Nutrition



Anthropogeny and the 3 S:
Soufflés
Symphonies
Space shuttles



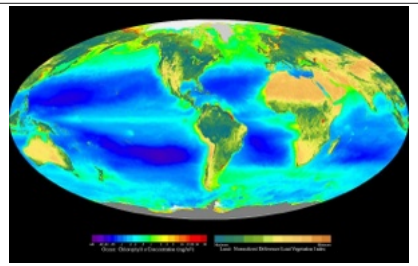


Introduction to Anthropogeny
Pascal Gagneux

Lecture 3
Wednesday October 8, 2026

Africa: 3 As, Axes (Acheulean Hand Axe), Art (pierced shell beads), Arrows (and bow),
China: 3 Ps, Powder (gun), Paper, Printing
Australia: 3Ws, wing (boomerang), woomera (spear throwers) , weirs (fish traps)
Inuit: 3Ks Kayak, Mukluk (Snow boots), Qamutik (dogsled)

Global Photosynthesis



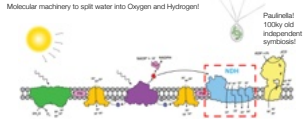
Provided by the SeaWiFS Project, Goddard Space Flight Center and ORBIMAGE - http://oceancolor.gsfc.nasa.gov/SeaWiFS/BACKGROUND/Gallery/index.html and from ex:
Image:Seawifs global biosphere.jpg
SeaWiFS Global Biosphere September 1997 - August 1998.This composite image gives an indication of the magnitude and distribution of global primary production, of both oceanic (mg/m3chlorophyll a) and terrestrial (normalised difference land vegetation index), see Normalized Difference Vegetation Index (NVDI).

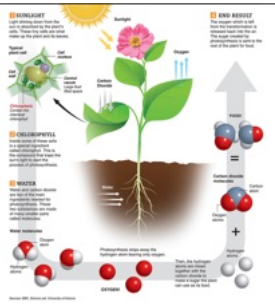
Marine organisms, mostly phytoplankton contribute greatly to global photosynthesis. Especially in colder, CO2 rich waters

---

Photosynthesis: sugars from light, air and water







When we get hungry, we make ourselves something to eat to restore our energy reserves. But what about plants, how do they get the food they need to grow and store energy? Plants get their energy through a process called PHOTOSYNTHESIS. By harnessing the light energy from the sun, the plant and leaves absorb the light into its cells. Within the cell is chlorophyll, a compound that starts the photosynthesis process to happen within the plant. The other components required in photosynthesis are water and carbon dioxide. Photosynthesis causes the water molecule to break apart and release oxygen into the atmosphere, leaving behind the hydrogen to bond with the carbon dioxide to create what we know as glucose (SUGAR), which translates to food for us to consume.
The capture of light energy for splitting water is performed by a collection of proteins located on the inside of specialized organelles (chloroplasts).

Animal pollinators



Many plants have evolved specialized structures to attract animal pollinators. The service is paid for in sweet nectar. It entices animal pollinators who feed on the sweet planet secretion and in the process move pollen between plants.

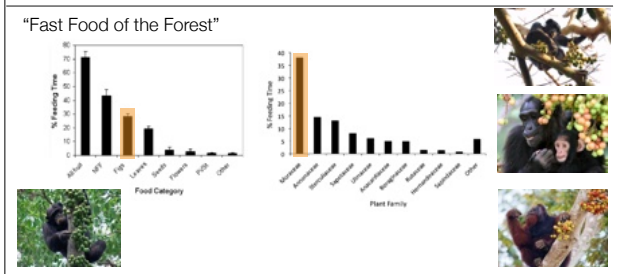
Seed Dispersal



Plants evolved colored and tasty fruit to recruit animals fro seed dispersal.
Many flowering plants rely on animal for two key steps in their reproduction: pollination and seed dispersal.

