistent with this hypothesis and with findings in America. Paleoindians have sundadont dental characteristics (Powell & Neves, 1998), and studies based on chromosome Y show two distinct patterns for America, one of them much older, reinforcing the idea of two primordial entries (Stix, 2008).

In America, as on the other continents, technological progress was a synonym for territorial expansion and increased mobility/circulation. As populations expanded, exposure to new conditions of natural or cultural risk created new pathocenoses (Grmek, 1983), related to different lifestyles and the colonized environments. Genetic variability, enhanced by the species' polymorphisms, helped make health conditions increasingly diversified, including as a response to the need to adapt. In recent millennia, disease as an adaptive response appears to have assumed a wide variety of expressions (Stearns & Koella, 2008).

Despite some moments of species exchange between Asia and America, the New and Old Worlds remained separate for millennia. When populations reached America, they would have found new foods, plants with peculiar pharmacological properties, and specific zoonoses (Reinhard, Fink & Skiles, 2003; Gonçalves, Araújo & Ferreira, 2003). Some characteristics observed among Native American peoples relate to a common ancestry. An example is lactase deficiency (Wiley, 2008), brought from Asia and maintained by the absence of domestication and use of milk and dairy products among the American peoples. Others, like the absence of forms of adaptive anemia, are probably due to the lack of adaptive pressure that was exerted for thousands of years by the more severe forms of malaria in Europe, Asia, and Africa.

Many of the differences, including those related to health, have only been elucidated recently. Paleopathology has studied diseases that originated in America, diseases brought from other continents, recent and ancient diseases, and parasitic infections resulting from eating habits developed in America. Recent studies have also focused on the genetic variety of current and ancient Amerindian populations and the evolutionary and health-related consequences. The prevalence and even the occurrence of some diseases were modified by migration itself.

Most authors agree that the crossing to the New World occurred from northernmost Siberia (Lima, 2006) by land, along the Bering Bridge, or navigating across the Kurila and Aleutian archipelagos. There is consensus that for successive generations the groups that crossed to America would have been forced to inhabit the cold regions of Siberia, the latitudes of the Arctic Polar Circle. This long process would have acted as a filter, partially modifying the repertoire of pathogens. However, this process would have been modulated by the capacity of humans to create their own microenvironments, like houses and shelters, ensuring the persistence of some parasites or the transmission of some pathogenic conditions which would have been unable to persist in the natural environment.

Thus, the environmental filter always added to culture, so that some diseases occurred more in some human groups than in others. Some infectious diseases, for example, would only have important population consequences

if the human groupings reached a given size and density. Others depended on specific subsistence strategies, and while still others were favored by cultural habits. Examples of biocultural interactions that explain the prevalence of diseases in human groups are unlimited.

Meanwhile, health-related human evolution cannot be separated from the evolution of disease-causing parasites and organisms. The evolutionary study of microorganisms points to the emergence, over time, of numerous evolutionary strategies by which parasites ensured their multiplication and success (Stearns & Koella, 2008). Causing acute or chronic problems, leading to death or not, these organisms optimized their own dispersal and perpetuation. From this perspective, infections that produce a permanent immune response, but which lead to rapid death in susceptible individuals, such as those involving certain types of virus, appear to be incompatible with the maintenance of infection in small populations, for example. In large groups occupying extensive territories, there would always be individuals somewhere without previous contact with the disease, forming a sufficient reserve of susceptible individuals to maintain the disease in circulation.

This model helps explain why in America and other areas there was no experience with such viral diseases as smallpox and measles. After such infections were naturally eliminated by the death of susceptible individuals or the immunity of survivors, geographic isolation from the Old World would have maintained the American groups away from new cycles of contagion.

Although some urban areas were already developed in America when the Europeans arrived, they were free from the viral diseases affecting Europe and Africa and were thus susceptible to contagion.

When paleopathologists began their studies on this topic in the 1960s, they believed that this model would serve for other infections, such as tuberculosis. Currently, however, it has already been confirmed that TB can maintain itself even in small populations, which helps explain its antiquity in prehistoric America (Roberts & Buikstra, 2003).

When dispersing across the planet, the human species carried some diseases and eliminated others, but also entered into contact with new parasites. In America, for example, Chagas disease (Reinhard, Fink & Skiles, 2003; Souza et al., 2009) was a zoonotic disease on the continent that became an endemic human disease.

