THE SOURCE OF HUMAN BIPEDALISM

by Gary S. Tong

Throwing stones as the source of human bipedality was advanced by F. C. Fifer in *The adoption of bipedalism by the hominids: A new hypothesis*, Journal Human Evolution Volume 2, Number 2, April, 1987. The present article proposes that assigning the source to aggression with sticks and clubs is preferable. Although the latter idea has also been mentioned, those arguments are drawn from conclusions made on fossil bones. The hypothesis laid out here differs in that it offers the documentation of **real-time physiological experiments** that anyone willing can perform and can then evaluate of the argument. See s**ection 7a.**

0. Uniformitarianism in human bipedalism

The well-established principle of **uniformitarism** proposes that agents that have operated in the past in particular physical and biological processes are still operating in those systems today. This notion that "the present is the key to the past", first demonstrated for the geological history of the earth holds true for biological evolution as well. It can also be shown to exist in the development of **human bipedalism**.

The use of **sticks** as **weapons** is the key in the theory presented here. The employ of sticks today is the **same** as it would have been during the evolution of bipedality and this use has been **continuous** since the time when hominids lost their biological armament and speed of quadrupedal locomotion.

Bipedality is necessary to strike with a club with **optimal efficiency**, not only in the **ballistics** of the action, but also for the optimal efficiency of the **respiro-musculoskeletal** machinery of the body, a factor considered in the **experiment** in section 7a. Even without that experiment this is quite evident: if we want to strike with a club, which is better, to crouch, bent over, partially erect, or to stand fully erect? The notion needs little explanation—when wooden clubs are substituted for fangs, arms and claws, essentially increasing the length, speed, weight and hardness of the arm, then the use of sticks or clubs in aggression will select for bipedal competence. It is as if *Homo*'s arm and fist turned into wood and became much longer and heavier and thus could swing with much greater speed, force and range. For our relatively small ancestors this new weapon would be superior to fangs and bare arms and even to stone throwing.

In nature man and the stick, just as the lion and its fangs and claws or the buffalo and its horns form an inseparable fighting **unit**. Without their weapons they cannot survive.

1. The weaponless primate—how far back?

Boys and men, born without biological weaponry, universally tend to find sticks (along with other elongated weapons and objects) attractive. Is this a coincidence? Before the coming of gunpowder, did men, ever in serious combat willingly fight each other or animals without the help of sticks, that is, spears, swords, axes, clubs, bows and arrows, etc.? No instances can be imagined except in friendly combat or when the weapon was not available. The naturalist Colin Tudge in *The time before history* argues for fitness advantages in throwing spears by early man. Spears are long, sharp and heavy sticks, and a group of men wielding them is transformed into a great porcupine lethal to approach. Lions in many places have learned to fear men. Cf. the Greek phalanx and the Swiss pike men. How far, then, does the use of sticks in aggression reach back in our evolution?

2. How could hominids survive loss of anatomical weaponry?

How **could** *Homo* and its forebears, with diminished biological weaponry and strength, survive among carnivores and same species competitors, even in the forest, let alone in the woodland and savanna? Escape to the trees may be practical, but trees are few in the grasslands and it does not guarantee safety anywhere when facing climbing predators like leopards or apes. How far does the use of sticks in aggression reach back in our evolution?

3. Seamless transition in changing weaponry

It is reasonable to argue that our emerging human forebears through a **continuous** process were able to relinquish fangs and claws only as they **gradually substituted** something else to compensate for decrease in relative strength and speed: an increasing skill in the employment of **sticks**. They were able to make this shift without developing any new faculties because elements for hand grip and arm swinging were already present as essentials in arboreal movement. Perhaps the only function still undeveloped would be the opposable thumb grip, but there would be strong evolutionary pressure to perfect this ability through the need to most efficiently grasp clubs.

4. Comparative significance of selective adaptations

The relative **fitness significance** and **immediacy** of adaptations are important factors in evolution. Acquisition of food, mate and territory are crucial but they can generally be gradual processes, whereas direct combat has **decisive** and **immediate** consequences. The efficacy of an animal's weaponry is a more powerful determinant of fitness than adaptation in less immediate ones—physical victory can instantly bring possession of food, mates, territory and status elevation.

