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Short communication

The Human Robber Hypothesis: Humans Used Fire to Steal Prey from Large Carnivores, Thereby Providing the Brain with Nutrients to Enlarge It after Birth

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Bipedalism paved the way to delivery of immature babies and development of the brain after birth. This communication presents the argument that hairlessness allowed hominins to access fire through wildfires, which occurred frequently after a climate shift from a wet to a dry environment 2.5 million years ago (Ma). Initially, naked hominins approached fire for warming, but soon must have come across burnt animals in the aftermath of wildfires. They learned the taste of burnt meat, which must have been a driving force compelling them to become meat-eaters. Hominins must have learned gradually how to control fire and how to repel hairy animals that abhor fire. Because they could neither run fast nor have muscles sufficiently strong to compete with large carnivores' fangs and claws, they chose not to be hunters but robbers. When they found that a carnivore had killed a prey animal, they approached the hungry predator and repulsed it using fire and stones, then claiming the prey intact. This is the core of the human robber hypothesis. The timing of global cooling, the appearance of savannahs, the appearance of transitional humans, decline of large predators, the manufacture of stone tools, and the start of cooking largely coincide at 2.5 Ma. They also smoked out animals from their dens or caves, and robbed them of shelter and territory. Cooked meat is both tasty and easily digested, providing hominins with rich nutrients sufficient to enlarge the brain, while most large carnivores were forced to extinction. Consequently, the use of fire, facilitated by hairlessness, must have played important roles in protecting hominins from cold, in repelling predators, in robbing large carnivores of prey and dwellings, and in providing the brain with nutrients for strong growth into adolescence. Development of the eccrine glands is also discussed as a result of hairlessness.

Key words: brain enlargement, carnivore, cooked meat, eccrine gland, hairlessness, humanization

Coincidence of Climate Change and Appearance of Humans

Hominins evolved from the chimpanzee/human last common ancestor (CLCA). Early hominins were *Sahelanthropus tchadensis* (7 Ma), *Orrorin tugenensis* (6 Ma), *Ardipithecus kadabba* (5.2–5.8 Ma), and *Ardipithecus ramidus* (4.4 Ma). They were arboreal denizens. Chimpanzees have a body structure adapted to suspension, vertical climbing, and knuckle-walking (Fig. 1A). They have longer arms than legs, a narrow, long pelvis, and a small brain. Ardi, a female of *Ar. ramidus*, was 120 cm high, weighed 50 kg, and had a small brain of 300–350 cc like that of a female chimpanzee (1). She had a bowl-shaped wide pelvis. This and the mode of connection of the femur to the pelvis indicate that she was a biped. However, she had an opposable hallux, indicating that she was doubtlessly an arboreal denizen (Fig. 1B).

After early hominins, archaic hominins appeared. They are australopithecines represented by *Australopithecus anamensis* (4.2–3.9 Ma), *Au. afarensis* (3.9–2.9 Ma), *Au. africanus* (3.02–2.04 Ma), and *Au. sediba* (1.95–1.78 Ma) (Fig. 1C), with brain size estimated as about 400 cc. The small brain presents a great contrast with those of modern humans, with brains of about 1350 cc (Fig. 1D). The respective intermembral indexes (IMIs), the ratios of the forelimb length to the hindlimb length) of a chimpanzee, Ardi, *Au. afarensis*, and humans are 106, 90, 88, and 69 (1). Consequently, the IMI and brain size of both hominins and archaic hominins are closer to those of chimpanzees than to those of humans. Tree-climbing adaptations can be understood by seeing the long arms, curved finger bones, small skulls, and robust shoulders commonly equipped

