

Possible Relevance between Evolution of Human Bones and Behaviors

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Abstract. Throughout the course of human evolutionary history, a distinct species diverged from early primate ancestors, which belongs to the apes clade. Humans have undergone remarkable morphological transformations that enabled them to successfully adapt to their surroundings, resulting in enhanced fitness and positioning them as the predominant species on Earth. This research centers on the progression of human evolution by presenting diverse sections of the evolutionary progression: spanning from quadrupedalism to bipedalism, from basic behaviors to advanced capabilities, and the corresponding adaptations that accompanied these behavioral shifts. Considering the synthesizing insights from various perspectives, the evolution of humans appears an exceptionally fortunate phenomenon. The primary purpose of this paper is establishing a focal point for future investigations on human evolution. Nevertheless, fractional and scattered fossil records and interpretation of behavior are the two major difficulties when studying human evolution. Many transitional forms of bones, for example, may never be fossilized, and those that have been preserved are often found in small, isolated fragments, making it challenging to reconstruct the complete story of human evolutionary history. Moreover, behavior does not fossilize, so researchers must rely on indirect evidence such as tool use, symbolic artifacts, and morphological features to study the human evolution of behaviors.

Keywords: Bipedalism, Quadrupedalism, Evolution, Pelvis.

1. Introduction

The evolutionary history of human controversial topic that always causes hot debate because we are whimsical species that develop special skills that can conquer other animals. Based on the study of human bones, we can simply draw out the conclusion that human evolution follows Darwinism, that is humans evolved consistently over 7 million years. Moreover, humans can find their closely related ancestor with other primates and the evolutionary trace from the evolution process.

At the start of this paper, we shall dive into a comprehensive analysis of the progressive changes observed in the human pelvis structure across various pivotal splitting points of evolution that underlies the profound transition of humans from quadrupedalism locomotion to bipedalism. This evolutionary transition has, in turn, engendered a terrestrial habitat for humans, departing from the arboreal habitat, which is a shared living style with early humans and other primate species. It is noteworthy that while the transformation of the pelvis has brought about certain challenges in the process of childbirth due to the inherent trade-off between mediolateral expansion and facilitating enhanced load-bearing capacity, the advantages provided by the adoption of bipedalism confer augmented fitness benefits upon the human species [1]. Consequently, this alternation in pelvis morphology is intrinsically tied to the evolutionary success of bipedal hominins.

Moreover, a crucial point of inquiry within this paper is about the braincase (skull) in Homo sapiens. The skull assumes a salient role as it exerts influence over intelligence, a factor that may intricately connect with the progression of human behavioral traits. The rationale behind this phenomenon is clear through a comparative analysis of the evolutionary process of cranial morphology and behavioral propensities. Noteworthy is the emergence of stone tools designed for excavation purposes, happening with the evolution of Australopithecus approximately 3 to 4 million years in the past. By paralleling the cranial features of this species with Homo heidelbergensis, an observable twofold increase in cranial capacity is apparent [2]. However, it is plausible that Homo

Heidelbergensis developed arts and engendered intricate tool fabrication, thus signifying a potential linkage between heightened cranial capacity and the proliferation of sophisticated behaviors.

Additionally, the emergence of complex human language stands as a critical turning point signifying the attainment of advanced social structure within the human species. This linguistic capability facilitated communication among early human groups for collaborative activities, such as hunting large animals and the establishment of barter networks between diverse individuals. While language holds a shared occurrence across various animal species, its expression in distinctive forms in the context of humans. Nevertheless, the nature of this evolutionary progress is vague because of a scarcity of definitive evidence, in contrast to the fossil records that document other evolutionary turningpoints. The abrupt emergence of language has led to a hypothesis of it as a bestowed divine skill rather than a gradual product of evolution. Notwithstanding this, a prevailing hypothesis explicates language evolution through the perspective of natural selection – a biological mechanism where nature favors traits that provide enhanced fitness upon organisms [3]. Language aligns with such adaptive traits, as humans with advanced linguistic capacities exhibit heightened survival rates under specific environmental conditions. It is within these selective pressures that the role of language in human is important.