Figs and apes

"Fast Food of the Forest"



data on diet of chimpanzees from Ngogo, Uganda

Watts et al. ***Am. J. Primatol.*** 2012

Figs are extremely important in tropical forests.
Fig syconia are both, flower and fruit at the same time….. All apes have a great taste for figs.

Figs and apes



Chimpanzee on a tall fig tree in Gombe N.P., Tanzania. Dr. Alex Piel holding figs of varying ripeness, mostly unripe figs.

Digestible plant sugars: sucrose and starch



Fruit evolved as enticement for seed dispersal by animals
They advertise readiness by switching to red/yellow colors



Giant E/Kwa tuber in Tanzania, has to be cooked in order to eat large quantities. Evolved as storage organ of the plant, not in order to manipulate animal behavior.

Feeding on ripe fruit provides rich amounts of easily digestible sugar (sucrose)
Feeding on tubers can provide starch, but many tubers protect the starch by producing toxins.

---

starch granules in grain of maize



each granule measures between 5 and 20 um.

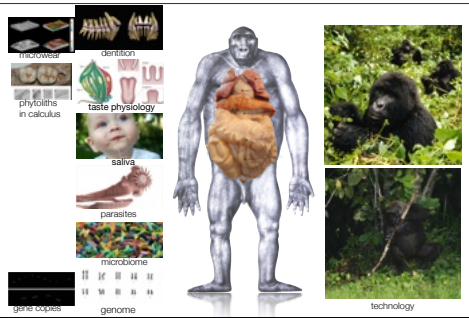
Electron microscope image of maize starch granules, the colors are added, as there is no color at this small scale!

Diversity of primate diets…



Primates display a large variety of diets, from the narrow and plant based (tree gum eating marmosets) to the varied, omnivorous diet of chimpanzees who eat hundreds of species of plants, several dozen animals prey species (insects and small mammals) and fungi.

Evidence of dietary adaptations



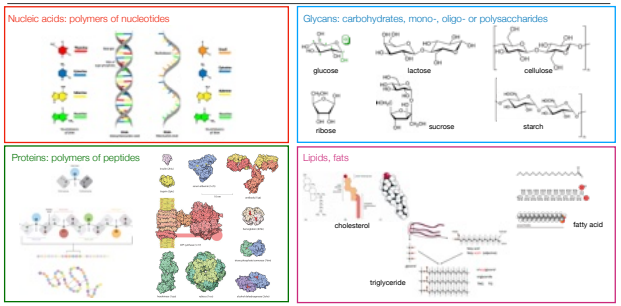
Diets shape many aspect of each animal, from dentition, to physiology, to genome, microbiome, and behavior, including tool use.

Living cells consist of



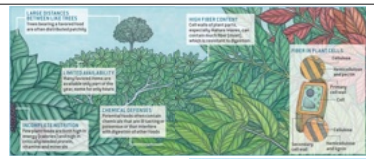
Four different classes of biomolecules are required to form living cells.

Major Classes of Biomolecules



Plant Fiber: Cellulose and other polysaccharides:

Cellulose:
most abundant
biopolymer









Most abundant biopolymer

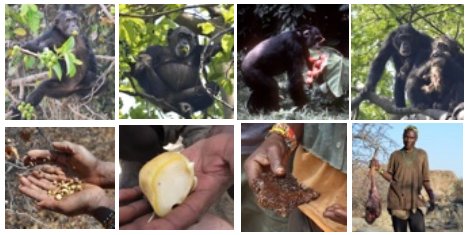
sugar/fat

Katharine Milton ***Scientific American*** 16, 22 - 29 (2006)

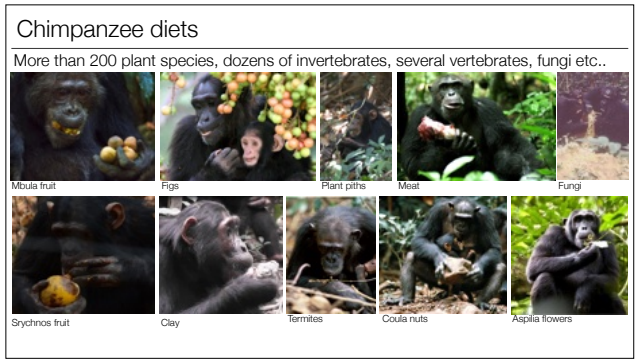
Beta-linked polyglucose (cellulose) is the most abundant biopolymer on the planet. Problem is that no mammals can digest it. Microbial helpers are required to cleave the cellulose into digestible and energy rich glucose.