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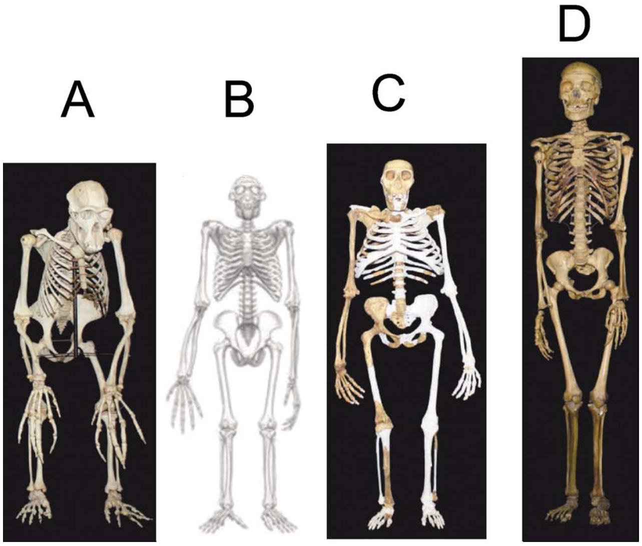

Fig. 1. Mosaic nature of early and archaic hominins. Skeletons of a chimpanzee (A), an early hominine *Ardipithecus ramidus* (B), an archaic hominine *Australopithecus sediba* (C), and the modern human *Homo sapiens* (D). The long arms, robust shoulders, and small head were adapted for arboreal life (A, B, and C). The straight legs and bowl-shaped pelvis were adapted to terrestrial life (B, C, and D). A, C, and D from LR Berger, Science, 340, 163, 2013 and B, from CO Lovejoy *et al.*, Science, 326, 100–106, 2009, with permission.

in a chimpanzee, Aldi, and *Au. sediba* (Fig. 1).

The global average temperature in the mid-Pliocene (3.3–3 Ma) was warm: 2–3°C higher than today (2). The earth entered a phase of global cooling about 3 Ma, with formation of ice in the Antiarctic areas, Greenland, and other areas. This cooling is thought to have spurred the disappearance of forests and the spread of grasslands and savannahs. Climate changes to dry climate probably forced australopithecines to adapt to a terrestrially oriented life, but the ground was full of danger. Therefore, trees were indispensable for them as refuges and nesting. Consequently, they had mosaic characteristics; the upper body had the long arms, robust shoulders, and a small skull resembling those of a chimpanzee that were well adapted for arboreal life. Its lower body had human-like feet and a bowl-shaped pelvis that were adapted for terrestrial life (Fig. 1C). Indeed, footprint fossils of australopithecines show that they walked like us (3). They lived in fairly wooded, well-watered regions and were thought to be collector-gatherers because their body structures do not seem suitable for use by scavengers or hunters. In contrast, they would be the victims of carnivores. When attacked by them, they would have to flee up nearby trees. Their lower body was adapted for terrestrial life, but it facilitated neither scavenging nor hunting. Most probably it was most useful for fleeing.

The archaic hominins were followed by transitional humans such as *H. habilis* (2.4–1.5 Ma), *Homo rudolfensis* (2.4–1.6 Ma), and *H. georgicus* (1.8 Ma). Their brain sizes were approximately 600–800 cc. Consequently, transition from hominins to humans was accompanied by an apparent brain size shift. In fact, a criterion to judge humans is the brain size of 750 cc, although exceptions exist. A nearly complete new skull was found in Dmanisi, Georgia, dated to 1.8 Ma (4). The find comprises five crania from the same time and place. They appear to be quite different from one another; their wide morphological variations imply the existence of a single evolving lineage of transitional humans. If this is not confined to Dmanisi, then the possibility exists that *H. habilis*, *H. rudolfensis*, and *H. erectus* are combined into one species, as the authors suggest (4). Humans seem to have appeared around 2.4 Ma.