5. Upright stance and aggressive use of the sticks as source of bipedality

Therefore, if aggressive weapon use, both in interspecific and intraspecific aggression, is of the highest and most immediate selective significance, then, human **bipedalism** may have arisen through gaining optimal efficiency in wielding sticks and clubs. The reasons are simply that: a) efficacy in striking with such weapons directly varies with skill in the ability to stand erect and move and manage the position and movements of the body bipedally, and b) the accomplished biped has gained the **freedom** of its forelimbs and can use of one or both hands to swing a weapon.

A **quadrupedal** primate, even if capable of thumb-gripping (perhaps otherwise developed from breaking hard food with stones or clubs), would utilize sticks with lower efficiency; the reach and height of action possible and precision control would be minimal. However, the fully **bipedal primate** would necessarily be a highly efficient employer of sticks (and of clubs, spears, swords, tools, etc.) just as we are today. Selection for **upright stance** to gain the fighting advantages of height is employed by mammals capable of limited bipedality. Standing on two legs is seen in intraspecific combat whenever that behavior is possible: for instance, among apes, dogs, bears, kangaroos, horses, zebras, even lizards (like the komodo dragons), balancing themselves against each other's bodies.

6. Other hypotheses on the origin of bipedalism

The various proposals for the origin of bipedalism, such as freeing the arms to be able to carry food to a distant mate or to regulate body heat by standing up into the wind are fine by themselves, but you cannot carry food or stand to cool yourself for long in the savannah without adequate defensive weaponry—self protection and tools of aggression are importantly needed at first. Throwing stones is of value in attack and defense, but stones must be picked up or possibly carried to places lacking stones, holding stones ties up the hands and are lost after casting it, whereas the staff or club stays in place. Only a coactive group of hominids can throw stones at a sufficient rate to make the action meaningful. The academic aquatic wading theory was simply labeled "gratuitous", by Colin Tudge in *The time before history*. The employ of **sticks** is by no means the sole source of bipedalism, but it is **arguably** its strongest driving force.

7. Experimental evidence for our built-in psycho-physiological adaptation for the use of sticks

An unequivocally valid body of physiological data can be offered to support the theory proposed, but that material is a rather different and sizable topic and is covered in detail elsewhere. In a nut shell, the material deals with the **coordination** of the muscles of **body action** and posture in relation to the action of the musculature and the air flow valves (glottis, velum, diaphragm, etc.) of **respiration**. Such **regulative** coactivity is also fundamental in the integration of physical and mental behaviors, and is recognized as important in Eastern thought as well as in many Western practices, but it has never been systematically described and explained in the past.

7a. Experiment: quadruped vs. biped stance and respiration

The following experiment that anyone can easily perform demonstrates this fundamental somato-respiratory regulatory mechanism and shows how that process creates **evolutionary pressure** towards perfecting bipedality.

Part 1. Quadrupedal stance and unimpaired respiration flow

Setup: Take a quadrupedal stance, not "on all fours" with knees on the ground, but supported on the toes (metatarsals) and on the palms or fingertips. This is the true position quadrupeds take. The human squatting position can also be tried.

Observe: Respiration is normal, with no special impediment to movement of respiratory muscles; the thorax and abdomen remain loose and the flow of air is unobstructed.

Conclusion: The normal four-footed stance of animals and the squatting stance of humans does not impede respiration. **Fig. 1.**

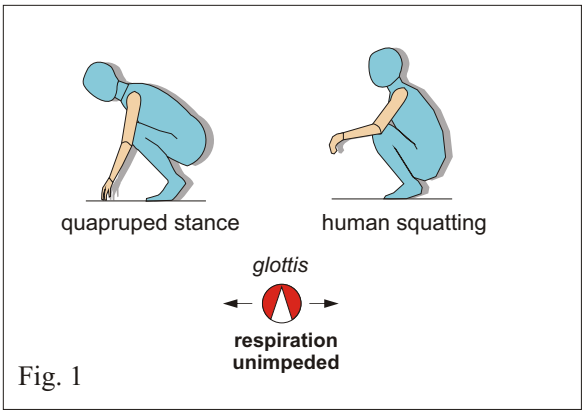

Fig. 1

Part 2. Bipedal stance and impairment respiration flow

Setup: Take the bipedal stance.

Observe: Now it takes more effort to breathe due to increased weight of head, neck, arms and torso downwardly compressing the laryngeal apparatus, the respiratory muscles of the thorax and the diaphragm.

