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EDITORIAL

Geriatric issues from the standpoint of human evolution

Introduction

Mankind is thought to have separated from a common ancestor shared with chimpanzees approximately 7 million years ago.[1] At the time, among our ancestors was a group that decided to come down from the trees to live in the savanna as desertification of Africa's forests progressed. Although the term "ape-man" was used for early mankind who walked on two feet, improvements in the precision of dating methods and excavations from the latter half of the 20th century made it clear that many types of human species coexisted. Thus, the term "ape-man" is now only rarely used. Bipedalism was likely something attempted by many groups, and although many theories exist, the underlying reason for this transition is unclear.[2] However, the advantages are clear – it enabled viewing vast distances and the use of hands to carry food, and ultimately led to the expansion of brain size. Interestingly, it took our ancestors an additional 4 million years to expand their brain size. This evolutionary delay might have been caused by climate changes in Africa. The progressively drying climate led to reductions in forestland, and our ancestors who lived on the plains were subjected to a new type of natural selection pressure, causing changes in their physique and behavior. One possible reason that orangutans remained in the trees when transported to Asia by continental drift was that although Africa and the Northern hemisphere began to dry and cool from approximately 30 million to 2.5 million years ago, Asia's forests in the tropical regions remained intact.

Evidence of brain size expansion and the use of tools can be found from approximately 2.5 million years ago. Mankind at this stage is referred to as *Homo habilis* or *Homo rudolfensis*. The concept of pre-adaptation refers to gradually altering physique in advance so that it works to one's advantage once subjected to a particular environment. For instance, the advantages of walking erect are thought to have played an important role in the evolution of mankind much later; that is, approximately 2.5 million years later. The expansion of brain size also brought about a revolution in food energy, which accompanied the use of stone tools – the ability to ingest high caloric and nutritious meat products. Although they were "meat-eating" and hunted herbivorous animals on occasion, their meat supply likely came from food left over by carnivorous animals. In addition to increasing meat-eating efficiency, the expansion of brain size was accompanied by acquisition of modern man's physique, an expanded range of activity and loss of body hair.

Although many human species remained in Africa, one group, the Peking man or Java man (also known as *Homo erectus*) moved to Eurasia approximately 1.8 million years ago in an event referred to as the first African exodus. At least one group of *Homo erectus* began using fire, a monumental event in mankind's history. *Homo erectus* existed until 250 000 years ago.

We enter the age of modern man from approximately 200 000 years ago. The Neanderthals were another species of man that coexisted with modern humans during this period. This period saw the use of symbols, language and original art-forms. One group of modern humans left Africa approximately 100 000 years ago, and eventually adapted to all global environments in an event famously known as the second African exodus. Many terrains were conquered, including grasslands, deserts and mountains, and humans began living under various climates (tropical, temperate and polar). The conquering of various terrains is evidenced by the existence of Eskimos in polar regions, Bushmen in the deserts, Pygmies in the tropical rain forests, and Tibetan highlanders. The spreading of humans was particularly fast, with humans reaching Europe, Asia, North and South America, and Australia within the span of tens of thousands of years.

Mankind at the time formed small nomadic groups and lived as hunter-gatherers. From a modest population of approximately 100 000 about 1 million years ago, the global population dramatically increased to 500 000 about 200 000 years ago, and further to approximately 10 million with the advent of agriculture about 10 000 years ago.[3]

Dawning of the agricultural revolution

Domestication of wild plants and animals approximately 10 000 years ago was a groundbreaking event in mankind's history. With the introduction of agriculture, increased food production and storage became possible, and those not involved in food production became soldiers, bureaucrats, and technicians, evolving society and bringing about social and gender inequalities. As

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human cultures diversified further in the past 10 000 years or so, the divide between them also increased.

Lifestyle became settled with the advent of agriculture, naturally leading to explosive population growth. Indeed, this translated to a more than 10-fold increase in global population in the past 5000 years.