Primate frugivory and omnivory:

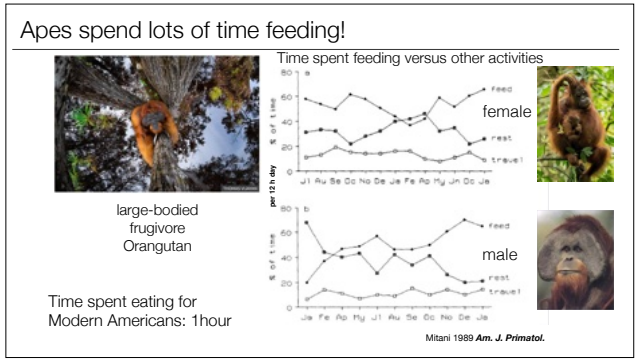
color vision, loss of vitamin C synthesis, taste for sweets
chimpanzees and humans are omnivores



Some apes, such as chimpanzees are omnivorous, like humans.



Our closest living relatives are omnivores like most humans. They do not hunt animals larger than themselves. Access to meat is very much biased to adult males.

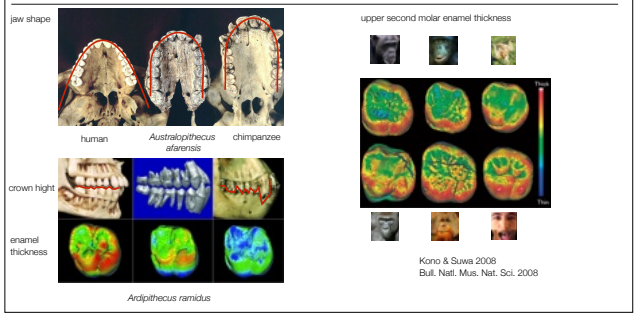


Apes such as orangutans spend the majority of their waking hours feeding on dispersed, nutrient poor food….



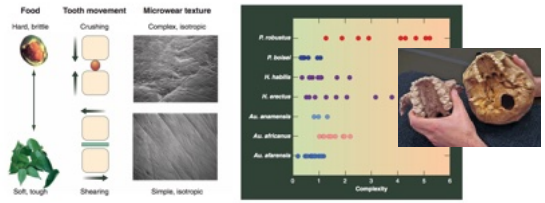
Good years in Southeast asian forests yield bumper crops of rich food, including rambutans, durian, and jackfruit.

Dentition



Between food and our guts: teeth.
Major changes between humans, living apes and extinct hominins. Humans shortened their jaws, and reduced the size of their teeth, but have much thicker enamel.

Dental Microwear



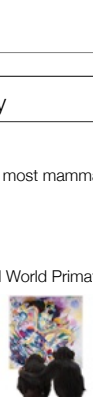
Ungar & Sponheimer ***Science***, 2011

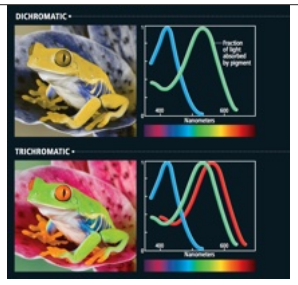
Dental micro wear allows inferences about the type of food consumed by the orgnism: more complex isotropic micrower texture indicates consumption of hard foods and mineral grit (seeds, nuts, un cooked tubers….)

Trichromacy

most mammals

all Old World Primates





Jacobs and Nathans 2009 ***Sci Am.***

Old World primates, with exception of some males are mostly trichromatic.