Hernández and Vrba (5) investigated palaeoclimatic change using mammal fauna as environmental indicators, showing that biomes in the Turkana Basin changed from semi-evergreen rain forest to deciduous woodland and savannah during the middle-late Pliocene. They reported the continuous presence of savannahs from 2.5 Ma onwards. This pattern of climatic change is apparently consistent with isotopic evidence related to global climate, and with independently derived regional palaeoenvironmental evidence. Therefore, this 2.5 Ma is apparently the turning point of the shift from rainy forest to savannah. Woody vegetation, fire, and climate constitute key factors to form and maintain savannah (6). Although fire-tree cover feedbacks theoretically maintain savannah and forest as alternative stable states, savannah seems to be more stable than forest, because fire suppresses tree cover and low tree cover promotes fire spread (7). It is quite difficult to prevent fires from recurring in savannah, because grasses become fuels; a savanna state hardly gets back to forest when it burn down in a fire once. The appearance of savannah matches fairly well with the appearance of humans 2.4 Ma and the start of decline of carnivores suggested by Werdelin and Lewis (8) (see below). Australopithecines adapted to wooded, well-watered regions must gradually find difficulty in dwelling in open, arid environments, although transitional humans adapted to them well, probably by making use of fire and stone tools, as discussed next.

Humans Must Have Been Neither Scavengers nor Hunters, but Robbers

Arid climates must be associated with frequent wildfires. It is of interest to learn the behavior of birds and animals: ‘‘even at the time a wildfire is still burning, birds of prey (such as falcons and kites)—the first types of predators to appear at fires—are attracted to the flames to hunt fleeing animals and insects. Later, landanimal predators appear when the ashes are smoldering and dying out to pick out the burnt victims for consumption. Others, such as deer and bovine animals appear after that to lick the ashes for their salt content. Notable as well is that most mammals appear to enjoy the heat radiated at night at sites of recently burned-out fires (9).'' What did fire mean to hairless transitional humans? Fire must have been a daily concern. Because they did not have hair to be burnt, hairless humans must have delightedly approached the flames and smoke when a wildfire started to burn low. Humans had excellent opportunities to become the first to discover burnt food animals, beating other animal predators to a prehistoric feast. Instantaneously they knew that burnt meat smelled good and tasty. They must have started to add meat to their menu, which consisted mainly of fruits, nuts, insects, snails, and so forth. Even if they had been unable to control fire at first, they must gradually have become accustomed to and familiar with fire. Sooner or later, they must have learned that hairy animals did not approach a burning fire, and that they were able to repel beasts using fire. Furthermore, sooner or later, tasty and easily digested burnt meat must have been their daily concern.

An important report by Werdelin and Lewis (8) divided carnivorous fossils into large animals of more than 21.5 kg, to which hominins belong, and those which were smaller, and analyzed their functional richness and functional evenness in eastern Africa at a 0.5 Ma time span from 3.5 Ma to 1.5 Ma together with the present fauna. Results indicate that the functional richness and functional evenness of the large carnivores consisting of 29 species decreased rapidly from 2 Ma to the present, while those for small carnivores, consisting of 49 species, increased. Because climate change alone is unlikely to be sufficient to explain that decline and because this decline coincides closely with the appearance of *Homo* species, they conclude that the evolution of humans into the carnivore niche space played a critical role in the decline of large carnivores' functional richness. The author can readily agree with and support this 'human invader' hypothesis.

A hypothesis was put forward that humans were scavengers (10). If they were scavengers, then they had to walk long distances to find carcasses, most of the meat of which might have been consumed already. Moreover, there must have been a high probability of being attacked on those long treks to find carcasses competitively with other scavengers. If they had been scavengers, then they could not have violated the carnivore niche space. This scavenger hypothesis does not match well with the human invader hypothesis. Then, if transitional humans were hunters, would they have been able to compete for niche space against carnivorous hunters such as saber-toothed cats? To become hunters is much more difficult for humans than to become scavengers because grazing herbivores were able to run faster than bipedal humans. Moreover, they would not be put down with a few or even several stones, even if humans were experts at throwing them. Primarily right from the start, humans as hunters were unable to compete with muscular predators with fangs and claws. However, an economic means to get full portions of meat was available to them, not as hunters, but as robbers. When humans found that a predator had killed a game animal, they approached the beast shouting in a group, each with a torch in one hand and maybe a stone or club in the other, and were probably able to repel the animal and rob it of the intact prey animal. Which was the most powerful weapon: fire, stone, or club? A stone or club attack can be sustained by hairy beasts. They might even counterattack humans. Hairy beasts must be instinctively vulnerable and unable to resist fire, however. Stealing prey animals must have delivered a more severe blow to carnivores than being competitors as hunters because the energy spent by a predator to capture a prey animal comes to yield nothing. Consequently, this human robber hypothesis better explains the rapid decline of large carnivores than the human invader hypothesis does (8).

