

Homo Erectus Foodways

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HOMO ERECTUS

Extinction of Early Homo, Homo Rudolfensis & Habilis, and the Emergence of Erectus

Around two million years ago, another hominid emerged in Africa called Homo Erectus that survived for over one million years, becoming extinct only about one hundred and fifty thousand years ago. At the beginning of its existence, it evidently co-existed with both Homo Habilis and Rudolfensis, as well as Australopithecus Boisei and at the end of its time, it overlapped with itself, Homo Sapien. In any case, soon after its emergence, Homo Habilis and Rudolfensis went extinct; at least that is what we have concluded based on our limited number of fossils.

ENVIRONMENT

HOMO ERECTUS (Ergaster) (co-existed, too, with Bosei: the grass eater likely seed, so inhabiting another ecosystem.) Also with Habilis and Rudolfensis, so likely inhabited different ecosystems.

During this time the environment was continuing its trend towards dryer and cooler, with fewer trees, and more changes in the environment. It's possible that the extinction of early Homo happened similarly to the extinction of Australopithecus before him--that is, during one of the Glacial Maximums, conditions became more extreme and competitive in Africa and even more of the trees disappeared. Since both Habilis and Rudolfensis were still dependent upon the trees both for food and protection from predation, they were likely severely compromised in their ability to survive. While their greater intelligence could help in many ways, it could not overcome their inefficient movement over the ground, combined with greater predation and competition there as well. So, while the trees and their food became even more scattered, they probably could not move fast enough from one stand to another; and if they needed to migrate long distances, they were probably even more vulnerable if they were ever forced to sleep on the ground. While their intelligence was improved, it likely was not enough to create greater, complex cooperation between individuals to effectively defend against predation, as well as to collectively hunt animals on the ground. Since they co-existed, it's also possible that they may have also been outcompeted and even hunted by Erectus.

Incidentally, even though they lived at the same time as Erectus, it's still possible and even likely that Erectus evolved from one of these prior Hominoids in another ecosystem and then migrated outward to inhabit ecosystems inhabited by their ancestors. In any case, Erectus lived for another million years and, as such, overlapped with most of the other future Hominoids, including ourselves. Since we emerged about 200k years ago, and Erectus became extinct about 150k years ago, it appears we lived concomitantly to them, if only in Africa.

At the Plio-Pleistocene boundary, the grasslands expanded and more open, dry, and seasonal environments with longer dry seasons came to characterize the time period from 2.0-1.0 million years ago. Throughout this one million years, an environment in constant flux would lead to the rise and fall of many different environments so that areas that were once grasslands would transition into bushlands or woodlands, later returning again to grasslands in periods of aridity. It was in this unpredictable environment full of a mosaic of different habitats always in flux that Homo erectus originates and Paranthropus continues to live. The appearance of Homo erectus was accompanied by a marked overall shift towards cooler, drier, and more seasonal conditions that lead to the more open and less wooded communities. Thus, the later Homo species inhabited more open woodland and grassland habitats than that of any previous hominids.

While these early hominins were able to adequately adapt their diet to a new environment, other frugivorous primates living in the same East African localities as the hominins were forced into extinction after 1.8 million years ago likely due to the restriction of closed forest habitats that bore their preferred foods. Thus, the apes and other more frugivorous primates were left to

inhabit the rain forests of central and west Africa, leaving the woodlands and savannas of east and south Africa to the early hominins.

Homo erectus therefore may have been distinct in being the first hominid to exist and be adapted to areas of fairly open and arid grassland. The hominins living in these habitats had to undergo longer and more intense dry seasons. The earlier hominids such as *Australopithecus* and *Paranthropus* would have been maladapted for such dry, open, and grassland filled environments, possibly contributing to their extinctions.

RAINFOREST

Did the rainforest play any role in human evolution???

It is known that the earliest bipeds of Africa (*Kenyapithecus*, *Victoriapithecus* etc.) successfully inhabited rain forests, but the debate is still in full swing over whether or not *Homo erectus* had the biological or behavioral capacity to successfully inhabit rainforests. At this time, there is no direct archaeological evidence to either allow us to conclude or reject the possibility of *Homo erectus* doing so. Until more data is acquired, any assertions on whether or not *Homo erectus* was able to successfully subsist in the rain forest will remain speculative in nature.

Research today actually questions whether or not humans ever subsisted by foraging in the rain forests. This may be due to the challenges of foraging in the rain forests where animal prey may be more rare and may blend well into their surrounding environment making them hard to come by, and where sources of carbohydrate and fat may be unpredictable and inconsistent. For these reasons, it is not surprising that a group of human ecologists and socio-cultural anthropologists from the late 1980s concluded that there has been no documented cases of foraging without some form of agriculture on the side in the tropical rain forest today or in the recent past. Foraging for food on the savanna is considered to be easier and more reliable than in the rain forest.

However, other scientists still contend that the rain forests were extensively settled beginning in the Later Stone Age approximately 50,000 years ago. At this time, every part of the African rain forest appears to have supported dense populations of foragers who were able to successfully utilize technologies such as stone tools to occupy a habitat with fewer food resources.

OUT OF AFRICA

Once evolving in Africa, *Erectus* was then the first of the Hominoids to migrate out of Africa into eastern and western Asia, during times called the Saharan Pump. While Africa is separated both from Europe and Asia by bodies of water, it is connected to the Middle-east by one, narrow strip of land, just above the Red Sea, called the Levant. Ordinarily, this strip would have been covered in desert--and thus impassable. But during Saharan Pumps which happened during warmer and wetter periods, this strip would transform into grasslands--thereby allowing *Homo Erectus* to travel into Asia. As we shall see, this same phenomenon allowed other Hominoids to pass out of Africa as well. Since *Erectus* was raining during the Ice Age, its most likely that his forays into Asia and even Europe happened during the Interglacials when temperatures are

more similar to what they are now; and during the Glacial Maximums, he was forced to retreat southward again--and perhaps even forced into regional extinction.

Some researchers deem the African and Asia versions as separate species, as *Ergaster* and *Erectus* respectively, but for our purposes, they are similar, if not obscure enough, to clump them into one category, especially regarding the foodways. It is curious to note that while *Australopithecus* and other primates radiated outward to become different species, as they adapt to new eco-systems, *Erectus* did not; he more or less stayed the same species and then spread throughout Africa and later Asia and even Europe so that for about one million years he seemed to be the dominant and almost exclusive hominoid on the planet. All of this, as we have seen, follows the traditional evolutionary pattern seen for other animals: that animals that range over long distances, do not tend to differentiate because their genes travel so far; whereas animals that are isolated into small groups tend to differentiate.

DIFFERENT ENVIRONMENTS

But this raises the question: why was *Erectus* enabled to travel so far from his homeland? As we have seen most animals tend to adapt morphologically to changing environments and stresses--a process that can take thousands of years. But as Hominoids started becoming more intelligent, they no longer needed to adapt their genes and therefore their morphology to changing environments: they could merely use their greater intelligence to overcome the obstacles in other environments around finding food, avoiding predators and dealing with the climate. As *Erectus* ranged across the earth, it's not entirely clear as to whether he was settling into the same ecosystems on various continents is not clear; we do not even know necessarily what kind of ecosystems he may have preferred, though we make some good guesses. However, research clarifies that *Erectus* was the first of the Hominoids to inhabit other ecologies than the tropics; in fact, when *Erectus* moved into Asia, he settled into seasonal environments that could be described as cold winters and mild summers. Naturally, this raises many questions, which we will explore later, about their ability to make and wear clothes and build fires to keep themselves warm.

Evidence of occupation of temperate (nontropical) environments by *Homo Erectus*—Hominids left Africa and occupied mainland Asia by 1.8 myr ago. About 1.15 myr ago *Homo erectus* and an associated *Stegodon*–*Ailuropoda* fauna migrated from subtropical China across the Qinling Mountains into the temperate Loess Plateau. This migration may be an evolutionary milestone in human adaptability because it may represent the first occupation of a nontropical environment. Loess–paleosol stable isotope ratios from the last interglacial–glacial cycle provide comparative data for reconstructing the hominid paleoenvironments. The climate during Gongwangling hominid occupation about 1.15 myr ago was influenced by both Siberian–Mongolian winter and Indian summer monsoon systems characterized as a cold/cool, dry winter and warm/mild, semihumid summer and fall. The Gongwangling hominids preyed mainly on warm-climate-adapted animals such as *Stegodon*–*Ailuropoda* fauna, suggesting a warm season occupation. The stable isotope ratios also indicate that the Chenjiawo hominids occupied an environment similar to that of the Gongwangling about 650,000 yr ago. The associated fauna, with a mixture of forest and steppe, warm- and cold/cool-climate-adapted

animal assemblage's, suggests a permanent occupation by this time. Thus, the reliable earliest and permanent occupation of temperate environments may have occurred 150,000 yr earlier in eastern Asia rather than in Europe." (Wang, Ambrose, Jack Liu, & Follmer 1997).

Footprints assigned to *Homo erectus* indicate the intensive occupation of lake margin environments:

"Here we present data from 481 fossil tracks from northwestern Kenya, including 97 hominin footprints attributed to *Homo erectus*. These tracks are found in multiple sedimentary layers spanning approximately 20 thousand years... The geology and associated vertebrate fauna place these tracks in a deltaic setting, near a lakeshore bordered by open grasslands. Hominin footprints are disproportionately abundant in this lake margin environment, relative to hominin skeletal fossil frequency in the same deposits. Accounting for preservation bias, this abundance of hominin footprints indicates repeated use of lakeshore habitats by *Homo erectus*. Clusters of very large prints moving in the same direction further suggest these hominins traversed this lakeshore in multi-male groups. Such reliance on near water environments, and possibly aquatic-linked foods, may have influenced hominin foraging behavior and migratory routes across and out of Africa." (Roach et al. 2016).

"Near-water microhabitats may have had a strong selective role in altering the behavior and evolution of *H. erectus*. Although our fossil survey findings and previous faunal analyses indicate that *Homo* was commonly associated with grassland habitats³⁶, finer scale ecological data presented here suggest that at 1.5 Ma in the northern Turkana Basin at least some of these grasslands were near water and likely edaphic³⁶. Further, oxygen isotope data collected from *H. erectus* teeth show lower $\delta^{18}\text{O}$ values than earlier *Homo*, consistent with better-watered habitat and food³⁷. Evidence of hominin consumption of aquatic plants and animals such as fish, turtles and molluscs dates back to at least *H. erectus* and such dietary resources may have contributed to brain expansion in later *Homo*^{38,39,40}. Near-water habitats are also effective places to both hunt and scavenge animals coming to drink. The proliferation of stone tools and cut-marked bone in the fossil record are contemporaneous with the emergence of *H. erectus* and indicative of increased carnivory. Given that the acquisition of meat is both costly and has a high probability of failure (e.g.⁴¹), reliance on high-quality aquatic foods⁴² and social support⁴³ may have been crucial for early hunters.

As the first hominin species to migrate out of Africa, *H. erectus*' global expansion would have required moving through and surviving in inhospitable environments. Consistent access to water would have allowed *H. erectus* to sweat effectively without dehydrating⁴⁴, increasing day range and mobility. Near-water habitats such as lake margins and rivers may have provided corridors for long distance travel and migration^{45,46}. These aquatic corridors would have made access to food and water more predictable, buffering hominids from climate change, particularly the increasingly arid conditions in North Africa that our ancestors would have faced as they spread out of the continent." (Roach et al. 2016).
(Roach et al. 2016).

MORPHOLOGY & LOCOMOTION

Erectus' Home Range has been estimated to have been 8 to 10 fold greater in size than late Australopithecines, due to increased body size, and assuming Erectus included a moderate amount of meat in the diet. This increase in home range may have in part spurred the expansion out of Africa.:

“Rutgers University geochronologist Carl Swisher III and his colleagues have shown that the earliest H. erectus sites outside of Africa, which are in Indonesia and the Republic of Georgia, date to between 1.8 million and 1.7 million years ago. It seems that the first appearance of H. erectus and its initial spread from Africa were almost simultaneous.

The impetus behind this newfound wanderlust again appears to be food. What an animal eats dictates to a large extent how much territory it needs to survive. Carnivorous animals generally require far bigger home ranges than do herbivores of comparable size because they have fewer total calories available to them per unit area.

Large-bodied and increasingly dependent on animal foods, H. erectus most likely needed much more turf than the smaller, more vegetarian australopithecines did. Using data on contemporary primates and human hunter-gatherers as a guide, Robertson, Susan C. Antón of Rutgers University and I have estimated that the larger body size of H. erectus, combined with a moderate increase in meat consumption, would have necessitated an eightfold to 10-fold increase in home range size compared with that of the late australopithecines-- enough, in fact, to account for the abrupt expansion of the species out of Africa. Exactly how far beyond the continent that shift would have taken H. erectus remains unclear, but migrating animal herds may have helped lead it to these distant lands.” (Leonard, W.R. 2002).

Modern hunter-gatherers living in more open woodland and grassland habitats often travel 6 to 8 miles a day in search of food, whereas chimps, gorillas and orangutans in forested environments need only travel a mile or so to find enough food to eat. An increase in day range may have selected for more energetically efficient locomotion in Homo. Bipedalism would have decreased the number of calories expended upon obtaining more widely dispersed food resources.: “Apes, in contrast, are not economical when moving on the ground. For instance, chimpanzees, which employ a peculiar form of quadrupedalism known as knuckle walking, spend some 35 percent more calories during locomotion than does a typical mammalian quadruped of the same size-- a large dog, for example. Differences in the settings in which humans and apes evolved may help explain the variation in costs of movement. Chimps, gorillas and orangutans evolved in and continue to occupy dense forests where only a mile or so of trekking over the course of the day is all that is needed to find enough to eat. Much of early hominid evolution, on the other hand, took place in more open woodland and grassland, where sustenance is harder to come by. Indeed, modern human hunter-gatherers living in these environments, who provide us with the best available model of early human subsistence patterns, often travel six to eight miles daily in search of food. These differences in day range have important locomotor implications. Because apes travel only short distances each day, the potential energetic benefits of moving more efficiently are very small. For far-ranging foragers, however, cost-effective walking saves many calories in maintenance energy needs--calories that

can instead go toward reproduction. Selection for energetically efficient locomotion is therefore likely to be more intense among far-ranging animals because they have the most to gain.

For hominids living between five million and 1.8 million years ago, during the Pliocene epoch, climate change spurred this morphological revolution. As the African continent grew drier, forests gave way to grasslands, leaving food resources patchily distributed. In this context, bipedalism can be viewed as one of the first strategies in human nutritional evolution, a pattern of movement that would have substantially reduced the number of calories spent in collecting increasingly dispersed food resources." (Leonard, W.R. 2002).

"Homo ergaster was not only significantly larger than the australopithecines and parathropines, but also had significantly longer legs in relation to its body mass. This has further ramifications for energy turnover." (Aiello, Leslie C. & Wells, Jonathan C.K. p. 331).

"Some of the most widely discussed aspects of hominin post-cranial morphology are related to differences in body size, shape and proportions between the different species which comprise our genus. The African species, H. ergaster, appears to have undergone a 'body revolution' consisting of, among other things, a significant increase in stature and the acquisition of human-like limb proportions around 1.8 Ma (millions of years ago)." (Carretero et al. 2012).

"H. ergaster is the first known hominid to approximate modern human body proportions (Ruff and Walker 1993)...Modern human trunk proportions in early Homo would have had additional significance if active hunting and/or long-distance migration was important to the ecology of these hominids. High levels of sustained activity require an extremely efficient cardiovascular system, the key components of which are located within the thoracic cage. In apes and australopithecines the construction of the shoulder girdle restricts the elevation of the upper portion of their funnel-shaped rib cages during respiration (Schmid 1991). Ventilation of the lungs was probably mainly dependent on the movements of the diaphragm and would therefore have been less effective than in Homo, in which the upper part of the rib cage can be raised to enlarge the thorax during inspiration. In addition to this physiological consideration, Schmid (1991) has identified biomechanics advantages of the Homo body form. A significantly narrower waist than in the australopithecines would have allowed the arms to swing more freely in the lowered position and permitted greater torsion in the abdominal region, both of which are essential in stabilizing the upper body during bipedal running." (Aiello & Wheeler 1995).

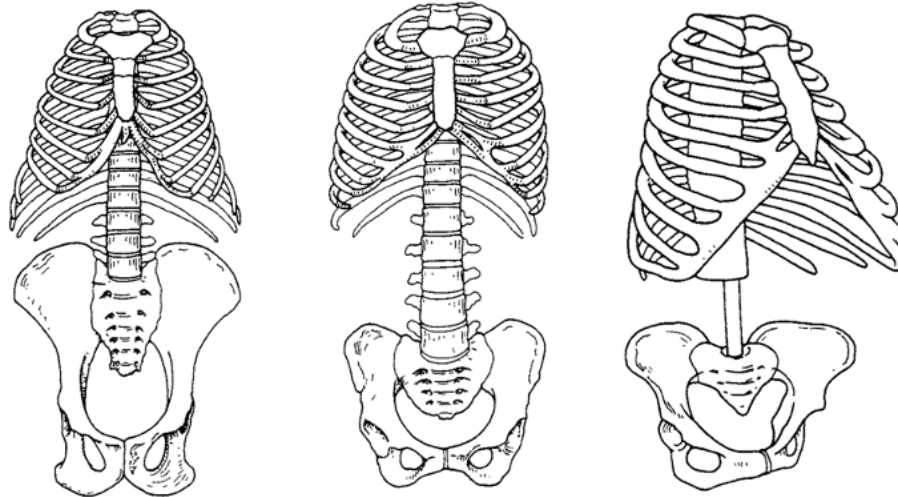


FIG. 8. Trunks of a chimpanzee (left), a human (center), and *Australopithecus afarensis* (right), showing the protruding rib cage in the latter. (*A. afarensis* reconstruction after Schmid 1983, chimpanzee and human after Schultz 1950.)

(Aiello & Wheeler 1995).

Author Note: We have many fossils of *Homo Erectus*, including multiple crania from different parts of the world and many jaws and teeth, as well one specimen, Turkana Boy, that includes most of the bones of the body, including a skull that is more or less complete. For this reason, we can reliably reconstruct their morphology. As we have seen all previous hominoids have been shaped roughly like Chimpanzees that walked upright, seemingly with distended stomach and undefined hips. But *Erectus* became physically much more like ourselves; in fact, almost exactly like ourselves with the exception of his smaller brain. His arms became shorter and his legs longer, to the same proportions as ourselves. And while previous primates had more conical chests, *Erectus* was more barrel-like like ourselves. He also was about the same size as ourselves or possibly taller, ranging from around five foot eight to six feet while appearing generally more slender than most humans with his neck slightly elongated. His face however was shorter than our own, with his forehead more sloped and receded. If many of the artist's renditions of him are correct, you might recognize him as human if he was walking down the street; you just might think he was a crack-head.

When he changed his morphology, he then was not any better than us at climbing trees; or in other words, he is the first of the Hominoids to not rely upon the trees anymore and most likely did not sleep in them unless he was in a pinch.

ERECTUS—“Anatomically, full shoulder rotation disappeared (which is why modern humans cannot brachiate well), indicating a final break from arboreal life.” (Massey 2002).

At the same time he became greatly more efficient at moving over the ground—in fact more efficient than nearly all other animals in some aspects anyway. The previous Hominoids were not particularly good at running or maybe even jogging. But with *Erectus*, it is clear that not only was walking more efficient for him, allowing him to walk greater distances with less energy, but he was also the first of the hominids to really be able to both sprint, run and jog;

in fact, he became better at distance running than most other animal in Africa. In fact anatomical studies have revealed that most of the changes in his morphology were geared towards making him an endurance runner like our marathoners of today. In one particular study, scientist listed around ten different attributes that differentiated Erectus from Australans and that, in turn, led to their ability to run much faster. For example they developed tendons in their legs and foot that acted like springs to help them push off the ground; buttocks that supported the legs in motion; shoulders that rotated independently of the head and neck, allowing for better balance; muscle and skeletal features that made their bodies stronger and more efficient; and heads that balanced better over the shoulders to allow for better balance and movement.

Reference: (Bramble & Lieberman 2004)

“Judged by several criteria, humans perform remarkably well at endurance running, thanks to a diverse array of features, many of which leave traces in the skeleton. The fossil evidence of these features suggests that endurance running is a derived capability of the genus Homo, originating about 2 million years ago, and may have been instrumental in the evolution of the human body form.” (Bramble & Lieberman 2004).

“Given that hominins were habitual bipeds for at least 4 million years before the origin of H. erectus with little evidence for any major change in postcranial anatomy (reviewed in Ward, 2002), it is difficult to imagine that selection for walking alone was responsible for the derived features of Homo. The most likely scenario is that H. erectus was the first hominin with a substantially expanded diurnal day range made possible by both walking and running... In addition, many ancestral features of australopithecines that improve climbing performance, such as long forearms and heavily muscled shoulders, do not conflict with the biomechanical demands of walking, but may impede the ability to stabilize the head. Selection for running capabilities may thus have selected against arboreal capabilities in Homo.

Put together, there is much evidence that H. erectus but not Australopithecus was capable of ER[endurance running]...In addition, there are some hints that H. habilis may have possessed some ER capabilities, but the evidence is sparse and equivocal (see Bramble and Lieberman, 2004). While it is possible that ER capabilities had evolved by the time of H. habilis, it is premature to be definitive, and there are theoretical reasons to hypothesize that such capabilities, if they existed, were not as developed as in H. erectus. Natural selection tends to take advantage of existing variations in the context of some fitness benefit. Thus, it is unlikely that selection would have favored the evolution of ER-related features if hominins had not already been engaged to some extent in a form of ER. One potential scenario is that early Homo during the Oldowan started to scavenge and/or hunt to a limited extent. At some point, hominins that were better at ER for various reasons (longer legs, larger anterior and posterior semicircular canals, and so on) had a slight fitness benefit, leading to the evolutionary changes that we observe in H. erectus.” (Lieberman, Bramble, Raichlen, & Shea 2009).

“Several lines of evidence suggest that H. erectus was probably the first hominin species regularly able to exploit open, hot and arid savanna environments conducive to endurance running. One source of evidence is the body of form of H. erectus itself, whose long limbs and

narrow thorax is ideally suited to thermoregulating in the midday sun (Ruff, 1991).” (Lieberman, Bramble, Raichlen & Shea 2009).

They also developed the ability to dissipate heat better than their predecessors, and better than more or less all other mammals, giving them distinct advantages. Its likely that he lost some of his hair and became somewhat more naked like ourselves. And by becoming thinner, he increased the amount of surface area on his skin--which allows heat to escape the body better. Further, while most mammals sweat, Erectus--and humans--are better at sweating than any other animal--which allows heat to escape from the body by evaporating or vaporizing into moisture. So when considered all together, we have estimated that Erectus was able to move twice as fast across the ground as Australapithicus. Given his more slender and longer frame, he was probably even more efficient and faster than most modern humans. However, relative to most other terrestrial mammals, such as antelopes and lions, he was rather slow at sprinting, so he could not chase down prey, like other predators and kill them. However, he was one of the best endurance runners in Africa, able to chase down other animals, even antelopes, over many hours if he so chose.

As we have seen with other primates, locomotion is extremely important in the quest for food and, in that light, it does seem rather obvious as to why this adaptation happened. As trees became more scarce, intermittent and subject to climate changes during the Ice Age, Hominoids could not rely upon them anymore, so they needed to become better adapted to the ground; even with larger brains, they would still be rather helpless on the ground, if they were slower and clumsier than other animals. This greater locomotion would help them cover and claim more territory for food; it would additionally help them escape predators by outjogging them and even their greater speed in sprinting could help some. Meanwhile they could begin to use this greater efficiency in hunting; while they could rarely outspurt their prey, they could use their greater endurance to locate marrow and brains and even meat before they spoil; they could also better track down living prey and then perhaps guide them off cliffs or rocks or into lakes. They could also outjog their prey over the course of many hours into exhaustion and then easily kill them--a form of hunting, called persistence hunting, still practiced today by various foragers in Africa.

Did Homo Erectus still sleep in the trees?

“There is, however, no reason to conclude that Homo habilis and rudolfensis had given up sleeping in trees. But Homo erectus (sensu lato) almost certainly had. This conjecture is supported by the post-cranial anatomy of Nariokotome. The remains of this individual include at least one example of all the major limb bones, excepting only the radius and small finger and toe bones, along with the majority of the axial skeleton, and the skull. From this virtually complete skeleton, paleoanthropologist have been able to reconstruct a detailed picture of Nariokotome’s biology and life history. This was a pre-adolescent male, who was 160 cm tall at the time of death, but who would have attained an adult stature of over 170 cm. He was tall and thin, with an ideal body type for heat dissipation, and had led a rigorous life (Walker & Leakey 1993). Otherwise, his limbs were little different from those of a modern human – he had the anatomy of modern bipedalism, and no remnants of climbing anatomy in his forelimbs (McHenry

& Coffing 2000; Wood & Collard 1999)...It is the anatomy of a hominid adapted to hot, open environments, and to traveling longer distances on the ground. It was larger than earlier hominids, and had lost all remnants of climbing anatomy. The differences between Homo erectus and earlier Homo, including Homo habilis and Homo rudolfensis, and the similarities to modern humans, are so significant that Wood and Collard (1999) have suggested relegating habilis and rudolfensis to the genus Australopithecus. The advent of Homo erectus was clearly one of the most significant transitions in human evolution.” (Coolidge & Wynn 2006).

(exploration of where Erectus slept: caves, tree houses, with sentries (nests, also does not have protection of other prey: ungulates sleep standing up, hyper alert, so can bolt in an instant, dolphins with half their brains, but primates appear to have long history of sleeping soundlessly protected by the trees)

As we have noted Erectus was not all that well-suited to the trees anymore and probably did not sleep in them anymore, unless he was able to build tree-houses or nests made from sticks (which I suppose is possible). But if was sleeping on the ground, he would be rather vulnerable to predation. Many animals have defenses even while they are sleeping: many ungulates sleep while still standing so they can make quick escape from predators; some animals, like dolphins, sleep with half of their brains and therefore still stay somewhat alert and functional. But primates, perhaps coming from their secure past in the trees, do not seem to possess these skills, making Erectus all the more vulnerable on the ground. It's conceivable that he built structures to protect him or, otherwise, inhabited caves for which we have evidence. But its also possible that he was dependent upon fire for his protection, as predators, across the world, are afraid of fires and torches are even more effective at warning them away.

Fire had advantages

*protection from predation

*allow to sleep on the ground: (may want to reposition this)

Additionally, we do not have any evidence that Erectus has any morphological adaptation to deal with cold, even when he was inhabiting more northern and colder environments. So it's difficult to imagine how he survived in these environments without the use of fire. Furthermore, as we shall see, Erectus, due to changes in his anatomy and encephalization, was dependent upon the cooking of his food--all issues that we will explore later.

More on sleep...

“Several aspects of behavior relating to sleep in monkeys and apes are reviewed, including sleeping site selection, approach to and departure from sleeping sites, social behavior at the sites, and nocturnal activities. Illustrative examples are given for each topic. Good sleeping sites for primates give protection from predators and/or some physical comfort from the elements and other sources of disturbance. Availability of sleeping sites may determine ranging patterns and whether an area is exploited or not. Times of retiring and resumption of daytime activities are influenced by foraging and ranging requirements. Social relationships and their influencing factors continue during the night, including dominance, kinship, affiliation and sex. Social partners may be used for thermoregulation and for increasing postural stability. Primates show a

range of solutions to the problems surrounding sleep, and similarities and differences between monkeys and the large-bodied, nest-building great apes are described. Knowledge of natural sleep-related phenomena in non-human primates can provide valuable insights for human sleep research, and vice-versa.” (Anderson, J.R. 2000).

“Every weaned great ape builds a new nest, or bed, to sleep in every night, and sometimes nests are built during the day as a place to rest. Chimpanzees (*Pan troglodytes*), bonobos (*Pan paniscus*), and orangutans (*Pongo pygmaeus*) generally sleep in arboreal nests, whereas gorillas (*Gorilla gorilla*) often nest on the ground (see review in Fruth and Hohmann, 1996). As nest-building occurs in all living great apes, parsimony suggests that the common ancestor also built nests (Sept, 1992; Sabater Pi et al., 1997). Arboreal nesting in chimpanzees and bonobos further suggests that the last common ancestor of *Pan* and *Homo* slept in trees. Australopiths and early *Homo* may have continued to use trees for overnight sleep in safe, inaccessible locations from ground predators (Sabater Pi et al., 1997; Stewart, 2011). These early hominins likely used bipedal terrestrial travel as the main form of locomotion (Ward, 2002; Haeusler and McHenry, 2004), but their morphology suggests they were still able to climb trees (McHenry and Coffing, 2000). The shift to a more fully terrestrial life style in *Homo erectus* (Ruff, 2009) has been proposed to include a transition from arboreal to terrestrial sleeping (Coolidge and Wynn, 2009), possibly facilitated by the controlled use of fire (Wrangham, 2009)....

Chimpanzees usually make arboreal nests (Fruth and Hohmann, 1996), but occasional ground nests have been recorded at some study sites (Reynolds and Reynolds, 1965; Goodall, 1968; Boesch, 1995; Furuichi and Hashimoto, 2000; Maughan and Stanford, 2001; Pruett et al., 2008; Hicks, 2010). However, ground-nesting is rare in most populations (i.e., less than 5% of nests), especially for night-time use (but see Hicks, 2010).... Arboreal nest-building in apes has been proposed to function as anti-predation strategy (McGrew, 2004). Safety from terrestrial predators may have been especially important in early hominins living in open habitats with a high predation pressure (Sabater Pi et al., 1997; Stewart, 2011).... In chimpanzees, predation pressure is generally low in populations where ground-nesting occurs (Furuichi and Hashimoto, 2000; Maughan and Stanford, 2001; Koops et al., 2007; Pruett et al., 2008), but at Bili (Democratic Republic of Congo) chimpanzees nest on the ground (10.9% of nests, n 5 273) despite the presence of leopard (Hicks, 2010). Hence, presence of predators in paleohabitats of early hominins does not preclude terrestrial sleeping, in nests or otherwise. For *H. erectus*, sleeping on the ground may have been facilitated by the use of fire to protect against large terrestrial predators (Wrangham, 2009). However, ground-nesting in chimpanzees, especially at Bili, suggests that use of fire may not have been a prerequisite for ground sleep.” (Koops et al. 2012).

Author notes: great apes sometimes sleep on the ground, but in the trees if predators around, build nests, not active at night only great apes build nests not monkeys for thermoregulation and sleep quality

Female gorillas and immatures more vulnerable to predation show preference for sleeping in trees, especially if a leading male is not present.—

“To analyze the factors influencing nesting by gorillas on the ground, three kinds of data were collected in the Kahuzi-Biega National Park: from a single group for 3 years, from 25 groups during a population census, and from a habituated group before and after two social events. The data on the proportion of ground nests built by the single group for 3 years show no significant differences between rainy and dry seasons. Significant differences were found between some vegetation types: in particular, between bamboo forest and others (primary and secondary forests). However, these differences were not prominent or consistent across age–sex classes of gorillas. By contrast, large differences were found in this proportion between adults and immatures in both primary and secondary forests. The low proportion of ground nests built by immatures indicates their vulnerability. The present study suggests that the proportion was not influenced by group size but strongly influenced by the presence or absence of a leading silverback. Data on a habituated group that lost its leading male and acquired a new male after several months clearly show that females and immatures preferred sleeping in trees in the absence of a protector male. Immatures drastically decreased terrestrial nesting (from 54% to 6%, $P < 0.001$) and increased it (from 6% to 19%, $P > 0.05$) less dramatically than females did (from 24% to 60%, $P < 0.01$) after immigration of the new male. These results suggest that vulnerability of female and immature gorillas to predators, in spite of their large body size. Small body size and considerable sexual dimorphism in early hominids implies their frequent use of tree nests and the importance of the male's role as protector.” (Yamagiwa 2001).

Male Chimpanzees also nest on the ground more than female chimps:

“Our results showed that ground-nesting is a strongly male-biased behavioral pattern, albeit not exclusively male...Females made many fewer ground nests...Male chimpanzees have been found to nest lower than females in Budongo, Uganda (Brownlow et al., 2001).” (Koops et al. 2012).

CAPTURE

“Our hypothesis also leads us to expect that the life history changes indicated for *Homo erectus* were associated with the exploitation of previously unused or little-used resources, items that were especially suitable as provisioning foods...The best prospective candidates for increased exploitation may be USOs...Archaeological evidence of tuber exploitation is often limited and indirect. Still, we can point to at least four lines of evidence consistent with increased use of tubers beginning with the appearance of *H. erectus*:

a) Geographical range: *H. erectus* occupied a far broader range of habitats than any previous hominid and was the first to disperse beyond Africa. Early examples are found as far east as Java and as far north as latitude 50 degrees. The sharp change in distribution strongly implies access to a new food source. All new habitats occupied were likely have offered tubers in variety and quantity; 50 degrees north is the approximate limit of reliance on tubers as a staple among ethnographically known hunters in continental habitats.

b) Digging tools: Efficient exploitation of deeply buried USOs requires, at minimum, a digging tool. The earliest known examples date to about 1.7 Ma.

c) Evidence of fire: ...Though highly controversial, the earliest dates for humanly controlled fires, suitable for tuber processing, fall within the range of 1.4-1.6 Ma. The ability to control fire may be the key factor distinguishing *H. erectus* resource use from that of australopithecines, at least some of who are also thought to have been involved in tuber exploitation.

d) Digestive anatomy: Reductions in digestive tract size and molar surface area associated with earliest *H. erectus* clearly point to increased use of resources that require less post-consumption processing, implying either a narrower range of foods exploited or increased investment in pre consumption processing. Tuber cooking is a good example of the latter strategy." (O'Connell, James; Hawkes, Kristen; & Jones, Nicholas Blurton p. 58-59).

"Evidence of abundant starchy tubers in many African hominin sites has been taken to suggest that USOs, the predominant food source for these animals, were plentiful (Reed and Rector 2007). The presence of palms in the Olduvai Gorge region date from around 1.8 mya (Albert et al. 2009); palms often have abundant edible starch in their trunks, and some species also produce dates. The roots of lilies (Liliaceae), rushes (Juncaceae), and sedges (Cyperaceae) have also been identified at Olduvai Gorge from a horizon dated to between 1.89 and 1.75 million years ago (Bamford et al. 2008). Edible USOs from these monocotyledons, along with grasses (Poaceae) identified at the same sites, offer evidence for the abundance of edible starch at a time that hominins were present." (Hardy et al. 2015).

TEETH AND JAW

Both microwear and carbon analysis confirms that it appears *Erectus* continued the more general primate tradition, of maintaining a diverse and varied diet: the evidence seems to suggest that they have wear on their teeth suggestive of other animals that eat different types of food, both hard and tough. At the same time the evidence suggests that they both feed both from the trees, like most of their ancestors, as well as from the ground, probably in the form of seeds and tubers. It's also possible that they ate more animal foods, since their teeth are more adapted to eating less tough and hard foods.

—Microfossil remains of grass seeds were found in the dental calculus of a *Homo* living in Europe 1.2 million years ago providing the earliest direct evidence of plant foods consumed by *Homo*.

“Sima del Elefante, Atapuerca, Spain contains one of the earliest hominin fragments yet known in Europe, dating to 1.2 Ma. Dental calculus from a hominin molar was removed, degraded and analysed to recover entrapped remains. Evidence for plant use at this time is very limited and this study has revealed the earliest direct evidence for foods consumed in the genus *Homo*. This comprises starchy carbohydrates from two plants, including a species of grass from the Triticeae or Bromideae tribe, meat and plant fibres....Several small groups of bimodal starch granules (A, 20–30 µm; B, 5–8 µm, Fig. 2.2, 2.3) were found in the hominin calculus and a small group of similar bimodal starches was also detected in the deer dental calculus, confirming that these plants were present in the surroundings and exploited by both the hominin and animal

populations. Bimodal distribution of starch granules is a distinctive characteristic present in the edible seeds of the Triticeae tribe and some species of the Bromideae tribe of the grass family (Poaceae). It is plausible that these ancient grasses were ingested as food. Grasses produce abundant seeds in a compact head, which may be conveniently chewed, especially before the seeds mature fully, dry out and scatter...Several different types of fibres were recovered in the calculus, including non-edible wood debris as well as other indeterminate fibres of plant origin.” (Hardy, K. et al. 2017).