Conclusion: The body tension needed to remain upright loads and tenses the muscular mechanics of respiration. **Fig. 2.**

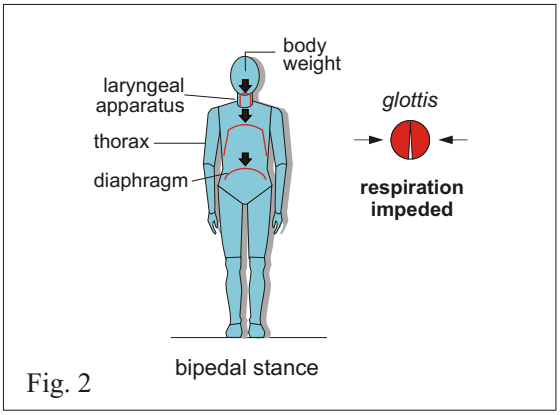

Fig. 2

Part 3. Compensation for impairment of respiration

Setup: Standing bipedally, **grasp** with one hand a supporting object, such as railing, furniture, etc.

Observe: The **impediment** to **respiration** is significantly **reduced**.

Next: firmly **hold** a stick or rod (c. 1-1.5 in. in diameter) in the hand. The angle and position of the arm should chosen should be **comfortable** to maintain. See **note** to Part 3.

Observe: The obstruction to respiration generated by standing erect is noticeably **decreased**.

Conclusion: Thus any respiratory impediment arising from bodily strain in arboreal movement or in the bipedal stance is attenuated once the muscular map of the body in hand gripping equalizes the distortive forces in these behaviors . **Fig. 3**.

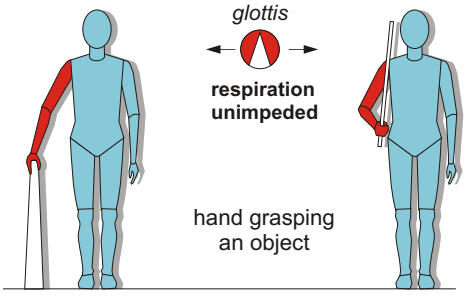

Fig. 3

Note to part 3: in holding the stick the angle in the transverse plane between the arm and the body must be considered. The most natural and comfortable position is when the lower arm is about 45º to the lateral axis of the body, and somewhat elevated from the horizontal. It may sound tautological, but the most comfortable configuration is also respirationally optimal, and therefore one is liable to spontaneously assume it. But the position the lower arm lies in also defines the **plane** in which a club is moved backwards, as the arm and shoulder rotate posteriorly to "cock" or empower the strike. This is important because placing the hand grasping an object in other places, e.g., close to the torso, at chest level actually impedes respiration. **Fig. 4.**

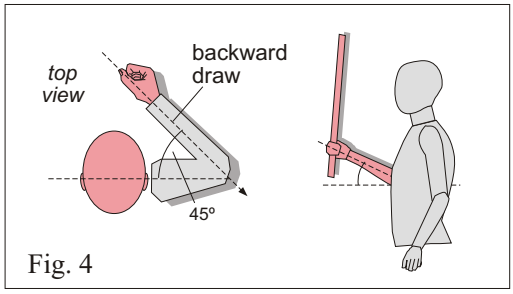

Fig. 4

Built-in hand grasp behavior appears in the well-known reflexive clutching by infant primates of the mothers' fur and also with the sense of safety when holding on to branches in the trees at all ages. Human infants likewise instinctively grip an adult's finger, which in relation to their miniature hands is the proportional equivalent of a branch. That is, becoming bipedal is positively reinforced by the hand grasp. Holding a stick is "pleasant"—at least for males—and it gives the feeling of security of being armed. Cupping hands around a solid ball is a related Chinese practice for aiding mental tranquillity and this also is achieved by equalizing the distorting load on the respiratory muscles.

