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BIPEDALISM AND THEIR DEVELOPMENTS

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Abstract
The History of human evolutions is considered as such a long journey in the history of human. Starting from 19th or 20th century, we had look back to find a trace of the origin of human by studying on fossils and some other primates such as simian, chimpanzee, bonobo etc.The evolution of bipedalism is involving with the human history since the origin of human have evolved. Many Anthropologists have proved some theories and some other evidences on how human develop from habitual of walking on four legs until the using manner of walking on two legs. Sometimes they believe of finding traces or evidences which is so-called "the missing link" between monkey and human of which they are thinking of "finding our ancestors".

This paper is focusing on how human develop from walking on four legs until having habitude of walking on two legs and some evidences of the development of bipedalism through time.
Key words: Bipedalism, Australopithecine, Homo erectus, Human evolution, Footprints, Chimpanzee.

Intorduction

The word Bipedalism is derived from Latin's word which is significant meaning of "The habit of standing, walking, moving, running or hopping on two appendages (typically legs". Human, animal or machine that usually moves in a bipedal manner is known as a Biped (/'bai. Ped/), meaning "two feet" (Latin *bi* = two + *ped* = foot).

Diversity and evolution of bipedalism

Type of bipedal movement

There are a number of states of movement commonly associated with bipedalism[1]

1. *Standing:* Staying still on both legs. In most bipeds this is an active process, requiring constant adjustment of balance. Energy-efficient means of standing bipedally involve constant adjustment of balance, and of course these must avoid overcorrection.
2. *Walking:* One foot in front of another, with at least on foot on the ground at any time. Efficiency, walking habit is more complicated than standing. It entails tipping slightly off balance forward and to the side, and correcting balance with the right timing. In humans, walking is composed of several separate processes:
    - Rocking back and forth between feet
    - Pushing with the toe to maintain speed
    - Combined intruption in rocking and ankle twist to turn
    - Shortening and extending the knees to prolong the "forward fall"
3. *Running:* One foot in front of another, with periods where both feet are off the ground. Running is an inherently continuous process, in contrast to walking; a bipedal creature or device, when efficiently running, is in a constant state of falling forward. This is maintained as relatively smooth motion only by repeatedly "catching oneself" with the right timing, but in the case of running only delaying the nearly inevitable fall for the duration of another step.
4. *Hopping:* Moving by a series of jumps with both feet moving together.

Diversity and difference types of bipedalism

There are many difference types of bipedal in history of evolution with involved through time. Scientists and Anthropologists have believed that there are at least two big different types of bipedal and their evolutions such as bipedal animals and bipedal humans.

Bipedal Animals

The bipedal animal is evolved in many numerous times rather than bipedal human, mostly among the vertebrates. Bird is the most obvious movement in a history of bipedal and their ancestors the *theropod* dinosaurs.

[1] For more information through the evolution of characteristic of bipedal, please see in « The Cambridge Encyclopedia of Human Evolution » Edited by Steve Jone, Robert Martin and David Pilbeam

The first well known bipedal are might have though to be a dinosaurs. All dinosaurs are believed to be a descended from their ancestors, perhaps similar to Eoraptor. Indeed, among their descendants, the larger flightless birds, the patiltes, such as the ostrich, perhaps epitomize the capacity to move bipedally, able to reach speeds of up to 65km/h. Some extinct members of the crocodilian line, a sister group to the dinosaurs and birds, have also evolved bipedal forms, a crocodile which is relatively from the Triassic, was believed to be bipedal. Larger birds tend to walk with alternating legs, whereas smaller birds will often hop. Penguins are interesting birds with regard to bipedality as they tend to hold their bodies upright, rather than horizontal as in other birds.