C3/C4 ANALYSIS

Plant Foods:

“The stable carbon isotope analyses reviewed here indicate that early South African hominid diets did have a significant C4 component. But it was not dominant. It is estimated to have averaged ca. 25% for all three hominid species sampled, *Australopithecus africanus*, *Paranthropus robustus*, and *Homo ergaster*. Some caution in interpreting the isotopic data is warranted. The samples are small and the minimum number of individuals represented has not been presented in the original reports. There are differences in variation across the species, even with these small samples, that may be significant. The samples span unknown temporal durations, with varying degrees of contemporaneity among the specimens and species within a particular deposit...the similarity between the three species of hominids is unexpected, given general assumptions that *A. africanus* was an omnivore, *Paranthropus* was a specialized vegetarian, and *Homo ergaster*, like *H. erectus*, was more carnivorous than either *Australopithecus* or *Paranthropus*...Accepting the ca. 25% C4 dietary estimate for all three hominid species at these sites, some hypotheses need to be developed as to how that percentage theoretically could be met...As a starting point we can offer the following theoretical formulation of possibilities for a 30% C4 contribution to a subadult hominid diet based on minor potential C4 food categories:

5% C4 input from sedge stem/rootstock, green grass seed, and forb leaves

5% C4 input from invertebrates

5% C4 input from bird eggs and nestlings

5% C4 input from reptiles and micromammals

5% C4 input from small ungulates

5% C4 input from medium and large ungulates...

The place in the formulation where hominid species differences perhaps are potentially the strongest is the C4 component from medium and large ungulates. This input might be acquired through hunting or scavenging, but either method is more likely an adult male rather than subadult capability, so food sharing is another underlying assumption...For the adult, if 25% of the diet were to be ascribed to the meat of C4 grazers, it would be reasonable to assume a more or less equal contribution from C3 browsers, and such a large dependence (ca. 50%) on meat would be difficult to accept for any of these early hominids.” (Peters & Vogel 2005).

Homo (species unidentified) in the Turkana basin had C3/C4 ratios that ranged between 75/25 to 45/55.:

“Between 2.0 and 1.4 Ma, numerous *P. boisei* and *Homo* sp. indet. specimens show that the diets of the two genera were distinct, with *Paranthropus* having a diet composed of a 20/80

C3/C4 diet ratio, whereas *Homo sp. indet.* shows C3/C4-derived ratio values that range from 25/75 to 45/55.” (Cerling et al. 2013).

“By ca. 2 Ma, hominins in the Turkana Basin had split into two distinct groups: specimens attributable to the genus *Homo* provide evidence for a diet with a ca. 65/35 ratio of C3- to C4-based resources, whereas *P. boisei* had a higher fraction of C4-based diet (ca. 25/75 ratio). *Homo sp.* increased the fraction of C4-based resources in the diet through ca. 1.5 Ma, whereas *P. boisei* maintained its high dependency on C4-derived resources...1.99–1.67 Ma...The 16 *Homo sp. indet.* specimens have $\delta^{13}\text{C}$ values significantly different ($P < 0.001$, ANOVA, Tukey posthoc) from the *P. boisei* individuals in the same age range ($-7.0 \pm 1.5\text{‰}$, $n = 16$; i.e., a C3/C4-based resources ratio of ca. 65/35)...1.65–1.45 Ma...Ten *Homo sp. indet.* specimens in this age range have an average $\delta^{13}\text{C}$ value of $-4.3 \pm 1.1\text{‰}$ (i.e., a C3/C4-based resource ratio of ca. 45/55). The *Homo sp. indet.* individuals in this age range...differ from *Homo sp. indet.* individuals from the earlier (1.99–1.67 Ma) time range in that there is a ca. 20% increase in the C4 diet component...By the 1.99- to 1.67-Ma time period, at least two morphologically highly distinctive hominin taxa, *P. boisei* and *Homo sp. indet.*, had shifted in the direction of consuming higher but different proportions of C4 resources.” (Cerling et al. 2013).

Potential C4 Plant Foods available to *Homo* in Africa:

“A small minority of Africa’s wild plant foods are C4. These are primarily the seeds of some of the C4 grasses, the rootstocks and stem/leaf bases of some of the C4 sedges (especially papyrus), and the leaves of some of the C4 herbaceous dicots (forbs). These wild food plants are commonly found in disturbed ground and wetlands (particularly the grasses and sedges)...The environmental reconstructions available for the early South African hominid sites do not indicate the presence of large wetlands, and therefore probably the absence of a strong potential for a C4 plant food diet. However, carbon isotope analyses of tooth enamel from three species of early South African hominids have shown that there was a significant but not dominant contribution of C4 biomass in their diets. Since it appears unlikely that this C4 component could have come predominantly from C4 plant foods, a broad range of potential animal contributors is briefly considered, namely invertebrates, reptiles, birds, and small mammals. It is concluded that the similar average C4 dietary intake seen in the three South African hominid species could have been acquired by differing contributions from the various sources, without the need to assume scavenging or hunting of medium to large grazing ungulates. Effectively similar dominantly dryland paleo-environments may also be part of the explanation. Theoretically, elsewhere in southern and eastern Africa, large wetlands would have offered early hominids greater opportunities for a C4 plant diet...a gradient of seasonal freshwater wetlands, or a large tropical wetlands complex with floodplains and perennial marsh probably would be the ideal environment for generating a strong C4 component from most of these potential dietary sources... The type of landscape where wild C4 plant foods would be relatively abundant is that of a mosaic of extensive seasonal and perennial shallow-freshwater wetlands. Extensive marshes dominated by the giant sedge *Cyperus papyrus* are a special case. Acknowledged as a food source by the ancient Egyptians, the young shoot and mature culm bases and heart-of-rhizomes from extensive stands of papyrus might have provided a dominantly C4 plant food diet. However, reconstructions of the settings around the South

African early hominid cave sites indicate only limited possibilities for herbaceous wetlands. These reconstructions do not suggest extensive wetlands where C4 plants would have been a major part of the potential dietary environment. Other parts of southern, south-central, and eastern Africa, where extensive freshwater wetlands existed, were probably much more productive in this regard.” (Peters & Vogel 2005).

Potential Nutritional Contribution of C4 Plant Foods:

“The fresh young leaves of the edible forbs are good sources of moisture, minerals, and vitamins (sometimes including vitamin C), but because of their high water content, they provide very limited amounts of carbohydrate and protein, and almost no fat (Wehmeyer, 1986; Maundu et al., 1999). The fresh tubers, bulbs, and rhizomes of *Cyperus* are primarily sources of moisture and carbohydrate (Wehmeyer, 1986; Peters, 1999). Fresh grass seed is a source of minerals and some vitamins, and is high in carbohydrate, but intermediate in protein (which may not be balanced in amino acids; Ward, 1971), and low in fat (Wehmeyer, 1986; Maundu et al., 1999).” (Peters & Vogel 2005).

Potential C3 Plant Foods available to Homo in Africa:

“The vast majority of Africa’s wild food plants are C3. These plants provide the wild plant food diets characteristically consumed by the higher primates, including humans. There are 145 families (33 monocot, 112 dicot) and several hundred wild African species known to have been utilized by humans (Peters et al., 1992).

The wild C3 food plants of Africa provide food types both similar to and different from the C4 food plants. Similar food types include leaves, rootstocks, and a variety of seeds provided by C3 herbaceous and woody plants. In both growth form and habitat distribution, these plants are not as restricted as those of the C4 syndrome. Some are found in the same general habitats as members of the C4 group, e.g., seasonal and perennial shallow freshwater wetlands. Others are common where C4 plants are not, e.g., riverine forest and woodland.” (Peters & Vogel 2005).

“The wild C3 food plants also provide food types not occurring in the potential C4 African plant food diet. Some of these may be of minor significance, e.g., nectar, gum, mushrooms. Others are clearly very important. Notably significant are the fleshy fruits and nutlike oil seeds that constitute important core staples in the potential wild plant food diet of sub-humid and semi-arid Africa. The fruits are provided by numerous trees and shrubs covering a variety of habitats (e.g., Peters et al., 1984; Peters and O’Brien, 1994). They are good sources of carbohydrates (sugars), minerals, and vitamins. The proteinaceous nutlike oil seeds are a special category of staples. In woodland savanna plant species, the nutlike seeds are part of an edible fruit, often a keystone fruit species for a variety of mammals (Peters, 1993). The nutlike seeds are rich in fat and protein, and an additional source of minerals and vitamins. For early hominids, they could have provided supplementary nutrients needed to put on fat reserves seasonally (Peters, 1987). In terms of landscape, C3 food plants are found almost everywhere. In the general habitats occupied by C4 food plants, C3 food plants also occur. It is difficult to envisage an environment with C4 food plants without important C3 food plants nearby. One exception might be a vast marsh, dominated by papyrus...

We conclude from this analysis that the hypothesis of a plant food diet for early hominids with C4 plants contributing the majority of food intake appears unlikely.”(Peters & Vogel 2005).

Potential C4 Animal Foods available to Homo:

“Animal sources for the C4 component of an early hominid diet are theoretically diverse. We may not have to assume that the early hominids were hunters with humanlike capabilities. The possibilities of C4 insects, reptiles, birds, and rodents recognized in Table 3 are notable because potential competitors for these foods probably do not include large (potentially dangerous) mammals...We have not been able to include fish in this analysis because of the lack of relevant isotope data...The small ungulates are not a clear case. Generally they are mixed feeders and many are predominantly browsers. Among the medium to large ungulates, however, there are a number of C4 grazers...Without positing special hunting capabilities, the possibilities of a predominantly C4 diet would appear to depend on special combinations of environmental opportunities. Theoretically, the outstanding case would be a papyrus marsh (a source of wet and dry season plant food) in a landscape mosaic that included very large rainy season aggregations of mass nesting birds and mass calving ungulates with C4 diets.” (Peters & Vogel 2005).

Source for Table 3: Peters & Vogel 2005

“The stable carbon isotope signature of a meat-based diet depends on the nature of the prey: small bovid herbivores less than ca. 10 kg (e.g., dik-dik and other neotragines) tend to be browsers and have C3-based diets (14, 32), whereas large herbivores can have diets that are C3-based (browsers such as most tragelephines, black rhinos, and giraffes), C4-based (grazers such as warthogs, zebra, alcelaphines, reducines, and bovines), or mixed(e.g., impala, and some gazelles). Thus, the size of prey may be important in considering possible secondary diet C3 or C4 resources. Other small mammals (e.g., hyrax, lagomorphs, or rodents) could have been an important dietary resource and would contribute to isotope mixing lines between C3- and C4-based end member values.” (Cerling et al. 2013).

AUTHOR NOTE: As with early Homo we do not have complete or accurate analysis for carbon ratios in Homo Erectus for several reasons. For some reason which I have not been able to understand, we do not have enough fossils from Erectus that can be clearly identified as Erectus, or that have the necessary conditions for the testing. Rebecca note: The organic bone collagen that is usually used for carbon isotope analysis is no longer present in the bones of these earlier hominids. Thus, the analysis must be done on tooth enamel, limiting the sample size. In some cases we have testing that the scientist have generally applied to early Homo, which could include Habilis, Rudolfensis, Erectus or even some Hominoid not clearly identified at this point; in some case, we have extremely limited analysis on several species that were clearly identified as Erectus. While we would expect to see that Erectus consumed more C4 foods, given that his environment and morphology supported these foods, we do not necessarily see that happening. For example we have one sample of sixteen specimens identified just as early Homo who, when averaged out, consumed 65 percent C3 and 35 percent C4. Another study of ten specimens identified as early Homo showed 45 percent C3 and 55 percent C4 with 20 percent towards C4 foods in later specimens, which would refer to Erectus. But then another

study of early Homo from the Turkana Basin in eastern Africa, from around 1.4 to 2 million years ago, showed ranges from 75 percent C3 to 25 percent C4, to 45 and 55 percent respectively. And yet another study of three Erectus specimens showed, surprisingly, that their diet was 75 percent c3 and 25 percent c4. Since this information is so incomplete and splotchy and hazy, most scientists, and myself as well, do not consider this evidence as necessarily conclusive in any way. In fact the evidence or some of it may be misleading, especially since it does not support the pattern.

Perhaps from this evidence we can perhaps surmise that Erectus ranged somewhere between 75 percent to 25 percent of their food from C3 sources--which includes, if we remember, food from the trees, such as fruits, nuts and animals that feed off the trees; it can also include foods from shrubs and bushes which, however, is more or less limited to berries. But its hard to imagine that Erectus acquired larger amounts of his diet from foods that are so small, so seasonal and comparatively low in sugars and almost devoid of protein and fats. We can also explore the possibility that Erectus was hunting animals that feed on trees or bushes but for the most part, that tends to include birds, rodents and other primates--animals which would later prove impossible even for Homo Sapiens to hunt even with their superior weapons and intelligence, so its hard to imagine that Erectus could hunt them. In other words, it seems reasonable to conclude that his C3 foods came directly from parts of the trees--either fruits, nuts or even possibly some leaves.

But that conclusion, too, is problematic because Erectus had lost much of his mobility through the trees, making him grossly inefficient at gathering food there--and therefore easily outcompeted by other animals and even other primates or Hominoids. As we have seen evolution does not make animals less, but more adapted, at gathering foods from their environment. Furthermore the trees, at least at certain times during the Glacial movements, were becoming more and more scarce and while we might think that Erectus inhabited, like early Homo, pockets of trees, it appears that he spread all the way through Africa, Asia and even parts of Europe and the evidence seems to suggests that they did not focus on just forests but rather more open terrain. Anyway, for now, we just need to acknowledge that our inkling of data about Erectus, in this particular case, seems somewhat contradictory--but in later sections, I will attempt to reconcile this information.

Sources: mostly from co-author, and mostly the same sources used for Habis and Rudolfensis Sponheimer from email: we do not have sufficient taxonomic control to say much. You can look at the recent papers in PNAS by Cerling and Sponheimer that speak of this a bit too. but no, we can't say with great confidence what the carbon isotope compositions for various taxa were. most data suggest that Homo did have a source of C4 derived carbon generally.

Co-author Research: cannot make distinctions between homo species because some of the fossils could not be identified as one taxa or another: also limited fossils, and even more limited in quality.

But results for 16 early Homo: 65 c3 and 35 c4

another study showed: ten homo species: 45 and 55 with 20 percent increase towards c4 in later specimens

--another between 2.0 and 1.4 million years ago: 25/75 to 45/55 for Homo in the Turkana basin and Paranthropus 20 to 80

--early Homo diet was 25 percent c4 and 75 percent c3

HOARDING

These foods, seeds, including tree nuts and tubers, provide other advantages; they are foods that are not all that perishable and can, therefore, be stored for an extended period of time, especially if they are kept dry. Of course, we do not know if early Homo possessed the intelligence for this sort of planning--but there are many animals that use this sort of behavior, called either hoarding or caching. We have all seen the squirrel burying nuts in secret locations for consumption later down the line--and this and similar behaviors are practiced by many other rodents and birds. In some cases they are caching food to eat within one week, much of the time just to allow the food to ripen; in other cases they are caching food that preserves well, like seeds, for eating later when those foods are not available later. On the carnivorous side, crocodiles have teeth that are particularly good at killing their prey; however, those teeth can not butcher their prey, so they hoard that prey in dens under the water until the flesh becomes more tender, if not just rotten, and then eats later down the line. To my knowledge primates do not hoard--which seems odds given their intelligence and the great advantages of this strategy--but obviously, as we get further into our own evolution, we become the master of hoarding--and obviously everything we eat these days, with the exception of what you pull from your garden, is hoarded. Naturally, the question is when did this strategy begin (NOTE: can hoard when foods become more hoardable: also the much greater Energetics).

ANIMAL FOODS

"Equally, the trunk proportions in Homo ergaster suggest a relatively small gut that is compatible with a higher quality and more easily digested diet (Aiello & Wheeler 1995). The more open xeric habitat occupied by Homo ergaster would also offer different dietary opportunities. It is probable that meat comprised a greater proportion of the Homo ergaster diet than it did for the earlier and contemporaneous australopithecines and paranthropus (Aiello & Wheeler 1995). However, it is unlikely that meat by itself would have met the increased energy requirements of Homo ergaster. It is clear from analyses of modern people that humans are incapable of metabolizing sufficient protein to meet more than 50% of their energy needs (Speth & Spielmann 1983, Speth 1989). Those modern people who rely more heavily on animal-based resources also rely heavily on fat for the remainder of their energy requirements. For a number of reasons such a diet would have been unlikely for Homo ergaster. The specific dynamic action, the rise in metabolism or heat production resulting from ingestion of food, is very high for protein. If modern people such as the Eskimos for whom 90% of caloric needs are met by meat and fat are anything to go by, such a diet would elevate RMR by 13%-33%, with significant implications for thermoregulation in a hot open country environment. This also means that they would have had to eat correspondingly more meat to satisfy their basic energy requirements. A high meat diet also demands increased water intake, and this is an unlikely strategy to adopt in a hot open environment." (Aiello, Leslie C. & Wells, Jonathan C.K. p. 326-327).

"Homo ergaster would undoubtedly have made use of a variety of other food resources such as invertebrates (e.g., termites) or nuts, seeds, honey, etc. However, increased reliance on mammalian meat and fat would have altered the basic balance between dietary quality and dietary bulk and would be consistent with the assumptions of the expensive tissue hypothesis (ETH) (Aiello & Wheeler 1995) and also the work of Barton (1992), which suggests that for our body sizes, humans eat less bulk than nonhuman primates. The diet of Homo ergaster was therefore not an australopithecine diet with added meat, but involved a change in the proportions and type of both animal and vegetable foods (Leonard & Robertson 1992, 1994)." (Aiello, Leslie C. & Wells, Jonathan C.K. p. 327).

"Archaeological data on early hominin exploitation of large bodied prey are reported from 19 sites in the East African Rift (Table 1). Sixteen are in terminal Pliocene and early Pleistocene deposits— eight at Olduvai, seven at Koobi Fora, and one at Peninj. The remaining three (Kanjera South, Bouri, and Hadar/AL 666) are older... Taxa most commonly represented are mid-sized [so-called "class 3" (Brain, 1974; Bunn, 1997)] ungulates, mainly bovids, with adult body weights in the 100– 300 kg range. Equids, suids, giraffids, hippopotamidae and proboscideans are also frequently present. Most of these animals were prime-age adults at the time they died (Potts, 1988; Bunn, 1997)." (O'Connell et al. 2002).

"LP [Lower Paleolithic] diet was based mainly on the consumption of large (e.g., elephant, rhinoceros, hippopotamus) and medium (e.g., horse, cattle, deer) animals (e.g., Kretzoi and Dobosi, 1990; Anzidei, 2001; Biddittu and Celletti, 2001; Mania and Mania, 2003; Suwa et al., 2003; Anzidei et al., 2012; Rabinovich et al., 2012; Sacca, 2012a)... The archaeological record reveals that LP Acheulian early humans exploited elephants by hunting and/or by collecting carcasses apparently for meat and fat consumption, and possibly for extracting bone marrow. This pattern of behavior and adaptation was practiced over three continents of the Old World for hundreds of thousands of years (e.g., Leakey, 1971; Goren-Inbar et al., 1994; Mania and Mania, 2003; Ben-Dor et al., 2011; Anzidei et al., 2012; Rabinovich et al., 2012; Sacc a, 2012a,b)." (Zutovski & Barkai 2016).

"Several Lower Paleolithic Acheulian sites clearly demonstrate butchering and processing of elephants for dietary purposes (Goren-Inbar et al., 1994; Wenban-Smith et al., 2006; Yravedra et al., 2010; Rabinovich et al., 2012; Sacc a, 2012a). Acheulian hominins experienced long term parallel existence with elephants and were, in our opinion, dependent on this important dietary source for hundreds of thousands of years (Kaplan et al., 2000, 2007; Ben-Dor et al., 2011; Domínguez-Rodrigo et al., 2012; Barkai and Gopher, 2013)." (Zutovski & Barkai 2016).

HUNTING AND SCAVENGING

--hard evidence that hunted beyond Chimps: bones from larger animals: bones from smaller animals more likely to disappear

sources: butchered bones as evidence of hunting

--issues: hunting or scavenging: maybe both, consider, too, that lions will scavenge and hunt only if necessary...

“Sometime about 1.35 Ma, a group of *Homo erectus* butchered a number of large mammals at a site at Olduvai Gorge, including an elephant, a hippopotamus, a rhinoceros, a *Sivatherium* (related to modern giraffe), and two *Pelorovis* (related to Cape Buffalo). There is no evidence that the hominins killed the animals, and scavenging was the likely means by which they accessed the carcasses. Remains at the site (BK) also include bones from small and medium sized mammals, which may have been hunted. Percussion and cut marks on the bones confirm extensive butchery of all of the remains. Clearly, meat had come to be an important part of the *Homo erectus* diet (Dominguez-Rodrigo et al., 2014).” (DeLouize, Coolidge, & Wynn 2016).

The evidence (below) does not indicate whether *Erectus* was a hunter or scavenger, but whether *Erectus* was hunting or scavenging, it appears that *Erectus* had early or primary access to carcass foods that would have helped supply the extra nutrition needed to support *Erectus* larger body and brain....

“Since the first systematic descriptions of stone tool cut marks on larger mammal bones from early archaeological assemblages (Bunn, 1981; Potts and Shipman, 1981), much of the literature concerning Early Pleistocene zooarchaeology has focused on the order in which hominins and carnivores accessed carcasses at the Bed I, FLK 22, *Zinjanthropus* level, Olduvai Gorge (Binford, 1981, 1986, 1988; Bunn and Kroll, 1988; Blumenschine, 1988, 1995; Bunn and Ezzo, 1993; Oliver, 1994; Selvaggio, 1994, 1998; Capaldo, 1995, 1997, 1998; Domínguez-Rodrigo, 1997; Domínguez-Rodrigo and Barba, 2006). Interpretations of the site have been contradictory, with some researchers suggesting hominins had primary access to carcasses at the site based upon the location of cut marks on limb bones in the assemblage (Bunn and Kroll, 1988; Bunn and Ezzo, 1993; Domínguez-Rodrigo, 1997) and others asserting that hominins were scavengers of flesh scraps and bone marrow abandoned by felids based upon the frequency of tooth and percussion marks (Blumenschine, 1988, 1995; Selvaggio, 1994, 1998; Capaldo, 1995, 1997, 1998). Most recently, Pante et al. (2012) argued that these contradictions arose due to inconsistent methods among researchers, and suggested the examination of all types of marks simultaneously as a solution. Their analysis using statistically refined feeding trace models that include tooth, cut, and percussion marks suggests the FLK 22 hominins likely acquired larger mammal carcasses through scavenging, but may have typically had access to as much as 50% of the flesh and all bone marrow.” (Pante 2013).

“Researchers have also applied some of the methods originally developed for interpreting Oldowan hominin feeding behavior to fossil assemblages associated with African *Homo erectus* from Bed II, Olduvai Gorge (Monahan, 1996; Domínguez-Rodrigo et al., 2009), Member 3, Swartkrans (Pickering et al., 2004), and the Okote Member, Koobi Fora (Pobiner et al., 2008). In all cases, it is argued that the species likely had early or primary access to carcass foods. These results are not unexpected as *H. erectus* is distinguished from its predecessors by its larger brain and body size (Wood, 1992; Walker and Leakey, 1993; Kappelman, 1996), the metabolic costs of which may have required a corresponding increase in nutritional intake (Milton, 1987; Shipman and Walker, 1989; Speth, 1989; Ruff and Walker, 1993; Aiello and Wheeler, 1995).” (Pante 2013).

“The proportions of tooth-, cut-, and percussion-marked bones in the JK2 assemblage all suggest that both hominins and carnivores accessed flesh and marrow at the site. The low incidence of percussion marking relative to the HO and H—C models suggests hominins did not break all long bones in the assemblage. Tooth and cut mark frequencies independently suggest that both hominins and carnivores had access to flesh, but neither indicate hominins or carnivores as the dominant consumers of flesh. Finally, the presence of specimens that are both tooth- and butchery-marked demonstrates occasional hominin and carnivore feeding from the same carcass.

Together, the bone surface modification data suggest hominins had early access to flesh and marrow either through hunting or confrontational scavenging at the site, while carnivores also had access to flesh and marrow, either through scavenging of partially consumed carcasses abandoned by hominins or through sole access to some carcasses...

The results for the JK2 assemblage are consistent with the known feeding behavior of *H. erectus* based on fossil assemblages associated with the species from Olduvai Gorge, Tanzania (Monahan, 1996; Domínguez-Rodrigo et al., 2009), Swartkrans, South Africa (Pickering et al., 2004), and Koobi Fora, Kenya (Pobiner et al., 2008). The large brain and body size exhibited by the species would likely have required a higher intake of nutrients than was necessary for its smaller predecessors (Shipman and Walker, 1989; Aiello and Wheeler, 1995). This study suggests that *H. erectus* had early access to the carcasses it acquired, which could have provided the nutrients necessary for the species to manage its increasing metabolic costs.” (Pante 2013).

AUTHOR NOTE: If early Homo and Erectus did scavenge, they would have faced two main challenges:

- 1) Carcasses would have been relatively rare and quickly consumed by other scavengers who had long evolved to be incredibly efficient at locating and obtaining past kills.
- 2) Once early hominins arrived at the kill, they would have faced serious competition with other scavengers. Without particularly strength or power relative to other scavengers, and lacking sophisticated weapons, early hominins may have had trouble outcompeting other scavengers who also had arrived at the kill. Though, perhaps simple weapons such as stones and sharpened sticks would have been enough to drive away other scavengers.

One advantage early hominins (especially Erectus) may have had over other carnivores and scavengers was their ability to engage in endurance running. Although, if there was a race towards a recent kill, necessitating speed rather than endurance, the early hominin of course would not win.

“Regardless of the extent to which scavenging occurred, the most likely source of scavenged carcasses would have been lion kills, because lions, unlike hyenas, do not consume all their prey, but instead leave behind marrow, brains and sometimes flesh (Blumenschine, 1987, 1988)... hominins might have sought out scavenging opportunities strategically by searching for carcasses through long range cues, the most common of which is seeing vultures circling in the air from a distance.

Apart from whether hominins were scavenging opportunistically or strategically, to do so effectively they would have faced two considerable challenges, both of which are relevant to ER [endurance running]. First, carcasses are comparatively rare and ephemeral resources, largely because of hyenas, which are impressively efficient at finding kills. According to Cooper (1991), hyenas in Kruger Park typically arrive at lion kill sites within 30 min of a kill, even at night. Given that a large percentage of kills occur at night, it is probable that only a fraction of kills, notably those made during the day, were available for scavenging by diurnal hominins... The second serious challenge that hominins would have faced while scavenging is competition. To become scavengers (or hunters), they would have entered the carnivore guild, which means competing with other carnivores... Carnivores compete through a combination of strength, speed, stealth, and cooperation, and the risk of mortality associated with these interactions is quite high. Human hunters are no exception to this competition: a high percentage of scavenging opportunities observed among modern hunter-gatherers are classified as “competition” or “power” scavenging in which groups of foragers drive off lions or hyenas from a kill using weapons (O’Connell et al., 1988; Potts, 1988; Bunn and Ezzo, 1993). According to O’Connell and colleagues (1988), 85% of the total carcass weight that the Hadza scavenged was acquired by driving off or killing the initial predator (mostly lions). Since it is probable that early Homo, like modern humans, was neither strong nor powerful, but also lacked the sophisticated weapons available to modern foragers, it is debatable to what extent they would have been able engage in competition scavenging. It may strain credulity to imagine hominins successfully driving off a pack of lions or hyenas armed only with stones and sharpened sticks, but Hadza foragers seem to be able to do just that with relatively simple weapons. It must be remembered, however, that the Hadza’s armature includes projectile weapons, and the carnivores in question have undergone thousands (perhaps millions) of years of natural selection for avoiding encounters with groups of well-armed humans....

The combination of ephemerality and competition has led many researchers to suggest that scavenged meat was not a commonly available resource for early hominins (e.g., Bunn, 2001; Tappen, 2001; Dominguez-Rodrigo, 2002). However, it is possible that ER [endurance running] provided an additional means to improve access to this potentially very valuable resource. In particular, hominins during the day in open habitats would be able to identify scavenging opportunities by seeing vultures in the distance, often many kilometers away. If they just walked to the kill site, it is likely that little meat would be left to scavenge, and/or there would be considerable competition with hyenas. But, as demonstrated above, early Homo might have been able to run the few kilometers necessary to get to the kill before other scavengers. Since hyenas face the same thermoregulatory constraints as other non-human mammals for running long distances in extreme heat (they run primarily at night and during the dawn or dusk), hominins would have had a competitive advantage over hyenas for getting to diurnally available carcasses, particularly in the dry season. Whether and to what extent hominins did this is debatable, but modern ethnographic evidence provides some support for this potential strategy. As reported by O’Connell et al. (1988: 357), when Hadza believe they have a scavenging opportunity, they “abandon other activities and move quickly to the spot, often at a run [emphasis added].” In another example, a !Kung bushwoman, Nisa (Shostak, 1981: 93),

recounts an instance in which she used ER to secure quickly an opportunistically discovered carcass before it is lost to other scavengers...In short, ER [endurance running] might have opened a new niche for scavenging that was previously unavailable...Although the extent to which scavenging was an important behavior among early hominins is still debated, it is likely that scavenging played some component of early Homo subsistence strategies, just as it now does among the Hadza and Bushmen. Since carcasses are an evanescent resource in which early access improves the chance of getting something to eat and minimizing competition with other carnivores, then it would have benefited from ER capabilities." (Lieberman, Bramble, Raichlen & Shea 2009).

"Hominin capacities for capitalizing on scavenging opportunities depended on their abilities at interference competition. If these were limited, the chances of gaining significant amounts of edible tissue from scavenged carcasses would have been very low, whatever the potential encounter rate. Blumenschine (1986) shows that, unless they are interrupted, various East African carnivores, acting in sequence, either completely consume most of their large animal prey, or reduce the edible remains to small amounts of residual flesh and "within-bone nutrients", mainly marrow and brain cavity contents. Our experience in Hadza country is consistent with this observation (see also Bunn et al., 1988). For size class 3 and smaller animals (mean adult weights <200 kg), these remnant bits generally represent no more than about 5000 kcal, often much less (Blumenschine, 1991b; Blumenschine & Madrigal, 1993; Lupo, 1998). Substantial quantities of flesh are abandoned on only the largest, least often encountered prey (size classes 5–6; mean adult weights >900 kg) (Blumenschine, 1986). All but one of the scavenging opportunities identified by the Hadza during the study period were created by large predators: hyenas, leopards, and lions. [The exception, a sub-adult elephant, was speared by local pastoralists (O'Connell et al., 1988a).] In 18 of the other 19 cases, these initial predators were still present when Hadza arrived on the scene. In all 18 cases, Hadza drove them off immediately. Their ability to do so was largely a function of their use of heavy bows, capable of delivering a killing or seriously disabling blow to animals as large as lions at distances of up to 40 m (Bartram, 1997). Without similarly effective weapons, it is unlikely that Hadza would have done nearly so well per encounter, especially against lions, which were responsible for most of the kills they seized.

As with the Hadza, the great majority of scavenging opportunities potentially available to Plio-Pleistocene hominins were probably created by large carnivores, including lions, leopards, spotted hyenas, the now extinct hyenids, Chasmaporthetes and Pachycrocuta, and the several machairodont cats, Homotherium, Megantereon, and Dinofelis (Blumenschine, 1986; Marean, 1989; Lewis, 1997; van Valkenburgh, 2001). Their large body size and, in some cases, highly social behavior would have made these predators very dangerous adversaries in aggressive scavenging situations...This leaves us with stone-throwing or perhaps club-wielding as the only remaining options. While these may have been effective at driving off the initial predators in some cases, they are unlikely to have done so nearly as consistently as the bow and arrow do among the Hadza...But unless those hominins were at least as effective as the Hadza at interference competition, meat from large game cannot have been an important day-to-day food source for them except in unusual circumstances." (O'Connell et al. 2002).

Erectus may have scavenged more strategically by frequently visiting sites where predators commonly made kills. The Hadza will frequently visit certain sites near water (especially in the dry season) where both predators and large prey will be in order to both hunt and scavenge when the opportunity arises.:

“The second alternative is based in part on Binford’s (1984:262–264) “routed foraging” model. According to this scenario, hominins routinely visited a range of locations in search of food, among them sites where predators frequently made kills, and where scavenging opportunities might often have been available. Recurrent visits over long periods of time, including the periodic transport of edible remains to the nearest shade, led to the creation of some- times sizable accumulations of animal bones and the stone tools used in processing them...They [sites visited by Hadza] are located on and around perennial water points, usually in stream channels. They are visited in all seasons, but are monitored most closely in the late dry, a 3–4 month period when surface water is otherwise scarce, and large ungulates and their various predators are drawn to the relatively few remaining sources. Hadza build hunting blinds on elevated ground immediately overlooking these waters and along trails leading to them, and shoot large prey as they move within range. They also monitor prey and predator traffic around these sites, and are especially attentive to evidence of predator kills and related scavenging opportunities, commonly signaled by circling vultures and distinctive predator calls. On evidence of such an opportunity, all Hadza who notice it move quickly to the site, sometimes from different directions, often over distances of several kilometers, and on arrival attempt to drive off any predators still present and secure the prey. Roughly 20% of all large carcasses acquired by the Hadza during our fieldwork were taken in this way, most in relatively complete condition, many at perennial water points.” (O’Connell et al. 2002).

If Erectus did hunt, he may have practiced persistence hunting, a form of hunting that involves endurance running, essentially running down an animal to a point of exhaustion. Endurance running may also have been important in scavenging, allowing early hominins to reach a carcass before other scavengers.

“Another key, perhaps even more important role for endurance running in *H. erectus* and possibly earlier *Homo* may have been during hunting. As noted above, a wide array of evidence suggests that hominins were actively hunting, at least by the time that *H. erectus* appears circa 1.9 Ma (for reviews see Potts, 1988; Bunn, 2001; Dominguez-Rodrigo, 2002). The evidence for hunting includes a large proportion of bones with cut-marks indicative of flesh removal from regions of shafts that would not have had flesh had they been scavenged.” (Lieberman, Bramble, Raichlen, & Shea 2009).

“Endurance running may be a derived capability of the genus *Homo* and may have been instrumental in the evolution of the human body form. Two hypotheses have been presented to explain why early *Homo* would have needed to run long distances: scavenging and persistence hunting. Persistence hunting takes place during the hottest time of the day and involves chasing an animal until it is run to exhaustion. A critical factor is the fact that humans can keep their

bodies cool by sweating while running. Another critical factor is the ability to track down an animal. Endurance running may have had adaptive value not only in scavenging but also in persistence hunting. Before the domestication of dogs, persistence hunting may have been one of the most efficient forms of hunting and may therefore have been crucial in the evolution of humans.” (Liebenberg 2006).

“Competition to reach carcasses before other scavengers would have increased the fitness benefits of features that improve endurance running capabilities. Another hypothesis, presented by Carrier (1984), is that early hominin hunters used endurance running to run some mammals to exhaustion. Bramble and Lieberman suggest that such behavior might have been too energetically expensive and low-yield for the benefits to have outweighed the costs (for details see appendix A). Data from observations of !Xo and /Gwi hunters of the central Kalahari in Botswana presented here suggest that persistence hunting was a very efficient method under certain conditions.” (Liebenberg 2006).

If practiced, persistence hunting involving a high level of prolonged aerobic activity may have increased carbohydrate requirements.:

“It has been suggested that early Homo acquired the capacity for endurance running, considered essential to exhaust prey or outpace other scavengers in hunting, by 2 million years ago (Bramble and Lieberman 2004). Although the need for thermoregulation during sustained exercise has been explored (Wheeler 1991a,b; Liebenberg 2006; Ruxton and Wilkinson 2011), the energy source for prolonged high level aerobic activity is also an important consideration. Glucose is the only energy source for sustaining running speeds above 70% of maximal oxygen consumption (Romijn et al. 1993).” (Hardy et al. 2015).

Persistence Hunting in the Kalahari & by Native Americans, & Australian Aborigines: “Various forms of persistence hunting have been recorded in the Kalahari...Animals such as eland, kudu, gemsbok, hartebeest, duiker, steenbok, cheetah, caracal, and African wild cat were run down in the hotter part of the day and killed when exhausted (Steyn 1984). Duiker, steenbok, and gemsbok were run down in the rainy season and wildebeest and zebra during the hot dry season (Schapera 1930). It was believed that when a ruminant was prevented from chewing its cud during the chase it developed indigestion which eventually slowed it down, allowing the hunter to come close enough to kill it with spears (Heinz and Lee 1978).