However, the expansion of knowledge in paleopathology does not always prove the proposed epidemiological models. The presence of tuberculosis in America nearly 3,000 years ago greatly predates colonial contacts (Pratt & Souza, 2003; Wilbur & Buikstra, 2006). For more than three decades, this confirmation by Marvin Allison of the Medical College of Virginia in 1973 has forced researchers to rethink epidemiological models.

THE LAST MILLENNIA: CULTURE, COSTS, AND BENEFITS

Humans lived in small groups in the most basic form of social organization throughout a million years in their evolution. Based on contemporary primitive groups, 20th-century anthropology referred to this structure as “bands” (Service, 1966; Sahlins, 1968), considering this model of organization as a good approximation of how our ancestors lived. Bands are groups formed by individuals that maintain close kinship ties, living in extended families. They usually have 25 to 125 members, sometimes reaching 300. This limit appears to be explained by the possibilities of their leadership system, distribution of authority, and limitation of their linguistic structure, generally very simple and reduced to vocabularies of up to 600 words. Bands were the structure by which humankind developed and dispersed throughout the planet for hundreds of thousands of years.

Between 10,000 and 5,000 years ago, on different continents, changes in the environment announced the definitive transition from the geological period known as the Pleistocene, or that of the great glaciations, to the Holocene, or the current warmer period. On all the continents, changes occurred in response to the need for a new balance between population density and environmental sustainability. Domestication, or the cultural control of plants and animals, profoundly changed human evolutionary history. Allowing the privileged production of foods that ensured higher calorie content in the diet and controlled storage of surpluses, domestication freed human groups from spontaneous supply. It also led to a rapid reduction in the mobility of human groups, shrinking their territories, crowding, new social and political orders, and many other changes in an extremely short time.

Domestication, combined with food preservation techniques, allowed the development of increasingly larger groupings and higher population concentrations. Domestication was also used for the production of other material goods besides food and generated surpluses that could be used for barter and trade, spreading rapidly in areas like the Middle East, leading to more sedentary living, which unprecedented health impacts.

Escaping the dictates of environment constraints, modern human groups began a transition that would affect their health conditions more seriously than ever, forcing them into new adaptive cycles. This process, known as the Neolithic Transition, based on the European periodic division of prehistory, occurred very quickly, and the health changes in human groups occurred on most of the continents (Cohen & Armelagos, 1984; Dittmar & Teegen, 2003; Geigl & Pruvost, 2004). With the diversity of economic strategies developed in the last millennia and the ever-increasing variety of environments occupied by humans, in addition to the human sociocultural divergence that developed in this final phase of our prehistory, health conditions and their relations with subsistence strategies and lifestyles multiplied.

Paleopathology provides an approximate idea of the diversity of health conditions over prehistoric time and space, as well as the repercussions on the current distribution of human health conditions.

Thus, the transition to agriculture was also the first great epidemiological transition experienced by the species. Humans' progressive dependence on diets based on cultivated carbohydrates as the principal source of calories brought the settlement of family groups to the places where the food was produced, in permanent dwellings. Larger groups became possible and even desirable, allowed by agricultural activities and new forms of social organization. Birth and death rates and longevity changed, rapidly transforming the population growth rate (Hassan, 1981).

In areas where it was possible to compare paleodemographic studies, the population growth rate increased rapidly with the advent of agriculture. Increased food production allowed more growth; meanwhile, in order to grow more food, humans needed more growth. Throughout the Northern Hemisphere, paleodemographic studies of these transition periods point to a rapid increase in population growth rates (Bocquet-Appel & Najji, 2006).

Sedentary and numerically larger groups suffered huge health impacts, mainly from infectious diseases and nutritional disorders (Cohen & Armelagos, 1984). Greater social complexity brought economic systems and political organizations that allowed adding ever-increasing numbers of individuals. Other levels of organization, such as tribes, chieftainships, and states, have been proposed to explain this growth (Sahlins, 1968). Groups formed by large states expanded across territories in cycles of political dominance over less powerful or smaller groups. Values, ideological systems, economic strategies, cultures, and languages were thus transferred, transformed, or reproduced. In each region on Earth, the history of expansion of states, empires, and kingdoms armed with greater persuasive, economic, bellicose, and other forms of power led land ownership to alternate, individuals and groups to shift, large population contingents to migrate, and new economic strategies to be implemented in large areas.