Humans Stole Not Only Meat but Also Shelter

Hairlessness is an important shortcoming in a usual sense because hairless animals have difficulty maintaining body warmth, to protect their body from injury, to protect the skin from ultraviolet light, and to avoid rain. Oil-coated hair of animals is water-repellent and can be rid of raindrops by shaking. Hiroo Onoda, a former Imperial Japanese Army intelligence officer who passed away on January 16 at 91, fought in World War II and did not surrender in 1945. He had spent approximately 30 years holding out in the Philippines when he was found on Lubang Island and was relieved of duty in 1974. A news reporter asked him in an interview how he spent his long time of boredom of 30 years. His answer was that there had never been a time of boredom; he had always been alert because he was in fighting mode. When he was asked what the hardest time was, the answer was rainy days. All he could do was endure the rain patiently. Rain quenches fire. Rainy days are still miserable now. Onoda opened Onoda's Nature Academy in Fukushima and taught children basic techniques of how to survive in natural conditions, i.e., how to start a fire, to take water, to cook food, and so forth based on his life in the Philippines. Fire is truly indispensable for humans.

Hairless humans were certainly miserable on rainy days. Trees were not good rain shields, while dens made by beasts or natural caves must have been ideal refuges. These were effective not only on rainy days but also in daily life to protect them from attacks by predators. Caves are, however, also good refuges for beasts and predators. Moreover, they were the earlier inhabitants than humans. Humans were able to smoke out hairy inhabitants from caves easily if they had knowledge and techniques to control fire. We know that caves are good places to excavate high-quality human fossils. Consequently, most probably humans were robbers not only of meat but also of shelter, delivering a one-two punch to large carnivores. The human robber hypothesis well explains the downhill decline of large carnivores reported by Werdelin and Lewis (8).

Stone Tools and Fire, Enhancers of Brain Enlargement

Small-brained australopithecines lived in wooded, well-watered regions. They must have encountered wildfires only rarely. They would not be good fire users. Transitional humans would have had numerous chances to encounter wildfires in savannahs from around 2.5 Ma on and to learn how to control fire. They found burnt bodies of animals in the ruins of fires. The roasted meat with favorable smells was tasty and readily digestible. The taste of cooked meat must have been a driving force compelling transitional humans to become robbers as described above. To be robbers, alert vigilance, verbal warnings, and use of weapons such as stones, rods, and fire must have been helpful. For full use of these Methods and Materials, a larger brain became advantageous and selective. Fire was indispensable to rob carnivores of carcasses. Stone tools were also indispensable to dissect carcasses and to break bones for the bone marrow. Usefulness of fire was fully achieved using stone tools. Stone tool occurrences are now dated securely between 2.6–2.5 Ma (11,12), which by and large coincides again with the climate change to savannahs, appearance of transient humans, and decline of large carnivores, although natural stones might have been used much earlier. Wild bearded capuchin monkeys presently use stones to open seeds by placing them on stone or wood surfaces and then pounding them with rocks (13). Bone fossils with cut marks were dated to 3.4 Ma (14).