Bipedal movement is less common among mammals, most being quadrupedal. The largest mammalian groups using bipedal movement are the Kangaroos and their relatives. However, these tend to move mostly by hopping, which is quite different from humans and many birds. There are also various groups of hopping rodents, such as the kangaroo rats. A primate, the sifaka, also moves by hopping when on the ground. Possibly the only mammals other than humans that commonly move bipedally by an alternating gait rather than hopping are gibbons when on the ground, and giant pangolins.

Limited examples of bipedalism are found in some other mammals, for example, the bonobo ape and proboscis monkey, who both live in forests that are often flooded, will wade through water in a bipedal stance. On occasion bonobo and proboscis monkeys and less frequently some other primates, will also walk or stand bipedally on land. A number of other animals, such as rats, will squat on their hind legs in order to manipulate food objects. The raccoon often stands erect or squats in water to use its hand to manipulate food and rocks/sticks. Beavers will also move bipedally at times when carrying branches. Some other animals such as bear may raise up and move bipedally during physical confrontation, so as to better be able to use their forelegs as weapons. Also a number of mammals such as ground squirrels or meerkkats will stand on their hind legs, but not walk on them, in order to survey their surroundings. Finally, gerenuk antelope are known to stand on their hind legs in order to eat leaves from trees. The extinct giant ground sloth had sip joints whose from indicates that they also did this. Another extinct group, the bizarre rhino/gorilla like chalicotheres may also have behaved similarly. One unusual from of limited bipedalism is the spotted skunk which when threatened stands on its forelimbs. This allows the skunk, while still facing the attacker, to direct its anal glands towards the attacker. The anal glands can fire offensively odorous oil.

Bipedalism is unknown among the amphibians. Among the non-archosaur reptiles bipedalism is rare, but is it found in the “reared-up” running of certain lizards. An interesting example is found in at least one genus of basilisk lizard that by this method can run across the surface of water for some distance. Bipedalism in the form of reared up running can also be found in some insects such as the cockroach. Otherwise, bipedal movement is unknown in arthropods. Bipeds are almost exclusively terrestrial animals. However, at least two types of octopus are known to walk bipedally by moving on the tips of two of their arms. According to the study, this form of locomotion may allow them to remain somewhat camouflaged while moving quickly, as the animal are still able to se the remaining six arms for disguise (taking a form like a coconut or seaweed), and as the necessary walking movements are hypothesized to be possible with minimal control from the brain.

The first known biped is the lizard Eudibamus cursoris whose fossils data from 290 million years ago found in Gotha in Germany. Its long hind legs, short forelegs, and distinctive joints all suggest bipedalism. This may have given increased speed. The species was extinct before the dinosaurs appeared. Independent of Eudibamus, some modern lizard species have developed the capacity to run on their hind legs for added speed (Fig. 1).

Bipedalism also developed independently among the dinosaurs. Dinosaurs diverged from their archosaur ancestors approximately 230 millions years ago during the middle to late Triassic period, roughly 20 millions years after the Permian-Triassic extinction event wiped out and estimated 95 % of all life on earth. Radiometric dating of fossils from the early dinosaur genus Eoraptor establishes its presence in the fossil record at this time. Paleontologist belive Eoraptor resembles the common ancestor all dinosaurs. If this is true, its traits suggest that the first ninosaurs were small, bipedal predators. The discovery of primitive, dinosaur like ornithodirans such as Marasuchus and Lagerpeton in Argentinian middle tiassic strata supports this view; analysis of recovered fossils suggests that these animals were indeed small, bipedal predators.

A number of mammals will adopt a bipedal stance in specific situations such as for feeding or fighting. A number of groups of extant mammals have independently evolved bipedalism as their main form of locomotion. For example, humans, giant pangolins, and macropods. Humans, as their bipedalism has been extensively studied are documented in the next section[2]. Macropods are believed to have evolved bipedal hopping only once in their evolution, at sometime no later than 45 million years ago (Burk et al 1998).

