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## The Evolution of the Human Diet

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May 5, 2010

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It is obvious that today's human diet is dramatically different from other living primates. What did our ancestors eat and how did their diet change with time? Based on trends in hominid brain size, number and characteristics of teeth, mandible biomechanics, as well as modern human health problems, I will attempt to trace back what factors shaped, and continue to shape, our diet.

When we look at the anatomy of the modern human, we find that the brain is quite large, and large brains are costly in energy. When compared with 33 living and nonliving primate species, humans have the highest relative brain size and highest quality diet. Also, human brain metabolism is 20-25% of the resting metabolic rate, while it is only 8-10% in other primate species. This shows that a disproportionately large amount of energy is sacrificed for the human brain. Large-bodied primates have long colons (large intestines) for fermenting plant fibers to gain fatty acids; humans have short colons and instead have long small intestines, as well as a smaller gut volume compared to body size. These human features are in fact more like carnivore intestines. Compared to other primates, humans have less muscle and more body fat. This allows more energy to feed the brain and less total energy cost to the rest of the body, such as with fat replacing energetically more expensive muscle. Human infants, much fatter than the infants of other mammals, have highest body fat around 12-18 months after birth, which then declines, showing that most fat is present when the metabolism of the brain needs it most. These facts show that humans are adapted to a nutritionally rich, high energy, easily digested diet which supports the cost of the brain's energy.(4)

What exactly are foods that give this energy? How are they different from what today's primates eat? Studies show that meat is highly valued by many primate species, but they cannot afford the energy and foraging time to get it often. Chimpanzees get 5-10% of calories from vertebrate food, while large primates such as gorillas eat lots of low quality foods (leaves, bark). Humans eat foods rich in calories and nutrients, of which they need a lower amount.(4)

How and when did we convert to such energetic food? Let us first look back into history. Over a period of 2 million years, the australopithecines had a relatively slow increase in brain size from 430 to 530 cm<sup>3</sup>. When the genus *Homo* emerged 2 to 1.7 mya, brain size rocketed from 600 cm<sup>3</sup> in *Homo Habilis*, to 980 cm<sup>3</sup> in *Homo Erectus*, to 1300-1400 cm<sup>3</sup> in *Homo Sapiens*. At the same time as this, the large back teeth seen in the australopithecines gradually became teeth with smaller surface area in the *Homo* species. Whereas the australopithecines had a trend in increasing numbers of back teeth, *H. habilis* had a reduction in number of back teeth. *H. habilis* was also probably the first to use stone tools, which could help in processing vertebrate meat.

**Table 2 Geological ages (millions of years ago), brain size (cm<sup>3</sup>), estimated male and female body weights (kg), and postcanine tooth surface areas (mm<sup>2</sup>) for selected fossil hominid species**

Species	Geological age (mya)	Brain size (cm <sup>3</sup> )	Body weight		Postcanine tooth surface area (mm <sup>2</sup> )
			Male (kg)	Female (kg)	
<i>A. afarensis</i>	3.9–3.0	438	45	29	460
<i>A. africanus</i>	3.0–2.4	452	41	30	516
<i>A. boisei</i>	2.3–1.4	521	49	34	756
<i>A. robustus</i>	1.9–1.4	530	40	32	588
<i>Homo habilis (sensu strictu)</i>	1.9–1.6	612	37	32	478
<i>H. erectus (early)</i>	1.8–1.5	863	66	54	377
<i>H. erectus (late)</i>	0.5–0.3	980	60	55	390
<i>H. sapiens</i>	0.4–0.0	1350	58	49	334

Table is from (4)

Looking at *H. Erectus*, which already had humanlike proportions and a smaller face, the brain increased at a greater proportion than the body size. The teeth and jaw size decreased (area of grinding teeth now only 390 mm<sup>2</sup>). Therefore *H. Erectus* was likely making major adaptations to an energy-rich diet! What can we tell from whether *H. Erectus* cooked its food? Using fire on savanna plant foods would soften them and make them able to be digested. When they are raw, root and tuber starches cannot be absorbed, but when cooked, starch granules burst from the cell wall, which our digestive enzymes can then access. However, the first cooking is estimated to be anywhere between 2 million and 200,000 years ago. (4, 5) What we do know is that with the small area of grinding teeth, now only 390 mm<sup>2</sup>, and large brain volume, *H. Erectus* was enjoying higher calorie foods. This was probably due to the climate getting drier, with therefore less forest and more grassland and woodland. High productivity of grazing animals in the grasslands led to a redistribution of food sources. In archaeology, this is the time that stone tools were found, and our ancestors became hunter-gatherers that took meat to a “home base” to be shared. Addition of more meat, and sharing it, made a higher quality and more stable diet. An argument that supports this theory is that for mammalian brain growth, docosahexanoic acid and arachidonic acid are needed, found in much greater quantities in African herbivores than in plant materials.(4)