Seeing your food (30 m)

Finding ripe fruit



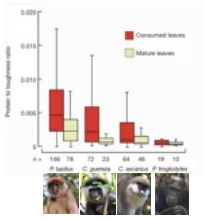


Wolf K. ***Current Biology*** (2002)

Trichromacy helps in finding and identifying ripening fruit and young, protein rich leaves. Fruits viewed close up and at a distance. The top two scenes show in full colour (A) a distant picture of ripe fruit against a leafy background, and (B) a close-up of the same fruits. To remove any advantage in seeing fruit conferred by trichromacy, (C) and (D) on the bottom have had all red–green variation filtered out, but are otherwise identical to pictures (A) and (B). The fruit in (C) is less salient to dichromatic observers. In (D), individual fruits are easily visible, but colorcues to ripeness are weakened.

Finding young leaves

Younger, red leaves are more tender, digestible and protein-rich. Half of African trees have red young leaves.

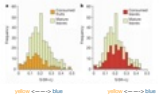


Fruit discriminated by red-green and yellow blue



Leaves discriminated only by red -green

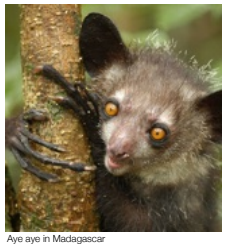




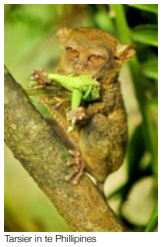
Dominy and Lucas 2001, ***Nature***

Four different primate species in Uganda discriminate between the colors of young and mature leaves. Even more so between the yellow hue of ripe fruit and the mature leaves.

Hearing your food (right next to you or 2 km away..)



Aye aye in Madagascar



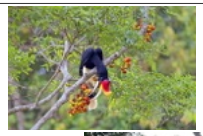
Tarsier in te Phillipines



Galago in Africa

Hearing your food (indirectly)





Siamang in Sumatra



Hearing food calls of others: chimpanzees macaques

Vocalizations about food can be exploited within and across species!

Smelling your food (nearby, or up to 200 m away)



Photo: Alain Houle

Smell is not the best developed sense in primates, but the smell of food is a very important aspect of food and test.



Getty Images

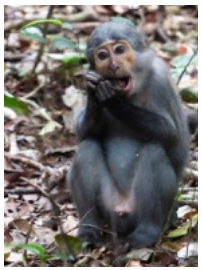
More than half of the >1000 genes that encode olfactory receptors in humans have lost their function.
Individual humans can differ very strongly in how many functional or non-functional genes they carry.

Genetic variation across the human olfactory receptor repertoire alters odor perception
C. Trimmer, A. Keller, N. R. Murphy, L. L. Snyder, J. R. Willer, M. H. Nagai, N. Katsanis, L. B. Vosshall, H. Matsunami, and J. D. Mainland
PNAS May 7, 2019 116 (19) 9475-9480; first published April 30, 2019



Playing with your food, or the left overs, squirrel skin chewing gum, Issa Valley, Tanzania, summer 2022. Movie by Meghan Rossi.

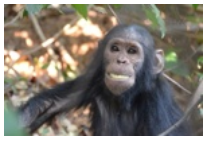
Mouth feel and 歯ざわり(tooth feel)











teeth and mouth as gate keepers…

Sooty mangabey cracking a hard *Coula edulis* nut in West Africa, red tailed guenons in Tanzania eating a gall above and bush mango below, chimpanzees wadging fruit pulp in Gombe.

Leaves: red colobus monkeys





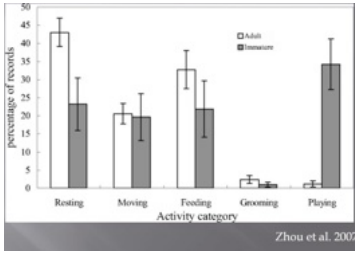
Red colobus monkey on a tree in Gombe Stream National Park. Table lists major food plants of this mostly leaf eating species.