Native American tribes also had various traditions of chasing down animals on foot (Nobokov 1981; Heinrich 2001). Tarahumara chased deer through the mountains of northern Mexico until the animals collapsed from exhaustion and then throttled them by hand (Bennett and Zingg 1935; Pennington 1963). Paiutes and Navajo in the American Southwest are reported to have used this technique to hunt pronghorn antelope (Lowie 1924; Foster 1830, cited by Lopez 1981, 111). Aborigines of northwestern Australia are known to have hunted kangaroo in this way (Sollas 1924; McCarthy 1957).” (Liebenberg 2006).

“Persistence hunting via endurance running has several key advantages. First, this method of hunting is low risk, and comparatively easy for any human capable of ER [endurance running] and who has the ability to track animals. Second, PH has a relatively high success

rate. Approximately 50% of the persistence hunts documented by Liebenberg in the Kalahari were successful, leading to an approximately 70% higher yield of meat per day than hunting using a bow and arrow (Liebenberg, 2006). Third, persistence hunting has a surprisingly low metabolic cost. Although PH has frequently been discounted as an unlikely strategy for hunting because the metabolic cost of human running is about 50% higher than an average quadrupedal mammals after adjusting for body mass, closer inspection of the evidence reveals that the actual cost of endurance is not that high, particularly compared to the potential pay-off... Assuming an average conversion rate of 4.8kcal/l O₂, then running 15km at any ER speed costs approximately 980 Kcal, whereas walking the same distance at an optimal speed costs 750 Kcal. Put in everyday terms, running 15km to kill a large antelope requires fewer calories than the 1,040 Kcal consumed from a Big Mac® and medium-sized french fries at McDonald's! Since a large antelope weighs more than 200 kg and contains several orders of magnitude more calories than McDonald's can manage to pack into one of its meals, one can easily appreciate that the pay-off is clearly worthwhile, even if the chances of success are only 50%... A final, possibly important advantage of PH is that it does not require any sophisticated technology other than the simplest weaponry such as a spear or club." (Lieberman, Bramble, Raichlen & Shea 2009).

"The sweat glands of humans are distinctive for the high secretory level at which they operate. No other species is known to sweat as much per unit surface area as humans (Eichna et al. 1950; Schmidt-Nielsen 1964; Newman 1970). The great increase in eccrine (as opposed to apocrine) sweat glands and their copious secretions have permitted modern humans to undertake vigorous exercise in hot environments. The rate at which heat is lost in running humans is greatly increased by their relative lack of hair and by convection during running. The combination of well-developed sweat glands and the relative absence of body hair makes it probable that running humans display very high thermal conductance, with maximal values well above those of most cursorial mammals (Carrier 1984)." (Liebenberg 2006).

HUNTING METHODS

Perhaps Erectus used a technique called "Persistence Hunting," which was used by our own kind later in time—a technique which is rather hard to believe: They run down their prey. Due to the similarities of our anatomy with Erectus, we can easily assume that this technique was, in fact, possible for them to practice. Even to this day, the San people of the Kalahari practice this form of hunting frequently during the late, dry season when the animal is less nourished, and also during the hottest part of the day as well. This allows the San to use their ability to dissipate heat to their advantage. As mentioned, Homo Sapiens, like Erectus, can dissipate heat better due to enhanced sweating, absence of fur; also bipedalism enhances cooling, too, by elevating the body above the ground where there is less heat and more wind; bipedalism, also, reduces the amount of skin and body actually exposed to the sun—thereby also reducing heat. After fully hydrating their bodies with water, the San would then begin to track and follow a herd of animals and, when one of the animals would swerve from the herd, the hunters would begin to track that animal alone. The ruminants in the Kalahari, such as the Kudu, are covered in fur, low to the ground and sweat and cool themselves less efficiently than themselves and, as such, while they are being pursued, they are always trying to avoid getting caught while at the same trying to

keep themselves cool by stopping in the shade of trees to cool themselves down. All the while the San stay in pursuit, using a combination of tracking and running, hoping all the while that they will not lose track of the animal. If they sometimes lose sight of the animal, they imagine themselves existing inside the mind of their quarry and, from there, try to imagine where the animal might have run. At one point, once most of the San are becoming too tired to pursue further, and the animal seems closer to its end, only one San will then pursue the Kudu. Generally the hunt will last anywhere from two to six hours. By the time the hunter reaches its prey, it is generally too tired to move and collapses on the ground; the hunter then merely stabs the animal to death. From respect for the animal, the hunter then performs a ritual to assure that the animal is returned into the spirit of the desert.

Under certain—but not all—conditions, persistence hunting, despite the huge amounts of energy spent in the hunt, is nonetheless efficient: large ruminants provide large amounts of calories—way more than the amount of calories expended by the hunters—thus providing meat and fat for many people for days into the future—and if the meat is dried or otherwise preserved, even months into the future.

Many accounts, from a variety of sources, testify to this type of hunting being used across the globe by hunter-gatherers; for example, the Tarahumara of Mexico used this form of hunting to track and kill deer in the mountains, and the Navajo of the American south-west for antelope. As for the Erectus, we can easily assume that he possessed the endurance and speed for this type of hunting and the weaponry as well. As for his ability to carry water with him on the hunt, we perhaps assume that he possessed the technology to use gourds for this purpose or satchels made from animal integuments, such as stomachs and hides. However, persistence hunting obviously requires extreme skills not only in tracking, but also in navigating large swaths of land without getting lost—and whether or not Erectus possessed that level of intellect is not known. (Louis Liebenberg 2006).

“The third key characteristic of PH [persistence hunting] is the need to track the animal. As noted by Liebenberg (1990, 2006), tracking is a considerable skill that requires the hunter to be able to distinguish tracks in the ground, but also to think like the animal...When the cognitive capacity necessary for tracking first evolved is impossible to document, but it seems reasonable to hypothesize that tracking abilities were present in H. erectus given its relatively larger brain not to mention its ability to make symmetrical tools that required some mental template (Wynn, 2002).” (Lieberman, Bramble, Raichlen & Shea 2009).

“...we recall our empirical observations that small bovids can be walked to exhaustion—not requiring ER—by modern, highly skilled Kua hunters at a significant physical cost to them, in the sparsely vegetated, soft sandy substrate of the Kalahari that is the ideal context for using sophisticated tracking skills. In the more heavily vegetated savanna–bush–woodlands that characterize the East African Rift Valley today, and paleoenvironmental reconstructions of the habitats in which early Homo evolved in the Pleistocene, even greater tracking skills beyond those possessed by modern foragers would be required to succeed at ER hunting. Despite long-term ethnographic research, the Hadza have not been observed either attempting, much less succeeding at ER hunting in the more vegetated East African Rift Valley. This demonstrates

a likely cause–effect relationship between vegetation cover and viability of tracking, and it casts doubt on the likelihood of highly sophisticated, successful tracking by early Homo.

This, of course, does not mean that ER-PH never happened in the Pleistocene... Rudimentary tracking skills would not enable successful, much less, efficient ER, in the vegetated East African Rift Valley paleoenvironments in which early Homo evolved. And it is not reasonable to assume sophisticated tracking skills in early Homo, while at the same time discounting any intellectual ability to ambush prey.” (Bunn & Pickering 2010).

Of course, other hunting techniques may have been used as well by the Erectus, which were used by primitive Homo Sapien, such inglorious methods, which we will explore later, such as chasing animals off cliffs or into lakes or into traps of some sort.

Rebecca: Yes, recall Neanderthals practiced this form of hunting.

Erectus may have also been an ambush hunter...

A hypothesis that early Homo engaged in ambush hunting was formed based upon the analysis of prey mortality profiles—i.e. their age. The prey mortality profile is thought to reflect the means by which the prey were acquired, and may be used as a tool to differentiate between an assemblage of bones that was scavenged versus one that is hunted. If the prey was obtained by scavenging animals that died from natural (non-predatory) causes, the profile would consist of old adults and young juveniles. If the prey was scavenged from the kill of a wild cat (leopard or lion), then it would mostly resemble what these cats typically kill—old adults. If the prey had been hunted by way of persistence hunting, the profile would primarily consist of animals that could most easily be run to exhaustion—the weakest and most vulnerable young juveniles and old adults. Ambush hunting, on the other hand, would be reflected either by a profile that represented that of the living animal due to a lack of selectivity, or by one that was mostly the most nutritionally attractive prey—prime adults.

The prime dominated prey mortality profile for large bovids at one Oldowan site matches most closely with that which would be expected if the prey had been acquired by ambush hunting. Ambush hunting by early Homo would have required these early hominins to have some sort of weapon and to be able to get close enough to inflict a wound. Chimpanzees are intelligent enough to construct a stabbing weapon from a sharpened branch in order to kill small prey. Wood tipped spears may have been sufficient for short distance throwing. Hiding behind a bush or up on a low hanging branch may have enabled early Homo to get close enough to throw a spear. It is unlikely that the small size of the earliest Homo — habilis— would have been sufficient to engage in such hunting, nor does it seem plausible that they would have attempted to kill a large bovid. However, the larger and stronger Homo erectus seems like a more likely candidate as an ambush hunter.

“...at very ancient archaeological contexts, such as Early Pleistocene Oldowan sites, the meat-foraging capability of early Homo is contentious. This enduring ‘hunting and scavenging’ debate can be resolved with the evidence of prey mortality profiles...In this paper, we focus on the apparent prime-dominated mortality profile for large bovids at FLK Zinj, which we seek to evaluate further through comparisons with other actualistic and archaeological data. For

decades, the larger bovids from FLK Zinj have been the principal evidence used in the hunting and scavenging debate. We argue that the main reason the debate has endured is that the two conventional classes of taphonomic data employed — skeletal element profiles and bone surface modifications—are insufficient to differentiate convincingly among different methods of acquiring carcasses in the first place. We identify four broad methods of carcass acquisition that Early Pleistocene Homo could have practiced: (1) first-access scavenging from animals dead from causes other than predation; (2) passive scavenging from defleshed and abandoned felid kills; (3) aggressive, confrontational or power scavenging from intact or nearly intact felid kills; (4) hunting by, for example, ambush or endurance running methods... This is where mortality profile analysis has the exciting potential to achieve a breakthrough and bring the longstanding hunting and scavenging debate to closure. Prey mortality profiles can distinguish among the four broad methods of carcass acquisition outlined above, because the methods are linked to a range of testable mortality predictions, as follows. (1) First-access scavenging from animals that died from causes other than predation, such as accidents in which relative strength or health might confer survival advantage to some individuals, should yield some individuals of all ages with an abundance beyond natural population proportions of the weakest or most vulnerable young juveniles and old adults. (2) Passive scavenging from abandoned field kills and (3) aggressive scavenging from field kills should match what fields are known to kill... the mortality profiles of large bovids scavenged from lions should plot near the upper (old age) end of the living-structure zone on a triangular graph because of an elevated number of old adult prey. Mortality profiles from (4) hunting by early Homo are more challenging to predict. Persistence hunting by endurance running, for example, should, like other forms of cursorial predation, yield abundance of the weakest, most vulnerable young juveniles and old adults. Ambush hunting, if selective and efficient, should yield an abundance of the nutritionally most attractive prime adults; non-selective ambush hunting should yield a living-structure mortality profile... From comparative analysis of these varied mortality profiles, we see the emergence of a strong pattern and a straightforward explanation for FLK Zinj and the meat-foraging capabilities of Early Pleistocene Homo: effective ambush hunting. We have documented what the mortality profiles from modern bow hunting look like from an ecological setting closely analogous to that reconstructed for Early Pleistocene Olduvai (Lake Eyasi; Ashley et al., 2010a, b; Barboni et al., 2010) and from a contrastive ecological setting of drier and open grassland (Kalahari). In both cases, the prey mortality profiles are the same, and FLK Zinj resembles them quite well statistically. We have documented the mortality profiles from probable spear hunting at several Late Pleistocene archaeological sites. They, too, are living-structure profiles, and FLK Zinj resembles them as well.

Notably, FLK Zinj is a statistically significant mismatch to other likely sources for the large bovids, including first-access scavenging from mass drownings, scavenging from lion kills, and persistence hunting.” (Bunn & Gurtov 2014).

“The prime-dominated profile at FLK Zinj is significantly different from profiles formed by the three scavenging methods, which likely indicates hunting by Early Pleistocene Homo.” (Bunn & Gurtov 2014).

“Achieving hunting success with large bovids likely necessitated a larger and stronger species of early Homo than the one OH 62 [i.e. Homo habilis] represents because it required that two conditions be satisfied: (1) getting close enough to inflict a mortal wound, and (2) having the technology to do so. Ambush hunting from bushes on the ground or, perhaps better, from the low branches of trees along active game trails, would alleviate the distance issue. Large ungulates expect attack from terrestrial predators, and their vigilance is consequently directed horizontally, not upward where a motionless hominin hunter would be difficult to detect even at short distances of five to ten meters or less. We suggest that wood-tipped spears would have provided the lethal weapon for short-distance throwing. No wooden spears of Early Pleistocene age have been discovered and preservational biases make this unlikely, but there are some intriguing clues of an Early Pleistocene wood technology, including microwear evidence of sawing or scraping wood from ~1.5 Ma at Koobi Fora (Keeley and Toth, 1981), and wood phytolith evidence on stone tools of about the same age from Peninj (Domínguez-Rodrigo et al., 2001). Experimental work with wooden spears indicates that impacts can produce distinctive bone damage (Smith, 2003), and more experimental research is warranted.” (Bunn & Gurtov 2014).

“If a chimpanzee level of cognitive ability can yield a sharpened branch stabbing weapon for killing small mammal prey (Pruetz and Bertolani, 2007), then how capable would more encephalized early Homo have been at fashioning wooden weapons and tools?” (Bunn & Pickering 2010).

“In addition to *H. habilis*, there are larger, alternative species of early Homo known from Bed I at Olduvai and from the East African Rift Valley several hundred miles to the north during the time span when Bed I formed. At Olduvai, OH 65, which has been compared to *Homo rudolfensis* from the Turkana Basin (Blumenschine et al., 2003), establishes that a large-bodied species of Homo and a more likely producer of the Oldowan and FLK Zinj, was present when Bed I formed. Moreover, remains of early *H. erectus* have been identified from the Turkana Basin by ~1.9 Ma (Wood and Collard, 1999). Although *H. erectus* fossils have not been found in the rather sparse hominin fossil sample known from Bed I, we think it is likely that its early distribution was more widespread than the Turkana Basin, and that it likely existed elsewhere along the Rift Valley. Thus, our working hypothesis is that *H. erectus* could also have been present in the Olduvai Basin as a plausible Oldowan toolmaker and hunter. Perhaps they only foraged seasonally at Olduvai, where they were attracted to the oasis-like freshwater spring area near FLK (Ashley et al., 2010b), left an Oldowan archaeological record, and departed. If either of these hominins standing around ~1.6–1.8 m tall were responsible for FLK Zinj, that changes the game significantly. Adjust the image of who produced the FLK Zinj site to include a robust, large-bodied Homo, and our reconstruction of ambush hunting and killing large bovids with wooden spears may not be so provocative after all.” (Bunn & Gurtov 2014).

But we can also make some guesses about whether *Erectus* hunted, and particularly large game, by analogy with other animals which, in the past, like hominids, made the transition from herbivores to carnivores in the process of Evolution. Not many of these cases exist—or at least ones for which we have sufficient data to draw conclusions. But it seems that, in the process of

making that conversion, animals generally follow similar patterns. For example, the animal will become more sociable, which is likely the case with Erectus: as we know his brain increased in size which, as we have already learned, is an indicator that he was becoming more sociable. Secondly, animals naturally develop different apparatus for processing foods which, in most cases, mean they develop carnivorous teeth, such as large canines. In the case with Erectus, this apparatus would be stone-tools, which increased his ability to kill animals and process their flesh for food. Thirdly, animals increase their speed—which is obvious with Erectus and, along with that, their geographic range and we can assume this was the case with Erectus, perhaps due to the simple fact that fossils of their bones are spread beyond Africa, into Asia and Europe, suggesting that they were capable of covering large swaths of land. Fourthly, in the transition from herbivore to carnivore, animals generally have more free-time; for example, in general studies across the animal kingdom, it has been noted that herbivores spend much more time feeding than carnivores; for animals that are about the same size as humans, the herbivores will spend six hours in feeding to every two from a carnivore, due likely to the fact that meat is more dense in calories and nutrients than plants. Of course, we cannot measure the amount of free-time in Erectus; however, in the evolution from Australopithecus to human, we can easily assume that hominids increased their amount of free-time and likely that was the case with Erectus—and evidence, explored later in this section, will confirm that possibility.

And, finally, animals tend to have changes in their digestive system in the transition; their colons shrink in size due to the fact they need not process as many fibers from plants while their small-intestines expand in size because that is where most, if not all, absorption of fats and proteins takes place. Of course, we cannot measure the size of Erectus's gut; however, we can surmise that, due to his narrower, more lithe frame and the shape of his hips, that his skeletal structure could not support the gut, say, of a gorilla. Furthermore, we can make assumptions by analogy: If we assume that australopithecus had a gut about the size of a chimp—a safe assumption considering their similarities in diet and skeletal structure—we can say safely that the trend in the evolution of hominids, regarding their gut, is moving consistently towards smaller colons and larger small-intestines, as witnessed by the fact that, as soon as we arrive at Homo Sapiens, that is exactly the case. So the argument by analogy suggests that Erectus was likely not only scavenging, but also hunting, animals. (source: Shipman & Walker 1989).

Luke Notes from article by Shipman & Walker 1989 (covered in writing above):

Transition from herbivore to carnivore:

more sociability, change in food-processing apparatus (stone tools) , increased free time, increase in geographic range, increase in gestation relative to the brain.

in transition from herbivore to carnivore, must become faster and more sociable—both likely happened with erectus. Also carnivores spend much less time feeding, for human size 6 hours in plants, 2 hours eating animals. about average for all species.

other animals teeth, humans stone

claims that in transition, would increase small intestine, decrease large intestine. But claims evidence is not available—true—but can make assumptions.

Expansion in geographic range—enormous with erectus.

The items are: evidence of sociality among early hominids; changes in food-processing apparatus (i.e., stone tool industry); possible evidence for increased free time (novel technological developments, the elaboration of language); increase in geographic range; increase in gestation length relative to brain size.

SEAFOOD

“Knowledge about dietary niche is key to understanding hominin evolution, since diet influences body proportions, brain size, cognition, and habitat preference. In this study we provide ecological context for the current debate on modernity (or not) of aquatic resource exploitation by hominins. We use the *Homo erectus* site of Trinil as a case study to investigate how research questions on possible dietary relevance of aquatic environments can be addressed. Faunal and geochemical analysis of aquatic fossils from Trinil Hauptknochenschicht (HK) fauna demonstrate that Trinil at ~1.5 Ma contained near-coastal rivers, lakes, swamp forests, lagoons, and marshes with minor marine influence, laterally grading into grasslands. Trinil HK environments yielded at least eleven edible mollusc species and four edible fish species that could be procured with no or minimal technology. We demonstrate that, from an ecological point of view, the default assumption should be that omnivorous hominins in coastal habitats with catchable aquatic fauna could have consumed aquatic resources. The hypothesis of aquatic exploitation can be tested with taphonomic analysis of aquatic fossils associated with hominin fossils. We show that midden-like characteristics of large bivalve shell assemblages containing *Pseudodon* and *Elongaria* from Trinil HK indicate deliberate collection by a selective agent, possibly hominin.” (Joordens, Wesselingh, de Vos, Vonhof, & Kroon 2009).

Mussel shells containing small perforations a few millimeters wide were found in Trinil (Java, Indonesia), dating to a time in which only *Homo erectus* is known to have inhabited the island, suggesting that *erectus* collected and processed freshwater shellfish from along the banks of a river running through Java. The holes could have been made with a sharp object of some sort such as a shark’s tooth (also found in the assemblage at Java), and may have been used like an oyster knife to pierce the adductor muscle causing the animal to lose muscular control and the shell to open. Holes resembling those at Trinil were made by pre-Hispanic modern humans living in the Caribbean with the intent on detaching the adductor muscle. The holes do not resemble damage that may have been done by any other consumers of mollusks known to inhabit Java. Clearly, for *Erectus* to have processed mollusks in this way, a high level of manual dexterity and knowledge of mollusk anatomy would have been required.

“Most (79%) of the holes observed in the *Pseudodon* specimens correspond to the location of the anterior adductor muscle scar inside the shell; their diameter is about 5–10 mm. Potential mollusc-consuming agents at Trinil that could have produced the holes include otters (*Lutrogale* sp.), rats (*Rattus trinilensis*), monkeys (*Macaca* sp.), and hominins (*H. erectus*). However, the holes in the Trinil shells do not resemble the various types of damages caused by any of these non-hominin agents, nor those caused by birds, marine predatory snails, mantis shrimps, octopuses, and abiotic abrasion and dissolution processes (Extended Data Fig. 3a–f). Holes comparable to those of Trinil were made by pre-Hispanic modern human inhabitants of the Caribbean region in the gastropod *Lobatus gigas* (formerly known as *Strombus gigas*) (Extended Data Fig. 3g–i), with the purpose of detaching the adductor ligament.” (Joordens et al. 2015).

“To assess possible perforation techniques we conducted experiments with living freshwater mussels of the same family, comparable in size and shell thickness to the extinct Trinil *Pseudodon* (Extended Data Fig. 3j–m). A pointed object such as a shark tooth—several of which were present in the Trinil Hauptknochenschicht—(Extended Data Fig. 3n–s), employed with a rotating motion into the living shell at the location of the anterior adductor muscle, produces a hole similar in size and morphology to the holes from Trinil (Fig. 1d). As soon as the shell is pierced and the muscle has been damaged by the tool tip, the animal loses control of the muscle, the valve part and the shell can be opened without breakage (Supplementary Video 1). Our experiments indicate that a high level of dexterity and knowledge of mollusc anatomy is required to open shells in this way. The absence of holes similar to those at Trinil in natural shell assemblages, the difference between the holes observed in the Trinil assemblage and those produced by non-human animals and abiotic factors, and the similarity between our experimental holes, human-made *Lobatus* holes and Trinil holes all suggest that *H. erectus* was the responsible agent. We conclude that the Trinil *Pseudodon* assemblage reflects the remains of shellfish collected and processed by *H. erectus* along the banks of a river.” (Joordens et al. 2015).

The heavy bones of *Erectus* are similar to creatures that wade and/or dive for hard-shelled invertebrates in shallow water. Their bones may have provided buoyancy control.:

“Fossil skeletons of *Homo erectus* and related specimens typically had heavy cranial and postcranial bones, and it has been hypothesized that these represent adaptations, or are responses, to various physical activities such as endurance running, heavy exertion, and/or aggressive behavior. According to the comparative biological data, however, skeletons that show a combination of disproportionately large diameters, extremely compact bone cortex, and very narrow medullary canals are associated with aquatic or semi-aquatic tetrapods that wade, and/or dive for sessile foods such as hard-shelled invertebrates in shallow waters. These so-called pachyosteosclerotic bones are less supple and more brittle than non-pachyosteosclerotic bones, and marine biologists agree that they function as hydrostatic ballast for buoyancy control. This paper discusses the possibility that heavy skeletons in archaic *Homo* might be associated with part-time collection of sessile foods in shallow waters...heavy skeletons are typical of slow, shallow-water dwelling mammals such as seacows (especially the skull and ventral parts of ribs), walruses (especially the skull) and hippopotamuses (especially the limbs), and even of faster species such as sea otters (especially the limbs) that collect sessile foods at the sea bottom (Thewissen et al., 2007).” (Verhaegen & Munro 2011).

“...it is not clear which activities in *H. erectus* could have led to thick as well as dense bones and medullary stenosis, not only in the arm and leg bones, but also in the skull...most *H. erectus* were about twice as heavily built as chimpanzees, and even more heavily built than Neanderthals.” (Verhaegen & Munro 2011).

“*Homo* fossils are typically found in the presence of permanent bodies of water, including rivers, lakes and coastal deltas, and, at many of these sites, edible slow-moving or sessile foods including invertebrates were present...Coastal populations could have originally inhabited forests that comprised mangrove elements, from which they may have plucked not only fruit from trees, as all apes do, but also oysters from the roots and trunks of mangrove trees. If human ancestors learned to exploit molluscs attached to trees, as capuchin monkeys (*Cebus*

apella apella) do in mangrove forests using tools (Fernandes, 1991), it is only a small evolutionary shift to gathering molluscs also from under the water, though, to do this efficiently, significant changes in the anatomy would be expected.” (Verhaegen & Munro 2011).

“Although we think it unlikely that human ancestors ever relied exclusively on seafood since this could have induced hypovitaminosis C, it is possible that human ancestors were once partly or strongly reliant on seafood, supplemented with terrestrial fruits, plants and animals.” (Verhaegen & Munro 2011).

Luke Note: Also consider other theories: Australopithecus--upright walking was an adaptation to marine environments

SUMMARY

When using all this information to reconstruct the lifestyle and foodways of early Homo, we can see that at night they probably gathered collectively in the trees, just like Chimpanzees, but then during the day, broke into smaller groups to look for foods that were rich in the three macronutrients and lower in fiber--foods that, in other words, that were refined, perhaps even more refined than the Chimpanzees diet. Given limited carbon analysis, we can assume that at least at certain times of the year, they feed in the trees which typically create three kinds of more refined foods, fruits, leaves/shoots and nuts. But given the changes in the climate, we can perhaps assume that fruit and tender leaves were not as abundant, so we have to wonder if early Homo consumed lots of nuts--which makes sense for several reasons: since early Homo could use stone tools and greater manual dexterity, they could more reliably crack nuts and extract their flesh; furthermore since other animals could not access this food, early Homo would have limited competition for this food, in an environment where competition was escalating. And furthermore, nuts are one of the most nutritious and refined foods on earth, for several reasons: they typically possess large amounts of two of the most vital fats, the monounsaturate, oleic, which is especially healthy for primates, including humans and the absolutely essential fatty acid, the polyunsaturate, Omega 6, linoleic acid. Furthermore, nuts provide an abundance of proteins which are not too far away from providing most the amino acids that primates need. And like grains, they have one of the best compliment of macrominerals of any food on earth for primates.

At the same time, too, we have to acknowledge the limitations of nuts, as well: they are not complete foods and therefore, even on a daily basis, would need to be counterbalanced with foods that provide the other nutrients that primates need for health. They would need other sources of: amino acids, omega 3, and glucose.

However, early Homo would not just stay in the trees; at certain times, they would feed on the ground, likely focusing on the usual foods rich in starches, tubers, seeds, and corms, as well as some occasional berries and greens and possibly other vegetables. While they were on the ground, they would be about equally as subject to predation as Australopithecus and, as such, may have stayed together in larger groups and, at the same time, used stone tools and perhaps primitive spears to keep the predators away. As we have noted, it seems unlikely that early Homo were effective hunters, despite their use of tools, given that their morphologies were not well-suited for throwing or running down prey and they probably did not yet possess enough

strategic intelligence to hunt animals (whole nother realm here, even though Chimpanzees do.) However, like the extant Great Apes, it's most likely that early Homo was still dependent upon animal foods and needed at least small amounts of them, accounting for around ten percent or so of their overall calories. They likely hunted the usual termites and other bugs, perhaps other primates. But otherwise they were opportunistic feeders of brains and marrow from small and large animals, especially given that they possessed the tools to access those foods.

We also should consider the possibility that early Homo relied upon another animal food--that is, shellfish. As our line of evolution inhabited drier terrains, and as their foods, like fruits, nuts, grains and roots, possessed less water, early Homo and even Australapithicus before him would need to locate next to some source of water to survive, to essentially keep themselves hydrated. As we have already seen, many of the environmental reconstructions of the diets of early Hominids, including the one we have for the time of early Homo, can typically include riparian or otherwise wet environments, like swamps, lakes and others. However, most aquatic sources of foods would not be available to early Homo: anything that swims would be uncatchable and would only be eaten opportunistically. While some researches have suggested that Hominoids ate the sedges around lakes as staple foods, I find it hard to imagine creatures, quite similar in construction to Chimpanzees, wandering through water full of crocodiles, hippos and snakes, trying to pull the roots of sedges from the bottom of the lake. It is, however, conceivable that Hominoids gathered some forms of seaweed or algae--all foods eaten by contemporary man. However, shellfish of various sorts were likely gathered by early man, perhaps starting as soon as Australapithicus, based on this reasoning. Shellfish are like nuts in the sense that their protection from predation is hard, outer shells impenetrable to nearly all other animals; but early Homo with his use of tools could have easily smashed these shells with rocks or other tools, therefore making them available to themselves mostly free of competition. These shellfish, too, since they tend to stick onto various things and not swim about, were probably somewhat reliably available, unlike other foods. And perhaps most of all, shellfish provide an abundance of nutrition: complete proteins that are even better than most forms of meat, as well as easy to chew and digest. And perhaps most importantly, next to brains themselves, they are probably the best forms of nutrition for the building-blocks of the brain: containing both high amounts of the long-chain Omega 3 used in our brains, as well as inordinately high amounts of cholesterol--which is incredibly dense in our brains. Furthermore, omega 3 increasingly rare, when not eating greens, omega 6 much higher in this environment (in nuts, grains, roots) so provided a source to allow for the energetics for the brain.....

NOTE: shellfish is one of the most ubiquitous foods of mankind: the easiest meal around.....

PROCESSING & INGESTION

TOOLS

--Oldowan

Erectus likely used all the tools of his predecessors. And while we have surmised that Australopithecus and early Homo used Oldowan technology, we are clear that Erectus used this technology--which is just chipping sharp flakes away from cores to be used in all the ways that we have already explored.

--Acheulean

However, Erectus in Africa also advanced their technology to another level called Acheulean, starting later in their existence about 1.7 millions years ago. Rebecca Note: WIKI "Homo erectus"—"Homo erectus' earliest fossil evidence dates to 1.9 million years ago and the most recent to 70,000 years ago."...so Acheulean was not developed too late in Erectus' existence. This technology is similar to Oldowayan except that they chipped away flakes, which they then may or may not use, to create a pear or oval shaped core that could then be further sharpened and balanced using antler or bone, creating in the end, creating what we call hand-axes--basically large, heavy, shapely, sharpened rocks, with about eight inches of sharpened blade, that could be used in the same way as we use axes today. On many sites in Africa, we find evidence of the use of these tools. It appears that Erectus in Asia did not develop this technology--but stayed more primitive.

NOTE: these cores are found across many sites, dated to the time of Erectus, and some along with the remains of Erectus; so the evidence is rather incontrovertible.

But what were they used for? Microscopic analysis reveals that they were used for cutting grass, wood, and animals. (Origins p. 36.) If we can extrapolate, we can imagine many uses for these types of foods: to unearth tubers and other plants, to cut grass to gather grains, to crack, cut, chop and grind various plant foods, like nuts, tubers and even grains. We can imagine, too, that they could use these tools to sharpen wooden spears and as weapons to defend themselves against predation and from intrusions from neighboring troops. Certainly with these tools Erectus would become one of the most dangerous creatures in the world, feared even by its own predators and certainly feared by neighboring troops.

However, we do not have any reason to believe that they could use stone tools on any sort of projectile weapons like spears or arrows, so in that sense, they may not have helped all that much in hunting. We also have conclusive evidence that these weapons were used to butcher animals, especially larger but leaner game found in their territories. At Erectus sites around the world, archaeologists have typically found the bones of big game, such as antelope, giraffe, hippos, zebras and even the spines of catfish, on the same layers as Erectus, leading many to just naturally conclude that Erectus must have hunted or eaten these animals. But its possible that other animals ate these ungulates. But with later technology, they did micro-studies on the bone, finding evidence of butchering via the variety of stone tools. They could also ostensibly use these tools for scraping hides to turn them into clothing or blankets or shelter.

(Origins, 69).

Notes: as cultural clout, for ladies, for trust, for beauty, look like penis and poon combined--or maybe first form of art, because so beautiful, perhaps even beyond their usefulness. Also keep in mind that some of these looked like spikes just for stabbing--but what were they stabbing--kind of sad...

"The Acheulian tool kit is best known for its bifaces, but is actually dominated by flakes of varied sizes (Lycett and Gowlett, 2008; Barkai, 2009; Machin, 2009; Sharon, 2009, 2010; Agam et al.,

2014). In fact, the excavation of some Acheulian sites have not yielded bifaces at all, and game animals (megafauna and smaller taxa) were most probably processed with other flaked stone implements, rather than stone bifaces (Watanabe, 1985; Anzidei et al., 1999; Zaidner et al., 2010; Fluck, 2011; Anzidei et al., 2012). This was one of the reasons for scholars to wonder why early humans invested so much effort in symmetry of stone bifaces and their peripheral shaping if it is possible to cut and disarticulate animals with chopping tools, flakes or other shaped items (e.g., Kohn and Mithen, 1999). This focal issue regarding the function and significance of Acheulian stone bifaces is in long debate, and after a century of research consensus was not reached. Some scholars claim that bifaces were intended to carry out specific dismembering and butchery tasks, and thus were highly usable tools for manipulating carcasses of large mammals (Jones, 1981; Mitchell, 1995; Machin et al., 2007). The very few micro wear studies of Acheulian bifaces (Keeley, 1977, 1980; pp. 160e170, 1992; Mitchell, 1997; Solodenko et al., submitted for publication) support this interpretation. Keeley (1980, pp. 160e170) also discusses the contextual evidence for bifaces as general multi-purpose tools often used for butchery. Dominguez-Rodrigo et al. (2001) presented residue analysis results compatible with woodworking activities. Several scholars proposed that bifaces were used for hunting large mammals (O'Brien, 1981; Calvin, 1993; Wayman, 2010; Cannell, 2014 but see; Whittaker and McCall, 2001)...Others, however, find this over-investment in the aesthetic aspect very conspicuous, and thus several theories referring symbolic and social meaning of those tools were raised (Kohn and Mithen, 1999; Pope et al., 2006; Gowlett, 2011; Hodgson, 2011; Spikins, 2012)...Regarding the symmetry of bifacial tools, Wynn (2002 and references therein) added that bifaces were the first human made (stone) tools that exhibited an imposition of shape, and “... almost certainly did exist as a category in the mind of *H. erectus*”. Kohn and Mithen (1999) raised a hypothesis according to which bifaces were “products of sexual selection”, and served as indicators of the potential benefits of their makers by means of high quality genes, good health, and intellect...In our opinion, there is sufficient evidence to support the claims of the Acheulian stone bifaces as mostly practical butchering and dismembering implements...However, by the same veins, we believe that these highly invested, extraordinary durable and significantly efficient items were also embedded with cultural, symbolic and social significance.” (Zutovski & Barkai 2016).

“Bifaces, and other large cutting tools, present other paradoxes. The tool form itself often displays such attention to detail in terms of symmetry and form that they appear over-engineered for the range of simple functional tasks envisaged. The finesse, exactitude and apparent aesthetic sense worked into what are essentially meat knives continues to demand an adequate explanation, an explanation which might throw some light onto the fundamental relationship between form and function in the material culture of early humans...That these ratios, and perhaps the quality of symmetry itself, might have been cued by proportions found commonly in nature, perhaps suggests that early *Homo* possessed a rudimentary aesthetic sense, echoes of which might still be preserved in classical definitions of beauty.” (Pope, Russel & Watson 2006).

“In the cases of the Acheulian sites presented above, elephant bones received special attention, were flaked and shaped as tools, and most particularly as bifaces (handaxes). As far as the

archaeological evidence reveals at the moment, Lower Paleolithic hominins manufactured bone tools, and bone bifacial tools especially, in relatively small numbers compared to stone tools.” (Zutovski & Barkai 2016).

“There seems to be a special link between bifaces and elephants, as at several sites stone bifaces were found in close association with processed elephant carcasses or elephant bones (e.g., Gaudzinski et al., 2005; Mussi, 2005; Rabinovich et al., 2012; Sacca, 2012a, b; Beyene et al., 2013; Solodenko et al., submitted for publication). Arguments suggesting the probable use of Acheulian bifaces in heavy butchering tasks and as tools suitable for carcass dismembering, mostly of large mammals, clearly point in favor of such association (Machin et al., 2007; Bello et al., 2009; Yravedra et al. 2010; Solodenko et al., submitted for publication). A unique evidence came lately from Revadim site, Israel (Solodenko et al., submitted for publication), where a combination of use wear and residue analysis of a small flint biface revealed edge damage and polishing related probably to hide scraping, and residue of fat tissues and bone, suggesting butchering activity or hide working. The biface was found in close association with elephant rib bone exhibiting cut marks. It is suggested that this biface was possibly used in butchering and processing of large game carcasses, elephants included.” (Zutovski & Barkai 2016).