[2] Plese see Angela Burk, Michael Westerman, Mark Springer. (19998) The phylogenetic position of the Musky Rat Kangaroo and the evolution of Bipedal hopping in Kangaroos (Macropodidae: Diprotodontia) systematic biology, vol. 47, No. 3, pp. 457-474

Many animals that do not use bipedal locomotion in nature can be trained to walk on hind legs. Animals missing limbs due to injury or congenital deformity may adapt to bipedal motion, either on two hind legs or on one front and one back leg. For example, dog, macaque, Natasha, switching to bipedal walking completely after recovering from a serious illness. And at least one example of a captive chimp who only walked upright. Some animals can also be trained to walk on front limbs. Humans too, can learn to walk using solely their arms (handstand and hand walking).

Figure 1: Eudibamus cursoris, the first-known bipedalism.

Human bipedalism

There has been a challenge about the origin of bipedalism. Through human evolution, a theory of the evolution over bipedalism is running through time as many scientists have yielded out many papers about it origin. The first bipedal evidence in our human history evolution is believed to be a trace of early human footprint found in Laetoli, in Tanzanie which well- developed arches, on a paleosurface tuff dated to 3.56 millions years ago (Klein 1999:170). Paleoecological reconstructions for that time include bush land and aquatic fauna at Laetoli and closed woodland at Hadar. Direct evidence of bipedality in *Australopithecus anamensis* dates from between about 3.9 and 4.2 millions years ago (Leakey, et al. 1995). An *Australopithecus anamensis* tibia from Kenya has bipedal derived *Homo-like* characteristics. Bipedality is also inferred for the 4.4 millions ago *Ardipithecus ramidis* by the anterior foramen magnum (White, *et.al.* 1994). The pelvis and lower body of Australopithecus afarensis, dating after 3.4 millions years ago, provides even more extensive evidence of bipedalism.

Vrba's "turn-over pulse" hypothesis supports a major climate change, with onset of drier conditions and diminution of wooded habitats, beginning in the pliocence around 2.5 millions years ago. Faunal ratios evidence a change from frugivores to grasers spanning from 2.3 to 1.8 millions years ago, inferring a mosaic of ecological conditions during that span. Habitat reconstruction based on faunal association based on faunal hominid fossils demonstrate that *Australopithecus* species lived in wooded and well watered environments (Reed 1997). Homo is the first hominid known to have adapted to open, savannah like habitats, well after the evolution of bipedality. Arm-hanging anatomy persists long after the onset of bipedal characteristics, indicating occupation of wooded niches for the early bipedal hominid.

Habitual walking on two legs is one of the unique features that distinguish humans and their immediate fossil ancestors from the chimpanzees, gorillas and all other non-human primates. The evidence from fossil hominid leg bones and preserved trails of footprints shows that this change to bipedal walking happened very soon after the human evolutionary lineage diverged from the African apes, which suggests that bipedalism may have been an importance of bipedal locomotion is highlighted by the large number of theories that have been proposed to explain why walking on two legs is preferable to walking on all fours. Many of these theories argue that by using only your legs for wakling you are able to free up your arms for some other purpose, and it is often suggested that this other purpose involves manipulating or carrying something whether it is food, infants, tools, or weapons. This is supported by the fact that when chimpanzees are observed walking upright it is often when they are carrying items of food.

However, carrying is unlike walking, it is an activity that leaves no direct trace in the fossil record. One of the few ways of testing such theories relating to the advantages and disadvantages of behaviors in long extinct animals is to create computer simulations. These simulations allow us to estimate the actual numerical values of the benefits of behavioral change in terms of energy (and hence food) saved. If such a changed has a disproportionately large net benefit then we have some evidence to support our hypothesis, however if the effect is small then this would suggest that we need to look elsewhere.

Figure 2: The footprint found in Laetoli in Tanzania of which showing the first evidence of the bipedal in human evolution history (Source: Les origines de l'homme avant et après Lucy, Petite Encyclopédie Larousse).