Agriculture also brought about new threats to mankind's existence. Although hunter-gatherers had difficulty securing an adequate food supply, they were able to maintain diversity in their diet with an appropriate variety of foods with respect to protein, mineral and vitamin intake. Agriculture, however, prompted the transition to carbohydrates as the main source of energy, leading to nutritional bias and malnutrition. Paleopathological studies comparing nutrition between hunter-gatherers and farmers suggest that hunter-gatherers likely led healthier lives.[4,5]

The reliance on a small amount of crops also made difficult the securing of adequate food supplies to support large populations, sometimes leading to famine. It is likely that the threats of malnutrition and famine were much more pronounced after the introduction of agriculture compared with when humans were hunter-gatherers.

In addition to the foregoing, diseases were also products of the agricultural revolution. Dense populations brought about epidemics. For instance, the concentration of people and livestock, and the introduction of irrigation provided mosquitoes ample hosts to spread infectious diseases. Infectious diseases were rampant among highly populated settled groups with poor nutritional status, transmitting from animal to human and from human to human. Epidemics were not an issue with hunter-gatherers, who remained in small groups and constantly travelled. Diseases that transmit between humans (e.g. tuberculosis, leprosy and cholera) became prominent with the introduction of agriculture. Smallpox, the bubonic plague and the measles came about in the past several thousands of years, as populations became concentrated with the building of cities. From the advent of agriculture to recent times, approximately one-fifth of the population is estimated to have died before the age of 5 years from malnutrition in infancy and infectious diseases. The history of epidemics since the agricultural revolution is discussed extensively in McNeill's *Plagues and People*.[3]

Since the times of Archimedes and Eratosthenes of Greece, scientists such as Copernicus, Newton, Galileo, Descartes and Leibniz have made revolutionary discoveries, but before the 18th century, there were no discoveries relating to evolution or findings that would form the basis for modern medicine. It was Jenner, at the end of the 18th century, who developed the smallpox vaccine and greatly influenced society through his keen, experienced intuition.

Although the human population grew explosively with the advent of agriculture, it is estimated that the total population from Ancient Greece to the Roman period, and further through the period of explosive population growth that accompanied the period when agriculture became firmly rooted in society, was approximately 100 million or so.

Since the agricultural life became fixed a few thousand years ago until about 1700, there was no dramatic increase in population.

Evolutionary significance of lifestyle-related diseases

For at least the 6.99 million years since humans diverged from their chimpanzee ancestors 7 million years ago, our bodies were designed to live in small groups as hunter-gatherers. Genes maximally adapted the human body to the environment and lifestyle of the Stone Age by establishing an immune system to fight infectious diseases, hemostasis mechanisms to minimize bleeding from wounds, an energy-saving mechanism to overcome starvation, and neuro- and muscular-response systems to allow for strenuous movements. At most, the lifespan of an adult in the Stone Age was 30–40 years, and the body was designed to adapt to this lifespan. With agriculture and the transition to a settled lifestyle came the densification of populations; however, this transition was not accompanied by a substantial increase in lifespan.

However, substantial changes in mankind's history were brought about in the latter 50 years of the 20th century. Stabilization of the food supply curbed starvation, and brought about satiation. Food composition transitioned from a carbohydrate-based diet to being protein- and fat-based. Changes in industrial structure brought about transition to a sedentary lifestyle, accompanied by lack of exercise, from a physical labor-based agricultural lifestyle. Yet, the greatest change was the marked increase in human lifespan. Indeed, the human body, which was maximally adapted to the Stone Age, would experience a lifespan of 80–90 years for the first time.