2. The evolution of the human bones

2.1. The evolution of the human pelvis

The human pelvis is different from other primates, like chimpanzees, lemurs, and apes, in that the shape of the pelvis extends laterally providing a larger plane for supporting the upper body and muscles for bipedal walking and reproduction. The pelvis has evolved to provide some efficiency and stability in human locomotion. Early humans walked both bipedally and quadrupedally, similar to the ancestral primates.

2.1.1 The evolution of pelvis of non-homo Hominins

Ardipithecus ramidus provides the earliest pelvis fossil, from 4.4 million years ago, that resembles apes to some extent. The pelvis of *Ar. Ramidus* is a combination of ancient and early pelvises (see Figure 1) [1]. The upper pelvis of *Ar. Ramidus* resembles the chimpanzee's, mainly on the wings of the ilium which spread out laterally and is longer vertically (see figure 1-3). The lower pelvis resembles the gorilla's, mainly on the pubic arc and inferior pubic ramus. The angle of the arc is not as sharp as human, so the notch is more circular and the whole pelvis is not extended to the side. Therefore, the pelvis cannot provide enough stability that can support the whole upper body, so the early humans walked on both two legs and four legs. In addition, they can run but at a slower speed [1].

To compare with the *Ar. Ramidus* pelvis to show the evolution pattern, *Australopithecus Africanus* is the Hominin that evolved after *Ar. Ramidus*, around 2.1 million years ago (Mya) to 3.3 Mya. The iliac wing is widened and bulged out laterally, giving a bowl-shaped pelvis compared to *Ar. Ramidus* (see Figure 1) [4]. Moreover, the pubic arc concaved in, so that the lower body experienced a great lateral bulge. The biomechanical aspect of pelvis in the locomotion of early humans is that the broad pelvis of *Australopithecus* allowed greater stride which leads to higher efficiency and lower locomotion cost [1]. Moreover, the two long legs required for greater stride frequency can be supported by the broader pelvises, but from an energetic perspective, the increase of cost on two long legs may not be offset by walking longer stride [1].

In sum, the structure of the pelvis in early humans is indicative of their transition from arboreal (tree-dwelling) to terrestrial (ground-dwelling) lifestyles. With the evolution of hominins, the pelvic morphology changed to accommodate the demands of walking upright on two legs. The bipedalism was a significant adaptation that allowed to travel longer distances on the ground.

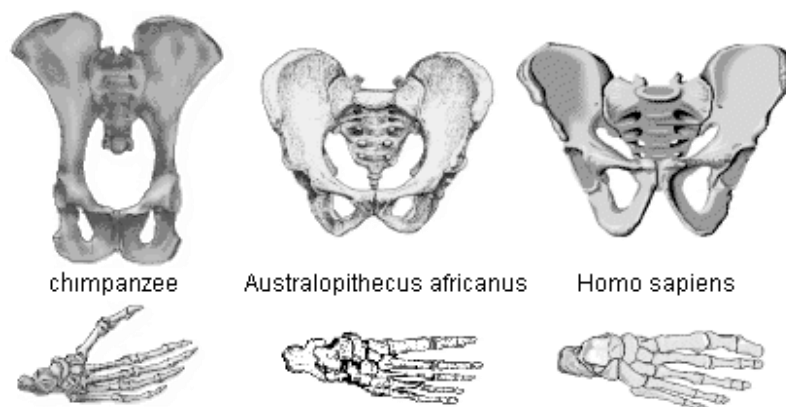


Fig. 1 This image contains both pelvis and feet fossils of a chimpanzee [4]

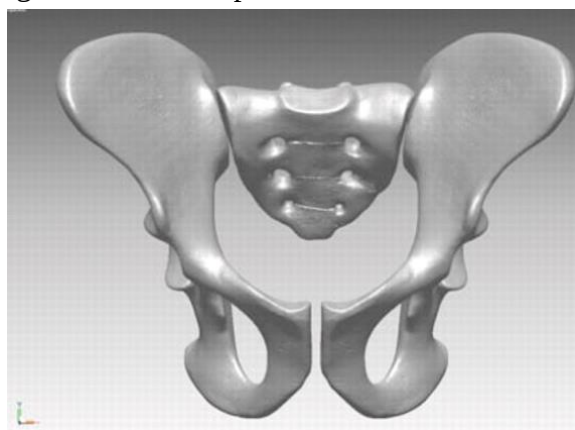


Fig. 2 The pelvis of Ar. Ramidus [5]