What can we tell from tooth shape? Since tooth shape adapts to the characteristics of the food that is eaten, it could show important clues as to how diet was changing. What the teeth are capable of processing – the so-called shearing quotient (SQ) – shows that where teeth that have tall peaks and where the upper and lower jaw teeth fit into each other as convex and concave, tough food can be chewed like insect exoskeleton and leaves. Teeth that are more flat and round are better for a diet of fruit. *Australopithecus afarensis* had more concave/convex teeth than the later appearing *A. robustus*, showing a change in diet. However, all australopithecines had flat and very large molars compared to other primates, and without the tall crests seen in today’s primates. This suggests that they could not chew tough foods like seed coats or leaf stems and veins; what they could eat were hard foods like nuts and fruits, and soft foods like buds, flowers, and shoots. Another thing the early australopithecines could not eat was meat. Their teeth simply did not have the ability to cut such foods.(6)

Australopithecines also had thick enamels compared to living primates, which might indicate that they ate hard, abrasive foods. Another way to study the teeth, dental microwear, shows that *A. afarensis* stripped hard plant material and ate seeds, roots and rhizomes. Folivores (whose main food is leaves) have more long, narrow microwear scratches on the molars, while frugivores (main food is fruit) have more pits, especially those that feed on hard foods. *A. afarensis* has long, narrow, homogenous scratches, while *A. robustus* has more pits on their molars. Therefore, *A. robustus* ate smaller variety and less abrasive foods.(6)

The biomechanics of the jaw, specifically the size and shape, reveal hows the jaw was adapted to the stress that food put on it. The corpus of the mandible was very thick in the australopithecines compared to living primates. Since no relationship was found between the large molars or reduced canine teeth seen in australopithecines and jaw thickness, it probably shows the demands of chewing. It likely distributed stresses from side to side bending and especially twisting of the jaw, possible stresses being fibrous plant parts. So what can we conclude are some things that the australopithecines ate based on these data? Probably seeds that they could crush with their flat molars, and soft fruits they could process with the small incisors. Meat, leaves, and tough fruits were likely not on the menu. Despite common features in the australopithecines, gradual changes are also found, implicating a change in diet over time.(6)

What about modern human teeth? Our teeth are very disordered in contrast to other mammals, and especially wisdom teeth are missing or do not have space to grow. The human jaw is becoming too small to fit all of our teeth. The disproportion could be due to the different evolutionary influence on the front teeth and jaws compared to the back teeth. Because the front teeth cut food into small enough pieces to chew, the fast rate at which our hominid ancestors began to chop food with tools and cook them could have thrown the selective pressures of the front teeth out of balance with the molars. Since the job of the back teeth (molars and premolars) is to grind food, the theory is that the toughness of food had not changed as fast as the size of food. Our teeth are likely evolving to eat softer and softer foods.(5)

Could cereal grains, a major part of our diet, play a role in the tooth decay that plagues modern humans? According to Cordain, yes.(1) Studies indicate that when hunter-gatherer diets are replaced by cereals, there is an increase in the number of dental caries and enamel defects, reduction in stature, an increase in infant mortality, a reduction in lifespan, an increased incidence of infectious diseases, an increase in iron deficiency anemia, and increased bone mineral disorders.(1) *Homo Sapiens* only began to use cereal grains extensively at around 10,000 years ago. Since cereal grains are hard to digest without grinding and cooking, the appearance of stone tools like grindstones indicate the first uses of these grains. Technically, our diet should be more adapted to that of millions of years of evolution as opposed to that of the last 10,000 years of agricultural and animal breeding changes in food, and industrialization taking place in the last 200 years.(1,3) Since human genes have changed very little in the past 40,000 years, our nutritional needs have remained in that time period while cereal grains have changed the modern diet drastically by becoming a staple food. Hominids, used to dicotyledonous plants from the tropical forests they evolved from, had little experience with monocotyledonous grass seeds. In addition, cereal grains have a low amount of needed vitamins, as well as antinutrients (like protease inhibitors and lectins). However, cereal grains have shaped human evolution by allowing us to maintain a huge population with the high energy content they provide.(1)

Another part of our diet that has changed compared with the diet of the Upper Paleolithic period, is that there is much more table salt (NaCl) and less potassium bicarbonate (KHCO<sub>3</sub>). So how does the reversed balance of Na and K, and Cl and HCO<sub>3</sub> ions affect our physiology?