THROWN TOOLS

While it's unlikely that Erectus as mentioned could attach his sharp rocks to shafts, as evidence of this only beginning to emerge at the earliest about 500 k years ago (University of Toronto & Wilkins et al. 2012) it's quite possible, though, that he could throw rather well. Recent analysis has revealed that Chimpanzees, who resemble Australopithecus and early Homo, can throw one third of the speed of one human aged twelve. However, since Erectus resembles humans anatomically, it's likely that he possesses all or most of our skill and velocity in throwing--in which case the hurling of wooden spears, as well as rocks, could have become powerful tools for them and significantly improved their ability to hunt, scare away predators and defend their territory. (George Washington University 2013 & Roach et al. 2013).

“The bow and arrow, crucial to hunting success of many ethnographically known foragers, dates to the late Upper Pleistocene (<40 ka; Knecht, 1997); the earliest spears and projectile points to the late Middle Pleistocene (<500 ka; Kuhn & Stiner, 2001). Spears in particular might have been used much earlier, but if so it has not yet been demonstrated. Early humans or hominins might also have been able to take animals as large as mid-sized bovids by throwing stones (Isaac, 1987) or by running them to exhaustion (Carrier, 1984)” (O’Connell et al. 2002).

“High speed throwing is one potentially important behavior enabled by shifts in shoulder anatomy. While a number of primate species throw (e.g., Goodall, 1964, 1986; Galdikas, 1982; Jordan, 1982; Nakamichi, 1999; Cleveland et al., 2003; Leca et al., 2008; Hopkins et al., 2012), humans are unique in our ability to throw objects with both tremendous accuracy and velocity. Even Pan troglodytes, which are prolific and accurate throwers (Sugiyama and Koman, 1979; Goodall, 1986; Whiten et al., 1999) with considerable strength advantages (Bauman, 1923; Finch, 1943; Walker, 2009), only reach projectile velocities that are about one-third the speed of the average human male's throw (Roach et al., 2013). Recent work has shown that modern

humans' remarkable throwing ability is linked to anatomical shifts that enable elastic energy to be stored and released at the shoulder (Roach, 2012; Roach et al., 2013; Roach and Lieberman, 2014). Furthermore, it has been hypothesized that the requisite anatomy for high speed throwing was first fully present two million years ago in *Homo erectus* and may have been critical for the advent of intensive carnivory and early migration out of Africa (Roach et al., 2013). However, reconstructing the *H. erectus* shoulder and attributing throwing proficiency to this taxon remain subjects of debate (Larson, 2007, 2009; Roach, 2012; Roach et al., 2013).” (Roach & Richmond 2014).

“The balance of the current evidence suggests that *H. erectus* had laterally oriented, modern human-like shoulders...In sum, the overall similarity in shape between modern humans and all currently available early *H. erectus* fossils strongly support the presence of modern human-like shoulders by two million years ago...The combination of inferiorly rotated, human-like shoulders with a tall, mobile waist and low humeral torsion, support *H. erectus* as the first known hominin possessing the full anatomical complex associated with proficient throwing (Roach et al., 2013). While direct evidence of early throwing behavior remains elusive, evidence for the intensification of hominin carnivory and hunting behavior dating back two million years is increasing (e.g., Dominguez-Rodrigo, 1997; Braun et al., 2010; Ferraro et al., 2013). We propose that this increased carnivory was facilitated by a flexible, situation-dependent hunting and scavenging strategy that included high-speed throwing.” (Roach & Richmond 2014).

A shell tool was found on the island of Java in Indonesia and was dated to a time when *Homo erectus* was the only known hominin inhabitant of the island. The shell tools appear to have been used for cutting or scraping. The lack of stone tools in Java may be due to the absence of suitable stones. Shells may have served as an alternative material.

“One of the *Pseudodon* shell valves from Trinil, specimen DUB5234- dL, shows signs of modification by retouch (Extended Data Fig. 4). The ventral margin features contiguous flake scars, which expose the nacreous layer between the ventral margin and the pallial line. The nacreous edge is smoothed and polished, suggesting its use as a tool for cutting or scraping. Indurated sediment and micro-concretions adhering to concavities produced by the retouch testify to the antiquity of the modification. Shallow striations run parallel to the retouched edge and traces of roots or fungi are present inside and across the striations, demonstrating that they pre-date weathering of the shell before or after burial. The striations most probably result from contact of the inner shell surface with hard materials while using the tool. Our results support the hypothesis that shell tools were part of the cultural adaptations of *Homo erectus* on Java...The reported use of shells as raw material for tool production is the earliest known in the history of hominin technology. It may explain the absence of unambiguous stone artefacts in the Early and Middle Pleistocene of Java, possibly the result of poor local availability of lithic raw material, as also suggested for the much younger (about 110,000 years old) Neanderthal shell tools from Italy and Greece¹⁹.” (Joordens et al. 2015).

BUTCHERY

Author: MAYBE *Erectus* or MAYBE *HEIDELBERGENSIS*—

Abstract: "800k years ago in Israel--sophisticated butchery... Three assemblages of fallow deer (*Dama sp.*) bones excavated from the early middle Pleistocene (oxygen isotope stage 18) layers of the Acheulian site of Gesher Benot Ya'aqov, Israel, furnish evidence of systematic and repeated exploitation of complete carcasses by hominins.

The excellent state of preservation of the bones and the presence of only minimal signs of carnivore involvement permit an investigation of the role of hominins as the primary agents responsible for the damage to these bones. Hominin expertise in dealing with fallow deer carcasses is manifested by cut marks, percussion marks, and hack marks on the bones. The archaeozoological analysis of the anatomical position and frequency of these marks suggests that carcass processing followed systematic practices that reflect an in-depth knowledge of fallow deer anatomy and a consistent behavioral strategy. These assemblages represent one of the earliest examples of methodological butchering practices in Eurasia. The evidence of carcass processing observed at Gesher Benot Ya'aqov resembles that seen in late Pleistocene sites in Israel, which were inhabited by modern humans. We interpret the Gesher Benot Ya'aqov data as indicating that the Acheulian hunters at the site (1) were proficient communicators and learners and (2) possessed anatomical knowledge, considerable manual skill, impressive technological abilities, and foresight.." (Rabinovich, Gaudzinski-Windheuser, Goren-Inbar 2008).

One study suggests *Erectus* may have been capable of some forms of butchery still performed upon hippo's today...

One fossilized mandible of *Hippopotamus amphibius* dating to the time of *Erectus* 1.5 million years ago was found to contain a large hole of similar size and position as the holes made by the Dassanetch tribe of Northern Kenya in order to extract the nutritious pulp from the hippo's large canine root. This hole could have been made by a sharp instrument akin to a knife...

"In the course of a survey of modern bone assemblages in the area to the east of Lake Turkana, northern Kenya (Hill, 1975), the mandible of *Hippopotamus amphibius* shown in Figure 1 was found. In this specimen there is a large hole towards the base of the horizontal ramus, below the premolars and near the mental foramen. It occurs on both rams and is about 90 x 70 mm in size. The edges of the hole are sharp, there are no chewing or teeth marks at its margins, nor any such traces on the internal faces of the bone. The bone in this region of the jaw is thick, and it seems unlikely that a carnivore or any other animal could produce such an effect with its teeth. Moreover, other similar specimens were found which had sharp straight intersecting cuts producing a rectilinear hole in the same position, clearly made by a sharp instrument such as a large knife. This technique appears to be a means of extracting the nutritious pulp from the large canine root, used by gal dies groups of the Dassanetch tribe who forage along the lake shore... The *Hippopotamus* specimen (TK OLD 63 I/L.F. 1972 2043) has a perforation in the external lateral face, in the same position as the modern example and about 65 x 55 mm in dimensions. The specimen is not well preserved so the margins are not sharp, but there is no sign of any carnivore activity. Observations of contemporary *Hippopotamus* remains (Hill, 1980) suggest that a hole of this size being formed in this position through natural weathering is unlikely. It is not known whether the individual had been hunted and killed, or scavenged, but it seems that this is an example of a butchery technique analogous to that found today, practised

some 1.5 ma ago on an extinct Hippopotamus by a member of an ancestral human species.” (Hill 1983).

PLANT TOOLS

“The archeological record also likely underestimates the functional versatility of the early hominin tool kit. The use of stone tools in butchery is evinced by cut marked bones, but tools were probably also used to process many other types of foods, as is evident from microwear of slightly younger Oldowan artifacts used to prepare vegetation, presumably for consumption, and perhaps to make other tools from plant tissues (Keeley & Toth 1981). Furthermore, we cannot assume that early stone tools served the same functions for all early hominin groups, especially given differences in both material toolkits and diet among living chimpanzee groups (Whiten et al. 1999) and human foragers (Milton 2002). Indeed, we might reasonably view early stone tools as indicative of an expanded toolkit that included perishable and durable implements, thus reflecting increased dietary versatility and flexibility (e.g., Mann 1972, Schick & Toth 1993).” (Ungar, Grine & Teaford 2006).

Edible nuts, pitted hammers and anvils were found together at the Acheulian site of Gesher Benot Ya’aqov (Israel) dating to the Early-Middle Pleistocene (~0.78 million years ago)—Erectus or Heidelbergensis?:

“The Acheulian site of Gesher Benot Ya’aqov (Israel) has revealed a unique association of edible nuts with pitted hammers and anvils. Located in the Dead Sea rift, on the boundary between the Arabian and African plates, the site dates to the Early-Middle Pleistocene, oxygen isotope stage 19. In a series of strata, seven species of nuts, most of which can be cracked open only by a hard hammer, were uncovered. Five of the species are extant terrestrial nuts, and two are aquatic nuts now extinct in the Levant. In addition, the site yielded an assemblage of pitted hammers and anvils similar in pit morphology to those used by chimpanzees and contemporary hunter–gatherers. This is the first time, to our knowledge, that a site has offered both paleobotanical and lithic evidence of plant foods eaten by early hominins and technologies used for processing these foods...Again, we may infer from the dietary role of nuts in present-day Africa (54, 55) that if nuts were available in ancient Olduvai, hominins probably gathered and consumed them.” (Goren-Inbar, Sharon, Melamed, & Kislev 2002).

DENTAL ADAPTATIONS

"In sum, there is some evidence for a change in dietary adaptations with the earliest members of the genus Homo, at least in incisor size and perhaps molar occlusal slope and relief. This might suggest a shift toward foods requiring more incisal preparation and molar shearing, perhaps including displacement-limited items such as tough-plant products or animal tissues. More substantial change seems to have come with *H. erectus*, which has both smaller incisors and smaller molar teeth compared with *H. habilis* and *H. rudolfensis*. A broader range of microwear texture complexity values in *H. erectus* compared with *H. habilis* accords with the consumption of a wider variety of foods, and smaller average feature size is consistent with the incorporation of more tough items in the diet.

Are these lines of evidence consistent with increased meat eating or tool use in food preparation? The short answer is yes; each of these might have played a role. Larger samples

and more work on the fossils it is hoped will allow us to choose among existing models or lead to new ones. The available evidence suggests a shift in diet in early Homo and especially H. erectus with broadening of the subsistence base to include at least some more tough foods." (Ungar 2012 p. S327).

HOMO ERECTUS: Size & Morphology of Teeth, and Enamel Thickness—

As noted before, in the transition from Austral to Habilis and Rudolfensis, we see a trend towards smaller and more defined molars even when the environment was producing food that was likely tougher. With Erectus we see the continuation and augmenting of that trend; in fact, their jaws and teeth, and their molars in particular, became substantially smaller as compared to Australopithecus and Habilis; their teeth are generally considered intermediate between Australopithecus and ourselves; additionally they have incisors that were shovel-shaped, sort of scooped out on the side that faces the tongue—which is a characteristic found in many foragers, especially Native Americans and Asians, of our own species, though nobody has attempted to explain the reason for this shape.

Interestingly enough, it appears that as Erectus continued to evolve, his teeth became increasingly smaller; researchers have noted differences in the sizes between earlier and later specimens. And as our line continued to evolve, we see that our teeth from here on out became increasingly smaller, which is probably due to these types of the foods included in our diet, as well as the fact that our foods were processed before they were consumed. While his teeth were becoming smaller, it does appear that Erectus, like his predecessors and even Homo Sapien, maintained relatively thick enamel on his teeth, which is ostensibly there to protect from the fracturing of teeth when eating especially hard or tough foods.

Author Note on Erectus' enamel thickness: "Tooth enamel thickness has been argued to be an adaptation to protect teeth against breakage given a diet including hard, brittle foods requiring high occlusal forces to initiate fracture (Kay 1981, Dumont 1995). Notwithstanding methodological differences between studies, scholars generally agree that the australopiths and early Homo had relatively thick enamel on their molar crowns compared with modern humans and most other living primates. Although it is difficult to separate early Homo from australopiths given isolated measures of enamel thickness from various sources (Tobias 1991, Ramirez-Rozzi 1998), H. erectus specimens had the absolutely thinnest enamel of those Plio-Pleistocene hominins analyzed by Beynon & Wood (1986). Thinner enamel facilitates quicker dentin exposure, which can increase surface jaggedness. This might therefore suggest another adaptation for efficient fracturing of tough foods (Kay 1981, Ungar & M'Kirera 2003)...H. erectus may have had thinner dental enamel, narrower mandibular corpora, and more small microwear pits in their cheek teeth. These observations suggest that H. erectus may have been less capable of crushing hard objects but better able to shear through tougher foods with their molar teeth than H. rudolfensis, H. habilis, and earlier hominins." (Ungar, Grine & Teaford 2006).

"H. erectus may also show adaptive changes, such as thinning enamel, to further improve efficiency in shearing and slicing tough foods such as pliable plant parts or meat. Although

increasing efficiency for fracturing tougher foods may have resulted in decreased ability to crush hard and brittle foods, tools such as the hammerstones observed for Ta'i Forest chimpanzees (Boesch & Boesch 1990) could have easily compensated. Thus, a combination of tools and morphological change would have allowed increased dietary versatility for *H. erectus*." (Ungar, Grine & Teaford 2006).

We can nonetheless draw some broad conclusions from our analysis of their teeth. Given that their teeth became smaller, when the environment was becoming tougher, it's reasonable to assume that *Erectus* was likely processing many of his foods before eating them--chopping them, grinding them, possibly even soaking, fermenting or cooking them, before putting them into his mouth.

MICROWEAR

Microwear studies seem to suggest that *Homo Erectus* did not specialize on either hard or tough objects--though there is some evidence that they occasionally ate some harder (R: brittle or tough) objects; and overall may have eaten harder foods as compared to their predecessors. However, whenever interpreting these results, we have to consider the possibility, as we shall see, that *Erectus* was first processing their foods before consuming them, through chopping, grinding and maybe even soaking and cooking--thereby changing their characteristics and making it difficult to interpret what kind of foods were actually being eaten. But, if we take into account the principal information, that *Erectus* did not seem to consume much hard or tough foods, we can possibly draw two meaningful conclusions: that they were eating either more animal foods or plant foods that were processed before they were placed into the mouth, especially given the fact that their environments were producing foods that were likely either hard, like seeds and nuts, or tough like tubers. Source: (Ungar, Grine, Teaford, & El Zaatari 2006).

"Evidence of an important role for meat eating is more compelling for *H. erectus*. Large concentrations of stone tools and modified bones after 1.9 Myr combined with thinner enamel may suggest improved abilities to slice and shear tough foods, including meat. A higher incidence of small pits in the enamel may indicate the consumption of soft, tough foods such as meat (Teaford & Runestad 1992). However, did meat dominate their diets? Not necessarily. The little lithic microwear evidence we have suggests that early Pleistocene tools were used to process animal and plant tissues (Keeley & Toth 1981)." (Ungar, Grine & Teaford 2006).

"Conventional wisdom ties the origin and early evolution of the genus *Homo* to environmental changes that occurred near the end of the Pliocene. The basic idea is that changing habitats led to new diets emphasizing savanna resources, such as herd mammals or underground storage organs. Fossil teeth provide the most direct evidence available for evaluating this theory. In this paper, we present a comprehensive study of dental microwear in Plio-Pleistocene *Homo* from Africa. We examined all available cheek teeth from Ethiopia, Kenya, Tanzania, Malawi, and South Africa and found 18 that preserved antemortem microwear. Microwear features were measured and compared for these specimens and a baseline series of five extant primate species (*Cebus apella*, *Gorilla gorilla*, *Lophocebus albigena*, *Pan troglodytes*, and *Papio*

ursinus) and two protohistoric human foraging groups (Aleut and Arikara) with documented differences in diet and subsistence strategies. Results confirmed that dental microwear reflects diet, such that hard-object specialists tend to have more large microwear pits, whereas tough food eaters usually have more striations and smaller microwear features. Early Homo specimens clustered with baseline groups that do not prefer fracture resistant foods. Still, Homo erectus and individuals from Swartkrans Member 1 had more small pits than Homo habilis and specimens from Sterkfontein Member 5C. These results suggest that none of the early Homo groups specialized on very hard or tough foods, but that H. erectus and Swartkrans Member 1 individuals ate, at least occasionally, more brittle or tough items than other fossil hominins studied.” (Ungar, Grine, Teaford, & El Zaatari 2006).

Another study states that Erectus’ microwear is more indicative of greater diversity and variation in their diet, as compared to earlier Homo or Australopithecus, with combination of hard and tough foods.

“Of note, H. erectus has substantially more variation in microwear complexity values than H. habilis, or indeed than that of any other hominin examined to date except P. robustus. This suggests that H. erectus had a comparatively broad-based diet, spanning a range of fracture properties including some hard and perhaps tough foods, which may also produce small pits through adhesive wear (26).” (Ungar & Sponheimer 2011).

One study suggests that as Homo Erectus expanded out of Africa, into present day Georgia in this case, he maintained basically the same teeth (and patterns of wear) as his brother in Africa, suggesting that they kept their diet somewhat similar in different environments. Note: small sample size here though based upon the analysis of only 2 molars from Erectus site in Georgia...

“Reconstructions of foraging behavior and diet are central to our understanding of fossil hominin ecology and evolution. Current hypotheses for the evolution of the genus Homo invoke a change in foraging behavior to include higher quality foods. Recent microwear texture analyses of fossil hominin teeth have suggested that the evolution of Homo erectus may have been marked by a transition to a more variable diet. In this study, we used microwear texture analysis to examine the occlusal surface of 2 molars from Dmanisi, a 1.8 million year old fossil hominin site in the Republic of Georgia. The Dmanisi molars were characterized by a moderate degree of surface complexity (Asfc), low textural fill volume (Tfv), and a relatively low scale of maximum complexity (Smc), similar to specimens of early African H. erectus. While caution must be used in drawing conclusions from this small sample (n = 2), these results are consistent with continuity in diet as H. erectus expanded into Eurasia.” (Pontzer, Scott, Lordkipanidze, & Ungar 2011).

The reductions in jaw muscle and dental size in Homo may not have required the adoption of cooking. By slicing meat and pounding USO’s, early hominins would have significantly reduced the amount of effort required to chew their food. It has been estimated that a diet composed of 1/3 meat that had been sliced and USO’s that had been pounded would have reduced early

hominins' number of chews by 17% and with 26% less force, which by some estimates may have been sufficient for the evolution of reduced dental size and chewing power in Homo. By simply slicing their meat, early hominins are estimated to have improved their ability to chew meat into smaller particles by 41%.

“Archaeological and palaeontological evidence indicate that hominins began to increase meat consumption by at least 2.6 million years ago (Ma) (ref. 7), and until the invention of agriculture, meat was an indispensable component of human diets. Archaeological data also indicate that hominins fabricated stone tools by 3.3 Ma (ref. 10), learned to control fire by 1 Ma (ref. 13), and started to cook on a regular basis by at least 0.5 Ma (refs 13, 14).” (Zink & Lieberman 2016).

“Muscle tissue is calorically dense than most plant foods, but is difficult to chew with low-crested (bunodont) hominoid molars. Chimpanzees reportedly spend approximately 5–11 h chewing small (~4 kg) animals, and although the carcasses include hide, cartilage and other tough tissues, such lengthy times highlight the challenges of masticating unprocessed meat using low-crested teeth.” (Zink & Lieberman 2016).

“Even so, we speculate that despite the many benefits of cooking for reducing endogenous bacteria and parasites, and increasing energy yields, the reductions in jaw muscle and dental size that evolved by *H. erectus* did not require cooking and would have been made possible by the combined effects of eating meat and mechanically processing both meat and USOs. Specifically, by eating a diet composed of one-third meat, and slicing the meat and pounding the USOs with stone tools before ingestion, early Homo would have needed to chew 17% less often and 26% less forcefully. We further surmise that meat eating was largely dependent on mechanical processing made possible by the invention of slicing technology. Meat requires less masticatory force to chew per calorie than the sorts of generally tough plant foods available to early hominins, but the ineffectiveness of hominin molars to break raw meat would have limited the benefits of consuming meat before the invention of stone tools approximately 3.3 Ma. Although recent and contemporary hunter–gatherers are less dependent on stone tools than early Homo because they eat mostly cooked meat, many of the oldest tools bear traces of being used to slice meat⁹, and the use of tools (now mostly metal knives) to process foods such as meat is well documented ethnographically³⁰. This dependency on extra-oral mechanical processing, however, does not apply to other animal-based foods such as marrow, brains and visceral organs that might have been difficult to access without tools, but are easier to chew than muscle.” (Zink & Lieberman 2016).

AUTHOR: The amount of chewing required to ingest raw roots would have made it difficult to subsist off of. Meat that had been pounded, sliced, or flaked would have required less chewing. “A better alternative were so-called underground storage organs (USOs)—root foods like beets and yams and potatoes. They pack a bigger nutritional wallop, but they’re not terribly tasty—at least not raw—and they’re very hard to chew. According to Harvard University evolutionary biologists Katherine Zink and Daniel Lieberman, the authors of the Nature paper, proto-humans eating enough root food to stay alive would have had to go through up to 15 million “chewing cycles” a year. This is where meat stepped—and ran and scurried—in to save the day. Prey that

has been killed and then prepared either by slicing, pounding or flaking provides a much more calorie-rich meal with much less chewing than root foods do, boosting nutrient levels overall.” (Kluger, Jeffrey 2016).

“In order to determine how much effort primitive humans saved by eating a diet that included processed animal protein, Zink and Lieberman recruited 24 decidedly modern humans and fed them samples of three kinds of OSUs (jewel yams, carrots and beets) and one kind of meat (goat, raw, but screened to ensure the absence of any pathogens). Using electromyography sensors, they then measured how much energy the muscles of the head and jaw had to exert to chew and swallow the samples either whole or prepared one of the three ancient ways...On average, they found that it required from 39% to 46% less force to chew and swallow processed meat than processed root foods. Slicing worked best for meat, not only making it especially easy to chew, but also reducing the size of the individual particles in any swallow, making them more digestible. For OSUs, pounding was best—a delightful fact that one day would lead to the mashed potato. Overall, Zink and Lieberman concluded, a diet that was one-third animal protein and two-thirds OSUs would have saved early humans about two million chews per year—a 13% reduction—meaning a commensurate savings in time and calorie-burning effort just to get dinner down...What’s more, while animal muscle eaten straight from the carcass requires a lot of ripping and tearing—which demands big, sharp teeth and a powerful bite—once we learned to process our meat, we could do away with some of that, developing smaller teeth and a less pronounced and muscular jaw.” (Kluger, Jeffrey 2016).

“The origins of the genus *Homo* are murky, but by *H. erectus*, bigger brains and bodies had evolved that, along with larger foraging ranges, would have increased the daily energetic requirements of hominins. Yet *H. erectus* differs from earlier hominids in having relatively smaller teeth, reduced chewing muscles, weaker maximum bite force capabilities, and a relatively smaller gut. This paradoxical combination of increased energy demands along with decreased masticatory and digestive capacities is hypothesized to have been made possible by adding meat to the diet, by mechanically processing food using stone tools, or by cooking. Cooking, however, was apparently uncommon until 500,000 years ago, and the effects of carnivory and Palaeolithic processing techniques on mastication are unknown. Here we report experiments that tested how Lower Palaeolithic processing technologies affect chewing force production and efficacy in humans consuming meat and underground storage organs (USOs). We find that if meat comprised one-third of the diet, the number of chewing cycles per year would have declined by nearly 2 million (a 13% reduction) and total masticatory force required would have declined by 15%. Furthermore, by simply slicing meat and pounding USOs, hominins would have improved their ability to chew meat into smaller particles by 41%, reduced the number of chews per year by another 5%, and decreased masticatory force requirements by an additional 12%. Although cooking has important benefits, it appears that selection for smaller masticatory features in *Homo* would have been initially made possible by the combination of using stone tools and eating meat.” (Zink & Lieberman 2016).

While unprocessed meat may require less masticatory effort than raw USOs to chew and swallow, in an experiment, modern humans were unable to break apart ingested unprocessed

meat into smaller pieces with considerable chewing. Even after 40 chews, a bolus of meat remained as one large particle, dramatically reducing its digestibility as well as the energy that can be derived from the animal tissue. Roasting meat allows for it to be chewed into smaller pieces.

“We therefore measured chewing performance in adult human subjects fed size-standardized samples of meat, as well as USOs, which are hypothesized to have been a particularly important component of the hominin diet. For meat, we used goat, which is relatively tough and therefore more similar to wild game than domesticated beef; for USOs, we used jewel yams, carrots and beets. As described in Methods, these samples were either unprocessed, processed using the two simplest mechanical processing methods available to Lower Palaeolithic hominins (slicing and pounding), or processed by roasting, the simplest form of cooking.

Comparisons of the number of chews and total applied force required to chew different foods until they were ready to be swallowed (Table 1) indicate that considerably less masticatory effort is required to consume unprocessed meat than USOs. Compared to unprocessed USOs, one kcal of unprocessed meat required on average 39% fewer chews and 46% less force to prepare for swallowing ($P = 0.01$ and $P = 0.02$, respectively). However, the participants we studied were unable to reduce effectively the particle sizes of unprocessed meat through mastication. As Fig. 1 illustrates, even after 40 chews, meat boli were predominately comprised of one large particle (Extended Data Table 1). Therefore, although unprocessed meat requires fewer chews and less force per calorie than USOs, the inability of hominin teeth to break raw, unprocessed meat into small particles probably reduced net energy gain from the food and limited the effectiveness of consuming substantial quantities of unprocessed muscle tissue. This is a conservative estimate since the goat meat samples tested here were already partly processed, lacked cartilage and other mechanically demanding tissue, and were thus relatively unchallenging compared with most of the meat eaten during the Palaeolithic...

Roasting also substantially improves the ability to chew meat, although through a different mechanism than USOs. Roasting increased muscular effort by 15.3% per chew ($P < 0.05$) and 32.8% per sample ($P < 0.05$), but decreased the size of the largest particle by 47.1% ($P < 0.0001$), a reduction not significantly different from the effects of slicing meat ($P = 0.81$). In other words, roasted meat required more muscular effort per unit mass to chew, but resulted in a swallowable bolus with smaller particles because of more effective oral fracture.” (Zink & Lieberman 2016).

“Cooking, whenever it was adopted, would have led to further benefits. Roasted USOs required 14.1% less muscle recruitment per chew ($P < 0.05$) and 22.0% less per sample ($P < 0.05$) compared with unprocessed USOs, but were ready to be swallowed at 82.1% larger particle sizes ($P < 0.01$). Since USOs tend to be tough, force-limited foods cooking would have substantially reduced hominin peak masticatory effort, in turn reducing selection to maintain large teeth. Assuming that maximum bite force capabilities per chew scale with molar area to the power of 0.9 across primates, we can estimate that a 15% reduction in muscle recruitment

resulting from roasting USOs would have allowed selection to reduce molar area by approximately 14%; a reduction nearly identical to the approximately 15% smaller post-canines of *H. sapiens* compared to *H. erectus*...

A diet composed entirely of unprocessed USOs would require approximately 40,000 chews per day” (Zink & Lieberman 2016).

COOKING

“While it is clear then that early *Homo* had access to mechanical food processing technology, the timing of cooking is much more controversial. Wrangham et al. (1999) hypothesized that cooking softens foods and increases net nutrient availability, helping to make possible the evolution of larger brains and body mass combined with smaller guts, teeth and less robust faces. Supporting this hypothesis, recent research has demonstrated that cooking significantly reduces cost of digestion and increases net energy gain in pythons and mice (Boback et al., 2007 and Carmody et al., 2011). A major problem with ascribing cooking to *H. erectus*, however, is a lack of evidence for controlled fire, let alone cooking use, around the time of early *Homo*. The oldest clear evidence of fire in the archeological record is from Wonderwerk Cave dated to 1 mya (Berna et al., 2012) and Gesher Bonet Ya’aqov at 790 kya (Goren-Inbar et al., 2004), but hearths and other features indicative of cooking do not appear until the Middle Paleolithic, leading many researchers to believe that habitual cooking is a relatively recent behavior (e.g., Brace, 1995, Ragir, 2000, Bunn, 2007, Ben-Dor et al., 2011 and Roebroeks and Villa, 2011).” (Zink, Lieberman, & Lucas 2014).

“Longer chronologies for the use of fire include Wrangham’s recent hypothesis that fire was a central evolutionary force toward larger human brains (6–9): eating cooked foods made early hominin digestion easier, and the energy formerly spent on digestion was freed up, enabling their energy-expensive brains to grow. Using fire to prepare food made early humans move away from the former feed-as-you-go-and-eat-raw-food strategy and toward the sharing of cooked foods around fires, which became attractive locations for increased social interaction between individuals. Wrangham situates these developments around the time of the emergence of *Homo erectus*, approximately two million y ago.” (Roebroeks & Villa 2011).

“The modern human gut also appears to be adapted to cooked foods (Wrangham et al., 1999; Wrangham, 2009). Wrangham argues that in the absence of cooking, the sheer amount of chewing time required to process meat would have limited its usefulness as a high-quality food. He argued that *Homo erectus* adopted fire for cooking; cooking both makes meat easier to chew and easier to digest.”(DeLouize, Coolidge, & Wynn 2016).

“According to Richard Wrangham's “cooking hypothesis,” *Homo erectus* was adapted to a diet of cooked food and therefore was capable of controlling fire (1). Recent phylogenetic studies on nonhuman and human primates based on associated trends in body mass, feeding time, and molar size support the hypothesis of the adoption of a cooked diet at least as early as the first appearance of *H. erectus* approximately 1.9 Ma (2).” (Berna et al. 2012).

“By contrast, the transition from late australopithecines or early Homo (*Homo habilis*, *H. rudolfensis*) to *H. erectus* is associated with significant changes to diet-related features that are consistent with the predicted effects of a cooked diet. Postcanine tooth area is smaller in *H. erectus* than in any previous hominin on an absolute basis, and so small as to be equivalent to *H. sapiens* when adjusted for body size. Correspondingly, *H. erectus* also exhibits a relatively smaller mandible and other aspects of facial shortening, which suggest reduced masticatory strain. Together, these craniodental features indicate that *H. erectus* was consuming a softer diet. Gut size also appears to conform to the expected pattern. For instance, *H. erectus* appears to have had a barrel-shaped thoracic cage, similar to later Homo and distinct from the funnel-shaped thoraces of previous hominins. *H. erectus* is therefore reconstructed as having a smaller gut than its ancestors. Given consistent trade-offs in gut versus brain size among primates, larger cranial capacity in *H. erectus* (849 cm³) compared to *H. habilis* (601 cm³) or *H. rudolfensis* (736 cm³) is also consistent with a smaller gut. Despite these reductions in digestive anatomy, *H. erectus* shows signals of increased energy use, including larger body size, adaptations for long-distance running, and possibly reduced interbirth intervals. The apparently softer, more digestible, and higher energy diet of *H. erectus* are all consistent with the expected effects of cooking.” (Wrangham & Carmody 2010).

However, Dental calculus from the molar of a Homo residing in Europe 1.2 million years ago suggests that food at this time was eaten raw and grains (grass seeds) were consumed unprocessed and intact...

Microfossils of raw animal tissue and uncooked, intact starch granules were obtained from the dental calculus of a species of Homo (unidentifiable) living in Europe—modern day Spain—1.2 million years ago. This provides the earliest direct evidence for foods consumed in the genus Homo, and indicates that these early European hominins consumed a varied diet of both raw meat and starchy plant foods. All food remains were raw (uncooked) and the starch granules from grass seeds showed no signs of processing prior to ingestion. Thus far, the earliest definitive evidence of the use of controlled fire in Europe dates to 800,000 years ago, and based on this study, early European hominins were not yet using fire to cook their food at 1.2 million years ago. Stone tools and a collection of animal bones found with the remains suggests that while they were not cooking, these early hominins may have been using stone tools to butcher meat and possibly to extract marrow.

“Sima del Elefante, Atapuerca, Spain contains one of the earliest hominin fragments yet known in Europe, dating to 1.2 Ma. Dental calculus from a hominin molar was removed, degraded and analysed to recover entrapped remains. Evidence for plant use at this time is very limited and this study has revealed the earliest direct evidence for foods consumed in the genus Homo. This comprises starchy carbohydrates from two plants, including a species of grass from the Triticeae or Bromideae tribe, meat and plant fibres. All food was eaten raw, and there is no evidence for processing of the starch granules which are intact and undamaged. Additional biographical detail includes fragments of non-edible wood found adjacent to an interproximal groove suggesting oral hygiene activities, while plant fibres may be linked to raw material processing. Environmental evidence comprises spores, insect fragments and conifer pollen grains which are consistent with a forested environment.” (Hardy, K. et al. 2017).

“The present study is consistent with the absence of archaeological evidence for controlled use of fire at Sima del Elefante and provides positive evidence for raw food; the intact nature of the starch granules demonstrates a lack of any form of pre-ingestion preparation, while all the fibres detected, both animal and plant, are uncharred.” (Hardy, K. et al. 2017).

“In 2007, a hominin mandibular fragment (ATE9-1) was uncovered in the TE9 stratigraphic level dated to the Early Pleistocene (1.2–1.1 Ma), making this one of the oldest hominin remains in Europe (Carbonell et al. 2008) together with Barranco León (Orce, Spain) (1.02 and 1.73 Ma) (Toro-Moyano et al. 2013). The fragment, and a nearby isolated tooth (lower LP4) from the same individual, is not complete enough for a taxonomic assignment and is therefore referred to as *Homo* sp. (Bermúdez de Castro et al. 2011). A large assemblage of animal bones suggests meat consumption, while stone tools provide evidence for meat processing and marrow extraction (Carbonell et al. 2008).” (Hardy, K. et al. 2017).

“Several different types of fibres were recovered in the calculus, including non-edible wood debris as well as other indeterminate fibres of plant origin. Some other fibrous remains lack the characteristics of plant cell walls suggesting an animal origin, possibly fragments of connective tissue such as tendons or ligaments, and likely to be linked to the consumption of food.” (Hardy, K. et al. 2017).

FIRE

*overview of debate: evidence ultimately inconclusive and when first started using, maybe at genesis, more evidence to support that came later (but maybe not)

*evidence:

We have multiple forms of evidence that *Erectus* was the first of the Hominoids to use fire. At one site occupied by *Erectus* dating back to one million years ago in a cave in South Africa, we have evidence of burned bones and plants. (Berna et al. 2012).

Burned bone and ashed plant remains provide evidence of the ability of *Homo* to control fire ~1.0 million years ago:

“The ability to control fire was a crucial turning point in human evolution, but the question when hominins first developed this ability still remains. Here we show that micromorphological and Fourier transform infrared microspectroscopy (mFTIR) analyses of intact sediments at the site of Wonderwerk Cave, Northern Cape province, South Africa, provide unambiguous evidence—in the form of burned bone and ashed plant remains—that burning took place in the cave during the early Acheulean occupation, approximately 1.0 Ma. To the best of our knowledge, this is the earliest secure evidence for burning in an archaeological context.... Thus, our data, although they do not show evidence of constructed combustion features, as listed by Roebroek and Villa as a criterion of controlled burning (3), demonstrate a very close association between hominin occupation and the presence of fire deep inside Wonderwerk Cave during the Early Acheulean. This association strongly suggests that hominins at this site had knowledge of fire 1.0 Ma. This is the most compelling evidence to date offering some support for the cooking hypothesis of Wrangham (1).” (Berna et al. 2012).