Subsequent moments witnessed intensive economic exploitation and the construction of human works with great impact on the natural scenario. Manipulation of the landscape for economic purposes or as a sign of power led to new living conditions and also impacted on health. By damming up waters, irrigating land for planting, shifting the course of rivers, and interconnecting previously separated environments still in the prehistoric period, humans modified the distribution of (or contact with) vectors, pathogenic agents, and natural risks.

Another example of the impact of Neolithic cultural changes is the capacity to digest milk. Until the Paleolithic, humans, like other mammals, only used milk from their own species and during early childhood. Domestication in some regions of the world led to the use of milk from goats, sheep, cows, and other animals, consumed *in natura* or in the form of yogurt, cheese, curds, and other dairy products. Cultural processing of milk makes it easier to digest, attenuating problems resulting from the lack of lactase, which allowed consolidating this cultural habit, even among groups that were genetically less fit for it. Milk is a very rich and complete foodstuff and became a staple in some areas, such as Northern Europe. As a result, the capacity to digest milk through lactase production came to be selected positively.

The mutation that produces lactase is very recent and dominant. Its frequency varies in different human populations and is consistent with the history of herding. The highest percentages of lactase-positive individuals are in Northern Europe (95%), African herders (80 to 85%), and herders from Central Asia and Arabia (70%). The lowest percentages are among peoples of Sub-Saharan Africa (10%), East and Southeast Asia (0 to 5%), the Pacific Islands (15 to 20%), and America (0 to 38%). Since Western habits have spread worldwide, and with the growing encouragement for the consumption of milk and dairy products, we have the paradox of a “healthy diet”, recommended on the basis of a product to which most of humankind was not adapted by evolution (Wiley, 2008).

By creating the means for increasingly rapid migration and intensifying mobility, for economic exploitation of natural resources or for trade and contact, human groups increased the spread of transmissible diseases. Exchanging goods, products, practices, beliefs, and habits, the shifting of persons to regions for which they were not adapted, or where they did not know how to protect themselves from natural risks, fostered new endemic and epidemic cycles. The concentration of human groups in areas for producing with successful agricultural techniques drew people much closer together, facilitating routine contact, especially through barter and trade that developed with the production of surpluses and with productive specialization. Settlement of productive lands and the growing complexity of societies led to more overwhelming forms of violence, through ritual or war.

For the first time in human history, cultural changes impacted health on the population scale. In prehistoric cities such as Catayulk or Cahokia in North America, the benefits, changes, and advantages (but also the problems) reached the thousands. Deaths were routine, mainly affecting young men, among the Moche in Peru, the Mayas in Central America, the Romans in Europe, and the Egyptians in Africa. Some health changes directly related to lifestyle and the resulting risks became permanent and endemic. War, famine, and disease produced apocalyptic historical cycles and left records in history.

Written records exist, but some still lack a clear explanation, for example, for the plague in Athens, the plagues of Egypt, or the *colerica passio* of Garcia da Orta (Carvalho, 1992). The changes resulting from these processes profoundly affected human health on unprecedented scales, contributing to the distribution of the health conditions known until recent historical times.

In the Late Middle Age, a grand cycle of technological development accelerated health changes with a global impact. As a result of accumulated experiences and advancements, a cycle of great navigations began, placing the

different continents in definitive contact in a very short time. Although occasional contacts through early navigation and other movements had already opened the passage between continents, long-distance contacts were sporadic and limited population flow was possible. Successful navigation, with rapid ocean crossings and reaching distant lands, led to the first regular contact between places and peoples separated by millennia, thus redistributing diseases, political projects, and cultural influences. The American continent opened up to contact with other peoples (from Europe and later Africa and Asia) beginning in the 15th century, producing intense biological and cultural exchange, hugely significant for health on both sides of the Atlantic (Verano & Ubekaler, 1992).

An exception on the American continent was the crossing of the North Atlantic by the Vikings in the 11th century. Excellent sailors and navigators, the Vikings, led by the successful epic seafaring journeys of Erik, the Red, already maintained colonies on Iceland and Greenland before they ventured further to North America, led by Erik's son, Leif Erikson. They managed to reach Cumberland Pen. They proceeded from there, exploring the coast until Hudson Bay and Chesapeake Bay. They established their westernmost colony in North America, taking domesticated animals with them and maintaining contact with the indigenous peoples for decades.