How apes might have become bipedal? How did apes bridge the gap between walking on four legs and walking on two? An animal half way between the two might have been more vulnerable than either his quadrupedal ancestors or his bipedal successors. The transition could perhaps only have been made in the absence of predation. What follows is an imaginary story, which probably could not have happened for any number of reasons. But it illustrates how the principle of peripheral speciation might explain one of the problems of our evolutionary origin. An island off the coast of East Africa was perhaps once connected to the mainland by a sandbar. It happened that a small group of chimpanzee like apes found their way across and no predators followed them. There was an earthquake: the island was cut off. The main food supply on the island consisted of mollusks on the beach. The apes population expanded and it became hard to find mollusks except on rocks under the water or just off the coast. Over a few million years, the apes evolved. They spent a lot of time standing on their back legs in deep water, gathering mollusks.

All was not always peaceful on the island. There were no predators, but as a result the ape population tended to expand beyond the limits of the food supply. There was intense competition for access to mollusk beds. The population divided itself into small competitive groups. In each group, the females and young gathered food, protected by male guards, who would drive away females and children from competing groups. A male standing upon a rock with a plentiful supply of large pebbles could perform this guard duty much more effectively than he could by struggling in the water. The arm movement became specialized for efficient and accurate throwing. On land territory was defended by battles between males. As they developed, the common gene pool meant that at any one time, all were at much the same stage of bipedal development. But gradually, those who were better at fighting with sticks and stones won battles against those who preferred to remain on all fours and to rely on their canine teeth. So that when the island was re-connected to Africa and the ape population was exposed again to the predators of the mainland, new techniques had already been developed for dealing with them.

Why did apes become bipeds? About 4 millions years ago or perhaps even earlier, appeared a group of apes who walked erect on their back legs. Modern science refers to these animals as *Australopithecines*. The australopithecines walked and ran approximately as we do, but their brains were no bigger than the brain of a chimpanzee. The Australopithecines were a very successful evolutionary development. They lived in equatorial Africa from about 3.5 to about 1.5 million years ago. A period about as long as that of their Homo successors, our own more immediate ancestors. During that time, they diversified into a number of different species. They were common enough to leave a good many fossils behind them, in a period from which no fossil remains of chimp-like or gorilla like apes have yet been found at all.

Was the secret of their success? They can not have climbed trees as well as their ape and monkey predecessors. They can not have run as fast as the lions and leopards which must surely have preyed on them and their young. They even lost the dagger-like canine teeth which are the main defensive weapons of apes and monkeys. Unlike their successors the later hominids, they had chimpanzee-sized brains and they could not make flint weapons or light fires. Yet somehow, bipedalism must have helped them to survive.

Why did the Australopithecines adopt the upright posture? Nature has left us a clue. There was a change in their canine teeth. In some of the earliest fossils, the canines are still bigger than the other teeth, though smaller and less dangerous than those of a chimpanzee. In the later fossils, the canines take their place, as ours do, as food-processing tools rather than weapons. Canine teeth are an essential piece of equipment to an ape. Apes have no horns, claws or hooves: the canines are their principal weapons. Canines are used to fight against, and to deter, predators and rival members of their own species. Occasionally, they are used to kill animal prey. If bipedality enabled the Australopithecines to manage without these essential weapons, it must have provided them with an alternative weapons system.

The Australopithecines were closely related to chimpanzees. Chimpanzees can throw stones but their bodies are not really designed for this way of fighting. Their forelimbs are general purpose organs, adapted for locomotion and needed for locomotion whenever the animal wants to move quickly and nimbly. A habitual quadruped is slow and liable to lose its balance when fighting on the back legs alone. But the Australopithecines were fully adapted bipeds, probably as quick on their tow feet as an active modern man. They had hands and arms which (not being required for locomotion) could afford to specialize in manipulation throwing and handling weapons and natural tools. They must have become much better able to carry a supply of stones around with them, and they would have natural clubs. As bipeds, able to keep their enemies at a safe distance much of the time with missiles and clubs, they had less and less need to bite or threaten their enemies with their teeth. It was more useful for the canines to be adapted for eating. The natural connection between bipedality and the loss of canine weapons was suggested long before the first Australopithecine remains were discovered by Charles Darwin.