Furthermore, sites in Europe and Asia seem to indicate controlled use for fire dating back to one million years ago as well. We also have evidence from Israel dating back 700k years ago; and in France evidence for use of fire by Erectus dating back to 300k years ago.

source: wiki (look up footnotes)

Sites in Europe and Asia seem to indicate controlled use of fire by H. erectus, dating back at least 1 million years.[46] A presentation at the Paleoanthropology Society annual meeting in Montreal, Quebec in March 2004 stated that there is evidence for controlled fires in excavations in northern Israel from about 690,000 to 790,000 years ago. A site called Terra Amata, located on the French Riviera, which lies on an ancient beach, seems to have been occupied by H. erectus; it contains evidence of controlled fire, dated at around 300,000 years ago.[47] Analysis of sediment by lead authors Francesco Berna and Paul Goldberg (pictured below right) of Boston University revealed ashed plant remains and burned bone fragments, both of which appear to have been burned locally rather than carried into the cave by wind or water. The researchers also found extensive evidence of surface discoloration that is typical of burning.

Rebecca Note: Did not find this anywhere on wiki. The entry may have been changed. Though, the evidence of controlled fire use in Israel dating back ~800,000 years ago is considered strong, although it is important to note that this is the only site in Europe/Asia dating back this far. The evidence from Terra Amata, France, dating to 300,000 years ago, is also considered strong. Currently, the evidence of habitual use of fire in Europe is not considered strong until 400,000 years ago during the second half of the Middle Pleistocene at Beeches Pit in England and Schöningen in Germany. The lack of more sites dating back to the same time as the site in Israel—about 800,000 years ago—may be indicative of more sporadic use of fire during this time.

Since we have use of fire dating back only to one million years ago, whereas Erectus emerged around two million years ago, some, if not most, researchers seem to think that Erectus only started using fire later in his existence--and perhaps even then only at times or by certain cultures. This may, indeed, be true, especially considering that Erectus, in his use of stone tools, became more evolved in his later existence. Its also possible that we just not have evidence for earlier use of fire at this point; and furthermore evidence for use of fire is way inclined to disappear due to the normal and wear and tear of the environment. We also have to conclude that Erectus did not seem to become more encephalized later in his existence, so he should have possessed the mental hardware from the beginning to make use of fire. But we also have reasons to believe that the use of fire was even endemic to Erectus.

For example, at the earliest sites in east Africa dated to 1.5 million years ago, the evidence consists of clay sherds—pieces of burned, hardened clay; analysis of the sherd suggested that they were heated to 400 degrees celsius—about the same temperature of a campfire; brush fires, by comparison, typically burn much cooler. At another site in East Africa comes the reddening of sediment that could only result from heating in that same temperature range. At yet another site was a depression that seemed hearth-like; however the microscopic charcoal that was found there could have come from a brushfire. At yet another site in South Africa, several

burnt bones were found amongst both stone and bone tools used by Erectus, along with bones with cut-marks from hominids. Other examples, too, extend through the Near East and Far East—mostly dated to around the time of Erectus. (Control of Fire by Early Humans, Wiki) Some scientists have smartly claimed that if Erectus, indeed, used fire, we would see a string of hearths designating their campsites; on the the other hands, these bits and pieces of evidence, dating, in some cases, to as far back as 1.5 million years ago, also lend credibility to the possibility that fire was used by Erectus; indeed, according to Wrangham, it might have even been necessary for his evolution.

“The timing of the human control of fire is a hotly debated issue, with claims for regular fire use by early hominins in Africa at ~1.6 million y ago. These claims are not uncontested, but most archaeologists would agree that the colonization of areas outside Africa, especially of regions such as Europe where temperatures at time dropped below freezing, was indeed tied to the use of fire. Our review of the European evidence suggests that early hominins moved into northern latitudes without the habitual use of fire. It was only much later, from ~300,000 to 400,000 y ago onward, that fire became a significant part of the hominin technological repertoire...We suggest that the European record displays a strong signal, in the sense that, from ~400 to 300 ka ago, many proxies indicate a habitual use of fire, but from the preceding 700 ka of hominin presence in Europe, we have no evidence for fire use.” (Roebroeks & Villa 2011).

“The earliest traces of hominin presence in Europe come from its southern parts and date to more than one million y ago (21)...However, surprisingly, evidence for use of fire in the Early and early Middle Pleistocene of Europe is extremely weak. Or, more exactly, it is nonexistent, until ~300–400 ka. Our review of the early European sites (Dataset S1) shows that the earliest possible evidence of fire comes from two sites dated to ~400 ka, Beeches Pit in England and Schöningen in Germany. At Schöningen, the evidence consists of some heated flints (although mostly natural pieces) (22) and charred wood, including a wooden tool, with the studies of possible remains of former hearths still in progress (23). At Beeches Pit, dated to Marine Isotope Stage (MIS) 11 (Dataset S1), the evidence consists of heated lithics and heated sediments (24, 25), interpreted as the remains of hearths. Terra Amata (France) and Vérteszöllös (Hungary) also provide credible evidence of fire, but estimates of their age vary from MIS 11 to 9.” (Roebroeks & Villa 2011).

“The European signal for fire use aligns well with what we know from other continents, where indications for habitual use of fire are present from the second half of the Middle Pleistocene onward. As in Europe, fire seems to have become a maintainable technology between ~400 and 200 ka, as illustrated by the evidence from the cave site of Qesem in Israel. Here, micromorphological studies suggest that recrystallized wood ash was a major part of the cave deposits over a long time period and that, at least in the upper part of the sequence, repeated use of fire was common (17). Another signal for habitual fire use in the 300- to 200-ka period comes from a study of heated flints from the Tabun site, also in Israel (53)...There is however, one well-established case for earlier repetitive fire use in western Asia: the Acheulian site of Geshert Benot Ya’aqov (GBY) in Israel, dating to ~780 ka ago (59–61). GBY has both charred plant remains and heated micro artifacts (≤ 2 cm) occurring in localized concentrations in various

levels throughout the sequence. Five superimposed GBY assemblages contain clusters with frequencies of burned flint microartifacts of 3.7–5.8%. The spatial distributions and the frequencies of burned microartifacts are comparable to those occurring at much younger Magdalenian sites in Western Europe, where knapping near a fireplace was a common occurrence, leading to the accumulation of lithic debris near the hearth (62)...In sum, the European evidence strongly suggests that the habitual and controlled use of fire was a late phenomenon, dating to the second half of the Middle Pleistocene, which is not to deny the possibility of occasional and opportunistic use of fire in earlier periods (5)...The evidence from GBY is suggestive of repeated use of fire at one location only, at ~800 ka. Together with the claims from some early African sites, the GBY evidence might testify to a sporadic use of fire by hominins before the second half of the Middle Pleistocene. Early hominins had expanded their ranges into the northern temperate latitudes of Eurasia much earlier, however, long before GBY. The finds from Dmanisi, Georgia (68), show that the southern Caucasus was already occupied by 1.7–1.8 Ma, whereas hominins were present in northern China at least by 1.66 Ma, as shown by data from the Nihewan Basin (69). The evidence from Dmanisi and the Nihewan Basin is older than any of the abovementioned African sites with contested traces of fire use. We suggest that early hominins did not need fire for their colonization of these areas where winter temperatures dropped below freezing.” (Roebroeks & Villa 2011).

How Erectus created or maintained fire is not clear. But grasslands are known to burn periodically, due to strikes of lightning and volcanoes or other causes and, somewhere along the line, some hominid probably noticed the power of fire to provide light and warmth, scare away other animals—and probably notices as well the ability of fire to make food both more eatable, more tender for example, but also more flavorful and, as already mentioned, more bioavailable. So we can easily imagine a scenario where an animal becomes trapped in a brushfire, stumbles and burns to death, slowly roasting and simmering like pot-roast, wafting meaty and fatty flavors across the savannah—only, of course, to be discovered by hominids. By the laws of physics, most cooked foods are necessarily more flavorful for this reason: most of our sense of taste, at least in modern humans, comes from our sense of smell; generally, we cannot tell the difference between the taste of foods unless we are able to smell them first. In the process of cooking, as we already know, larger molecules are separated into smaller ones—which are then able to waft into the atmosphere and into our olfactory nerves, giving us, most of the time anyway, pleasant sensations of craving food. Of course, it makes sense that cooked foods, especially meat, appeals more to our taste because it is, in some senses, more nutritious due to its nutrients being more available for digestion. Of course, it is possible, but not likely, that Erectus or some other hominids might have had different processes for discerning the desirability of food. Whatever the case, we can easily assume that, by the laws of physics, the first of the hominids to eat cooked food automatically found the results pleasant; otherwise, we may have never started cooking.

Advantages of Fire:

*fire, warmth into new lands

--homo would only lose hair if had an alternate way of warming himself—which, in turn, allowed man to stay cooler in the heat and thus persistence hunting—relationship between this and fire in other words (Wrangham 2009).

*used for protection from predation

*great cultural advances

*other advantages: more tools, more nighttime activity etc

*cooking

*and for attraction to food: apes prefer cooked food

Source: (Wobber, Hare, & Wrangham 2008)

rats prefer cooked starch

cats prefer cooked meat

Chimpanzees prefer seeds cooked by wild fires (BREWER 1978).

--primates and other animals prefer qualities caused by cooking: sweeter and cooking makes food sweeter.

Apes in captivity discriminate level of sugar, tannins and salt and so do wild ones

--cooking also increases the availability of glutamate, and all mammals have umami taste receptors

--primates and humans respond to similar textural properties, such as viscosity, temperature, fat content and grittiness--and both use similar neural mechanisms to discern those properties

--Overall theory: it's possible that most if not nearly all animals are designed to respond to certain tastes in food that communicate the presence of nutrients and antinutrients like glucose, fructose, fatty acids and amino acids, as well as the presence of toxins through bitter tastes. Since cooking enhances the presence and thus the flavor of the nutrients and breaks down the anti-nutrients, we have reason to believe that cooked food is preferred by many animals and primates most of all.

Captive Great Apes showed preference for cooked food—cooked beef and cooked tubers over their raw forms.:

“Here we use great apes to model food preferences by Paleolithic hominids. We conducted preference tests with various plant and animal foods to determine whether great apes prefer food items raw or cooked. We found that several populations of captive apes tended to prefer their food cooked, though with important exceptions. These results suggest that Paleolithic hominids would likewise have spontaneously preferred cooked food to raw, exapting a pre-existing preference for high-quality, easily chewed foods onto these cooked items. The results, therefore, challenge the hypothesis that the control of fire preceded cooking by a significant period...Overall, chimpanzees in this experiment preferred cooked tubers to raw tubers...Apes in this experiment preferred the cooked beef to the raw beef, but showed no discrimination between raw and cooked apple...This indifference is somewhat logical, as apple can be fairly easily eaten and digested in its raw form as compared to raw meat...Thus, these results further supported the notion that apes tend to prefer cooked food to raw, but potentially only when there are significant changes induced by cooking...It is important to note that in both cases where the cooked item was not preferred over the raw (white potato and apple), individuals did not prefer the raw item, but were simply indifferent between the two options...It is

important to note that our experiments were not designed to investigate what sort of preferences would have been found if the apes had been given extended experience with the cooked items, thus potentially using the post-ingestional consequences to change their preferences... Overall, our findings conform to evidence that wild chimpanzees choose seeds that have been heated by wild fires (Brewer, 1978), demonstrating that great apes possess a preference for cooked items. These preferences may be widespread in mammals, as shown by the evidence for rats and cats preferring cooked items (Ramirez, 1992; Bradshaw et al., 2000), and as would be expected from the improved quality of cooked items." (Wobber, Hare, & Wrangham 2008).

"Evolutionary anthropologists Victoria Wobber and Brain Hare tested chimpanzees and other apes in the United States, Germany, and Tchimpounga, a Congolese sanctuary. Across the different locations, despite different diets and living conditions, the apes responded similarly. No apes preferred any food raw. They ate sweet potatoes and apples with equal enthusiasm whether raw or cooked, but they preferred their carrots, potatoes and meat to be cooked. The Tchimpounga chimpanzees were particularly informative because there was no record of them having eaten meat previously, yet they showed a strong preference for cooked meat over raw meat. The first of our ancestors to control fire would likely have reacted the same way. Cooked food would have suited their palate the first time they tried it, just as a taste for cooked food, with its immediate benefits, is shared by a wide range of wild and domestic species. Chimpanzees in Senegal do not eat the raw beans of Afzelia trees, but after a forest fire has passed through the savanna, they search under Afzelia trees and eat the cooked seeds." (Wrangham, Richard p. 91).

"The spontaneous preference for cooked food implies an innate mechanism for recognizing high-energy foods. Many foods change their taste when cooked, becoming sweeter, less bitter, or less astringent, so taste could play a role in this preference, as some evidence suggests. Koko is a gorilla who learned to communicate with humans, and she prefers her food cooked. Cognitive psychologist Penny Patterson asked her why: "I asked Koko while the video was rolling if she liked her vegetables better cooked (specifying my left hand) or raw/fresh (indicating my right hand). She touched my left hand (cooked) in reply. Then I asked why she liked vegetables better cooked, one hand standing for 'tastes better,' the other 'easier to eat.' Koko indicated the 'tastes better' option." (Wrangham, Richard p. 91).

Evidence for primates:

cooked tubers:

although definite and even radical variation, Chimps overwhelmingly prefer cooked:

When given 15 choices between cooked sweet potatoes and carrots, they chose cooked, 11 times on average, with only three selecting below ten times.

Least preference for cooked white potatoes: but not part of their regular diet.

Other great apes show these same preferences.

--Hard to determine if preferred the cooked food raw or mashed or grated--did not necessarily show clear preference

--All Great Apes, including chimps, Bonobos, Gorillas and Orangutans, prefer cooked meat, almost overwhelmingly--with only two preferring it under ten times when given fifteen choices.

--As for apples, came down the middle: but raw fruit part of their indigenous diet--and not necessarily any known nutritional advantages to eating fruit cooked besides sugars may be broken down slightly Rebecca Note: plus, water soluble vitamins e.g. vitamin c may be destroyed with cooking

In conclusion, prefer cooked meat and tubers (unless tubers were 100 percent starch, in which case, not part of their diet. As for fruit, mixed). Rebecca Note: also recall that chimps don't have the salivary amylase that humans do, which in helping break down starch in the mouth, also makes the taste of a potato that much sweeter.

source: (Wobber, Hare, & Wrangham 2008).

--Smell of cooked food:

--assume, too, that we have similar receptors and smells is mos the way to taste small molecules vaporize in air and create smell—also more flavorful. Larger molecules cannot smell until eaten.

says must cook meats at high temperatures to get meaty flavors.

Meat made of large proteins that have little smell but only smell once cooked....

—CHIMPS NOT AFRAID OF FIRE: ability to strike matches and start fire (Wrangham) On another note even Chimpanzees seem to possess some considerable understanding of fire; one researcher has noticed that other animals when in contact with fire become stressed and panicked and cannot really predicts its movement; but chimps, on the other hand, tend to do their fire-dance and otherwise seem to remain calm in its presence and show some ability to predicts its movement. source: (Iowa State University 2009).

Also one bonobo named Kanzi was able to learn how to snap twigs and strike a match in order to start a fire to roast marshmallows on a stick or to cook food upon. Kanzi likes omelettes, and will cook them for himself, asking for the ingredients using a lexigram (a sort of keyboard with pictures):

"Examples of Kanzi's behavior. The following are highly suggestive anecdotes, not experimental demonstrations. In an outing in the Georgia woods, Kanzi touched the symbols for "marshmallows" and "fire." Susan Savage-Rumbaugh said in an interview that, "Given matches and marshmallows, Kanzi snapped twigs for a fire, lit them with the matches and toasted the marshmallows on a stick." [10]...According to a 2014 report, Kanzi not only enjoys eating omelettes, but also cooking omelettes for himself. He asks for the ingredients using his lexigram." (Wikipedia "Kanzi").

A series of photos were published of Kanzi making a fire and cooking food...

<http://www.telegraph.co.uk/news/picturegalleries/howaboutthat/8985122/Amazing-photos-of-Kanzi-the-bonobo-lighting-a-fire-and-cooking-a-meal.html>

Cooking also makes plant-foods softer, particularly cellulose, rendering rigid, near-unchewable foods such as broccoli and kale soft. While chimps spend five hours a day chewing food, hunter-gatherers spend only one hour and likely modern Americans, especially someone like myself known for swallowing his food dog-like, spend even less time—which, in and of itself,

saves a certain amount of energy. (Gibbons 2007). But on top of that, cooking ostensibly makes the nutrients in plants more bioavailable.

COOKING SUMMARY

In other words, if Erectus cooked his food, he could have exploited plant-foods better in all sorts of ways. For example, through cooking and deactivating anti-nutrients, Erectus could then specialize in one type of root or seed, for example, not needing to fear over-dosing on any particular anti-nutrients. In addition, many plants, once considered too toxic to eat, could become more palatable due to cooking. So Erectus would have his choice of specializing in just a few, rich plants foods, such as certain seeds and tubers, as Homo Sapien have been doing since the advent of the Neolithic, or he could chose to eat many different plants, decisions which probably would have been made dependent upon certain variables. Certainly, this sort of choice would have enabled Erectus to explore more territory and survive and thrive in different ecologies—thus, in part, explaining his expansion from Africa.

COOKED VS RAW CONSUMPTION

First of all the enzymes inherent in foods are not always the enzymes that your body uses to digest its own foods, so those food enzymes might not play any part in digestion. Furthermore, it is likely that, once those enzymes inherent in food, hit your gut, they are destroyed by your stomach-acid (Hydrochloric acid;—and thus even momentarily or permanently deactivated. Afterall, enzymes are proteins, short strands of amino-acids; and stomach-acid, as we shall see, is designed to break-down proteins into their smaller components—thus neutralizing enzymes.

Raw food: reduced reproductive function, enzymes are digested in our gut, their specific metabolic function not suited for humans (enzymes),
low bone mass in back and hips, low levels of good cholesterol, elevated homocysteine
Myths of raw food but never confirmed—proven wrong—Edward Tylor studied these claims found no evidence that any society lived on raw food
Blubber preferred raw by Inuit –Steffanson—ate lichen from the lumen of caribou
Unable to find any reports of people living longterm on wild, raw foods
Dougal Robertson and family—in dingy for 38 days, ate dried turtle, eggs and meat juice in rainwater—but still craved cooked food 32
Domesticated animals grow better on cooked food, cows produce more milk and fat in the milk on cooked, same for salmon and insects 38
Notes from: (Wrangham 2009).

*some foods eaten raw, some cooked

*how cooking affects food

*deactivates toxins

In fact, stronger evidence, not to mention common-sense, suggests that cooking food, especially certain kinds of foods, makes it more digestible, not less. For example, we have already covered that part of the problem of eating plants, especially wild plants, is that they tend to be loaded with a variety of anti-nutrients, substances that hinder the absorption of nutrients or interfere with the optimum functioning of the body—compounds that the plants create

themselves, for the most part, to protect themselves from getting eating out of existence. As we learned, too, animals, primates for example, have learned to deal with these anti-nutrients in a variety of ways, including avoiding eating too much of any one anti-nutrient by eating many different types of plants. But cooking tends to neutralize many of these anti-nutrients. For example, trypsin-inhibitors, which are found in most seeds and block the absorption of protein, are deactivated by heat. And cholinesterase found in fruits, which interfered with gastro and nervous functioning, are also deactivated by cooking—same for cyanogenic glycosides, tannins, Hemagglutinins, and even phytates found abundantly in grass seeds. All of these compounds, to one degree or another, are neutralized by cooking.

FERMENTED FOODS

THEORY ON FERMENTATION: first actual evidence of fermentation: mead:
reduction of volatile fatty acids: not as much fiber (replacing leaves with meat and fat) also overall size of colon is diminished dramatically, so no longer getting nearly the same amount of VFA (especially considering reduction in fruit)—so what gives.

Looked at strictly in terms of anatomy, fermentation may have actually started with *Homo Erectus*

But if all happened at *Erectus*—how did we get to *Sapien*—what food technology, allowed us to power our brain.....even expensive tissue hypothesis breaks down somewhat—seems that stomach remained the same size—yet our brains became larger—maybe just same size and increase in quality or ease of digestion.....
better cooking technologies.....
How would *Erectus* have cooked?

COOKING TECHNOLOGIES

*roasted over open flame:

marrow, skulls, shellfish, turtles, whole animals cooked
in their skin, beans, tubers and even nuts cooked in the shell
modern hgs known to roast nuts in their shell when mixed with sand and coals.....
marrow like butter when roasted

advantages and disadvantages: lots to manage, burning, loss of fat, some foods could not be cooked this way, such as small seeds, could not cook in water and etc

clay ovens: coals, hot rocks, leaves, food, covered in the earth

Boiling

(Wrangham 2009 p. 122).

COOKING STARCHES

experiments on starch on ileal patients (who do not have colon) 95 percent digestion on cooked oats, white, potato, plantains, banana, cornflakes, white bread and mixtures of starch, dairy and meat. raw starch much lower 71 percent for wheat, 51 for potatoes, and 48 for plantains and cooking bananas

Infinite number of polysaccharides. Even plants do not have enzymes to digest cellulose—do not want to eat their skeleton. Starch contains protein molecules—protein will absorb water—thus drawing moisture into the mix (consider rice) which can create fermentation.

Starches cooked in water: two sugar molecules in starch granules amylose or amylopectin. not affected by cold water. But on heating the water, the amylose and amylopectin move apart and become less dense—this allows water to penetrate these molecules that are soluble in water but do not fully dissolve but form a gel. These molecules can absorb 100 times volume without bursting. Once starch bursts, amylose dissolves in the water.

Disaccharides and polys undergo hydrolysis when heated with water: water reacts with oxygen atoms joining the sugar and breaks the complex into simples. sucrose broken into fructose and glucose when sweets are boiled. If heated further, then problems result: acids and aldehydes. if burn, called caramelization.

Cooking gelatinized starches, making it more digestible. For example, many carbohydrates in plants such as tubers and seeds are bound in starch granules which, without cooking, prove rather difficult for humans to digest. Also these granules tend to contain some amount of proteins which, in this case, when soaked or cooked in water, draw moisture into them and begin to swell. If this process continues—essentially cooking the starch in water or moisture—the two, starch molecules, within the granules, then begin to separate and spread; at that point, water then is absorbed into the starch, making them swell. In a process called hydrolysis, the water interacts with the oxygen joining the sugars and breaks the starches into simpler sugar; one of the starches, amylose, will even dissolve into the water. In other words, the process of cooking breaks their complex carbohydrates into simpler sugars, so by the time, the food reaches your gut, much of the process of digestion is already accomplished. (Barham 2001 pp. 5-37.) (or see: converts starch molecules, from such foods as tubers and grains, into more digestible dextrans—simpler sugars that are easier to digest. (Need further research: Stahl, Hominid Dietary Solutions Before Fire, current anthro—around p. 153 Lamb and Harden.) (and Wiki)

Author's Notes --

Heat processing generally increases the digestibility of starch through a process known as gelatinization, followed by hydrolysis (the breakdown of starch with water), and also dextrinization, the hydrolysis of starch molecules into smaller starch molecules known as dextrin. Raw starch granules consist of a semi-crystalline structure composed of the two carbohydrates amylopectin and amylose. In this crystalline matrix, the starch is protected from degradation by digestive enzymes (proteins). The application of heat, however, causes the grains to absorb liquid and swell, eventually resulting in a collapse of the semi-crystalline structure of the starch granule in a process called gelatinization. Once the starch granule bursts open, the starch molecule amylose is released into the surrounding water, and chemicals in the grain that may potentially help inhibit digestive enzymes are destroyed. In the ruptured state, digestive enzymes can gain easy access to the starch molecules, breaking them down into simple sugars (i.e. glucose, maltose) and shorter starch molecules called dextrans. Dextrans can

also be formed before the starch is exposed to digestive enzymes when starch is exposed to an intense, dry heat. All together, the processes of dextrinization and gelatinization coupled with hydrolysis act to increase the digestibility and therefore the energetic value of starch.

Without the application of heat and moisture, raw starch contains considerable quantities of resistant starches. These resistant starches bypass digestion and remain intact throughout the intestinal tract until they reach the colon where they may act as food for microbes who in turn transform the resistant starch into short chain fatty acids. While short chain fatty acids can be absorbed by the colon and used for energy by the colon and other body tissues to some extent, the energy obtained from the short chain fatty acids is significantly less than would be available from the simple sugars (i.e. glucose) acquired from the breakdown and digestion of cooked starch. Humans can only typically obtain about half of the available energy present in resistant raw starch. Comparing the estimated energy obtained from the conversion of resistant starch to short chain fatty acids in the colon with the expected energy available from cooked starch reveals the increases in energy acquired from cooking starch. The extra energy gained from cooking various commonly consumed starchy foods is estimated to range from 12-35% depending upon the type of food. Specifically, the estimated energetic increases are 12.1% for oats, 14.5% for wheat, 30.2% for plantain, 30.5% for potato and 35.0% for green banana.

However, cooked starch that is cooled will lose a portion of its digestibility, ultimately decreasing the energy gained from cooking. As cooked starch is cooled, some of the gelatinized starch molecules (amylose & amylopectin) may reassociate and recrystallize to form a type of gel-like resistant starch known as "retrograded starch" that is difficult to digest. Similar to other resistant starches, retrograded starch can be fermented in the colon to short chain fatty acids, but as already explained, this digestive pathway is much less energetically efficient. More energy could be obtained from the simple sugars (i.e. glucose) derived from the gelatinization, hydrolysis, and dextrinization of starch granules. Retrograded starch may provide benefits for the colon though by supporting the formation of short chain fatty acids which are integral in colon health and the prevention of colon cancer. The formation of retrograded starch is commonly encountered in food processing as well, underlying the staling of bread and the thickening of gravy.

Besides retrograded starch, another form of resistant starch is formed when starch undergoes prolonged high temperature heat treatments in the absence of water such as with the processing of breakfast cereals and the canning of beans and legumes where little water actually penetrates into the beans. It is estimated that over 10% of the total starch in canned beans and 2% of that found in bread is a form of resistant starch. With this type of treatment, the structure of the starch granule becomes so damaged that digestive enzymes have trouble breaking it down. The change in structure also makes it more difficult for the starch granule to absorb water and gelatinize. Thus, the resistant starch formed will remain resistant, but may be transformed by the colon's microbes into short chain fatty acids. All types of resistant starch can be digested by the colon's microbes, at least to some extent.

While it is clear that cooking provides many benefits to the digestibility and therefore nutritional value of starch rich foods, the exposure of starch to heat may result in the formation of some

toxic substances including acrylamide, a toxin that may promote the development of cancer. Acrylamide is formed in the process of baking or cooking starchy foods at high temperatures that commonly occur with frying, grilling, and deep-fat frying. Acrylamide is thought to be synthesized in the reaction between an amino acid and a sugar, a reaction formally known as the Maillard reaction best known for its ability to produce the tasty crust and golden color of fried and baked goods. Acrylamide concentrations appear to increase with heating time. In the developed countries of the Western world, starch based crisps, potato chips, french fries, white bread, breakfast cereals, crackers, hash browns, and biscuits are all popular foods that have been shown to contain relatively high amounts of acrylamide. Home cooked foods are thought to have lower levels of acrylamide overall than industrially produced foods manufactured at high temperatures. Avoiding overcooking will minimize exposure to acrylamide from cooked foods containing starch.

COOKING PROTEINS

cooking of eggs 91 to 94 percent absorption, raw: 51 percent, due to the denaturing of proteins

proteins—an almost infinite way of packing amino-acids to make proteins. Denaturation: internal bonds, hydrogen bonds, for example, hold amino acids together. when broken, protein is denatured. Protein like tightly bound ball of wool—imagine kitty playing, thus denatured. Heat increases vibration so shakes aminos so that break free of bonds. why our bodies create fevers to kill protein coats of viruses. Most proteins denatured at 40c around 104 f—when heated more than this, can break up and form even larger molecules.

above 200c meat create carcinogens temperatures that taste bad.

collagen: structure protein that is indigestible—three separate molecules twisted like rope, thus proving structure. To digest collagen, must break down into three separate strands. happens at 70c. some aminos are hydrophobic, some hydrophilic. when proteins denatured, the phobics clamor for air. Meaty flavors developed in cooking result of amino interacting with sugars

for boiled meat gone in two hours, raw, salted still present and intact 70
furthermore, tenderness of meat is rated as most important to consumer
and cooking of course accomplishes this

hunter gatherers cook their meat but eat certain soft animal foods: oysters, livers, kidneys

Similar process happens to the proteins in both animals and plants when cooked—a process called denaturing. When formed in the tissues of plants and animals, protein, taking instructions from genes, forms into strands of amino-acids linked together in specific sequences. Although the number of amino-acids is rather small, they can be linked together to form an almost infinite variety of proteins to perform all sorts of duties in plants and animals. Once the amino-acids are linked together, other atoms and molecules, such as zinc, iron and copper, are added and then the protein begins to fold and curl into itself and bond together using hydrogen, creating a

structure with depth and dimension. This structure, ultimately, determines how that molecule will interact with its environment.

However, in cooking, this process begins to reverse itself. As we remember from high-school physics, heat makes matter vibrate faster so when proteins are heated in the process of cooking, the amino-acids begin to vibrate, causing them to break their bonds; where once the amino-acids were sort of bound, as in a ball, they are now unravelled—rather like strings; they are essentially strings of amino-acids bound together with peptides. Most proteins begin to denature at around 104 degrees, although collagen, which is more or less indigestible raw, begins to unravel into distinct strands of amino acids at around 160 degrees. In other words, again through the process of cooking, proteins are to some extent predigested. So once the protein enters into the stomach, it requires less energy from our bodies—essentially our digestive systems—to digest. The acid in your stomach, along with other secretions, then dissolves the peptides, freeing the amino-acids for digestion into the body. In other words, with cooking, meat is partially-digested; and as such, it requires less energy from your body for complete digestion.

Strangely enough, we only have one study on the energetics of digesting cooked versus raw meat, done quite recently—not on humans but pythons of all creatures. Working with others, Richard Wrangham conducted a study where a python was fed raw meat, cooked meat, and cooked, ground meat as you find in hamburgers—then the snake was regulated to determine how much energy was expended. With cooked meat, the python expended 13% less energy and, with cooked, ground meat, the python expended 23% less energy. Mice eating cooked meat, as compared to mice eating raw meat, gained 29% more weight and were 4% longer. These studies are for animals, of course, that are not even designed to consume cooked meat.

Author's Notes --Note to add to discussion above: Unfolded (denatured) protein is also easier to chew.

The body breaks down all protein in the same way, chopping off segments of amino acids that can then be absorbed. In order to do so, the body's digestive enzymes (proteins) who do all the chopping must gain access to the proteins. The denaturation of proteins causes them to unfold and exposes more of the protein to the environment, ultimately giving greater access to the body's digestive proteins. Studies have shown that cooking meat at 70 °C (158 °F) results in the optimal denaturation of protein, thus significantly increasing the protein digestibility. However at higher temperatures ranging from 100-140 °C (212-284 °F) proteins clump together in a way that makes it much more difficult for digestive proteins to reach the proteins to degrade them.

Once unfolded, denatured proteins will undergo a process known as coagulation in which the proteins randomly get tangled up around one another, forming a solid or semisolid state composed of a disorganized network of proteins. This is the process that causes eggs to solidify when heated. Depending upon the temperature at which the proteins are unfolded (denatured) and subsequently reformed (coagulated), the protein may take on a more or less digestible form. At higher temperatures, the protein will quickly unfold and then tangle together into a tight, solid and dense mass lacking any water and fat that were squeezed out in the process. This will

ultimately make the protein tough and chewy and harder to digest. However, if low temperatures are applied, the protein will slowly lose its structure and then reform into a more loosely bound semisolid mass that still retains globules of water and fat, resulting in a softer, more tender and easily digestible form.

This is also one way in which moist heating methods such as stewing prove to be superior to other forms of cooking. The low temperature combined with the surrounding cooking medium of water and fat exposes meat and other proteins to heat more slowly and less intensely, causing the protein to denature and coagulate at a slower pace that allows for the retention of water and fat, maximizing tenderness in the process. The application of moist heat over long periods of time may also dissolve the fibrous connective tissue protein collagen into its soluble gelatin form, freeing the muscle fibers it previously bound together and adding to the meat's tenderness. Thus, it is not only the application of heat that alters a protein's digestibility, but more importantly, the way in which it is applied that will determine whether or not the protein will take on a more or less digestible form than its previous raw state.

Some protein may be made unavailable at high temperatures as a result of caramelization and maillard reactions that occur between carbohydrates and proteins. These reactions are commonly known for their browning effects upon foods. The amino acid lysine is particularly susceptible to these reactions when exposed to high temperatures. Cooking beef for three hours at 120 °C (248 °F) results in a loss of one-fifth its lysine content, and one-half is lost when the temperature is raised just 40°C to 160 °C (320 °F). Besides leading to a loss of protein, reactions between sugars and proteins or lipids that contribute to the browning of foods at higher temperatures also produce ALEs (advanced lipoxidation end-products) and AGEs (advanced glycoxidation end-products). When ingested in foods, ALEs and AGEs are absorbed and transferred into the blood where they may wreak havoc and increase inflammation. In fact, nearly every type of cell and molecule in the body may fall victim to the negative effects of AGEs. Once inside the body, AGEs are difficult to remove. It has been estimated that only one third of the AGEs ingested from food can be excreted, leaving two thirds in the body. These AGEs may accumulate over a lifetime, contributing to the aging process and playing a role in many of the age-related chronic diseases currently plaguing society including diabetes, atherosclerosis (i.e. plaque buildup in the arteries), chronic renal (kidney) failure, and even Alzheimer's Disease. Mice placed on a diet with high amounts of dietary AGEs have shown not only increases in markers of inflammation, but also organ damage and decreased lifespans. Thus, the current research indicates that minimizing dietary intake of AGEs and ALEs may be important for optimizing health and supporting a longer lifespan.

In human and animal studies, restricting dietary intake of AGEs has resulted in decreased levels of AGEs in the blood in conjunction with decreased markers of inflammation and stress (oxidative). This can be achieved by minimizing the consumption of processed foods with added AGEs and also restricting the use of high temperature cooking methods such as barbecuing, broiling, deep-frying, baking and roasting, and instead cooking foods with methods that employ lower temperatures such as boiling, poaching, stewing, and steaming. Cooking for long periods of time and/or at temperatures over 120°C (~248°F) significantly increase these reactions and

thus the formation of AGEs and ALEs. Accumulating evidence suggests that the average Western diet supplies a considerable quantity of AGEs. AGEs may even be added to processed foods by food manufacturers who are looking to enhance flavor and achieve a more desirable brown color. Donuts, cakes, dark colored soda pops, processed breads and crackers are just some of the processed foods that may have added AGEs present in them. AGEs may also occur in processed foods such as pasteurized dairy products, cheeses, sausages, processed meats, and commercial breakfast cereals due to the high-temperature processing involved in their production.

While the evidence clearly reveals the deleterious effects of consuming high amounts of AGEs and ALEs, it does not help to explain why AGEs, ALEs and other products of the browning so called "Maillard " reactions are so pleasing to the human taste buds. As already mentioned, food manufacturers have long used the flavor enhancing qualities of Maillard products including the AGEs, adding them to processed food products in order to increase their appeal in taste and color. While there is no definitive answer as to why these products, some of which are toxic, taste so good, some have hypothesized that our attraction to this class of compounds is rooted in the evolutionary benefits of consuming cooked food. In other words, while these compounds can have negative effects upon the body that would likely cause considerable harm if ingested in high amounts over time, somewhere along our evolutionary path these compounds also came to indicate that a food was in a sufficiently cooked, more easily digestible state, free from parasites, bacteria, and plant toxins.

Some new research has even revealed potential ways in which the human body may break down and detoxify dietary AGEs, suggesting that humans may have evolved ways of dealing with these toxins. Nevertheless, the amount of AGEs present in processed and fast foods of the Western diet may be more than the human body evolved to handle, resulting in a toxic overload that would contribute to inflammation, aging, and the development of a myriad of diseases. Thus, while these compounds may have once helped to direct us towards the most energy-rich and digestible foods, in our modern world where AGEs are much more widespread and abundant thanks to our high heat cooking and processing methods, our attraction to them may prove to be an evolutionary disadvantage that causes us to ingest greater amounts of AGEs than we evolved to be able to detoxify.

Subjecting protein to high temperatures can also result in the generation of other toxic chemicals such as heterocyclic polycarbon compounds that may support the development of cancer.

COOKING FATS

In the process of cooking, fat is subjected to the elements of air, fire (or heat) and water which alter its chemical composition. These chemical changes may be both favorable in their promotion of lipid digestion and human health as well as unfavorable due to the formation of toxic and potentially even disease causing chemicals within the fat.

Cooking may facilitate the digestion and absorption of lipids by transforming solid fat into liquid oil that can more easily be emulsified and dispersed into smaller fat globules with greater surface areas for the body's digestive enzymes (proteins) to act upon. Some scientists suspect that the heat from cooking may decrease the energy required to digest fat by warming the fat to body temperature or above so that the body does not have to expend energy to do so. However, this theory still remains to be tested.