The fact that hand grasping compensates for impediment to breathing arising from certain body behaviors is an underlying physiological adaptation to primate arboreal life where gripping a branch is of the greatest importance and this function is transferable to holding a stick. **Section 13** offers data on today's chimpanzees employing sticks and branches. **Fig. 5.**

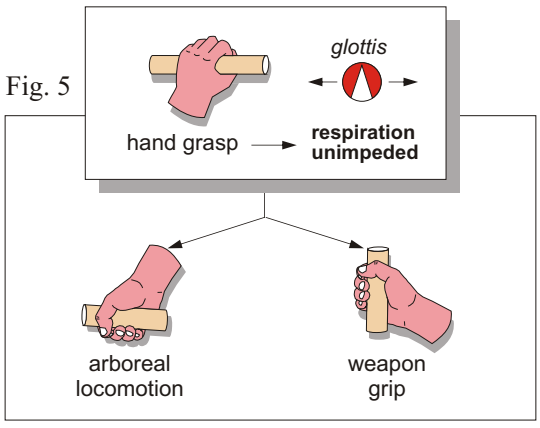

Fig. 5

8. The physical advantages of stick use:

a. Requires the development the **opposable** thumb and so selects for this ability to be used in other specifically human functions.

b. Extends manipulative **reach** (in feeding, exploration, combat) and so also protects the body in conflicts.

c. Significantly multiplies **leverage** power and **focuses** impact energy to small surface area as do fangs and claws.

d. Magnifies the user's apparent **visual size** and **dimension** of movements in the perception of an antagonist. This is standard animal aggression/protection device, a process that enlarges the field to which an opponent's **attention** must be extended and helps confuse its judgment.

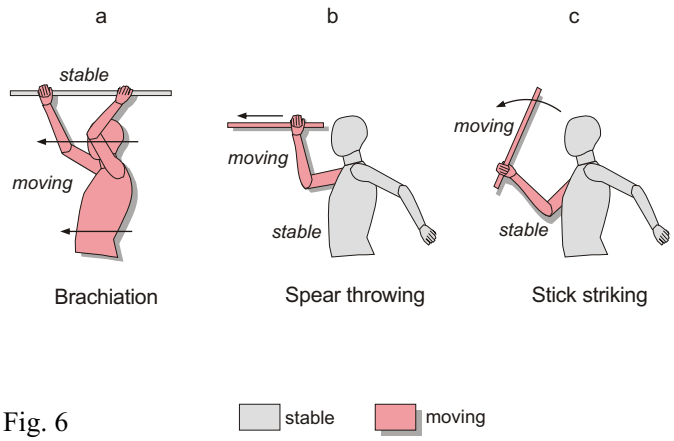

Fig. 6

9. Arm striking action in infant behavior

Young animals play by practicing their chief aggressive and defensive behaviors: among the antelopes equids, deer, cattle, antelope run and jump, felines bite and claw, birds flap wings and peck, canines bite and shake, etc. Innate arm behavior of infants vis-à-vis people and objects include hitting (along with a bit of throwing). Infants typically hit one in the face, or knock off one's eye-glasses for fun. Thus human infants appear to practice a basic essential human behavior: arm striking. The analogy in the preparations for adult actions in human and mammalian infants seems valid.

10. Preadaptation: brachiation as a source of hand grasp and arm rotation:

The mechanical elements of human spear and club handling are **inherent** in brachiation and generally in arboreal locomotion and differ basically in variations in the configuration of stable and moving elements. **Fig. 6**.

a) In brachiation the branch is **stable** and the arms and body **move.**

b) In spear throwing the arm and spear **move** while the body is **stable**.

c) In **striking** with weapons the relationship is the same as in spearing, but the tool is continuously grasped and its movement is not linear but radial. Throwing differs from stick striking in its releasing the weapon.

Note: There is another **difference:** direction of arm movement in throwing and striking with a weapon is forward, away from the body, whereas in forward moving brachiation, at least, the arms pull backwards, toward the body.

11. Stick—a universal tool shape

Elongated objects that can be manipulated by the hand have a great many applications. Tools and weapons in general are stick shaped: hammer, screwdriver, bow, arrow, sword, saw, ladder, spear, rifle, battering ram, dagger, knife, fork, spoon, chop-sticks, scissors, needles, brush, pencil, pen, oars, drills, nails, toothbrushes, etc. The stick form is extremely adaptable for use by our hands and arms, and we are skillful in its employment.

12. The chronology

Establishing a chronology for the argument can begin with the **question**: as the hominid adapted to the habitat transforming from forest to savanna when did he lose muscular power and fangs?

The **answer** is: if still in the forest, this diminution of anatomic armament could only have taken place if some substitute became available, which could only have been sticks and clubs or to some degree stones, or both. Spurred on by natural selection skill at handling clubs would advance bipedality, for reasons given by the experiments, at the expense of losing fangs and claws.