Fats, sugars and salt were constantly lacking in mankind's history. Humans had a lifespan of 30–40 years, and taking in as much of these substances as possible was considered healthy. However, as these substances became plentiful, the incidence of high blood pressure, and subsequent stroke, increased after the age of 40 years. Similarly, with satiation, the energy-saving mechanism designed to withstand starvation led to diabetes. The cholesterol system, which stores and effectively uses fat when the food supply is low, led to deposition of cholesterol in blood vessels after the age of 40 years, causing atherosclerosis and myocardial infarction. Colon cancer is also increasing at an alarming pace as a result of high fat diets and prolonged lifespan. The mechanism of calcium intake into bones during growth led to calcium deposition in blood vessels after middle age, promoting atherosclerosis.

Recently, gene polymorphisms that influence the development of chronic diseases, myocardial infarction and osteoporosis in the elderly are being identified one after another. Yet, these polymorphisms might be performing useful functions in younger years. The age-related "biological trade-off", wherein the effects are favorable when young, but become detrimental with aging, is easy to understand when considered from the evolutionary context.

The various lifestyle-related diseases faced by developed countries likely reflect the surpassing of the capacity of the human body, which was adapted to the 30 to 40-year lifespan of the Stone Age, due to rapid environmental changes and the extension of lifespan. Fifty years is obviously much too short a period for genes to evolutionarily adapt and promote changes to the human body.

Trade-offs from bipedalism and brain size expansion: Fractures, falls and cognitive disorders

The genetic design acquired by mankind over its 7 million-year evolutionary history was designed to adapt to Africa's ecosystem and environment. Acquiring the ability to walk on two feet was a paradigm-changing event. To achieve this feat, humans needed to morphologically alter the pelvis and acquire the complex ability of balancing. From the standpoint of human developmental ontogeny, the ability to achieve stable body balance requires many years of growth from infancy. Yet, this ability declines with the progression of age in the older years. It is unlikely that genes could have foreseen that 7 million years later, bipedalism would lead to falls and fractures in the elderly, which rank third among reasons that elderly people become bedridden.

Approximately 4 million years after beginning to walk on two feet, the brain size expanded, which led to the invention of stone tools, the first African exodus, the use of fire, the second African exodus, the invention of language, development of art-forms and the invention of agriculture. Since the agricultural revolution, humans have continuously altered the global environment. While increasing population density by adopting a settled lifestyle, some also sought farmlands and pasturelands, moving to and seeking livelihoods in various environments. By taking advantage of the natural ecosystem of a particular terrain, they established cities and inter-regional trade networks, creating a human-specific social structure called "civilization", and contemplating even the well-being of the spiritual world. All of these were brought about by the developed brain, which finds no equal in other animals. One can go as far as saying that modern political/economical systems, environmental health systems and the development of modern medicine were not products of genetic design, but rather brought about by civilizations, using the human brain as a vehicle.

As aforementioned, the genetic design that presumed a lifespan of 30–40 years likely did not expect the modern lifespan of 90 years. The evolution of intellectual ability that accompanied brain expansion, and the resulting super-aged human societies, will come to experience Alzheimer's disease as a common disease. Bipedalism versus falls in the elderly years, and brain expansion versus cognitive disorders in the elderly are representative biological trade-offs; that is, abilities that were advantageous in younger years, but function detrimentally in the elderly.

Conclusion

The basic principle in the evolution of life was "to live long enough to reproduce." Yet, 21st century humans are faced with a problem that transcends this principle, namely, "living much longer after reproduction." When considering the basis of survival of the anthroposphere, in addition to issues related to energy and the global environment, one task moving forward will be how to construct the advancing elderly society. While we have experienced the greatest scale of population increase since the agricultural revolution and the first major extension of lifespan in human history, the "cultural" genes of mankind will be faced with more problems related to survival than the many that have been experienced to date.

Elderly persons living a satisfying, purposeful life followed by a peaceful death is the ideal, but it poses a challenge as to whether we are able to create a society in which this can be achieved.[6,7]

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Kozo Matsubayashi
Center for Southeast Asian Studies, Kyoto University, Kyoto, Japan

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