Moisture from the food being cooked or from the method of cooking (i.e. boiling, stewing etc.) can also support the digestion of lipids by breaking apart the triglycerides and releasing their fatty acids in the same way the body's digestive enzyme lipase does in order to prepare the lipids for intestinal absorption. The combination of moisture and heat underlie this process formally termed hydrolysis, turning water molecules into reactive species that readily break the bonds joining the fatty acids to glycerol, the triglyceride backbone. Fatty acids are removed one at a time, producing modified triglycerides that contain one or two fatty acids. Eventually, hydrolysis transforms these modified triglycerides into free fatty acids and glycerol. Thus this process essentially acts to predigest fats, releasing the fatty acids from the glycerol backbone just as they are done by the digestive enzyme lipase in the gut.

While the liberated free fatty acids may be readily digested in their pure form, they may also be modified further by heat and oxygen from the air and in the food. These alterations to the free fatty acids are generally less favorable, often leading to the creation of toxic forms that are not easily digested and can cause great harm to the body. Thus, besides the positive effects cooking may have on the digestibility and absorption of fat already mentioned, the application of heat and the exposure to oxygen can have many negative effects upon fat, decreasing its digestibility and nutritional value, and in some cases, drastically increasing its potential to do harm upon the body.

Even without the application of heat, oxygen has the ability to modify fatty acids in a process known as oxidation. With heat, however, the rate of oxidation is greatly increased. The more unsaturated (the more double bonds) an oil has, the more susceptible it is to modification by oxygen. This is because oxygen atoms can easily attach to the double bonds on fatty acids. When they do, they form highly reactive species called free radicals such as peroxides and superoxides that will attack other lipids, further creating a range of oxidized lipid products including aldehydes, ketones, and lactones among others. Together these compounds contribute to the flavor of fried foods but are also difficult to digest, potentially toxic and over time may even cause disease if they are regularly consumed in considerable amounts.

Some lipid oxidation products can even inhibit immune system activity, change genetic material such as DNA, potentially promote the formation of tumors, and also the development of cancer. Higher amounts of the oxidized highly reactive free radicals hydroperoxides may cause symptoms of vitamin E and essential fatty acid deficiency. Furthermore, it has recently been observed that high intakes of oxidized lipid products lead to greater levels of oxidized fats in the blood that may then react with certain proteins in the blood and in the walls of the blood vessels to form atherosclerotic plaques. Similar deposits of plaque may also form in the nerve tissue as

well as the vital organs. Cholesterol, a type of lipid found in animal foods including meat, can also be oxidized from cooking, and can promote the development of atherosclerotic plaques, cancer, tumors, and also inhibit the immune system similar to other oxidized lipid products.

Fats or oils heated for longer periods of time and/or to very high temperatures, especially those that range around or above the temperature at which the fat or oil begins to smoke, will form greater amounts of unhealthy oxidized lipid compounds. The toxicity of oils is proportional to the concentration of the free radical peroxides and other lipid oxidation products. While relatively low levels of these toxins may not manifest in any symptoms or diseased states immediately, a large body of scientific evidence is now drawing light to the many negative effects that can occur with ingesting these toxins over time. In animal studies, diets containing extremely high levels of oxidized lipids obtained from heating oil at high temperatures for very prolonged periods (as in a few days) resulted in rapid death. While this is an extreme condition, it does highlight the potential degree of toxicity found in these modified lipids.

Overall, the lesson that should be drawn from the research on the effects of cooking on fat is that oil should be cooked at low temperatures and should not be stored or reused at a later date. Also, when choosing which oil to cook with, it is important to keep in mind that polyunsaturated fatty acid oils (i.e. corn, safflower oils) will oxidize more easily, forming more free radicals and other potential unhealthy substances than are formed when cooking with monounsaturated fatty acid oils such as olive oil. Thus, cooking with olive oil is a safer and healthier choice.

VITAMINS AND MINERALS

While cooking may increase the availability of the energetic components of food (i.e. the macronutrients - carbohydrates, proteins, and lipids), cooking of any form inevitably results in a loss of vitamins and minerals. The extent and nature of these losses is dependent upon the type of heat applied (moist or dry) and the intensity of the heat used. Cooking methods involving dry heat utilize higher temperatures than are used with moist heat cooking methods such as boiling or stewing. Thus, cooking by way of dry heat has a more dramatic effect upon those vitamins susceptible to heat's effects.

The most heat sensitive vitamins include vitamin C, thiamin (B1), and riboflavin (B2). Other B vitamins including folic acid (B9) and vitamin B6 are particularly susceptible to destruction by heat in the presence of air (i.e. oxygen). Vitamin B12 may be more stable at normal cooking temperatures, but is easily lost when exposed to higher temperatures. Vitamin A may also be damaged at very high temperatures, despite being rendered more digestible by the heat applied with normal cooking temperatures, especially when cooked with a source of lipid. Vitamin E is slightly more resistant to destruction at high temperatures, but is not entirely immune, and will be slowly destroyed if subjected to high temperatures over time. All together, all vitamins are affected to some extent by cooking with dry heat. The fat soluble vitamins (A,D,E,K), however, are only affected a little until frying temperatures are reached. On average, 20% of the B vitamins present in meat are lost when meat is cooked by dry heat methods such as roasting or grilling. Minerals, on the other hand, are generally stable in the presence of dry heat.

Moist heat involves lower temperatures that may be less likely to destroy vitamins, but the application of moist heat causes vitamins to be released from the food into the cooking liquid. If this liquid is discarded, these vitamins will be lost. Of course, if the medium is consumed with the food being cooked, the vitamins are not lost and are still ingested. Water soluble vitamins such as vitamin C and the B vitamins are particularly prone to leaching into the cooking liquid. One study showed that 22% of the folic acid in asparagus and 84% present in cauliflower leached into the cooking water when boiled. All together, vitamin losses from stewing and boiling meat range somewhere between 20-60%. Significant amounts of minerals such as magnesium can also leach into the cooking liquid during boiling and other moist heat methods.

Boiling involves higher temperatures than stewing which simmers food in hot water kept at a temperature below the boiling point. The higher temperatures applied through boiling destroys considerable amounts of the water-soluble vitamins, particularly thiamin (B1) and vitamin C which are particularly vulnerable to destruction by heat. Estimates of the amount of thiamin and vitamin C lost range around one-third for thiamin and two-thirds for vitamin C depending upon the cooking conditions and the time in which the food is boiled. However, not all vitamins are destroyed by boiling. Boiling destroys very little if any of the vitamin A present in foods.

PLANT DEFENSES

"An added advantage of including meat in the diet is the high methionine content of animal protein (Milton 1999). This would provide an adequate supply of sulfur-containing amino acids that are necessary for the detoxification of toxic (cyanogenic) plant foods." (Aiello & Wells 2002).

DIGESTION

"Aiello & Wheeler(1995) also suggest that the change in the size and shape of the thorax and pelvis between australopithecines and *Homo ergaster* reflects a reduction in the size of the gut in *Homo ergaster*." (Aiello, Leslie C. & Wells, Jonathan C.K. p. 328).

"It is difficult to infer relative gut size for the hominids, because, unlike the brain, the gut is not encased in a bony capsule whose volume can be measured. However, certain features of the postcranial skeleton of WT-15000 (*H. ergaster*) suggest that this hominid had a smaller relative gut size (consistent with its higher level of encephalization) than did the australopithecines, represented by AL-288-I (*A. afarensis*). The large gut of the living pongids gives their bodies a somewhat pot-bellied appearance, lacking a discernible waist. This is because the rounded profile of the abdomen is continuous with that of the lower portion of the rib cage, which is shaped like an inverted funnel, and also because the lumbar region is relatively short (three to four lumbar vertebrae)...Pongid and australopithecine trunk morphology contrasts with that of modern humans. The barrel-shaped thoracic cage and relatively smaller pelvis of *H. sapiens* border a narrower abdominal region with a distinct waist absent in the trunk of apes. *H. ergaster* is the first known hominid to approximate modern human body proportions (Ruff and Walker 1993). The inference is that it most probably also had a relatively smaller gut." (Aiello & Wheeler 1995).

Nutritional Advantages of Meat and Changes to the Digestive System:

In review, we have seen some considerable reason to believe that Erectus increased his consumption of animal flesh, both the protein and the fat; and at the same time came to refine his foods even more through grinding, chopping and perhaps even soaking and fermenting, and most of all through cooking--which when all encapsulated together means his diet became radically more refined in many ways. With the addition of meat and fat, Erectus was eating food that was devoid of both toxins and fiber, making them therefore extremely dense in fats and proteins and easier to chew and digest. When cooked these foods, and especially the protein, is even easier to digest. Furthermore since these foods are so dense, they require less space in the gut, which allows the gut to shrink and since they are devoid of fiber, they need less space in the colon, allowing it to shrink. When plant foods are cooked, they become softer and more of their surface area is subject to digestive processes; and at the same, plant toxins are deactivated, sugars and proteins predigested. Naturally for starters, this allowed our mouth and teeth to shrink. Since we needed less space for digestion, our whole digestive system shrunk--and since we were consuming less fiber, our colon in particular shrunk. At the same time, we needed to procure less stomach acid and enzymes, meaning the organs that make these substances could shrink or at least require less energy. Furthermore various parts of our bodies would not need to fight off toxins as much as in the past. Rebecca Note: Cooking theoretically would reduce the pathogen load and therefore reduce the need for stomach acidity to kill pathogens. However, note that modern humans have low pH (1.5).

—Meat Consumption, particularly in the form of scavenging for carrion, could have put strong evolutionary pressure upon Homo to develop a more acidic stomach in order to avoid exposure to potentially lethal pathogens growing on the carrion and to support the digestion of meat proteins which requires a lower pH. Carnivores, especially those who are scavengers have the lowest pH (most acidic), which makes one wonder how successful of a scavenger a hominin with a higher pH (less acidic) would have been since they would have been unable to kill potentially lethal pathogens growing on carrion. Humans, at some point in their evolution, developed the more acidic stomachs present among modern humans today. Since a more acidic stomach is more costly to maintain, as the production of acid and the protection of the stomach lining from acid-related damage both require energy, a more acidic stomach would not have been acquired unless it provided a critical adaptive advantage.

“Human evolution and stomach pH- It is interesting to note that humans, uniquely among the primates so far considered, appear to have stomach pH values more akin to those of carrion feeders than to those of most carnivores and omnivores. In the absence of good data on the pH of other hominoids, it is difficult to predict when such an acidic environment evolved. Baboons (*Papio spp*) have been argued to exhibit the most human-like of feeding and foraging strategies in terms of eclectic omnivory, but their stomachs--while considered generally acidic (pH = 3.7)--do not exhibit the extremely low pH seen in modern humans (pH = 1.5) [38]. One explanation for such acidity may be that carrion feeding was more important in humans (and

more generally hominin) evolution than currently considered to be the case (although see [39]).” (Beasley et al. 2015).

“Comparisons of stomach acidity across trophic groups in mammal and bird taxa show that scavengers and carnivores have significantly higher stomach acidities compared to herbivores or carnivores feeding on phylogenetically distant prey such as insects or fish.” (Beasley et al. 2015).

“Because maintaining an acidic pH environment is costly, acidic stomachs should be present primarily in those cases where it is adaptive (or where it was adaptive in a recent ancestor). The cost of stomach acidity is twofold. The host must invest significant energy for both acid production and protecting the stomach from acid-related damage [17]. In addition, the acidity of the stomach may preclude, or at least make more difficult, chance acquisition of beneficial microbes. At the opposite extreme are those specialized herbivores in which stomach morphology is derived to include an alkaline chamber (forestomach or pre-saccus) that house microbes critical for fermenting a plant diet [18–22]. In these animals, an acidic stomach is not only of limited value (because the risk of foodborne pathogens in plant material is low), it may also remove those microbes that aid in the breakdown of plant material. Broadly then, we expect stomach acidity to mirror animal diets in ways that reflect pathogen risk.” (Beasley et al. 2015).

“Carrion has the potential to sustain high pathogen loads because the dead host’s body has stopped suppressing bacterial growth. Similarly, carnivores and omnivores would be expected to have higher stomach acidities than herbivores with specialized fermenting forestomachs because pathogens found in prey are more likely to be capable of infecting the predator than plant-associated microbes [23]. . .Based on the available data, our analysis illustrates a general pattern in which species feeding on carrion and animals have significantly higher stomach acidities compared to species feeding on insects, leaves, or fruit. . .Carnivores need more acidic stomachs in order to lyse the protein in their meat-based diets. For example, secretion of pepsinogen and its activation to pepsin in the stomach is modulated by an acid pH (2–4) [30]. Also, activity of proteases in a simple acid stomach depends on an acidic environment (pH 2–4) [31]. However, while this might explain differences between predators and herbivores, it does not account for the very high acidity in the stomachs of scavengers, especially considering that the meat consumed by scavengers is not likely to be much harder to digest than that of predators. We suggest that these scavengers rely on the high acidity of their stomach to prevent colonization of their guts by foodborne pathogens [32].” (Beasley et al. 2015).

METABOLISM

--foods more refined: (need to cover the nutrition of fruit with primates: then nutrition of seeds and roots to Australopithecus; note, too, that smaller primates, with their greater metabolism, consume seeds to support that metabolism)

LIKELY SCENARIO

These foods would actually be more refined as compared to the previous foods--the fruits and leaves of earlier Hominoids and extant primates--that is, richer in the three macronutrients--glucose, fatty acids and amino acids--thereby providing them with superior nutrition; in fact tubers and seeds are the most superior plants foods on earth. As we have seen, fruit for example consists mostly of glucose and some amount of the troubling sugar, fructose, and then considerable amounts of fiber; its collection of vitamins is not complete for humans; it contains more or less only one macro-mineral, out of the seven, in any meaningful amounts--that is, potassium--and is extremely low in all the others. While tubers may not be much superior to fruit, they nonetheless contain huge amounts of glucose, without any of the problematic, fructose--and otherwise are nutritionally similar to fruit. Seeds, as we have seen, are the most nutritionally dense plant foods on the planet; because in addition to containing large amounts of either starches (grains) or fatty acids (nuts and fatty seeds) for energy, they also provide good amounts of amino acids, as well as nearly every vitamin and mineral that our line of evolution needs for survival and especially for the production of ATP, and relatively smaller amounts of fiber as compared to other plants.

Additionally, since we were not fermenting as much fiber in the colon, we were getting more of our fuel, for the production of ATP, less from the ferments and more from sugars and fatty acids--which produce way more energy than the other.

In other words his nutrition improved astronomically; or said in our usual parlance, his diet became hyper-refined. But the paradox is that this happened even as his body was becoming larger, causing his basal metabolism to slow down. As we have seen with other primates, the larger their bodies the slower their basal metabolism and this rule, we know, applies to humans and therefore, by default, to Erectus. When the basal metabolism slows down, the primates, like Gorillas, can then eat a rougher diet, mostly consisting of leaves. But starting with Erectus, we broke the pattern; apart from not becoming rougher as it should if he followed the pattern, it also did not stay the same but became exponentially more refined, so much so that he was eating a diet that was as refined as the Capuchin--a primate about one tenth of his size, with his much racier basal metabolism.

We also should keep in mind, too, that as primates become larger, their protein requirements decline, at least relative to their mass. Or, in other words, even though we associate our evolution with meat-eating, and even though that association has some relevance, we do not have any reason to believe that Erectus or ourselves actually need more protein than Chimpanzees: we actually need less. Furthermore, protein can be problematic, too, in the sense that if more of it is eaten than the body needs, it can become potentially either harmful or at the least inefficient. Protein, too, can paradoxically increase metabolism, which could make Homo Erectus increasingly uncomfortable in tropical environments.

There are other ways, too, in which his basal metabolism may have slowed as well; as we have noted, his digestive system shrank, as compared to his predecessors, so he needed less energy there, especially considering that all these organs are "expensive," meaning they need way more energy to run, per mass, than other parts of the body. He may have reduced the

energy of his liver as well, since he did not need to detoxify as much (though studies show that the livers of Homo Sapien are about the same size as Chimps, adjusting for size). Rebecca Note: Just a thought, but Homo and modern humans may have needed to maintain liver size to support glucose synthesis for larger brains and for the metabolism of extra lipids in diet. Recall that in lipid metabolism, the liver plays a major role in orchestrating the packaging and distribution of lipids in the body. As we have seen, too, Chimps chew about five hours per day while Erectus probably greatly reduced the amount of energy here.

EXPENSIVE TISSUE HYPOTHESIS

So the question emerges: why did Erectus break this pattern about metabolism--and require more refined foods even while his basal metabolism and other metabolic needs were slowing. One explanation for sure is the larger brain. Like the liver and digestive organs, the brain is also expensive; in fact the most expensive of all the organs and requires about the same amount of energy whether it appears to be at rest or active, using most of that energy to create neuro-transmitters and to move ions (charged minerals) back and forth its cell membranes to create electrical activity. Earlier in this book, for example, we established that more encephalized primates, like the Spider Monkeys, Chimpanzee, Capuchin, Orangutang and others, tend to require more sugars in their diets to feed their brains whereas others eat more leaves. While most animals use three or four percent of their resting metabolism to fuel their brains. most primates, in contrast, use eight percent. But, Homo Erectus probably uses about fifteen to twenty-five percent; and we know Homo Sapien uses around twenty to twenty-five percent of their basal metabolism to feed their brain. Said another way, most mammals our size need three watts to run their brain; we need fifteen watts. In more direct terms, the primary or at least preferred source of fuel for the brain is glucose--and by extrapolation, we could guess that Erectus needed somewhere around 100 grams of glucose per day for his brain--about the equivalent of two potatoes or five slices of bread. This, of course, is a lot of energy in evolutionary terms. Or in other words, though the basal metabolism of Erectus was slowing, along with the metabolic needs of his other expensive tissues, the metabolism of his brain was increasing--

which definitely explains in part why his diet was more refined.

"The Expensive Tissue Hypothesis, published about fifteen years ago, attempts to explain the larger brain merely as the result of the smaller gut; or in other words, since the gut needs less energy, more energy can be devoted to the brain. Furthermore, they noticed the correlation which we have already discussed: that as guts become smaller, diets become more refined, and brains become larger. However, its important to note that while this pattern is indeed seen amongst primates, it is not consistent and perfect. "Therefore the increase in the mass of the human brain appears to be balanced by an almost identical reduction in the size of the gastro-intestinal tract." (p. 204)

Source for "Expensive Tissue Hypothesis": (Aiello & Wheeler 1995).

But we also need to explore whether it's the brain alone that consumed all that extra energy coming from the refined diet: Did Erectus increase his metabolism in other ways? Yes, likely. As we have noted basal metabolism just refers to the body at rest--but of course, if we spend the day couch surfing or hiking, we radically change our active metabolism, otherwise known as TEE.

In primates, this form of metabolism, called TEE, is correlated to their territory: the larger the territory, the more they travel, the more energy they expend and the higher their TEE. As we have seen, too, the larger the territory, generally the more refined or fruit-filled their diet. With Erectus we have many reasons to believe that his territory expanded, from his predecessors which may mean that his TEE became substantially higher, from locomotion and other activities. Of course, this could be counterbalanced by the fact that his locomotion was more efficient. I do not know if this is true--or contains any truth--but its possible that the larger and likely more active brain caused Erectus to become more active in other ways, perhaps through curiosity, socializing and tool making and other "cultural" activities. Its also possible that Erectus ate more protein which also would have raised his metabolism by as much as fifteen percent.

Evidence:

"A bioenergetics model is developed to examine changes in metabolic requirements over the course of human evolution. Data on (1) body size and resting metabolism, (2) brain size and metabolism, (3) activity budgets, and (4) foraging patterns for humans and other anthropoids are used to evaluate ecological correlates of variation in diet and energy expenditure. Analyses of variation in these extant species provide a framework for estimating (1) resting metabolic requirements, (2) brain metabolic needs, and (3) total energy requirements in fossil hominids. Anthropoid primates spend about 8% of resting metabolism to maintain their brains, a significantly larger proportion than in other mammals (3–4%), but still significantly less than 20–25% in humans. Total energy expenditure among anthropoids is positively correlated with day range and dietary quality. Human foragers fit this pattern, having high levels of energy expenditure, large foraging ranges, and a high quality diet. Within the fossil record, it appears that both total energy expenditure (TEE) and energy required by the brain increased substantially with the emergence of Homo erectus. For H. erectus, the percentage of resting metabolism used by the brain falls beyond the nonhuman primate range and approaches the modern human range. Additionally, TEE is 35–55% greater than in the australopithecines. The high total metabolic needs and the large proportion of energy required by the brain imply that important dietary changes occurred with H. erectus. These metabolic and dietary changes are linked to (1) the emergence of hunting and gathering, (2) the evolution of the human pattern of prolonged development, and (3) the coexistence and competition with the robust australopithecines." (Leonard & Robertson 1992).

NUTRIENTS FOR ENCEPHALIZATION

"From a nutritional perspective, what is extraordinary about our large brain is how much energy it consumes-- roughly 16 times as much as muscle tissue per unit weight. Yet although humans have much bigger brains relative to body weight than do other primates (three times larger than expected), the total resting energy requirements of the human body are no greater than those of any other mammal of the same size. We therefore use a much greater share of our daily energy budget to feed our voracious brains. In fact, at rest brain metabolism accounts for a whopping 20 to 25 percent of an adult human's energy needs-- far more than the 8 to 10 percent observed in nonhuman primates, and more still than the 3 to 5 percent allotted to the brain by other mammals.

By using estimates of hominid body size compiled by Henry M. McHenry of the University of California at Davis, Robertson and I have reconstructed the proportion of resting energy needs that would have been required to support the brains of our ancient ancestors. Our calculations suggest that a typical, 80- to 85-pound australopithecine with a brain size of 450 cubic centimeters would have devoted about 11 percent of its resting energy to the brain. For its part, *H. erectus*, which weighed in at 125 to 130 pounds and had a brain size of some 900 cubic centimeters, would have earmarked about 17 percent of its resting energy-- that is, about 260 out of 1,500 kilocalories a day--for the organ...brain expansion almost certainly could not have occurred until hominids adopted a diet sufficiently rich in calories and nutrients to meet the associated costs.

Comparative studies of living animals support that assertion. Across all primates, species with bigger brains dine on richer foods, and humans are the extreme example of this correlation, boasting the largest relative brain size and the choicest diet [see "Diet and Primate Evolution," by Katharine Milton; *Scientific American*, August 1993]. According to recent analyses by Loren Cordain of Colorado State University, contemporary hunter-gatherers derive, on average, 40 to 60 percent of their dietary energy from animal foods (meat, milk and other products). Modern chimps, in comparison, obtain only 5 to 7 percent of their calories from these comestibles. Animal foods are far denser in calories and nutrients than most plant foods. For example, 3.5 ounces of meat provides upward of 200 kilocalories. But the same amount of fruit provides only 50 to 100 kilocalories. And a comparable serving of foliage yields just 10 to 20 kilocalories. It stands to reason, then, that for early *Homo*, acquiring more gray matter meant seeking out more of the energy-dense fare...As to what prompted *Homo*'s initial shift toward the higher-quality diet necessary for brain growth, environmental change appears to have once more set the stage for evolutionary change. The continued desiccation of the African landscape limited the amount and variety of edible plant foods available to hominids. Those on the line leading to the robust australopithecines coped with this problem morphologically, evolving anatomical specializations that enabled them to subsist on more widely available, difficult-to-chew foods. *Homo* took a different path. As it turns out, the spread of grasslands also led to an increase in the relative abundance of grazing mammals such as antelope and gazelle, creating opportunities for hominids capable of exploiting them. *H. erectus* did just that, developing the first hunting-and-gathering economy in which game animals became a significant part of the diet and resources were shared among members of the foraging groups. Signs of this behavioral revolution are visible in the archaeological record, which shows an increase in animal bones at hominid sites during this period, along with evidence that the beasts were butchered using stone tools." (Leonard, W.R. 2002).

"Whereas brain metabolism accounts for 20%–25% of resting needs in adults, in an infant of under 10 kg, it uses upwards of 60% (Holliday, 1986)!...To accommodate the extraordinary energy demands of the developing infant brain, human infants are born with an ample supply of body fat (Kuzawa, 1998; Leonard et al., 2003). At ~15%–16% body fat, human infants have the highest body fat levels of any mammalian species (cf., Dewey et al., 1993; Kuzawa, 1998). Further, human infants continue to gain body fat during their early postnatal life. During the first year, healthy infants typically increase in fatness from about 16% to about 25% (see Table 1.4). Thus, the very high levels of adiposity seen in early human growth and development coincide

with the periods of greatest metabolic demand of the brain.” (Leonard, Snodgrass, & Robertson 2010).

“Improved dietary quality alone cannot explain why hominid brains grew, but it appears to have played a critical role in enabling that change. After the initial spurt in brain growth, diet and brain expansion probably interacted synergistically: bigger brains produced more complex social behavior, which led to further shifts in foraging tactics and improved diet, which in turn fostered additional brain evolution.” (Leonard, W.R. 2002).

PROTEIN

We have been using the word, "refined," thus far to refer to general qualities--but if we are making the claim, in part, that the more refined diet allowed Erectus to develop the larger brain. But what nutrients in particular? And what nutrients in particular does the brain need. Many researchers--in fact the bulk of them--have made the claim that it was "meat" that allowed for the emergence of the larger brain--but this claim does not ultimately make any sense, at least per se, given that the brain does not really need much meat or protein. As far as I can tell, there is nothing all that unusual about the protein requirements of the brain--and therefore more meat in the diet, either cooked or raw, would not have helped much, if at all. We should also note that frugivorous primates, not carnivores (with the one exception of dolphins) who have tend to develop larger brains.

Humans can catabolize protein only to meet 50 percent of their needs.

Rebecca Note: “Explanations for Homo's increase in relative brain size and abilities have focused on the energetic costs of large brains (Pontzer, 2012). There is a direct relationship between number of neurons and caloric requirements (Fonseco-Azevedo and Herculano-Houzel, 2012), a link that could possibly be related to protein calorie nutrition, as a lack of dietary protein has been shown to lead to a decrease in brain weight and in the protein content of the brain (Lucas and Campbell, 2000).” (DeLouize, Coolidge, & Wynn 2016).

There is also an interesting hypothesis that increased meat consumption supplied greater tyrosine, a precursor to the neurotransmitter dopamine, which may have supported the expansion of dopaminergic systems... “In addition to providing more energy, meat provides the precursors necessary for increases of dopamine in the brain, and increased dopamine has been shown to aid in thermoregulation, exercise, novelty-seeking behavior and exploratory behavior, increased visuospatial abilities, single integrated sleep periods and extended REM sleep, increased sociality (extraversion), and hand preference.” (DeLouize, Coolidge, & Wynn 2016).

“This increase in consumption of meat also provided the precursors necessary to significantly increase dopamine, a chemical neurotransmitter in the brain, and when combined with ecological pressures could have led to an expansion of dopaminergic systems. Previc (1999), appears to be the first to propose that this change in the hominin diet was the critical precursor to the expansion of the dopaminergic system that may have led to a revolutionary cascade of changes in later Homo cognition...Dopaminergic systems have been shown to be important to

essential modern human behaviors, particularly motor movements and cognition. In particular, it systemically and neurologically allows for thermoregulation, novelty seeking, sociality, handedness, increases in REM sleep, goal achievement and reward, behaviors that are thought to have arisen or increased during the grade shift that led to *Homo erectus* (Fig. 1)...Some aspects of the dopaminergic system, as well as complex traits that arise from such systems are only possessed by *Homo sapiens*. When comparing the human genome to the chimpanzees, the D5 dopamine receptor in humans has an unusually large number of DNA sequence changes, pointing to adaptive evolution (e.g., Somel et al., 2013).” (DeLouize, Coolidge, & Wynn 2016).

“Many studies have shown that dietary changes in protein and fat consumption lead to an increase in both dopamine, by converting tyrosine into the dopamine precursor levodopa, and to an increase in the expression of other dopamine related genes, including other dopamine receptors (Montgomery et al., 2003, Lee et al., 2010 and Vucetic et al., 2010) and increases in a dopaminergic phenotype (Harmer et al., 2001). Tyrosine can easily be turned into dopamine, using just two enzymes, tyrosine hydroxylase, and DOPA decarboxylase. The rate limiting step of this conversion is the hydroxylation of tyrosine, which depends on the availability of this amino acid (Fig. 2). Therefore a diet higher in tyrosine can create more dopamine...Thus, an increase in tyrosine, which is found readily in meat, could have led to an increase in dopaminergic systems by increasing dopamine, dopamine receptors, dopamine neurons, and dopaminergic pathways in the brain...Such epigenetic mechanisms are easily selected upon due to the fact that mothers who eat meat expose their embryos during gestation to higher levels of tyrosine which in turn leads to a greater synthesis and postsynaptic activity of dopamine in the central nervous system of their offspring (e.g., Santana et al., 1994 and Previc, 2009). Given that genetic mutations happen randomly and at a relatively fixed speed, epigenetic transmission is possibly a faster mode of transmission than genetics alone, allowing for a host of changes in a relatively short amount of evolutionary time, which appears the case between the australopithecines and *Homo*...Interestingly, another behavior that has been shown to increase dopamine levels in the brain is physical exercise...An increase in thermoregulatory functions and exercise performance might have provided some of the physiological traits necessary for the huge expansion of territories, often in disrupted environments, of *Homo erectus* near the beginning of the Pleistocene era...In addition, dopamine signaling in the hypothalamus and nigrostriatal pathway has long been shown to be associated with behaviors such as novelty-seeking and exploration (Cloninger, 1987)...Thus, there is sufficient evidence from animal models and in modern humans to suggest that increased dopaminergic signaling in *Homo erectus* could have provided and enhanced the behavioral traits that would have been needed to expand into and explore new territories...Along with other forms of working memory, dopamine has long been shown to be the key player in visuospatial working memory, which is the ability to update and reference visual and spatial information while performing a spatial task (e.g., Glickstein et al., 2002 and Reeves et al., 2005)...Dopamine has long been known to be associated with extraverted behavior (e.g., King et al., 1986 and McClelland et al., 1987).” (DeLouize, Coolidge, & Wynn 2016).

As for the fatty acids found in animal tissues, the issue is more complicated. First of all the brain greatly prefers glucose as its source of fuel. Secondly, it cannot burn fatty or amino acids as sources of fuel, unless they are first converted to either glucose or something called ketones--both of which require energy--and are therefore non-efficient. So, in conclusion, as a source of fuel, these fatty acids would not have provided any direct advantages to the brain as a source of fuel.

But Erectus could have used animal tissues to build his brain. The brain, indeed, is made mostly of fatty acids and other fatty compounds, cholesterol.

However most of the fatty acids found in the brain are rather rare in most animal tissues, except of course for their brain or eyes. For example, most of the fats in the brain are in the cell-membranes, which tend to be long chain fatty acids from these categories, with the least from the saturates, and next the monounsaturates and most from the Polyunsaturates from the Omega 3 family--which is one of the reasons why your nutritionists always tells you to eat your Omega 3's. While these are found to some degrees in the cell-walls of the flesh from terrestrial mammals, they are not found in much abundance there. It's also important to note that all these longer-chain fatty acids can be made from precursors from fatty acids found in plants, though perhaps not enough to optimize the development of the brain.

Brains, too, are extremely high in cholesterol--which is also found in animal flesh but in lower amounts--perhaps not enough to be of significance. Furthermore cholesterol appears to be readily manufactured in primates bodies from precursors--though there is probably some advantages in efficiency in getting these nutrients from the diet, rather than through the body having to make them.

However, all these fatty acids and cholesterol are found in most abundance in this order: the brains of other animals, shellfish and seafood. As we have noted, brains have been available as far back as the Chimpanzees--who appear to prize this food most of all from animals; and its likely that it stayed in the diet through all of the Hominoids. We do not necessarily have any reason to believe that Erectus was especially capable of harvesting shellfish, much more than his predecessors. It is conceivable that because Erectus was just, overall, much better in gathering animal foods, including brains, that he added way more of these nutrients to his diet--therefore creating some evolutionary advantage.

But in conclusion, there does not necessarily seem to be any direct correlation, in nutrition, between the eating of more animals and the development of the brain.

Author Notes: It is true that increased fat, with the exception of those essential long-chain poly's, would have not have directly provided the building materials for the brain. Though, another alternative perspective is that through fat's superior energetics, an increased intake of fat as a result of the consumption of more animal foods, raised early hominin's energy budget, and in doing so helped to break through the normal energetic limitations associated with large brains. In other words, by consuming greater amounts of fat from animal foods, early Homo may have

been able to cover more of its basic energetic needs, which in turn would have allowed for ingested glucose to be reserved for their expanding brains.

Also, while animal flesh (as in muscle, liver, intestines etc.) may not be a major source of the long-chain poly's, they do contain some—see chart below. One wonders if this small amount would be sufficient to support brain expansion—maybe there is some research on this?. While there is some evidence to suggest that Erectus may have at least occasionally exploited seafood when in coastal habitats, it does seem hard to imagine that seafood consumption alone fueled brain expansion, but when combined with the intake of some animal foods—well, maybe.

TABLE 1.3

Energy, Fat, Protein, AA, and DHA Contents of African Ruminant, Fish, and Wild Plant Foods per 100 g

Food Item	Energy (kcal)	Fat (g)	Protein (g)	AA (mg)	DHA (mg)
African ruminant (brain)	126	9.3	9.8	533	861
African ruminant (liver)	159	7.1	22.6	192	41
African ruminant (muscle)	113	2.1	22.7	152	10
African ruminant (fat)	745	82.3	1.0	20–180	Trace
African fish	119	4.5	18.8	270	549
Wild tuber/roots	96	0.5	2.0	0	0
Mixed wild plants	129	2.8	4.1	0	0

Source: Data derived from Cordain, L. et al., *World Rev. Nutr. Diet.* 90, 144, 2001.

(Leonard, Snodgrass, & Robertson 2010).

“In addition to the energetic benefits associated with greater meat consumption, it appears that such a dietary shift would have also provided increased levels of key fatty acids necessary for supporting the rapid hominid brain evolution (Cordain et al., 2001). Mammalian brain growth is dependent upon sufficient amounts of two LC-PUFAs: docosahexaenoic acid (DHA), and arachidonic acid (AA) (Crawford et al., 1999; Cordain et al., 2001). Because the composition of all mammalian brain tissue is similar with respect to these two fatty acids, species with higher levels of encephalization have greater requirements for DHA and AA (Crawford et al., 1999). It also appears that mammals have a limited capacity to synthesize these fatty acids from dietary precursors. Consequently, dietary sources of DHA and AA were likely limiting nutrients that constrained the evolution of larger brain size in many mammalian lineages (Crawford, 1992; Crawford et al., 1999).

Cordain et al. (2001) have demonstrated that wild plant foods available on the African savanna (e.g., tubers, nuts) contain only tiny amounts of AA and DHA, whereas muscle tissue and organ meat of wild African ruminants provide moderate to high levels of these key fatty acids. As

shown in Table 1.3, brain tissue is a rich source of both AA and DHA, whereas liver and muscle tissues are good sources of AA and moderate sources of DHA. Other good sources of AA and DHA are freshwater fish and shellfish (Broadhurst et al., 1998; Crawford et al., 1999). Cunnane and Crawford (2003) have suggested that the major increases in hominid encephalization were associated with systematic use of aquatic (marine, riverine, or lacustrine) resources. However, there is little archeological evidence for the systematic use of aquatic resources until much later in human evolution (see Klein, 1999)...Greater consumption of animal foods would have increased total dietary fat consumption in early Homo, and markedly increased the levels of key fatty acids (AA and DHA) necessary for brain development. Together the nutritional stability provided a critical foundation for fueling the energy demands of larger brain sizes.” (Leonard, Snodgrass, & Robertson 2010).

“Comparative analyses of primate dietary patterns indicate that the high costs of large human brains are supported, in part, by diets that are rich in energy and fat. Relative to other large-bodied apes, modern humans derive a much larger share of their dietary energy from fat. Among living primates, the relative proportion of metabolic energy allocated to the brain is positively correlated with dietary quality. Humans fall at the positive end of this relationship, having both a very high-quality diet and a large brain.” (Leonard, Snodgrass, & Robertson 2010).