Bicarbonate ions ( $\text{HCO}_3^-$ ), can be obtained from salts found in vegetables in the form of bicarbonate precursors like potassium malate and potassium citrate, and are needed for the acid-base balance of our body. In general, fruits and vegetables have an alkaline effect on the body, while proteins, like that found abundantly in meat, have an acidifying effect. Metabolism of proteins with sulfur-containing amino acids such yields sulfuric acid. Also some organic acids may not be burned during digestion; bicarbonate helps neutralize these. If through the acidic foods or lack of alkaline foods we eat, the acid-base balance cannot be maintained properly, a condition called diet induced metabolic acidosis results. What foods are can cause this? Animal products and cereal grains have little alkaline components. In contrast, fruits have few sulfur-containing amino acids. Other problems in our diet come from high sodium (Na) ingestion, which leads to high blood pressure, and a greater urinary excretion of calcium: this can lead to hypercalciuria, kidney stones, and osteoporosis. Loss of bone substance is also related to metabolic acidosis, since bone contains alkaline salts of calcium that are released into the bloodstream when the system's acid is too high; these salts are then lost through the urine and are uncompensated for. One study showed that hip fracture incidence in older women correlated with animal protein intake. Metabolic acidosis has also been linked to decreased growth hormone production. Dietary potassium lowers blood pressure and supplemental  $\text{KHCO}_3$  stops or reverses excessive calcium excretion. Studies with  $\text{HCO}_3^-$  supplement show that it stops metabolic acidosis, corrects hypercalciuria, and improves growth in children, even when the growth is already seriously impaired.

So, eating alot of fruits and non-grain plant foods, like our hominid ancestors did, means more potassium bases in our metabolism and the correction of low-grade diet induced metabolic acidosis and its consequences.(3)

How much does eating meat really influence human metabolic acid-base balance? Deriemaeker and colleagues compared the foods eaten by vegetarians and nonvegetarians matched for sex, age, and BMI (2). They used a method called PRAL, or potential renal acid load. This is a model for showing the acid load of food based on the relation between food intake and urine-pH, and mineral elements in the individual foods. Since diets with more protein quantity cause higher pH value of urine, it has been shown that food contributes a great deal to the acid-base balance. They showed that on average, vegetarians had an alkaline value of  $-5,4 \pm 14,4$  mEq/d. Omnivores an acidic value of  $10,3 \pm 14,4$  mEq/d. The larger amount of fruits and vegetables consumed by vegetarians, and the meat and acid-forming drinks eaten by omnivores seem to account for these results. Potassium levels were much higher in vegetarians(2), and I find that this confirms the view of Frassetto and coworkers.

## Conclusion

The early hominids, the australopithecines, were not yet adapted to eating meat. Tooth shape analysis and dental microwear show a trend away from tough plant foods toward brittle or soft foods like nuts and fruit (6). Throughout our evolution, comprising the *Australopithecus* and later *Homo* genus, increasing brain size and reduction in area of grinding teeth is characteristic. The high metabolic energy of the *Homo Sapiens* brain, the gastrointestinal features, and high body fat show that during the course of our evolution, we converted to a more nutritious, energy-rich diet. These trends could have arisen from the ability of our ancestors to attain meat when other primates were less successful. Docosahexanoic acid and arachidonic acid, found in greater amounts in herbivore meat than plants, are needed for mammalian brain growth. Climate changes could have increased the number of herbivore prey in the vicinity of our ancestors. Stone tools and social developments, as seen in a hunter-gatherer and sharing way of life, increased our

capacity to attain a stable energy supply. Processing meat and other foods with tools and later cooking led to a smaller jaw size and further reduction in tooth size (4). This is the root of modern human disarrangement of teeth in the jaw, as we evolve further toward smaller food particles with an imbalance of selective pressures on front and back teeth (5).

Use of cooking, and mass use of cereal grains contributed greatly in energy to the diet of humans (1,4). Cooking allowed us to digest starches that we otherwise could not (4), and to soften animal products. Cereal grains began to be used in great amounts 10,000 years ago, and since then have allowed us to keep up a large population. Since humans have not had enough time to genetically adapt to them, problems such as antinutrient materials in these grains arise. In addition to low vitamin content and therefore deficiency disease if relied upon too heavily, cereal grains may also play a part in the numerous dental cavities we have (1). Finally, due to industrialization, there is a reversal of sodium chloride and potassium bicarbonate amounts in the modern human diet. Eating less potassium alkali salts (bicarbonate precursors) from fruits and vegetables and eating more grains and animal products leads to diet-induced metabolic acidosis. This is when the body is unable to keep an appropriate acid-base balance (3). A study based on urine pH showed that generally vegetarians have alkaline, while omnivores have acidic values (2). Less potassium bicarbonate and more sodium chloride in the body leads to high blood pressure, hypercalciuria, kidney stones, osteoporosis, and decrease in growth hormone production (3). This leads me to conclude that despite the importance of grains and meat in our evolution, the transition to extensive use of these foods at the expense of plant foods has been too sudden and large-scale for our body to adapt, leading to health problems.

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