In the mixed habitat of trees and grassland, possession of only its natural weaponry would be have been especially useless for a small hominid facing the swift and powerful predators of this flora. To survive there baboons have turned into the primate version of the quadrupedal carnivore. Neither could *Homo* still running on four feet have wielded a stick at optimal efficiency.

Logically, then, he had to be a **partial** or **full** biped equipped with the artificial armament of sticks or clubs just

to be able to enter and **survive** in a mixed habitat. Branches are easily found in the forest but are far less available in the **grasslands**, which fact would **minimize** the opportunities to learn their use in that environment. Thus, following this chronology *Homo* became a capable, though not yet a necessarily perfected biped, armed with the stick even **before** leaving the forest.

13. Documented evidence for chimpanzees using elongated implements:

The following stick and club use by chimpanzees have been observed:

1) *http://www.primates.com/chimps/chimpanzee-info.html*

a. Climbing up into trees armed with clubs to break up cola nuts found there.

b. Breaking bee hives with clubs.

2) *http://news.nationalgeographic.com/news/2007/02/070222-chimps-spears.html (Chimps Use "Spears" to Hunt Mammals, by John Roach for National Geographic News February 22, 2007)*

Primitive spear made by chewing end of stick to sharpen it and jabbing it into tree hollows to kill bushbabies. Ancestral hominid employment of sticks and clubs may be validly compared to the same practice by chimpanzees because they are our closest extant relatives and because such spearing behavior by them has occurred not in the forest but in the savanna habitat.

3) A chimpanzee probing the grass for the presence of a snake is described and shown in a photo in Adrian Desmond, *The Ape's Reflections*, 1979, photo 27. A connection between the hominid's arming with clubs and chimpanzees hunting behavior has been suggested in the same book (p. 214): "(chimps)...will dash baboons to death, fracturing skulls against tree-trunks. How much innovation is needed to switch the procedure, and dash the tree against the baboon?", that is bludgeon its head with a hand held branch.

4. *http://www.naturalhub.com/opinion_right_food_for_the_human_animal_evolution_of_the_human_diet.htm*.

The article *Feeding Ecology and Human Evolution* by Lorenzo Meadow quotes Darwin's emphasis on the significance of utilizing clubs: "as Darwin pointed out, canines would no longer be the telling factor in male competition; a club is a 'great leveler'—in both senses".

5) *http://www.emory.edu/LIVING_LINKS/pdf_ attachments/whitenetal1999.pdf.* Cultures in chimpanzees.

Table 1 of the article *Variation in occurrence of behaviour patterns across long-term study* at this site lists the employment of sticks occuring in seventeen chimpanzee behaviors, including forceful striking with club*, although details in this action are not described:

Nasal probe (clear nasal passage with stick)
Insect-pound (probe used to mash insect)
Branch-hook (branch used to hook branch)
Perforate (stout stick perforates termite nest)
Dig (stick used as spade to dig termite nest)
Dig (stick used as spade to dig termite nest)
Seat-stick (stick protection from thorns)
Stepping-stick (walking on sticks over thorns)
Sponge push-pull (stick and sponge tool)
*Club (strike forcefully with stick)
Ant-dip-single (mouth ants off stick)
Bee-probe (disable bees, flick with probe)
Fluid-dip (use of probe to extract fluids)
Marrow-pick (pick bone marrow out)
Lever open (stick used to enlarge entrance)
Expel/stir (stick expels or stirs insects)
Fly-whisk (leafy stick used to fan flies)

6) Evidence for a chimpanzee combining bipedality with the employment of a branch has been documented: an aggressively charging male uses a stick to assist bipedal running, in one episode of *Escape to Chimp Heaven*, a documentary shown in 2008 on the Discovery channel. A suitable branch wielded in aggression could evidently also be used as a crutch just as we use canes and staves the same way today.

14. Conclusion:

Chimps have been observed to kill mainly with their hands, but that is a matter of ingrained habits acquired in the trees where arms and hands must remain free to enable rapid movement. But the introduction of clubs to kill standing erect on the ground has obviously occurred in human evolution and it is only a question of when, something this article has attempted to answer.

Addendum:

Some months ago National Public Radio aired a scientist theorizing that bipedality arose as the ability to run long distances to follow previously wounded fast-running animals and to eventually claim their carcasses. He seems to have disregarded the fact that man first learning and even perfecting upright locomotion would be closely watched as prey by hyenas and lions and that these would also much sooner find the distant carcass.