CARBOHYDRATES

If any particular nutrient contributed to the expansion of the brain, it was likely glucose because that is the preferred fuel of the brain. We have already seen this pattern in primate evolution; as the more encephalized primates, including the Chimpanzee, need fruit in their diet to feed the demands of their brain for glucose. But as we know, fruit contains glucose and various amounts of fructose--the more inferior of the two--because fructose needs to be converted to glucose (Author: or lactate, or triglyceride) before it can be used in any way and, before then, can cause problems in the body. (Author: If fructose intake is excessive, and depending upon an individual's current metabolic state —i.e. whether in a state of energetic excess).

However starch is all glucose--and generally contains no fructose--and for that reason, is perhaps superior to fruit as fuel for the brain; it would at the least provide superior energetics. But as we have seen, hominoids likely started converting over to starch as far back as Australopithecus, with some of the C4 feeders, such as Bosei, getting much of their sugars from starches.

INTELLIGENCE

—Erectus' encephalization—

Regarding the size of their brains, there appears to be some considerable differences within the species, just as there are in modern humans; for example, on the low end, they seemed to have about the same size brain as early Homo, at around 800cc; on the high end, their brains seem about the same size as many modern humans, at 1250cc--but never as large as the brain of many Paleolithic humans which were typically about 1500 cc. In general scientists have concluded that from early Homo to Erectus, brain size increased about twenty to thirty

percent--which is about seventy percent of the size of humans. Perhaps we can conclude that Erectus was smart--but not quite as smart as most humans.

“Although the genus Homo semantically begins with the origins of habilines about 2.5 million years ago (Ma), there is a general consensus that a major grade shift occurred in hominin evolution beginning with Homo erectus about 1.9 Ma. The brain size of Homo erectus, about 900 cc to 1,000 cc, approaches the lower limits of modern Homo sapiens, about 1,000 cc to 2,000 cc (average = 1,350 cc).” (DeLouize, Coolidge, & Wynn 2016).

“According to the fossil record, the australopithecines never became much brainier than living apes, showing only a modest increase in brain size, from around 400 cubic centimeters four million years ago to 500 cubic centimeters two million years later. Homo brain sizes, in contrast, ballooned from 600 cubic centimeters in H. habilis some two million years ago up to 900 cubic centimeters in early H. erectus just 300,000 years later. The H. erectus brain did not attain modern human proportions (1,350 cubic centimeters on average), but it exceeded that of living nonhuman primates.” (Leonard, W.R. 2002).

“In addition, although the habilines are associated with the first stone tools, the stone tools of Homo erectus are thought to be more sophisticated technically, cognitively, and aesthetically (e.g., Wynn, 1989, 2002). Their bifacial and symmetrical design was to persist for the next million years and more. More critical, especially in terms of the evolution of modern cognitive abilities, may have been the full transition of Homo erectus to life on the ground instead of a life in trees. Coolidge and Wynn (2009) proposed that modern human cognitive abilities appear to have evolved in two major leaps (Coolidge and Wynn, 2006) with the first being the advent of Homo erectus, which is marked behaviorally by an expansion of territories, responses to ecosystem change, increased sociality, and increases in spatial cognition (e.g., Anton, 2003).” (DeLouize, Coolidge, & Wynn 2016).

“...as the progression from Homo habilis to Homo erectus was accompanied by a doubling of cranial capacity—from about 550 cc to 1,000 cc to 1,100 cc. The dome of the cranium rose, and the face flattened to accommodate expansion of the frontal, temporal, and parietal lobes of the brain. Homo erectus also provides the first evidence of brain laterality—a differentiation in size between right and left brain hemispheres—which is associated with handedness and communicative abilities (Donald 1991). Rather than the crude stone choppers of the Oldawan culture, the Acheulean tool kit evinced considerable manual dexterity (which goes along with handedness). Tools now consist of symmetrically shaped, carefully worked hand axes, cleavers, and knives with sharper and more effective cutting surfaces.” (Massey 2002).

SOCIAL DYNAMICS

Increased Intelligence also would have aided in maneuvering through increasingly complex social interactions:

“Humphrey (1976) was one of the first to note that complex social interactions may be correlated with humans' broad range of problem solving abilities, including the Machiavellian

theory of intelligence (e.g., Byrne and Whiten, 1988). Machiavellian intelligence is thought to be required to successfully navigate complex polyadic relationships, in which one must keep track of numerous players, each having their own agency and perceptions, and which must have been an integral part of the evolution of human intelligence. Dunbar (1992) and others have found a correlation between group size and cortex size, which suggests that increased computational power is needed to navigate larger groups.” (DeLouize, Coolidge, & Wynn 2016).

It has been hypothesized that some changes to the brain may have played an important role in the development of human emotions, morality, and ultimately, group solidarity, all of which would have been critical to survival on the savanna.:

“Much more interesting are the measurements of the subcortical areas of the brains for great apes and humans. By reading down the columns, it is clear that human centers for emotions are, on average, twice as large as the same areas in great apes...the pattern in these and other subcortical areas of the brain is clear: they are larger and, equally significant, they look like they were wired up in a punctuated process of very rapid selection. It appears as if natural selection was grabbing onto any area of the brain responsible for emotional production, experience, and memory in order to increase the emotionality of hominins on the human line. Since the subcortical areas of the brain are older in an evolutionary sense and since the neo-cortex only began to grow substantially with *Homo habilis* 2.5 million years ago (to 500 cc or 125 cc larger than that evident among chimpanzees and, in all likelihood, humans and chimpanzee’s common ancestor) and reach the very bottom of the smallest human brains some 1.8–20 million years ago with *Homo erectus*, the growth of the neo-cortex is a rather late evolutionary adaptation. Long before the big jump in brain size to the human measure (some 1,200 cc), the subcortical areas of the brain appear to have been under selection for millions of years longer than the neo-cortex. Why should this be so? What did enhanced emotionality provide? The short answer is the capacity to forge emotionally charged social bonds that could increase group-level solidarity...An alternative was found for humans’ hominin ancestors; the rest of the terrestrial apes – certainly hundreds if not thousands of species – could not get sufficiently organized at the group level to survive the vicissitudes of the African savanna...

How did selection rewire the hominin brain to make our ancestors... more emotional? Probably the first breakthrough was to give hominins more neo-cortical control over emotions so that they would not become loud on the savanna when excited because a loud primate is on the savanna is soon a dead one. Indeed, some species of monkeys on the savanna march across open territory in virtual silence, indicating that this is a fitness enhancing capacity to control loud emotional outbursts that might attract predators or cause panic that would separate individuals from the group. Some of the wiring that makes the amygdala a conduit between the subcortical emotion centers and the prefrontal cortex – the brain structure from which control must come – may have this function of gaining control of emotional outbursts. Once this wiring was in place, the emotion centers could grow without increasing the loudness of emotional reactions to danger. With a wider array of emotions, it became possible to forge more nuanced bonds which would increase attachments to group structures and thus make apes more fit on the savanna. There was, however, one major obstacle to using emotions to forge social bonds. Three of the four primary emotions are negative (sadness, anger, and fear) and only one (satisfaction–happiness) is positive. Other candidates for primary emotions – that is emotions that are hard

wired and universal among primates and indeed all mammals – are also negative...Negative emotions work against solidarity. Anger invites counter-anger; sadness distances individuals rather than bringing them together; and fear makes individuals wary of each other. These are not the emotions of bonding; anger can be used to sanction but negative sanctions alone do not promote solidarity. Solidarity is built from the flow of positive emotions and from positive sanctions that generate such emotions, not from negative emotions. How, then, did natural selection get around the fact that most primary emotions from which all other emotions are built (Plutchik 1980, Turner 2000) are negative?

Overcoming this obstacle accounts, ultimately, for the evolution of morality. Morality depends upon experience of two key emotions: (1) guilt for having violated moral proscription and prescriptions and (2) shame for having not behaved competently and in accordance with expectations in situations...Morality cannot exist without guilt and, to a lesser extent, shame. Moreover, guilt and shame are powerful mechanisms of social control, in several ways. First, shame and guilt are very painful, shame more than guilt, to self and motivate individuals to behave morally and competently to avoid experiencing these emotions. They are motivated to become re-integrated in social structure and culture. Second, shame and guilt also cause individuals to monitor and sanction self for either conformity to, or deviation from, moral codes and morally charged situational expectations...Over millions of years, as these subcortical areas of the brain were rewired produce more varieties of primary emotions, then first-order elaborations, and finally second-order elaborations like shame and guilt, hominins and then humans could become increasingly moral. Shame and guilt were the last of the emotions critical to morality to evolve, and it appears that only humans experience these two emotions. Chimpanzees, our closest primate relative, do not appear to experience either (Boehm, n.d.), or if they do, they experience them with much less intensity than humans...With further growth in the brain, the cognitive capacities of hominids continued to grow as *Homo habilis* gave way to larger-brained *Homo erectus*, with brains in the 750–900 cc range. This increase in brain size set the stage for full-blown morality because, with an upper range of a brain that was close to the lower range for humans, emotions tagged more complex cognitions, emotional syntax may have increasingly been supplemented by other gestural syntaxes – voice calls and hand signals like those of American sign language for some deaf persons – to communicate more purely cognitive content that was, no doubt, emotionally valenced...There is little more to say than this: morality is embedded in human biology; it is not wholly a social constructed, or at least it is a construction that is not possible without the necessary wiring in the human brain. And, this wiring is the outcome of natural selection as it decisively moved the primate genome toward a species that was highly emotional, that could tag all cognitions with complex emotional valences, that could evaluate self as an object and arouse self-related emotions like shame, guilt, satisfaction, and pride when deviating from, or conforming to moral codes, and that did not have a wide variety of emotional reactions and sanctioning options in assessing the moral behaviors of others...But a species that uses emotions in formulating moral codes and in sanctioning conformity to these codes can easily destroy itself, as the history of warfare and genocide document...They allow us to be moral, but they allow for potential violence when definitions of morality vary. Righteous anger and needs for vengeance can rip societies apart; and as species armed with weapons of incredible power can become emotionally aroused in

ways that cause great destruction. This is why insects are likely to outlive us all, despite our grand social structures.”(Turner, J.H. 2010).

Was Erectus capable of art, perhaps in its most elemental form? A geometric, zig-zag engraving found on a mussel shell was doodled by Erectus 0.5 million years ago, representing the oldest abstract marking yet found. While it is impossible to define the etching as art without knowing the maker’s intent, attempts to replicate the engraving that has no gaps between turns revealed that a degree of purposefulness and dexterity would have been required. Whether or not it is classified as art, the simple engraving suggests that Erectus was capable of abstract thinking, and that the foundation for the impressive cave drawings later done by Homo sapiens may have been laid by the predecessor Erectus. Art in its most elemental form may not have been restricted to Homo sapiens nor was it confined to Africa.

“The manufacture of geometric engravings is generally interpreted as indicative of modern cognition and behaviour. Key questions in the debate on the origin of such behaviour are whether this innovation is restricted to Homo sapiens, and whether it has a uniquely African origin. Here we report on a fossil freshwater shell assemblage from the Hauptknochenschicht (‘main bone layer’) of Trinil (Java, Indonesia), the type locality of Homo erectus discovered by Eugene Dubois in 1891 (refs 2 and 3). In the Dubois collection (in the Naturalis museum, Leiden, The Netherlands) we found evidence for freshwater shellfish consumption by hominins, one unambiguous shell tool, and a shell with a geometric engraving. We dated sediment contained in the shells with $^{40}\text{Ar}/^{39}\text{Ar}$ and luminescence dating methods, obtaining a maximum age of 0.54 ± 0.10 million years and a minimum age of 0.43 ± 0.05 million years... Together, our data indicate that the engraving was made by Homo erectus, and that it is considerably older than the oldest geometric engravings described so far. Although it is at present not possible to assess the function or meaning of the engraved shell, this discovery suggests that engraving abstract patterns was in the realm of Asian Homo erectus cognition and neuromotor control.” (Joordens et al. 2015).

“One of the Pseudodon shells, specimen DUB1006-fL, displays a geometric pattern of grooves on the central part of the left valve (Fig. 2). The pattern consists, from posterior to anterior, of a zigzag line with three sharp turns producing an ‘M’ shape, a set of more superficial parallel lines, and a zigzag with two turns producing a mirrored ‘N’ shape. Our study of the morphology of the zigzags, internal morphology of the grooves, and differential roughness of the surrounding shell area demonstrates that the grooves were deliberately engraved and pre-date shell burial and weathering (Extended Data Fig. 5). Comparison with experimentally made grooves on a fossil Pseudodon fragment reveals that the Trinil grooves are most similar to the experimental grooves made with a shark tooth; these experimental grooves also feature an asymmetrical cross-section with one ridge and no striations inside the groove (Extended Data Fig. 6). We conclude that the grooves in DUB1006-fL were made with a pointed hard object, such as a fossil or a fresh shark tooth, present in the Trinil palaeoenvironment. The engraving was probably made on a fresh shell specimen still retaining its brown periostracum, which would have produced a striking pattern of white lines on a dark ‘canvas’. Experimental engraving of a fresh unionid shell revealed that considerable force is needed to penetrate the periostracum and

the underlying prismatic aragonite layers. If the engraving of DUB1006-fL only superficially affected the aragonite layers, lines may easily have disappeared through weathering after loss of the outer organic layer. In addition, substantial manual control is required to produce straight deep lines and sharp turns as on DUB1006-fL. There are no gaps between the lines at the turning points, suggesting that attention was paid to make a consistent pattern. Together with the morphological similarity of all grooves, this indicates that a single individual made the whole pattern in a single session with the same tool...Our discovery of an engraving on shell substrate is unexpected, because the earliest previously known undisputable engravings are at least 300,000 years younger.” (Joordens et al. 2015)

CULTURE

As Erectus became nearly human in his morphology and encephalization, he may also have done the same in culture. When attempting to reconstruct his culture, we should consider several factors. First of all, since sociability is correlated with intelligence, we can assume that as Erectus became more intelligent, he probably become more social in all sorts of ways; he for example may have expanded the size of his groups or befriended neighboring tribes, became more cooperative or any number of other possibilities. Secondly, we can also assume greater culture because he was making tools--and perhaps even collaboratively with other members of his tribe. Thirdly, we can assume that they took even more active roles in the raising of their children: in part because of their more efficient bipedalism, they had narrower openings in their pelvis, which means they could only squeeze babies through with brains about one third of the size they would be at maturity. For this reason, its quite likely that Erectus needed way more time to mature, while still being raised by his parents, perhaps nearly the same amount of time as we humans need, as compared to Chimps who typically wean and separate from their children within several years. This, in turn, would dramatically provide the opportunity for more culture to be developed and handed down from one generation to another. Fourthly, while the Australopithecus became more sexually dimorphic, the Erectus became less so, meaning the males were probably less dominant and competitive with each other and more equal with the females. Note: Patrilocal....

But when getting into the details of their culture, I want to consider two other issues that relate specifically to foodways: One is the division of labor, especially between the sexes, that arose with Erectus especially around the gathering and processing of food. And second is the way that cooking accentuated the need to share food amongst more individuals and even larger groups--both of which Erectus towards greater levels of cooperation, and perhaps even compassion--making him perhaps the first of the Hominoids to express greater levels of our own humanity. While the expansion of our intellect drove much of our evolution, it would not have accounted for much as a solitary species; in fact, we could not have survived on the plains of Africa: perhaps it's our ability to cooperate, to share, to even have compassion, that, as we shall, has helped us in the battle for existence.

MATING & CHILD REARING

“An increase in interpersonal engagement, affiliation, and agency all might have helped Homo erectus to establish mating networks because of their expanding territories (Coolidge and Wynn, 2009) and would have undoubtedly aided pair bonding, which may have arisen or increased in

prevalence during this time period (Aiello and Key, 2002; Coolidge and Wynn, 2009).” (DeLouize, Coolidge, & Wynn 2016).

“A further effect of the increased size of *Homo ergaster* mothers and hence offspring would have been the greater energy requirements during gestation and lactation...Aiello & Key (2002) demonstrate that the DEE for a lactating *Homo ergaster* female is about 45% higher than for a lactating australopithecus or paranthropus and almost 100% higher than for a non lactating and non gestating smaller-bodied hominin (Table 1)...Aiello & Key (2002) argue that the increased requirements could only have been attained through a radical shift in foraging strategy involving the dietary changes highlighted earlier in this paper including increased exploitation of both animal products and underground storage organs (O’Connell et al. 1999, Wrangham et al. 1999).

An important aspect of this is that the energetic costs of feeding dependent off- spring need not be met only by the mother. Hawkes and colleagues (1997a,b; 1998) have proposed the grandmother hypothesis, whereby postmenopausal women contribute to the parenting of their daughter’s offspring. An increased level of paternal care, possibly mediated by changes in the stability of the parental pair bond, represents another potential source of energy for parental investment (Key 1998, 1999; Key & Aiello 1999, 2000; Kaplan et al. 2000). A recent analysis of data from the Gambia provided support for the grandmother hypothesis, showing that maternal grandmothers had a significant effect on offspring height (Sear et al. 2000). In contrast, the effect of paternal grandfathers and male kin on child height was negligible.” (Aiello & Wells 2002).

“The significance of this observation can be appreciated by comparing the estimated caloric requirements of a large-bodied *Homo erectus* female to those of smaller-bodied australopithecine females. An average *Homo erectus* female with a mass of 52.3 kg would have a DEE of approximately 1,815 kcal, which is 47% higher than the average DEE for the australopithecines and paranthropines. The DEE of *Homo erectus* is just within the range of variation for the average energy expenditures of lactating female australopithecines and paranthropus, which range from 1,634 kcal/d for *A. afarensis* to 1,827 kcal/d for *P. boisei* (Table 2). A *Homo erectus* female during the least energetically stressful period of her reproductive cycle would, therefore, have had higher energy demands than all but the heaviest paranthropus females during the most energetically stressful period, lactation. This implies that *Homo erectus* females would have required, on average, considerably more calories per day to survive and reproduce. *Homo erectus* females must have been eating more food, or eating food of higher quality, than their robust australopithecine counterparts. This increased caloric requirement probably had significant implications for all aspects of *Homo erectus* lifestyle that impinged on feeding strategy... The cost per infant to a *Homo erectus* female would, therefore, be about 40% more than the cost of an infant to an average australopithecine female...Irrespective of specific estimates of energy expenditure, it is difficult to avoid the general conclusion that an increase in body mass would have significantly increased the energetic requirements of reproduction for *Homo erectus* females...The problem for the *Homo erectus* female would have been the extra energetic burden of accessing these resources in sufficient quantities to support

herself, her gestating or lactating infant, and a dependent weanling. An economic division of labor whereby either females (Hawkes et al., 1997b, 1998; O'Connell et al., 1999) or males (Kaplan et al., 2000), or most probably both cooperated with the mother and supported her in a variety of ways that reduced her personal energy expenditure made short interbirth intervals an energetically viable reproductive strategy. The consequences of this strategy may well form the basis for modern human life history and modern human social organization based on cooperation and an economic division of labor between the sexes." (Aiello & Key 2002).

Besides enlisting the help of other females, male cooperation may have been key to Homo erectus females meeting their energetic needs for reproduction.: "Female female cooperation was selected for under conditions of high female energetic costs and, Key suggests that female cooperation would have been an important means by which Homo erectus females could have offset the high energetic burden of reproduction. However, under certain conditions males would cooperate with females...Applying the model of Key and Ross (1999) to the extinct hominins suggests that the increase in body mass and reduction in sexual dimorphism observed in Homo erectus would have had significant energetic costs for females compared with males. An increase in male cooperation to reduce the female's energetic burden would be an expected outcome of this situation. What advantages would males gain by helping females and their offspring? One possibility is that males, by contributing to the care of the female's children, are investing in their own inclusive fitness. This assumes that males have high paternity certainty. However, if Homo erectus lived in large multimale/multifemale groups (which is possible, given the high risk of predation in the open savannah environment; see Aiello and Dunbar, 1993), it seems unlikely that males would be able to guarantee the claim to fatherhood. Moreover, Key's model predicts that a mating probability of just 50% is enough to select for male cooperation, implying that inclusive fitness is not the primary advantage of this strategy. Rather, the model suggests that the two principal advantages that arise from male nonreciprocal altruism are 1) reduction of the interbirth interval, which increases the number of reproductively active females in the population at any one time; and 2) mating opportunities for the male (at least 50% of the time)...Although further study of this problem is warranted, male cooperation with females is in agreement with Smuts and Gubernick (1992) who found that male baboons form 'friendships' with females in order to increase their chance of mating rather than to invest in their own offspring. They are also in accord with the contention of Hawkes et al. (1997a,b, 1998) that in humans male hunting should be regarded as a display to attract mates rather than as a provisioning exercise...cooperation by males creates a win-win situation. Males gain valuable mating opportunities while females (and their offspring) gain much needed resources. Kaplan et al. (2000) have shown that in most hunter gatherer societies males provide at least half of the energy (and most of the protein) consumed by reproductive-age women and juveniles. On the basis of this finding, they argue that males play a major role in the energetics of human reproduction, particularly in providing large packets of high-energy, high-quality food items such as meat." (Aiello & Key 2002).

"A significant point that emerges from these models is that a change in reproductive strategy and social organization was essential if Homo erectus females were to

meet the increased energetic costs of maintaining larger body mass and caring for their large-brained, large-bodied infants. The changes in reproductive strategy involved shorter interbirth intervals, shorter lactation period, and a period of extrasomatic nursing where helpers could contribute to the energy requirements of the dependent weanling and possibly older dependent juveniles, thereby reducing the daily energy budget of the reproducing female.” (Aiello & Key 2002).

“...cooked food provided earlier weaning (Wrangham 2009).”

“The decline in sexual dimorphism [with Erectus] and the need to care for large-brained children who were helpless in infancy, vulnerable in childhood, and dependent through adolescence produced a radical change in human social structure and mating patterns (Ellison 2001). It was probably during this era that the human practice of pair bonding appeared, accompanied by a decline in intermale conflict, the disappearance of rigid dominance hierarchies, and a growing investment by fathers of their time and resources for the benefit of their mates and children (Lovejoy 1980). Male commitment to pair bonding was reinforced (though not guaranteed) by an entirely new reproductive biology, in which females were continually sexually receptive, breasts were enlarged and displayed, and the timing of estrous was hidden.” (Massey 2002).

“We believe that *Homo erectus* (= *ergaster*), as it emerged at around 1.8 Ma, was a good candidate for having extensive allomaternal care for two major reasons. First, they were likely the first systematic hunters of large game (Foley and Lee 1991; Pobiner et al. 2008). Large-game hunting requires cooperation during the hunt, cooperative defense against other dangerous carnivores, extremely high tolerance around kills, and frequent food sharing, perhaps even to the point of provisioning. These features are all more likely among cooperative breeders (van Schaik and Burkart 2010). Indeed, among mammals, carnivores are more likely to be cooperative breeders (Smith et al. 2012; Solomon and French 1997; Spencer-Booth 1970). Second, the weaned juveniles were less likely to make a living on their own and would have strongly benefited from allomaternal support. They lived on the savanna, where resources harvested as efficiently by juveniles as adults, such as soft fruits, are much scarcer than in forests (Hawkes et al. 1998), leading to reduced juvenile foraging efficiency. The latter is especially likely if they had already acquired a great reliance on meat (Domínguez-Rodrigo and Pickering 2003), because the difficulty of learning how to hunt means that provisioning meat has strong positive effects on the fitness prospects of the young. More seasonal habitats are more likely to contain cooperative breeders (Hatchwell 2007; Rubenstein and Lovette 2007). The argument is further supported by *H. erectus* (= *ergaster*) occupying a much larger geographic range than earlier hominin species. Hrdy (2005, 2009) has argued convincingly that colonizing hostile new habitats is facilitated by cooperative breeding...males were almost certainly involved in meat sharing and thus allomaternal care as soon as confrontational scavenging or hunting of large game was present (Marlowe 2007). In sum, while the brain size of *H. erectus* and various other indicators suggest that females of this species received much allomaternal care, we assume that male-female pair bonds accompanied by selective food sharing were sources of this care, but we can make no conclusions about the role of grandmothers.” (Isler & van Schaik 2012).

Meat acquired by *Erectus* males via hunting or scavenging would have provided critical nutrients, protein and fat for their offspring, but based upon the amount of meat obtained by modern hunter-gatherers—the Hadza—using modern weapons, meat could not have been acquired in sufficient amounts to satisfy the daily needs of children. Another food source such as underground storage organs would have also been required in order to support the increased energetic demand of *Erectus*' young growing brains.

Modern hunter-gatherer ethnography raises an important question: How often did the early humans responsible for these sites have access to large animal prey? Like all young primates, *H. ergaster* juveniles probably had to eat several times a day, every day. Like modern human children, they probably also relied on others to provide most of their food for years after weaning. The hunting hypothesis holds that early human males were the main source of this support, yet traditional East African hunters living in similar habitats today cannot meet this need, despite their use of sophisticated weapons. Though meat represents a sizable fraction of their families' annual caloric intake, it is not acquired reliably enough to satisfy the daily nutritional needs of their children. Unless *H. ergaster* was able to acquire the meat of large animals much more regularly than the modern Hadza, the sharp changes in diet, life history, and geography indicated by the fossil record must reflect increased access to some other food source." (O'Connell et al. 2012).

"Here we describe a nearly complete early Pleistocene adult female *H. erectus* pelvis from the Busidima Formation of Gona, Afar, Ethiopia. This obstetrically capacious pelvis demonstrates that pelvic shape in *H. erectus* was evolving in response to increasing fetal brain size." (Simpson et al. 2008).

"The modern human pelvis is uniquely modified to accommodate both bipedal locomotion and the birthing of large-brained offspring (1, 2). The earliest known fossil hominid adult pelvises are from small-bodied females (such as the 3.2-million-year-old *Australopithecus afarensis* specimen A.L. 288-1an/ao and the ~2.5- to 2.8-million-year-old *Au. africanus* specimen Sts14) that show anatomical adaptations to bipedal locomotion yet lack obstetric specializations... Here we describe a nearly complete early Pleistocene adult female *H. erectus* pelvis and last lumbar vertebra (BSN49/P27a-d)... the likely age of the fossil to 0.9 to 1.4 Ma (8)... The BSN49/P27 pelvis is obstetrically capacious for such a short-statured individual. The fossil's inlet circumference is within modern female ranges (8). The obstetrically important bispinous (pelvic midplane) and bitubercular (pelvic outlet) transverse breadths of BSN49/P27 are greater than in most modern females (Fig. 3) (8). Size-normalized comparisons and multivariate analyses of the pelvic inlet and midplane demonstrate the obstetrically derived shape of the BSN49/P27 birth canal (Fig. 3, C and D) (8)... It is now clear that the *H. erectus* pelvis retained many elements of its australopithecine heritage, although substantially modified by the demands of birthing large-brained offspring." (Simpson et al. 2008).

LIFE HISTORY

Analysis of enamel growth and dental development in early Homo and Erectus revealed that these early hominins had a shorter period of development than modern humans. Since dental development has been shown to be closely associated with certain life-history traits such as lifespan and age at first reproduction, these findings suggest that while Erectus nearly had the brain and body size of a modern human, this early hominin had not yet evolved to have the same slow level of development and life history as modern humans.:

“A modern human-like sequence of dental development, as a proxy for the pace of life history, is regarded as one of the diagnostic hallmarks of our own genus Homo^{1, 2, 3}. Brain size, age at first reproduction, lifespan and other life-history traits correlate tightly with dental development^{4, 5, 6}. Here we report differences in enamel growth that show the earliest fossils attributed to Homo do not resemble modern humans in their development. We used daily incremental markings in enamel to calculate rates of enamel formation in 13 fossil hominins and identified differences in this key determinant of tooth formation time. Neither australopiths nor fossils currently attributed to early Homo shared the slow trajectory of enamel growth typical of modern humans; rather, both resembled modern and fossil African apes. We then reconstructed tooth formation times in australopiths, in the 1.5-Myr-old Homo erectus skeleton from Nariokotome, Kenya⁷, and in another Homo erectus specimen, Sangiran S7-37 from Java⁸. These times were shorter than those in modern humans. It therefore seems likely that truly modern dental development emerged relatively late in human evolution...it now seems increasingly likely that a period of development truly like that of modern humans arose after the appearance of H. erectus, when both brain size and body size were well within the ranges known for modern humans.” (Dean et al. 2001).

“Representatives of H. erectus have been shown to display a shorter period of dental development, suggesting that a modern human growth pattern evolved more recently.” (Coqueugniot et al. 2004).

Analysis of the only well preserved skull of a Homo erectus infant revealed patterns of more rapid brain growth resembling that of great apes, and not that of modern humans who have a significantly slower rate of brain growth that continues long after birth, well into childhood. With a shorter period of brain growth after birth, Erectus would have had less direct contact with the environment during brain maturation. This likely would have prevented Erectus from developing the cognitive abilities of modern humans who through their reduced rate of brain growth have an extended period of brain development that occurs with environmental input.

“Humans differ from other primates in their significantly lengthened growth period. The persistence of a fetal pattern of brain growth after birth is another important feature of human development¹. Here we present the results of an analysis of the 1.8-million-year-old Mojokerto child (Perning 1, Java), the only well preserved skull of a Homo erectus infant, by computed tomography. Comparison with a large series of extant humans and chimpanzees indicates that this individual was about 1 yr (0–1.5 yr) old at death and had an endocranial capacity at 72–84% of an average adult H. erectus. This pattern of relative brain growth resembles that of living apes, but differs from that seen in extant humans. It implies that major differences in the

development of cognitive capabilities existed between *H. erectus* and anatomically modern humans.” (Coqueugniot et al. 2004).

“Another important aspect of human growth is 'secondary altriciality'. In most primates, brain growth slows down rapidly after birth¹ whereas hominids have to solve the evolutionary challenge of developing a large brain under substantial physiological, obstetrical and locomotor constraints³. An adaptive solution has been reached by giving birth to offspring with relatively small brains compared with adult brain size. Whereas *Macaca* newborns display an endocranial volume equivalent to 70% of adult size¹, the modern human brain represents only 25% of its adult size at birth and continues to grow at its fast fetal rate during the first year of life. At 1 yr of age the human brain is 50% of its adult size and at 10 yr 95% of the adult brain size is achieved. At birth, apes display an intermediate condition, with an endocranial volume approximately 40% of adult size in the common chimpanzee⁴, with 80% of the adult volume being reached by the end of the first year.

Secondary altriciality has social consequences: modern human children require many years of parental support. It also influences the development of cognitive abilities. Most of human brain growth takes place in an 'enriched environment', while the individual is already interacting with the extra-maternal environment. A prolonged interaction between peripheral somatic areas and developing related sensori-motor cortical areas could be one condition for the development of spoken language. When this important adaptation of the genus *Homo* appeared during the course of evolution has been much debated^{1, 2, 3, 8, 9, 10}. So far the fossil record has not provided clear evidence of when secondary altriciality developed. In this paper we address this question by analyzing the only well preserved brain case of a *H. erectus* infant...the various lines of evidence available on the Mojokerto calvaria more closely match an ape pattern of brain development rate than a modern human one (Fig. 3)...Although these results are based on the analysis of only one exceptionally preserved juvenile *H. erectus* skull, they suggest that secondary altriciality was established fairly late in the genus *Homo*, perhaps in the common ancestor of *Homo sapiens* and *Homo neanderthalensis*, which both displayed a very large brain and a reduced pelvic inlet size²⁶. These data also suggest that in *H. erectus* only a short period of brain maturation took place in the extra-maternal environment. This makes it unlikely that early *Homo* had cognitive skills comparable to those of modern humans, and it also implies that complex spoken language emerged relatively late in the course of human evolution.” (Coqueugniot et al. 2004).

“Humans are unusual among the hominoids in having a near identity in size between the neonatal head and the birth canal dimensions that places both mother and neonate at substantial risk of a traumatic birth. When these anatomical relationships in humans were used to estimate neonatal head size in *H. erectus*, it was seen that the BSN49/P27 pelvis was capable of birthing an offspring with estimated maximal brain volume of up to 315 ml (8)—over 30% greater than previously predicted from the KNM-WT 15000 pelvis (6), although this value is similar to growth-based estimates (20). Neonatal brain size was approximately 30 to 50% (the mean ratio is 34 to 36%) of early Pleistocene *H. erectus* adult brain size [~600 to 1067 ml (mean = 880 ml, n = 18 crania)] (21), an intermediate value between that of chimpanzees (~40%) and

modern humans (~28%) (20). This new estimate of *H. erectus* neonatal brain size, in tandem with the revised age at death (~0.5 to 1.5 years) of the child's cranium from Parning (Mojokerto), Indonesia (<1.81 Ma) (22), suggests that *H. erectus* had a prenatal brain growth rate similar to that of humans but a postnatal brain and somatic growth rate intermediate between that of chimpanzees and humans (23)." (Simpson et al. 2008).

"The young dental age, the older skeletal age and the apparent large body mass and stature of the Nariokotome youth show that a greater proportion of adult body mass and stature had been attained at an earlier age than would be expected for a modern human... To us, the most parsimonious explanation for this combination of facts is that the growth curve of early *Homo erectus* was more like that of modern chimpanzees. More specifically, whereas the precise growth curve of *Homo erectus* was likely unique, it apparently differed from ours in the direction of chimpanzees." (Dean & Smith 2009).

"A number of studies have found that *Homo erectus*, including KNM-WT 15000, does not share the primitive patterns of tooth formation observed in *Australopithecus* (Dean, 1987a; Beynon and Dean, 1988; Smith, 1986, 1993, 2004; Bermudez de Castro et al., 1999). *Homo erectus* shows the earliest clearly recognizable step towards a more human-like pattern of tooth maturation, particularly in early canine crown completion relative to other teeth. Even *Homo habilis*, judging from limited material, appears to echo *Australopithecus* in the pattern of synchrony of tooth maturation (Smith, 1993). This does not mean, however, that the pattern or sequence of tooth development is fully modern, indeed, the few juveniles we know share a tendency towards a more primitive pattern of dental development in which posterior teeth are slightly advanced compared to anterior teeth – i.e., when aged by human standards one consistently gets older ages for molars than incisors (e.g., see Table 10.2)." (Dean & Smith 2009).

GROUP SIZE

"*Homo erectus*'s increased brain size enabled another expansion in group size, to 90 to 120 individuals, yielding somewhere in the neighborhood of 6,000 dyadic relationships (N = 110)." (Massey 2002).

SEXUAL DIMORPHISM

Author: In *Erectus*, sexual dimorphism is thought to have decreased compared to earlier *Homo* but this is based upon limited sample size. Based upon the specimens available, there was a shift to greater female size that is not accompanied by an increase in male size. (Plavcan 2012).

Erectus— "...the size of *Homo erectus* became considerably more uniform (1.3 to 1.5 meters)—sexual dimorphism was reduced dramatically from a 60-percent male/female differential to one on the order of 15 percent, about the average for modern humans." (Massey 2002).

Author: Their sexual dimorphism became more like us as well. As we have seen, the best guess is that the sexual dimorphism of our common ancestor was probably about like the

Chimpanzees--that is, males were only a bit larger than the females. With Australopithecus, at least with certain species, the sexual dimorphism seemed to increase greatly. With early Homo, we do not have any evidence; but it is perhaps reasonable to assume that its middling between Australopithecus and Homo Erectus--or bit less than their predecessors. With Erectus, it appears that males were about twenty-five percent larger than the females; whereas with humans its more like only ten percent. GREATER COOPERATION

Most extant apes, as we already know, are sexually dimorphic; the males tend to be larger than females and, in the case of baboons, twice as large. We know that in the case of chimps—and probably other extant apes—they tend to control the female's access to meat. This, in turn, might play some part in keeping the females small. There is some debate, as mentioned, about the level of sexual dimorphism in previous hominids, such as australopithecus but, with the rise of Erectus, we know that women, relative to men, became larger—that is, there was a decrease in sexual dimorphism to level which are the same as modern man.

Why did this happen? Well, we can say that clearly evolution selected for women becoming larger; it evidently incurred some sort of advantage; certainly, for example, if women are larger, they can have better access to food which, in turn, might allow them to become more fertile and rear healthier, larger children. Larger women, too, would require more cooperation in a society, and less dominance, and cooperation would probably prove better for survival. Who knows?

(What are my own thoughts: Imagine the scenario that would make women larger to men.)

According to Wrangham, the dynamics worked this way—as food became more subject to being stolen by large, dominant males, the females learned to form relationships with males who could defend their claims to food. Males, being males, might not have been all that interested in this sort of relationship, namely monogomy, so the females needed to adapt to hold their attention for longer periods, primarily by extending their period of sexual attractiveness. Most female animals, in contrast, are only fertile for short periods of time during the year; the remainder of the year, the males are not attracted to them. (Quote from Wrangham's article—does not make any sense—need to review the article in full (quote also below): This would have increased the numbers of matings per pregnancy, reducing the intensity of male intrasexual competition. Consequently, there was reduced selection for males to be relatively large. This scenario is supported by the fossil record, which indicates that the relative body size of males fell only once in hominid evolution, around the time when H. erectus evolved. Therefore we suggest that cooking was responsible for the evolution of the unusual human social system in which pair bonds are embedded within multifemale, multimale communities and supported by strong mutual and frequently conflicting sexual interest.)