Fig. 3 The pelvis of a gorilla [6]

2.1.2 The evolution of the pelvis of modern Homo Hominins and the trade-off between two traits

The existing evidence suggests that the pelvis structure maintained a primitive shape, which are mediolaterally broad and anteroposterior narrow, but there are some changes related to distinctive behaviors that belong to the homo genus. However, the structure is still not well studied due to the lack of fossil records in other parts of the world, which were mainly discovered in Africa although they have migrated to Asia and Europe. According to Figure 4, the comparison between the pelvis of homo Erectus and homo sapiens, the ilium wing of the home sapiens is curved inward, making the

pelvis smaller but more stable when walking. Moreover, the pubic arc lifted the lower pelvis, creating a bowl-shaped surface plane for supporting the gluteal and upper body [4]. This effect on the gluteal abductors indicates adaptations to both efficient walking and potential endurance running since the homo genus spends much less time on the trees, even spending no time on the trees [7]. Moreover, a narrower pelvis changes the birth canal, indicating an evolution to rotational birth. The birth canal is larger, but still hard for larger-brained infants. This is a trade-off between bipedalism and parturition which is an important factor that influences the evolution of Homo Hominins. Childbirth is not a complicated work to accomplish until the evolution of Homo Hominins because this genus relies on bipedalism more than any other early humans as mentioned above. According to Figure 5, there is a great leap in the brain size between homo sapiens (modern humans) and Australopithecus. Childbirth is complicated by the need to pass a relatively large-brained infant through the birth canal. The challenge is balancing the benefits of efficient bipedal locomotion with the need to safely accommodate the birth of infants. Changes in pelvic dimensions, the orientation of pelvic bones, and the shape of the birth canal have all played a role in the adaptation to resolve this trade-off.



Fig. 4 The pelvis structure of homo sapiens and homo erectus [7]

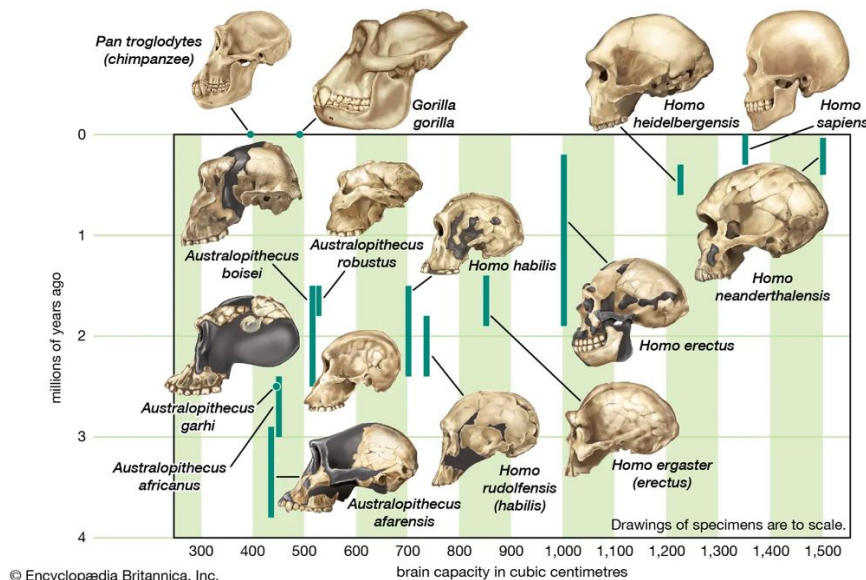


Fig. 5 The evolution of human brain size [8]

2.2. The evolution of human skulls

The evolution of the human behaviors can also be uncovered by the research on human brain, such as the evolution of language, tool use, and cooperative hunters. These behaviors evolved in line with the evolution of human brain size. Since the evolution of brain structure is hard to track, the braincase (skull) is a wise choice. The braincase of the homo sapiens was tripled in size compared to early hominins [2] (see Figure 5). Moreover, the pivotal shift towards bipedalism is characterized by the change of the foramen magnum, the opening in the skull for the spinal cord. In contrast to predominantly quadrupedal chimpanzees wherein the foramen magnum is situated posteriorly,

bipedal hominins exhibit a ventral migration of this opening beneath the skull [9]. Consequently, it leads to cranial flexion. Further, the face becomes smaller since the neurocranium (braincase) becomes more globular and the face rotates under the skull. Nevertheless, the smaller face leads to less room for the airway particularly in the development of human fetuses. However, the evolution of the human chin, an exclusive characteristic inherent to *Homo sapiens*, resolves this issue. This morphological attribute is understood to have emerged in response to an augmented necessity for accommodating the expanded dimensions of the posterior airway within the pharyngeal region. Notably absent in any other hominin species, the presence of a chin serves as a discriminative feature employed for the differentiation and classification of *Homo sapiens*.