However, difficulties in the ocean crossings, the distance from Europe, frequent hostilities with the indigenous groups, and other factors prevented the project from continuing, and the colony was eventually abandoned after several decades (Pohl, 1966).

Contact across the Atlantic, but especially the regular journeys and the colonial project, implemented in fact beginning in the 17th century, accelerated this process of changes. Added to this process the last great African Diaspora, that of slavery. The forced transfer of millions of human beings of different ethnic groups from Africa to America, as slave labor, together with the heavy mortality of indigenous groups in colonized areas, constitutes one of the most drastic demographic processes in history. This process, reaching its peak between the 17th and 19th centuries, was accompanied by a major modification of the worldwide health scenario, extended by the impacts of emerging technology and science.

The Industrial Revolution in the late 18th and early 19th centuries was accompanied by a new epidemiological transition. Life became urbanized at a fast pace, and people became subject to conditions of intense work, confined and far from food production and the autonomy of small rural places. Population density increased with the large agglomerations of individuals in diverse environments, in both factories and urban dwellings. There were even faster lifestyle changes in the following decades. Despite progress in medical and sanitary knowledge, with both preventive and curative effects, changes that harmed human health appear to have moved more easily than those improving quality of life. Antibiotics and basic hygiene had an important impact on mortality; however, persistent inequalities in food, housing, and access to goods made various clinical and pathological conditions endemic. And there was no more biological time for adaptation: the changes took place in just a few years.

Traditional peoples changed in just a few years to economies and lifestyles that included numerous industrialized diet items and tools. Bodies that had adapted for thousands of years to a certain energy and metabolic balance now became ill, due to the difficulty in adjusting to such changes. Throughout human evolution, for millions of years, slow adjustments have helped maintain the balance between health and living conditions. Movements and changes in lifestyle have accelerated in recent decades, making adaptability (and especially adaptation) a permanent challenge.

One of the most interesting questions in the peopling of America is the so-called New World Syndrome, with a high prevalence of three chronic conditions among Native Americans that have become veritable endemics: diabetes, obesity, and gallstones. Contact by Native American groups with the Western lifestyle and diet in the last century and the profound impact they have suffered since contact have led to extremely high rates of overweight and diabetes.

A new energy balance has resulted from the reduction in the effort expended to obtain foods (which are now also more energy-dense), with severe metabolic and cumulative effects. A widely accepted explanation is the “thrifty genotype” hypothesis, according to which the millennia-old selection that allowed successful survival under a regimen of irregular food supply in the Paleolithic (the “feast and famine” phenomenon) led to a metabolic mechanism which now (given our modern abundance of food) causes health problems such as high cholesterol and diabetes. Throughout human evolution, there was an adaptive advantage to rapid insulin release, favoring energy storage during periods of abundance. In a situation of excessive calorie supply, this mechanism causes obesity and diabetes.

According to Lieberman (2008), evolution conditioned a situation of frequent food deprivation, the consequences of which included triggering the impulse to eat whenever food was available. In cultures in which the food supply increased, this also led to consumption far above necessary levels and difficulty in controlling or reducing food intake, even through voluntary restrictions such as diets, thus further aggravating individual nutritional status.

Many themes have been discussed in this line of evolutionary medicine. For example, an evolutionary perspective helps explain our eating preferences. The human species prefers sweet flavors and fatty foods. This apparently bears a coherent relationship to the search for high-energy foods, a determinant factor for our survival. In a species with such a crucial organ as the human brain, this would certainly be an adaptive advantage (Turner et al., 2008).

Our sleep patterns are another issue under discussion. Worthman (2008), comparing sleep in different animal species and in different traditional human cultures, discusses such aspects as sleep duration and continuity, the setting in which one sleeps, darkness, silence, and the role of television as a replacement for the bonfires or noise that have rocked humans to sleep throughout evolution.

Evolutionary medicine has investigated other issues. Paleopathological studies complement such research in many cases. Such discussion includes problems never previously considered from an evolutionary perspective, such as eclampsia, an exclusively human disease, drug addiction, and altitude sickness (Trevathan, Smith & McKeena, 2008). Looking to the past through archaeological testimony, genetic processes, and other types of data increasingly help explain our current health condition and develop future strategies to deal with what we refer to as diseases.

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