“Cooking is a human universal that must have had widespread effects on the nutrition, ecology, and social relationships of the species that invented it. The location and timing of its origins are unknown, but it should have left strong signals in the fossil record. We suggest that such signals are detectable at ca. 1.9 million years ago in the reduced digestive effort (e.g., smaller teeth) and increased supply of food energy (e.g., larger female body mass) of early Homo erectus. The adoption of cooking required delay of the consumption of food while it was accumulated

and/or brought to a processing area, and accumulations of food were valuable and stealable. Dominant (e.g., larger) individuals (typically male) were therefore able to scrounge from subordinate (e.g., smaller) individuals (typically female) instead of relying on their own foraging efforts. Because female fitness is limited by access to resources (particularly energetic resources), this dynamic would have favored females able to minimize losses to theft. To do so, we suggest, females formed protective relationships with male co-defenders. Males would have varied in their ability or willingness to engage effectively in this relationship, so females would have competed for the best food guards, partly by extending their period of sexual attractiveness. This would have increased the numbers of matings per pregnancy, reducing the intensity of male intrasexual competition. Consequently, there was reduced selection for males to be relatively large. This scenario is supported by the fossil record, which indicates that the relative body size of males fell only once in hominid evolution, around the time when *H. erectus* evolved. Therefore we suggest that cooking was responsible for the evolution of the unusual human social system in which pair bonds are embedded within multifemale, multimale communities and supported by strong mutual and frequently conflicting sexual interest.” (Wrangham, Jones, Laden, Pilbeam, & Conklin-Brittain 1999).

DIVISION OF LABOR

But we can also assume that greater division of labor between the sexes, as well as cooking, radically altered *Erectus* culture from his predecessors, creating societies that were ultimately based more on cooperation and sharing--all emerging mostly through the evolution of foodways.

“Here we present analyses of an unprecedented discovery of 1.5-million-year-old footprint assemblages, produced by 20+ *Homo erectus* individuals...Further, print size analyses suggest that these *H. erectus* individuals lived and moved in cooperative multi-male groups, offering direct evidence consistent with human-like social behaviors in *H. erectus*...The observation of multiple *H. erectus* males interacting in close physical and temporal proximity, and possibly even moving together, on these footprint surfaces provides the first direct evidence of hominin social group composition in deep time. Among primates, cooperative male-male alliances tend to form in situations where they can provide direct advantages for accessing mates or acquiring food resources³⁶. Because male-male alliances are observed in both modern humans and several modern nonhuman primates, the presence of this behavior itself in fossil hominins may be expected and unsurprising. However, the Ileret footprint surfaces offer the first opportunity to directly observe such behavior in the human fossil record.

In modern human hunter-gatherers, male-male cooperation is a key component of foraging particularly when hunting animals and subsequently sharing highly-valued meat resources¹⁵. Furthermore, foraging for large mammals is a high-risk strategy that may not be possible without some degree of provisioning by other individuals, often females, who typically pursue more predictably obtained foods¹⁶. The orientations of the hominin trackways compared to those of other animals suggests that the other animals moved to and from the water shore while hominins moved along it and, based on observations of human and other animal behavior along the modern shore of Lake Turkana, this scenario suggests the possibility that the hominins may have been foraging...Regardless of the exact behavior that was taking place, the data from multiple sites clearly show that groups of *H. erectus* individuals including multiple adult males

walked together on the same landscape. These data are at the very least consistent with hypotheses that *H. erectus* had a group composition and dynamic that could have supported the emergence of human-like social behaviors such as patterns of increased cooperation and sexually-divided foraging behavior. ” (Hatala et al. 2016).

Erectus males may have faced the dangers of scavenging meat from aggressive large predators in order to signal their status, as is done by both chimps and modern human foragers today.:

“In both chimpanzee and modern human foraging communities, males spend substantial time and effort on the difficult, dangerous and/or skill-intensive task of acquiring prey. Much of this behavior appears to be promoted by status rivalry (Hawkes & Bliege Bird, 2002). The hypothesis that early *Homo* used the scavenging opportunities presented by Pleistocene carnivores as an arena for display flows from this argument.”(O’Connell et al. 2002).

Most animals have some level of division of labor. In the case of ruminants, the male at least provides the sperm, and the female the egg, as well as some care and feeding afterwards for the baby but only for the first, few months before the baby wanders off to fend for itself. While males, too, will behave differently in females, especially around issues of territory, they nonetheless all do the same basic job: wandering around grazing on plentiful foods like grass and leaves.

As we move further up the food-chain, with wolves for example, we do not see any further distinction in the division of labor, between males and females: while mothers feed their young, both males and females hunt as well as protect their territory but, at the same time, wolves made distinction in the packs based on rank that does not seem directly related to any sort of labor.

With Chimpanzees, we start to see the development of greater division of labor between the sexes. They share the commonalities with the previous animals--that is, the mothers tend to the children but for a much more extended period of time. Also both males and females gather nearly all of their food in the same way, frequently in the same groups. But male chimps are way more prone to both hunt and protect their territories than their females, as well as have greater political control over the rest of the group. (Reason for this: longer gestation, etc) But at some point in human evolution, these divisions of labor, between the sexes, became greatly accentuated and changed as well in some ways and we have every reason to believe that it probably started with *Erectus*.

As we have seen, *Erectus* likely hunted more than his predecessors--which means that the males spent more of their time hunting rather than gathering. When we look at human, foraging societies, we see universal and strict divisions of labor between males hunting and protecting and females gathering and cooking; and its quite possible that these or some of these divisions started with *Erectus*. With *Erectus*, as the men started to hunt and protect more, the females were then forced to gather more, as well as tend to the children, as well as cook, so that they came to inhabit entirely different spheres of labor and even place for most of their day--divisions

of labor that continued through all of human prehistory and history, with the exception of modern times.

In any cases these divisions of labor would provide great advantages to our evolution through the usual ways: specialization. Since men were solely devoted to hunting, they could become better at that chore; and the same for women; and in the end, they would each provide for their families and tribes greater survivability than they would if they were all performing the same chores. At that point, evolution could then start designing each of them to perform these various chores better: men become stronger, women more flexible and better at multi-tasking and even recent studies in brain function and anatomy have suggested that men and women are designed for different ways of processing information--and therefore different chores.

--FIRE CHANGES CULTURE — Division of Labor

NOTES FROM WRANGHAM:

--cooking by women in 98 percent of societies with some exceptions

--men provide the protection in brawn and politics, women the food

Reasoning: cooking takes time, so other could locate

--and developed intense aversion to competition during feeding—but nothing like this in any other species, including primates where intense battles result for food—restraint is rare

--Strong morays around feeding: women are dedicated to providing food for their families, husband and children, though other kin may help and participate sometime—if others ask for food, not good, especially if bachelor looks for food from another man's wife—if food is ever shared between man and woman, considered married—so therefore the need for a wife, for survival, was terribly strong

--when men kill prey, the prey becomes communal

--you can see elements of this in the animal kingdom

--Male cultural superiority? as a result? (Wrangham 2009).

Cooking and sexual division:

-- do not need to chew as much: chimps six hours per day, humans about one hour including subsistence societies—we a fifth to a tenth of the time—also chimps and apes have to circulate between feed and rest, over and over—and as a result, cannot take the risk of devoting their time to hunting? not sure about that one....

--example of the Hadza: live in woodlands, like ancestors: 131

--men and women obtain different foods but eaten by both: universal: 99 percent of societies

men hunt: women collect from 57 to 16 percent of calories

--specialization increases skill

--men were stronger so naturally hunted

--this specialization, food sharing and hearth becomes the basis of the family and other are not allowed

--allowed eating after dark (Wrangham 2009).

HELPED THEM SHARE: animal and plant

more reliance
more dependence
pair bonding
father bonding to son

FOOD SHARING

Evolutionary forces, all the way through fir

Most animals do not share food at all, unless with their young. But other animals use some levels of sharing: take ruminants for example, they share their milk with their young and otherwise teach their babies, too, about certain kinds of food; and while they move through their terrain, they can alert others in the herd to the presence of food. But the cooperation stops there.

While wolves will cooperate with each other to hunt, they will become incredibly competitive and fierce in the eating of that food: the alphas feed first, followed by the betas, all with various levels of scowling and snarling, the likes of which you may have seen with your dog, if you ever tried to retake that piece of steak you threw his way. Furthermore, nearly all animals eat their food on the spot--that is, right there, without needing to delay their gratification.

CHIMPS

It was once thought that Chimps do not share food but recent studies have shown conclusively that they share both animal and plant foods. After male Chimpanzees hunt they will usually share the meat amongst themselves, with alphas having more priority--but then the food is frequently passed around somewhat amicably; and if that does not happen, some chimps will beg which seems somewhat effective based on observations. But overall, the males are more likely to share their meat with females of reproductive age and thorough studies have confirmed that the males then have greater sexual access to these females--thereby following the rule that we men all know: that if you want to up your chances of sex, buy your date some dinner, preferably someplace classy. However, it does appear that other researchers have found other motivations for the sharing of meat. Sources: (Gomes & Boesch 2009) & <https://www.mpg.de/592528/pressRelease20090408>

While jungle Chimps, such as the ones observed by Jane Goodall, do not share plant foods, those non-conformists, the Savannah Chimps, do. Researchers observed forty-one cases of these chimps sharing either wild plant foods or hunting tools; on twenty seven of those times, the transfer was from male to female, especially if they were in estrus, showing some further confirmation of the "dinner for sex theory." Source: (Pruetz & Lindshield 2011) & (Iowa State University 2011).

Sharing, on this level, likely continued all the way through Australopithecus into early Homo--but presumably with Erectus, it became greatly increased with the advent of cooking. We can also assume that Erectus expanded his food-sharing greatly, especially if our assumption is correct that there was greater division of labor amongst them.

To understand this concept, let's imagine a day in the life of Erectus. The men head out to hunt, and the women to gather but instead of consuming their food on the spot, without sharing, as do all nearly animals, they would need to delay their gratification and curtail their appetite--which in and of itself may have been one of the most important evolutionary leaps in our story, given that so much of what we humans do, as compared to other animals, is delay and control our gratification.

They would then transport the food they gathered back to camp, to the fire, at which point they would then donate the food they gathered into one, collective pool, likely to be shared amongst everyone. While the flesh from hunting from the men would provide protein and fats, the plants from the women would provide sugars and other nutrients. Once all the food was cooked, it would likely then be divided amongst everyone, according to some kind of system--essentially, shared.

“With the evolution of early *H. erectus* at 1.8 mya, we find evidence of an important adaptive shift—the evolution of the first hunting and gathering economy, characterized by greater consumption of animal foods, transport of food resources to “home bases,” and sharing of food within social groups.” (Leonard, Snodgrass, & Robertson 2010).

“In addition, the archaeological evidence indicates that butchered animals were transported back to a central location (home base) where the resources were shared within foraging groups (Potts, 1988a,b; Harris and Capaldo, 1993; Bunn, 2006).” (Leonard, Snodgrass, & Robertson 2010).

Naturally, this preference for food-sharing conforms to evolutionary theory: by sharing with their babies, mothers maximize their chance of propagating their genes into the future. By sharing with females, especially ones in Estrus, males maximize their chance of mating and the propagating of their genes. In some sense this is the origins of the human family. And we can assume that Erectus practiced these same behaviors as well.

"The Grandmother Hypothesis posits that *Homo ergaster* evolved in response to climate-driven changes in female-foraging and food-sharing practices. In brief, they argue that climate change decreased the availability of food sources easily accessible to children, such as soft fruits, making *Homo* more dependent on adult-access foods with high-processing costs (tubers, nuts, hard seeds), especially during the dry season. They argue that under such conditions there would have been selective advantages to behaviors such as tool use and social strategies such as food sharing. They suggest that selection pressures would also have favored longevity in postmenopausal females because, by analogy with Hadza and other human foragers today, females with reduced maternal burdens could have shared food with the group and raised inclusive fitness."(Sept, J. 2007 p. 294).

“Our hypothesis leads us to expect that life history changes in *Homo erectus* were driven by a decline in the availability of food resources easily taken by children (e.g., fruit). Such declines should generally be associated with long-term trends toward cooler, drier, more seasonal

climates. In tropical Africa, cooler, drier winters would have been especially critical: Plant foods accessible to humans are limited in this season, and those that are available (e.g. seeds, nuts, underground storage organs) typically have heavy processing costs, making them difficult for children to acquire and/or process to edible form."(O'Connell, James; Hawkes, Kristen; & Jones, Nicholas Blurton p. 57).

went out gathered food

delay gratification

bring back to central location: the hearth

then work together to process and cook that food

it's quite possible that the food that one Erectus gathered was thrown into the pot overall

and finally that food would need to be shared.....

leading to:

protection from freeloading, stealing, cheating, deception

leading to ideas of sharing, fairness, justice,

leading to greater cooperation and maybe other traits

empathy and consideration and etc.

But we can easily imagine how this system could become unfair through intimidation, freeloading, laziness, stealing, cheating, bullying--all traits that we still see in our modern societies--all traits, too, that are found throughout the animal kingdom and which, in fact, can provide evolutionary advantage. Even though our wall-street banks may resort to all of the traits listed above, to one extent or another, they may survive and prosper quite well while the rest of us, who abide by good, moral principals, do not. But even while all these behaviors may exist in nature, they must nonetheless be counterbalanced and kept in check, especially in humans and especially in Erectus, as we have come to learn to share his food amongst others. We are now of course delving into the world of morality and ethics--and all of our devices and institutions--that we use to enforce and propagate these ideas. And while these ideas may be handed down from God, and contain spiritual dimensions, it is clear that we can nonetheless find their origin in food-sharing and other evolutionary processes needed for survival and the propagation of the species and particular individuals.

With Erectus we can imagine all sorts of scenarios. Under the category of intimidation, we can easily imagine the larger and even alpha males might try to eat more than their share simply by intimidating the others, including the women and children. Truth is, this probably happened, as it does now in our own society--but it likely was only tolerated if there was some sort of fair exchange: for example, in exchange for a disproportionate share of the food, those alphas may need to provide superior protection from predators and other rival tribes. In fact if they did indeed provide that protection, the others would likely want them to stay better-fed to better keep them safer. As we know Chimps have alphas and we have reason to believe that those alphas get dibs on meat; but we also know that if those alphas do not perform their job well, the other chimps, including the females, will collectively do what we humans have been doing for generations: defrock him--therefore ensuring some protection from an excess of corruption. And its important to note that, if these systems ever fail, if one Erectus tribe emerged without these

proper checks and balances on excess unfairness and incompetence in their leaders, they would sooner or later be wiped, along with their genes, from the face of the earth.

They probably needed to focus on free-loading as well. While some of the men head out to hunt, another one decides to try to increase his reproductive chances by charming the women into some lovey-dovey down by the river. While the men were out persistence hunting all day, he was replicating his genes and, in the evening, he nonetheless came around expecting to be fed. Naturally, if this was allowed to happen persistently, this whole system of food-sharing would collapse, as other men were drawn to that same strategy until nobody was gathering food anymore. Furthermore the shyster/charmer gene would get replicated more than the hardworking/competent/hunter gene, until the whole tribe would eventually be decimated by another tribe that took another path. In other words, these moral principles we have around fairness may have been handed down from God; but they nonetheless have their grounding in Evolution.

We can easily imagine scenarios, too, where others through their catch into the collective pot, some chose, instead, to stash it away for their own selfish use, pretending that they were just unlucky that day. Or other scenarios where more impulsive adolescents, unable to control their hunger, tried to eat much of the food before it was fully prepared--like I did at that age.

CULTURE

Also, given that Erectus was using fire, his culture would automatically be transformed into new levels of cooperation, sharing and understanding. As we have already noted, Erectus would need to carefully manage his fires all the time, even during the harshest of times and conflicts--which would have required some considerable vigilance and planning beyond anything seen by his predecessors. But fires, too, would have brought them during the night into greater proximity with each other--thereby making them more sociable, although I doubt they were drumming, dancing, singing and story-telling just yet--all of which, in and of themselves, may have created greater levels of play and community.

Fire likely changed the culture of hominids as well. When hominids were eating foods raw, they were probably feeding as most chimps and gorillas—that is, foraging around and eating the food when discovered; certainly they cooperated with each other, through hunting and gathering strategies; however, generally whoever found the food also ate the food at that location. So the need for social customs and morays and relationships to govern food-sharing was less. However, we can imagine how life changed once hominids began to cook: they would gather their foods in the wild and then, instead of eating then and there, would haul the food back to their camp or cave. They would likely then grind or mash or peel or butcher the food in some way; at that point, they would likely wrap the food in some sort of container, such as animals skins or leaves, or place in some sort of container—then wait patiently as the food was cooked. In other words, once cooking started, we learned to be patient and delay our impulses, such as hunger, until appropriate—sort of nature’s way of operating like your mother to tell you to keep your hand away from the cookie jar before dinner. Also, as they gathered their food in one

location, they would encounter many problems, regarding sharing, labor and relationship, that would require some adaptations in their behavior.

Richard Wrangham, in his scientific article on the subject, wrestled with this idea. In his own scenario, he had concluded the Erectus was primarily eating tubers. However, what is important about his article to me is less the focus on tubers, but rather on the complexities of food-sharing. Animals generally compete for food; consider, for example, the snarling wolves as they devour their kill. So, as we can imagine, problems might have developed as hominids collected food in one area that required more adaptation in behavior. For example, as food collected in one area, it became subject to being stolen. One likely scenario is that the larger, more dominant individuals, the males, would have waited around lazily while the smaller individuals, the females, collected all the food—then used their strength to steal the food—thus essentially leaching on the efforts of others. This would be the case especially in sexually dimorphic societies—where males are substantially larger than females—thus allowing them the opportunity to control them better through force.

CARE FOR OTHERS

“The evidence for ‘care’ of others in archaic humans shows a particularly interesting patterning. The most well known early example of long term support for an incapacitated individual comes from KNM-ER 1808, a female *Homo ergaster* dated to around 1.5 mya (Cameron and Groves 2004). Examinations of the skeletal remains of this individual have led to suggestions that she was suffering from hypervitaminosis A, a disease caused by excessive intake of vitamin A. Symptoms of hypervitaminosis A include a reduction in bone density and the development of coarse bone growths, both of which are present in KNM-ER 1808’s skeletal pathology (Walker, Zimmerman and Leakey 1982, Walker and Shipman 1996, Cameron and Groves 2004). The pathology present would have taken weeks or even months to develop, accompanied by symptoms such as abdominal pain, nausea, headaches, dizziness, blurred vision, lethargy, loss of muscular coordination and impaired consciousness. Symptoms of this type would have greatly hindered this individual’s capacity for independent survival, yet she survived long enough for the disease to be identifiable in her skeletal pathology, something which only occurs in the advanced stages of hypervitaminosis (figure 2). A. Walker and Shipman suggest “someone else took care of her” (1996: 134), and Cameron and Groves note:

“There is no way she could have survived alone for long in the African savannah...someone must have been feeding her, protecting her from carnivores...The group dynamics of early *Homo* must have been based on some form of mutual support(2004: 158). A capacity for compassionate support by providing food for several weeks in early hominins extends beyond the rather fleeting compassion in other higher primates, and is confirmed by similar evidence elsewhere.” (2004: 158). An even earlier example of long term care comes from Dmanisi in Georgia, 1.77 million years ago (Lordkipanidze et al 2005), figure 3. One of the Dmanisi hominins had lost all but one tooth several years before death, with all the sockets except for the canine teeth having been re-absorbed. This individual could only have consumed soft plant or animal foods, necessitating support from others. Indeed, in reviewing all the documented lesions and non trivial pathologies in Lower and Middle Palaeolithic hominin specimens, a sample of more than twenty, Shang and Trinkaus (2008: 435) remark on at least some degree of survival from severe injuries in all cases.” (Spikins, Rutherford, & Needham 2010).

References

- Aiello, L.C. & Key, C. (2002). Energetic Consequences of Being a Homo erectus Female. *American Journal of Human Biology*. 14, 551-565.
- Aiello, L.C. & Wheeler, P. (1995). The Expensive-Tissue Hypothesis: The Brain and the Digestive System in Human and Primate Evolution. *Current Anthropology*. 36(2), 199-221.
- Aiello, L. C. & Wells, J.C. (2002). Energetics & the Evolution of the Genus Homo. *Annual Review of Anthropology*. 31(1), 323-338.
- Aiello, L.C. & Wheeler, P. (1995). The Expensive-Tissue Hypothesis: The Brain and the Digestive System in Human and Primate Evolution. *Current Anthropology*. 36(2), 199-221.
- Anderson, J.R. (2000). Sleep-related behavioral adaptations in free-ranging anthropoid primates. *Sleep Med Rev*. 4(4), 355-373.
- Barham, P. (2000). *The Science of Cooking*. Berlin, Heidelberg, & New York: Springer- Verlag.
- Beasley, D.E. et al. (2015). The Evolution of Stomach Acidity and Its Relevance to the Human Microbiome. *PLoS ONE*. 10(7), e0134116. doi: 10.1371/journal.pone.0134116
- Berna, F. et al. (2012). Microstratigraphic evidence of in situ fire in the Acheulean strata of Wonderwerk Cave, Northern Cape province, South Africa. *PNAS*. 109(20), E1215-E1220.
- Bramble, D.M. & Lieberman, D.E. (2004). Endurance running and the evolution of Homo. *Nature*. 432, 345-352.
- Braun, D.R. et al. (2010). Early hominin diet included diverse terrestrial and aquatic animals 1.95 Ma in East Turkana, Kenya. *PNAS*. 107(22), 10002– 10007, doi: 10.1073/pnas.1002181107.
- Bunn, H.T. & Gurtov, A.N. (2014). Prey mortality profiles indicate that Early Pleistocene Homo at Olduvai was an ambush predator. *Quaternary International*. 322-323, 44-53.
- Bunn, H.T. & Pickering, T.R. (2010). Bovid mortality profiles in paleoecological context falsify hypotheses of endurance running-hunting and passive scavenging by early Pleistocene hominins. *Quaternary Research*. 74, 395-404.
- Cerling, T.E. et al. (June 2013). Stable isotope-based diet reconstructions of Turkana Basin hominins. *PNAS*. 110(26), 10501-10506.

Control of fire by early humans. (2017 Jan 2). In Wikipedia, The Free Encyclopedia. Retrieved from https://en.wikipedia.org/w/index.php?title=Control_of_fire_by_early_humans&oldid=757934340

Coolidge, F.L., Wynn, T. (2006). The effects of the tree-to-ground sleep transition in the evolution of cognition in early Homo. *Before Farming*. 2006(4), 1-18.

Coqueugniot et al. (2004). Early brain growth in Homo erectus and implications for cognitive ability. *Nature*. 431(7006), 299-302. doi:10.1038/nature02852

Dean, C. (2001). Growth processes in teeth distinguish modern humans from Homo erectus and earlier hominins. *Nature*. 414(6864), 628-631. Doi: 10.1038/414628a

Dean, M.C. & Smith, B.H. (2009). Chapter 10. Growth and Development of the Nariokotome Youth, KNM-WT 15000. In F.E. Grine, J.G. Fleagle, R.E. Leakey. (Eds.), *The First Humans: Origin and Early Evolution of the Genus Homo*. Springer Science+Business Media.

DeLouize, A.M., Coolidge, F.L., Wynn, T. (2016). Dopaminergic systems expansion and the advent of Homo erectus. *Quaternary International*. doi: 10.1016/j.quaint.2015.10.123

Dixson, A.F. (2009). *Sexual Selection and the Origins of Human Mating Systems*. New York: Oxford University Press Inc.

Franks, D.D., & Turner, J.H. (Eds.). (2013). *Handbook of Neurosociology*. Dordrecht, Heidelberg, New York, London: Springer Science+Business Media.

George Washington University. (2013, June 26). How throwing made us human. *ScienceDaily*. Retrieved from www.sciencedaily.com/releases/2013/06/130626142710.htm

Gibbons, Ann. (2007). Food for Thought. *Science*. 316(5831), 1558-1560. doi: 10.1126/science.316.5831.1558

Gomes, CM. & Boesch, C. (2009). Wild Chimpanzees Exchange Meat for Sex on a Long-Term Basis. *PLoS ONE*. 4(4), e5116. doi: 10.1371/journal.pone.0005116

Goren-Inbar, N., Sharon, G., Melamed, Y., Kislev, M. (2001). Nuts, nut cracking, and pitted stones at Gesher Benot Ya'aqov, Israel. *PNAS*. 99(4). 2455-2460. doi: 10.1073/pnas.032570499

Hardy, K. et al. (2017). Diet and environment 1.2 million years ago revealed through analysis of dental calculus from Europe's oldest hominin at Sima del Elefante, Spain. *The Science of Nature*. 104(2). doi: 10.1007/s00114-016-1420-x

Hardy, K. et al. (2015). The Importance of Dietary Carbohydrate in Human Evolution. *The Quarterly Review of Biology*, 90(3), 251-268.

Harmand, S. et al. (2015). 3.3-million-year-old stone tools from Lomekwi 3, West Turkana, Kenya. *Nature*, 521. 310-315.

Hatala, K.G. et al. (2016). Footprints reveal direct evidence of group behavior and locomotion in *Homo erectus*. *Scientific reports*. 6.

Hill, A. (1983). Hippopotamus Butchery by *Homo erectus* at Olduvai. *Journal of Archaeological Science*. 10(2), 135-137.

Iowa State University. (Dec. 2011). Savanna chimps exhibit human-like-sharing behavior, anthropologists say. *Science Daily*. Retrieved from <https://www.sciencedaily.com/releases/2011/12/111201094819.htm:%20plant%20sharing>

Iowa State University. (2009, December 23). Wild chimps have a near human understanding of fire. *ScienceDaily*. Retrieved from www.sciencedaily.com/releases/2009/12/091222105312.htm

Isler, K., van Schaik, C.P. (2012). How our ancestors broke through the gray ceiling: Comparative evidence for cooperative breeding in early homo. *Current Anthropology*, 53(S6), S453-S465.

Joordens et al. (2015). *Homo erectus* at Trinil on Java used shells for tool production and engraving. *Nature*. 518, 228-231. doi:10.1038/nature13962

Joordens, J.C.A., Wesselingh, F.P., de Vos, J., Vonhof, H.B., Kroon, D. (2009). Relevance of aquatic environments for hominins: a case study from Trinil (Java, Indonesia). *Journal of Human Evolution*. 57, 656-671.

Kluger, J. (2016, March 9). Sorry Vegans: Here's How Meat-Eating Made Us Human. *Time*. Retrieved from <http://time.com/4252373/meat-eating-veganism-evolution/>

Koops, K. et al. (2012). Terrestrial Nest-Building by Wild Chimpanzees (*Pan troglodytes*): Implications for the Tree-to-Ground Sleep Transition in Early Hominins. *American Journal of Physical Anthropology*. 148, 351-361.

Leonard, W.R. (2002). Dietary Change was a Driving Force in Human Evolution. *Scientific American*. 287(6), 106-116.

Leonard, W.R. & Robertson, M.L. (1992). Nutritional requirements and human evolution: A bioenergetics model. *American Journal of Human Biology*. 4(2), 179-195.

Leonard, W.R., Snodgrass, J.J., & Robertson, M.L. (2010). Ch. 1 Evolutionary Perspectives on Fat Ingestion and Metabolism in Humans. In J.P. Montmayeur & J. le Coutre. (Eds.), *Fat Detection: Taste, Texture, and Post Ingestive Effects*. Boca Raton, FL: CRC Press/Taylor & Francis.

Liebenberg, L. (2006). Persistence Hunting by Modern Hunter-Gatherers. *Current Anthropology*. 47(6), 1017-1026.

Lieberman, D.E., Bramble, D.M., Raichlen, D.A., & Shea, J.J. (2009). Ch. 8 Brains, Brawn, and the Evolution of Human Endurance Running Capabilities. In F.E. Grine, J.G. Fleagle, R.E. Leakey. (Eds.), *The First Humans: Origin and Early Evolution of the Genus Homo*. Springer Science+Business Media.

Massey, D.S. (2002). A Brief History of Human Society: The Origin and Role of Emotion in Social Life. *American Sociological Review*. 67, 1-29.

Mora, R. & De la Torre, I. (2005). Percussion tools in Olduvai Beds I and II (Tanzania): Implications for early human activities. *Journal of Anthropological Archaeology*. 24, 179-192.

O'Connell, J.F., Hawkes, K., Lupo, K.D., & Blurton Jones, N.G. (2002). Male strategies and Plio-Pleistocene archaeology. *Journal of Human Evolution*. 43, 831-872.
doi:10.1006/jhev.2002.0604

O'Connell, J., Hawkes, K., & Jones, N. B.. (2002). Ch 5: Meat-Eating, Grandmothering, and the Evolution of Early Human Diets. In P.S. Ungar & Teaford, M.F. (Eds.), *Human Diet: Its Origin & Evolution*. Westport, Connecticut & London: Bergin & Garvey.

Pante, M.C. (2013). The larger mammal fossil assemblage from JK2, Bed III, Olduvai Gorge, Tanzania: implications for the feeding behavior of *Homo erectus*. *Journal of Human Evolution*. 64(1), 68-82.

Peters, C. R., & Vogel, J. C. (2005). Africa's wild C4 plant foods and possible early hominid diets. *Journal of Human Evolution*, 48(3), 219-236.

Plavcan, J.M. (2012). Body Size, Size Variation, and Sexual Size Dimorphism in Early Homo. *Current Anthropology*. 53(S6), pp. S409-S423.

Pontzer, H., Scott, J.R., Lordkipanidze, D., Ungar, P.S. (2011). Dental microwear texture analysis and diet in the Dmanisi hominins. *Journal of Human Evolution*. 61(6), 683-687. doi: 10.1016/j.jhevol.2011.08.006

Pope, M., Russel, K., Watson, K. (2006). Biface form and structured behaviour in the Acheulean. *Lithics: The Journal of the Lithic Studies Society*. 27, 44-57.

Pruetz, J.D., Lindshield, S. (2011). Plant-food and tool transfer among savanna chimpanzees at Fongoli, Senegal. *Primates*. doi: 10.1007/s10329-011-0287-x

Rabinovich, R., Gaudzinski-Windheuser, S., Goren-Inbar, N. (2008). Systematic butchering of fallow deer (*Dama*) at the early middle Pleistocene Acheulian site of Gesher Benot Ya'aqov (Israel). *Journal of Human Evolution*. 54(1), 134-149.

Roach, N.T. et al. (2016). Pleistocene footprints show intensive use of lake margin habitats by *Homo erectus* groups. *Scientific Reports*. 6.

Roach, N.T. et al. (2013). Elastic energy storage in the shoulder and the evolution of high-speed throwing in *Homo*. *Nature*, 498(7455), 483. doi: 10.1038/nature12267

Roach, N.T. & Richmond, B.G. (2015). Clavicle length, throwing performance and the reconstruction of the *Homo erectus* shoulder. *Journal of Human Evolution*. 80, 107-113.

Roebroeks, W. & Villa, P. (2011). On the earliest evidence for habitual use of fire in Europe. *PNAS*.108(13), 5209-5214. doi: 10.1073/pnas.1018116108

Sept, J. (2007). Ch 15: Modeling the Significance of Paleoenvironmental Context for Early Hominin Diets. In P.S. Ungar (Ed.), *Evolution of the Human Diet: The Known, the Unknown, and the Unknowable*. (pp. 413). New York, N.Y.: Oxford University Press, Inc. Print.

Shipman, P. & Walker, A. (1989). The costs of becoming a predator. *Journal of Human Evolution*. 18, 373-392.

Sikes, N.E. (1994). Early hominid habitat preferences in East Africa: Paleosol carbon isotopic evidence. *Journal of Human Evolution*. 27(1-3), 25-45.

Simpson, S. W. et al. (2008). A Female *Homo erectus* Pelvis from Gona, Ethiopia. *Science*. 322(5904), 1089-1092. doi: 10.1126/science.1163592

Smith, T.M. et al. (2012). Variation in Enamel Thickness within the Genus *Homo*. *Journal of Human Evolution*. 62(3), 395-411.

Spikins, P. A., Rutherford, H. E., & Needham, A. P. (2010). From homininity to humanity: Compassion from the earliest archaics to modern humans. *Time and Mind*, 3(3), 303-325.

Steel, T.E. (2010). A unique hominin menu dated to 1.95 million years ago. *PNAS*. 107(24), 10771–10772, doi: 10.1073/pnas.1005992107

Turner, J.H. (2010). Ch. 7. Natural Selection and the Evolution of Morality in Human Societies. In S. Hitlin & S. Vaisey (Eds.), *Handbook of the Sociology of Morality*. (p. 125-145). Springer Science+Business Media, LLC.

Ungar, P.S. (2012). Dental Evidence for the Reconstruction of Diet in African Early Homo. *Current Anthropology*. 53(S6), S318-S329.

Ungar, P.S. & Sponheimer, M. (2011). The Diets of Early Hominins. *Science*. 334(6053), 190-193. doi: 10.1126/science.1207701

Ungar, P.S., Grine, F.E., Teaford, M.F. (2006). Diet in Early Homo: A Review of the Evidence and a New Model of Adaptive Versatility. *Annual Review of Anthropology*. 35, 209-228. doi: 10.1146/annurev.anthro.35.081705.123153

Ungar, P.S., Grine, F.E., Teaford, M.F., & El Zaatari, S. (2006). Dental microwear and diets of African early Homo. *Journal of Human Evolution*. 50(1), 78-95.

University of Toronto. (2012, November 15). Archaeologists identify spear tips used in hunting a half-million years ago. *ScienceDaily*. Retrieved from www.sciencedaily.com/releases/2012/11/121115141540.htm

University of York. (2016 Dec 14). Raw foodies: Europe's earliest humans did not use fire. *ScienceDaily*. Retrieved from www.sciencedaily.com/releases/2016/12/161214212012.htm

van der Merwe, N.J., Masao, F.T., Bamford, M.K. (2008). Isotopic evidence for contrasting diets of early hominins *Homo habilis* and *Australopithecus boisei* of Tanzania. *South African Journal of Science*. 104(3-4).

Verhaegen, M. & Munro, S. (2011). Pachyosteosclerosis suggests archaic Homo frequently collected sessile littoral foods. *Journal of Comparative Human Biology*. 62(4), 237-247.

Wade, N. (2006). *Before the Dawn: Recovering the Lost History of Our Ancestors*. New York: The Penguin Press.

Wang, H., Ambrose, S.H., Jack Liu, C.L., Follmer, L.R. (1997). Paleosol Stable Isotope Evidence for Early Hominid Occupation of East Asian Temperate Environments. *Quaternary Research*. 48(2), 228-238.

Wilkins, J. et al. (2012). Evidence for Early Hafted Hunting Technology. *Science*, 942-946. doi: 10.1126/science.1227608

Wobber, V., Hare, B., & Wrangham, R. (2008). Great apes prefer cooked food. *Journal of Human Evolution*. 55, 340-348.

Wrangham, R. (2009). *Catching Fire: How Cooking Made Us Human*. London, UK: Profile Books Ltd.

Wrangham, R. W. & Carmody, R.N. (2010). Human adaptation to the control of fire. *Evolutionary Anthropology*. 19(5), 187–199.

Wrangham, R.W., Jones, J.H., Laden, G., Pilbeam, D., & Conklin-Brittain, N. (1999). The Raw and the Stolen. Cooking and the Ecology of Human Origins. *Current Anthropology*. 40(5), 567-594.

Yamagiwa, J. (2001). Factors influencing the formation of ground nests by eastern lowland gorillas in Kahuzi-Biega National Park: some evolutionary implications of nesting behavior. *Journal of Human Evolution*. 40(2), 99-109.

Zink, K.D. & Lieberman, D.E. (2016). Impact of meat and Lower Palaeolithic food processing techniques on chewing in humans. *Nature*. 531(7595), 500-503. doi:10.1038/nature16990

Zink, K.D., Lieberman, D.E., Lucas, P.W. (2014). Food material properties and early hominin processing techniques. *Journal of Human Evolution*. 77, 155-166.

Zutovski, K., & Barkai, R. (2016). The use of elephant bones for making Acheulian handaxes: A fresh look at old bones. *Quaternary International*. 406, 227-238.