There is no evidence that Australopithecines made artificial stone weapons though like chimpanzee, they must surely have made some simple tools out of perishable materials. The appearance of Homo the next stage in human development coincides with the first stone artifacts. But the ability to throw stones and to carry around with them a stock of suitable natural ammunition, must have given our remote predecessors something which no other animal had. The ability to cause injury at a distance whilst remaining out of range of teeth, horns, hooves and claws.

Another theory of which focus on how and why did apes become bipeds is known as “East Side Story” proposed by Yve Coppens in 1982 over evolutionary of great apes become a bipeds. This story seemed refer most of all the changing of a climate through time of which caused the habit of walking on quadruple to be a habit of walking upright[3].

For sure, bipedalism requires strong leg muscles, particularly in the thigs. Contrast in domesticated poultry the well muscled legs, against the small and bony wings. Likewise in humans, the quadriceps and hamstring muscles of the thigh are both so crucial to bipedal activities that each alone is much larger than even the well-developed biceps of the arms. Whereas a nervous system which is related to the famous kneed jerk (a patellar reflex) emphasizes the necessary bipedal control system: the only function served by the nerves involved being connected as they are is to ensure quick response to imminent disturbance of erect posture; it not only occurs without conscious mental activity, but also involves none of the nerves which lead from the leg to the brain.

A less well-known aspect of bipedal neuron-anatomy can be demonstrated in human infants who have not yet developed toward the ability to stand up. They can nevertheless run with great dexterity, provided they are supported in a vertical position and offered the stimulus of a moving treadmill beneath their feet.

However, a biped also has the ability to breathe whilst it walk, run, stand or even hopping. Humans usually take a breath every other stride when their aerobic system is functioning. During a sprint, at which point the ana-erobotic system kicks in, breathing slows until the ana-erobotic system can no longer sustain a butt.

Apart from an adaptation to upright walking, bipedalism would be the primary hominid adaptation. The striding gait of human bipedalism involves the fluid flow of a series of actions collectively, the swing phase and the stand phase. One leg alternating with the other, the leg, the swing phase pushes off with the power of the toe, swing under the body in a slightly flexed position. Finally become extended as the foot makes contact with the ground first with the heel. Once heel strike occurred, the leg remained extended providing support for the body. The stance phase, while the other leg goes through the swing phase with the body moving forward.

[3] For more information on the story of East Side Story or how great apes became bipeds , just see Erick Seinandre « Les origines de l’homme avant et après Lucy” Petite encyclopédie LAROUSSE, 2005.

Table 1. Chart showing a difference between human and other primates.

	Homo Sapiens	Pan Troglodytes	Pan paniscus
Common Name	Homo	Chimpanzee	Bonobo
Actual Population	6 billions	145 to 230 000	15 to 20 000
Life Expectancy	+ 70 years	+ 40 years	+ 30 years
Height	170cm	100 cm	70 to 90 cm
Weight	60 - 70 Kg	40 – 50 Kg	33 – 45 Kg
Reproduction	All year	All year	All year
Gestation	270 days	230 to 240 days	230 to 240 days
Type of alimentation	Omnivore	Frugivore, insectivore, Carnivore by occ.	Frugivore, Insectivore

Two keys features differentiate human and chimpanzee bipedalism:

1. Chimpanzees are unable to extend their kneed-joints to produce a straight leg in the stance phase.
2. Muscular power has to be exerted to support the body
3. The constantly flexed positions of the chimpanzee leg also mean there is no toe off and heel strike in the swing phase.

During each swing phase, the center gravity of the body has to be shifted towards the supporting leg and the tendency for the body to collapse toward the unsupported side is countered by the contraction of the muscles (gluteal abductors) on the side of the hip that is in the stand phase.