When was fire first controlled by hominins? ''The answer is that fire was first controlled anywhere from about 230,000 years ago to 1.4 or 1.5 Ma, depending on which evidence you accept as definitive (9).'' Analyses of burnt bone and plant ash remains at the site of Wonderwerk Cave shows that burning took place *ca.* 1.0 Ma (15). Possibly burnt bones were recovered from Member 3 (about 1.0–1.5 Ma) in the Swartkrans cave, South Africa (16). Although abundant remains of *Australopithecus robustus* (2.2–1.2 Ma) and *Homo erectus* (1.8–0.14 Ma) were found in the older Members 1 (1.8 Ma) and 2 (1.5 Ma) at the cave, no evidence of fire was found. These findings indicate that fire was controlled by hominins at 1.5 Ma at best. Such are the fossil records. Analyses of reduced feeding time and molar size suggest that food processing originated after the evolution of *Homo*, before or around 1.9 Ma (17). As *Homo* appeared 2.4 Ma, cooking might have started from this time. The dating is not unchangeably fixed. When one considers the burnt bones were found in caves to date and that those made in the field must be difficult to remain as fossils, dating related to the use of fire is expected to be much earlier than 1.5 Ma.

Our brain occupies 2.5% of our body and consumes 18% of its energy. To develop the brain, nutrients of high quality are needed such as n-6 and n-3 essential fatty acids (18) in addition to animal-derived proteins. Cunnane *et al.* (19) reported that marine and estuarine ecosystems provided hominins with the appropriate stimulus to develop a large brain. Foods thus provided with little mammalian competition include invertebrates, molluscs, small or slow-moving fish, and marine algae. These might have contributed to enlargement of the human brain to some extent, but the main nutrients were apparently obtained from animal meat when it is considered that savannahs became a major landscape 2.5 Ma, humans with an enlarged brain started to appear 2.4 Ma, and large carnivores started to decline during 2.5–2.0 Ma. It is plausible that transient humans started to use and control fire around 2.5 Ma to expel carnivores, to get meat, to cook it, and consequently to enlarge the brain. Fire and stone tools and the brain and nutrients were very likely to have acted synergistically on the formation of the modern human brain.

Discussion

According to the hairless mutation hypothesis (20,21), a hairless mutation was a driving force of humanization from the CLCA by enforcing upright walking while holding a baby with both hands. If so, what would have happened to hairless hominins? Mammalian skin includes three types of glands: sebaceous, apocrine, and eccrine. In most species, sebaceous and apocrine glands, located near the base of hair follicles, predominate. Elephants lack eccrine glands and cool the body using their large ears, by bathing in water or mud, or by using saliva. Lions and tigers pant during hot periods. They breathe more than 80 times per minute instead of 10 times per minute during cold periods. Panting evaporates water from the surface of the mucosa by aerating only at the entrance part of the respiratory passage. Horses have numerous eccrine glands, which are activated by muscle movements, as well as humans whose glands are activated by heat stimulations or spiritual activities. We hairless humans have an extraordinarily large number of eccrine glands, 2–5 million, and produce up to 12 liters of sweat (22). The established theory is that the large volume of sweat is used to cool down our bodies. From an evolutional viewpoint, hominins had to cool their bodies during walking or running long distances as scavengers or hunters in savannahs if they were scavengers or hunters. Body cooling by sweat is supported empirically and experimentally. Another important role of sweat glands is noteworthy.

What supplies the water for 12 liters of sweat? Blood does. Each eccrine gland is surrounded by a mesh of blood vessels that convey the major raw material of sweat, water, and heat to be shed off from the body. When ambient temperatures are high, sweat evaporates and cools the body. When it is low, the 300 million glands help to maintain the blood supply to the body surface. The sympathetic nerve distributed to the eccrine glands is exceptionally cholinergic. Cold stimulation does not contract the capillary vessels around the gland, although other arteries under the skin are controlled by adrenalin and contact. If all arteries are under the control of adrenergic nerves and contract by cold stimulation, then the blood supply would be cut off from the body surface, and our body surface would soon be frostbitten. Fortunately, capillaries around the more than 2 million eccrine glands are open even on cold days. Children, who generally have 'thin skin', sometimes show reddish cheeks in winter, reflecting the supply of the blood to the cheek surface. From this viewpoint, common involvement of a single gene in the formation of human teeth, hair follicles, sweat glands, and breasts can be regarded as a legacy of the evolutionary history that these organs share. Eccrine gland development is expected to have occurred concomitantly with hair loss. Hairlessness must have provided the naked skin with plenty of space to develop millions of the eccrine glands. On hot days, the glands are useful to cool the body. On cold days, it is useful to supply blood as well as heat to the body surface.