The developmental trajectory of specific social behaviors appears to be correlated with the progressive elaboration of the human skull architecture. Over the transition from *Ardipithecus* to the *Homo* genus, the sophistication of tool employment has notably advanced. *Ardipithecus*, characterized by a skull mass similar to that of chimpanzees, exhibited an absence of tool utilization. In contrast, *Homo erectus*, distinguished by an augmented cranial capacity of around 1000 cubic centimeters (as illustrated in Figure 5), emerges to be the first human that engaged with fire. Furthermore, *Homo neanderthalensis*, boasting an even greater cranial size, attained a stage of intricate tool use, burials, art, and conceivably, language.

3. The evolution of human behavior

Throughout evolutionary history, the anatomy of the human body has undergone significant changes. These adaptations have conferred enhanced survival advantages within the environments. Additionally, unique patterns of human behaviors have emerged, which other animals do not possess. Furthermore, certain behavioral manifestations exhibit intricate interconnections with the evolutionary progression of skeletal structures, exemplified by traits like bipedalism, and linguistic capabilities.

3.1. Relevance between pelvis and the evolutionary history of bipedalism

The locomotion patterns of early hominids diverged from those observed in present-day humans due to distinct variations in their skeletal anatomies, as a focusing point within this paper. According to the information depicted in Figure 6, *Sahelanthropus*, the earliest hominin to branch away from apes, represents the first primate that exhibits bipedalism, i.e., walking predominantly on two legs [10]. This genus originated approximately 7 million years ago in Africa. Nevertheless, it preserved a combination of terrestrial and arboreal lifestyles due to a group of primitive traits similar to apes, alongside certain human-like characteristics such as the position of the foramen magnum—a cranial opening situated underneath the skull. This morphological feature implies that *Sahelanthropus* could locomote on two legs, albeit with a posture less straight than the contemporary humans. Notably, the locomotive behaviors of later hominids, like *Homo erectus*, began to mimic more human-like attributes. Consequently, the *Homo* genus achieved complete bipedalism, signifying a departure from arboreal habitats. *Homo erectus*, emerging approximately 1.8 million years ago, exhibited physical traits characterized by elongated hindlimbs and robust joints reminiscent of modern humans, further solidifying their bipedal nature [10].

3.2. Possible hypotheses for the evolution of language

Verbal communication serves as the auditory mode of interaction among humans, whereas *Homo Neanderthals* potentially represent an early instance of a hominin species engaging in sophisticated language systems owing to their development of intricate societal practices, exemplified by activities like burials. The emergence of language evolution is underpinned by one conceivable hypothesis. The initial proposition pertains to the influence of natural selection. Biological or morphological traits must provide selective advantages to the species for them to evolve and favor by nature. Language, an intricate and multifaceted system of communication, encompasses various components including

syntax, semantics, phonology, and pragmatics. It should be noted that the development of language is not a consistent trait that parallels the evolution of hominins. However, among the various theoretical frameworks, natural selection emerges as the most plausible explanation for the evolutionary origins of language [9]. This particular trait conferred significant advantages upon early hominins, enhancing their ability to engage in cooperative endeavors, share important information about available resources and potential threats, and establish intricate social structures. Consequently, this facilitated heightened reproductive success and increased overall fitness among these hominin populations.

Furthermore, the theory of group selection, a specialized form of natural selection, presents a more targeted perspective on the evolutionary emergence of language. Group selection pertains to scenarios in which a population that exhibits specific behaviors gains a competitive edge over other populations lacking those behaviors. Within this context, the population of hominins endowed with the capacity for communication held a distinct advantage. By effectively exchanging information with fellow individuals, this population was better equipped to navigate challenges and secure essential resources, thereby augmenting their likelihood of survival and reproductive achievement compared to populations devoid of linguistic capabilities.