In chimpanzees, the thighbone does not slope inward to the knees as much as humans do which means that the feet are normally placed well apart. The gluteal abductors are not highly developed. During bipedal walking the animal is forced to shift its upper body substantially from side to side with each step so to bring the center of gravity over the weight bearing leg.

- An extended knee joint.
- A platform foot.

We must view the human upright posture as an expression of an ancient primate evolutionary trend. The dominant motif of that trend is an erect body. That trend went through vertical clinging and leaping. Through quadrupedalism (monkeys and apes) to brachiation (apes).The transformation from ape to hominid was not between a true quadruped (horse, dog) and a true biped, a point to calculate evolutionary constraints that might have operated in the origin of hominids.

Charles Darwin essentially equated hominid origins with human origins and proposed an evolutionary package including upright walking, material culture, modified dentition and expands intelligence. Hominid diets remained predominantly vegetarian until 1.5 million years ago, the origin of *Homo erectus*.

- Women “gatherer” hypothesis
- Challenged the male the hunter model
- Plant not meat was the major foot model
- Plan, not meat were the focus for technological innovation and news social behaviors
- More conservative
- Focus on the need to carry things: specifically food for sharing within infants
- 2nd hypothesis that focuses on the need to carry things is “Man the provisionary”
- Male gathers food and return to home base to share food with female and offspring

The system would work only if the males could be certain the infants were his. The need for pair bonding and sexual fidelity, one criticism focused on calculations that purported to show large hominids were a reproductive disadvantage compared with humans. The most parsimonious scientific attractive explanation of bipedalism is they have evolved not as a change in the nature diet or social structure, but as a result of a change in the distribution of existing dietary resources. In late Miocene, hominid dietary resources become thinly dispersed in some areas, the continued exploitation of which demanded a more efficient mode of travel. Hence, the evolution of bipedalism has begun.

Bipedal Robot. For nearly the whole of the 20th century, bipedal robots were very difficult to construct. Robots which could move usually did so using wheels, treads, or multiple legs. Increasingly, cheap and compact computing power, however, has made two legged robots more feasible. Some notable biped robots are ASIMO, developed by Honda, HUBO and Albert Einstein HUBO developed by KAIST and QRIO, developed by Sony.

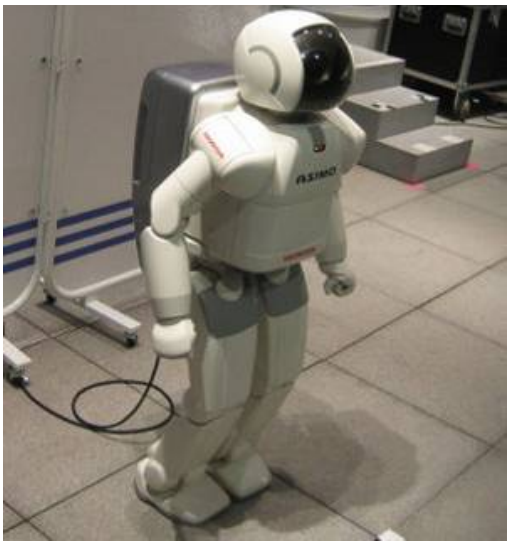

Figure 3: ASIMO, a new bipedal robot in history of human evolution.

Discussion

Development of bipedalism left many traces to study on how human evolution happened through time since 3.6 millions years ago until today. Anthropologists have yielded out many evidences to explain this kind of evolution in human history. A long journey back to find the origin of our ancestors has still involving in time and continuous by trying to interpret some evidences left in some areas of the world. The development of bipedalism is already yielded out by some evidences. Hence, bipedalism is not anymore secret to anthropologists and scientists. But the story of bipedalism and theirs development are such a kind of black ink of which scientists have written without ending in history of human evolution.

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