The hairless mutation hypothesis explains three major characteristics distinguishing humans from other primates: bipedality, practical nakedness, and the family as a social unit (20). Bipedality made it possible for the forelimbs to be used as arms and fingers. Holding a baby with one's arms allowed humans to deliver an immature infant and to enlarge the brain after birth (21). Hairlessness provided the skin with a space to facilitate 2–5 million eccrine glands that allowed hominins to adapt especially to hot temperatures. Hairless hominins were sensitive to cold temperatures and willingly approached fire, which gave humans more frequent chances to find burnt bodies of animals in the aftermath of wildfires. The tasty cooked meat was easily digested and drove hominins to become meat-eaters. Hairy carnivores were unable to resist the firearms monopolized by hairless hominins. Hominins were also smoked out from their dens or caves. Hominins thus conquered the savannah with *firearms*. The present largely accepted idea is that hominins were successful hunters in savannahs. They, as hunters, however, were unable to compete with mighty large carnivores such as saber-toothed cats. The idea presented herein is that our ancestors must not have been hunters, but robbers. Consequently, a new idea, the human robber hypothesis, is put forward here. Nevertheless, they would not be robbers from scratch. When they sought burnt bodies of animals in the aftermath of wildfires, they were a kind of scavenger. When they tried to obtain small animals, they were a kind of hunter. In this sense, hominins must not have been exclusive robbers. To become robbers, hominins must have gained mastery over fire. Fire treatment demands a sophisticated knowledge of how to find fire, how to light a fire, how to keep a fire from going out, how to find or make tinder, kindling and fuel, and so forth. The obtained and accumulated fire-treatment knowledge and techniques must have succeeded from generation to generation. To transfer that knowledge, a refined brain was necessary. The brain must have been nourished with rich nutrients that were endorsed by the full use of fire. Control of fire required a long period of time of trial and error. Early trials at becoming robbers might have failed, with the hapless students becoming victims. The ratio of wins to losses must have been small at first, but it would have increased gradually, with good students dominating the savannah, and finally extinguishing a large fraction of mighty carnivores.

Solar energy is fixed by plants through photosynthesis over a long period. Herbivores consume the plants to make their bodies, which are then consumed by carnivores. Activities of herbivores and carnivores are supported by ATP, which is produced mainly by the oxidative phosphorylation process in mitochondria. This is a mild oxidation process. By contrast, fire suddenly releases the solar energy fixed in plants. In modern days, fossil fuels such as coal and oil, when burned, support a rapid oxidation process. Humans made use of fire as firearms. Fire is so powerful that humans dominate the entire Earth now. Fire is used not only to obtain meat but also to cook it and other foods. Cooked foods are tender, easily digested, and nutritious. We need neither gigantic robust jaws nor long canine teeth any more. When humans radiated out from Africa to Europe and Asia in pursuit of prey animals, they must been accompanied by fire as their most precious inheritance and legacy. Indeed, humans are cooking apes: creatures of the flame.

Hairlessness enforced bipedalism, which liberated the forelimbs to arms and fingers, thereby allowing hominins to deliver immature babies, making it possible to enlarge the brain after birth. Fire attracted hairless hominins, who made stone tools and firearms, which made humans the true masters of the earth. When one accepts this context and sequence of the ascent of man, hairlessness can be said to have created humans.

Conflicts of interest: The author declares that there are no conflicts of interest.

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