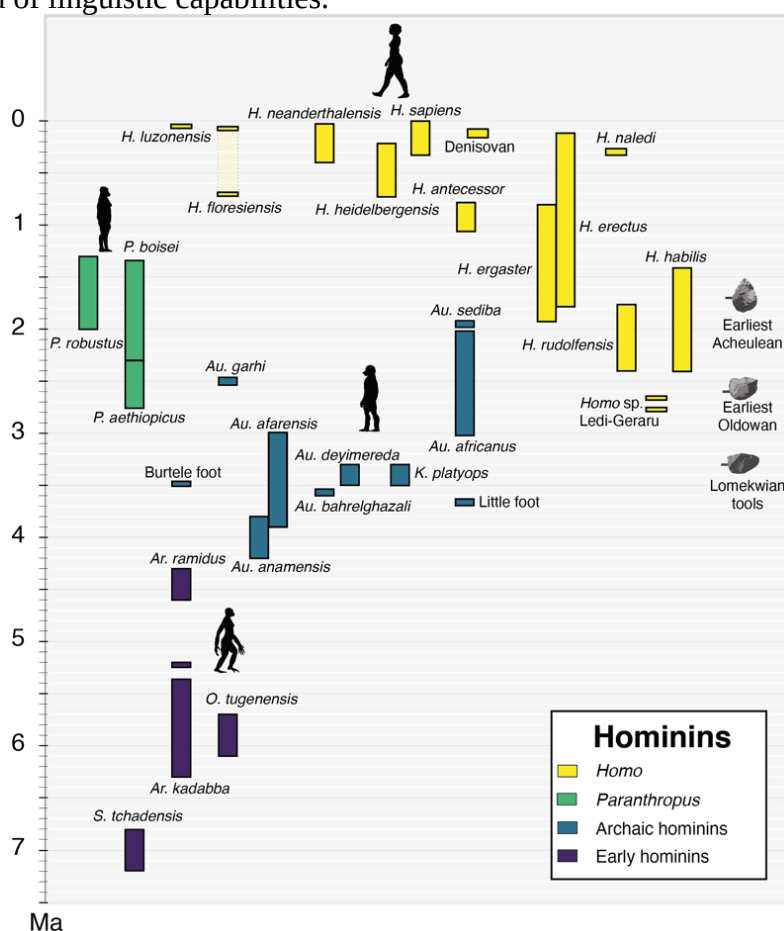


Fig. 6 The period of the evolution of humans [11]

4. Conclusion

In conclusion, the evolutionary trajectory of humans stands as an enigmatic and intricate episode within the annals of Earth's history. While underpinned by the power of mutations and natural selection, these processes have not merely imparted anatomical alternations, but also distinct behavior, which set humans apart from their animal counterparts. Evident in each morphological adaptation is an intimate correlation with specialized behaviors, reinforcing the intricate interplay between form and function. Although situated within the realm of the natural world, the evolution of humans

exhibits a unique fluctuation, adhering to the fundamental dictates of nature. The reshaping of the pelvis, transitioning from its anteroposterior prominence to a mediolateral projection, underscores a transition towards bipedalism, a trait that saves energy conservation and heightened efficiency, from quadrupedalism. The shift from slender to flat and wide pelvis shape aligns seamlessly with this transformative stride. Concomitantly, the human habitat has undergone a substantial shift, progressing from arboreal to terrestrial. The cranial vault, a crucible of intricate adaptations, has burgeoned in size to accommodate the demands of intricate behaviors pivotal for human survival. This expansion, tripling the braincase dimensions from early human antecedents, has endowed *Homo sapiens* with cognitive capacities capable of orchestrating sophisticated tool usage and intricate language systems. Illustrated through the utilization of tools to secure sustenance and enhance nutritional intake via cuisines, and further manifested in the facilitation of cooperative endeavors through communication, these evolutionary refinements illuminate the dynamic interrelationship between form and function. Natural selection, a selective force that propels these adaptations towards their apex points, is the prevailing agent throughout the evolution of humans. However, the underlying query remains: what impelled humans toward the development of these distinct capabilities? Finally, this paper aims to forge a cogent relationship between morphological changes and the parallel evolution of human behaviors. Serving as both a summary and an exploratory review, this work affords a panoramic vista of the intricate voyage charted by human evolution.

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