Leaf Eating Colobine monkey



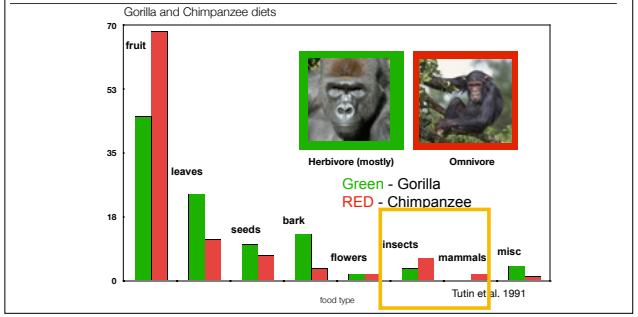
Medium-bodied
leaf eater
Langur of SE China:

"low energy life"



Feeding on leaves requires long bouts of feeding and resting (for digestion). Leaf eating primates sleep a lot.

African Ape Diets



Gorillas eat very little animal food (usually insects in the plant food). Chimpanzee actively hunt for a variety of animal prey, including insects and mammals, they also eat more fruit and insects than gorillas.

Vision for detecting movement



Chimpanzees hunt small monkeys such as red colobus that mostly live high in the canopy of trees. Spotting these monkeys involves sight and sound. Hunting them requires cooperation as the chimpanzees can face fierce resistance by larger monkey males trying to defend their group members.



Chimpanzees capturing an olive colobus in Taï National Park, Côte d'Ivoire, West Africa in 1991.
Most of the meat is consumed by males, but some high ranking females with special relationship to the dominant males also get some meat.

Apes eating monkeys



Chimpanzees are omnivores like humans. They regularly hunt other mammals for meat, especially monkeys like this red colobus monkey.
They do not hunt prey animals larger than them selves.

From predator to prey



Photo: C. Boesch

Adult female chimpanzee killed by leopard is mourned by two adult males who arrived too late to protect her, but they did chase the leopard away.

Fellow predator



Photo: D. Jenny

Main predator of chimpanzees in the forest: leopards. They will attack an adult chimpanzee if they have the element of surprise. Chimpanzees cooperate in anti-predator defense and will take large risks when trying to injure a leopard.

Fighting back and stealing prey







Chimpanzees can steal a kill from a leopard, they can also kill leopard cubs, and of course they also eat leopard tortoises. Very little scavenging has been reported for wild chimpanzees.

Grazing herds: narrow baboon diet but not just grass









Opuntia cacti were introduced by the Portuguese near the end of the 15th Century, they now grow all over Africa and gelada baboons eat the leaves and fruits.

Dietary flexibility and survival:









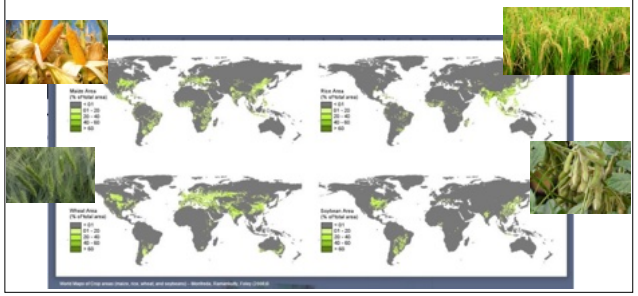




Baboons and Macaques, among the few non-human primate species not to be endangered!

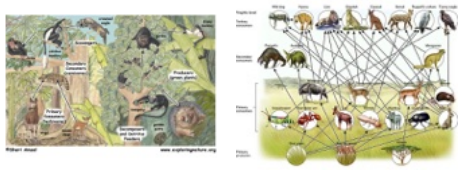
Baboons in Africa and macaques in Asia are good example of flexible species with regard to their diets.

Humans: 3 main Grasses and one Bean!



Modern humans have become grass eaters! And most legume is accounted for by soy beans

Trophic levels and megafauna biomass

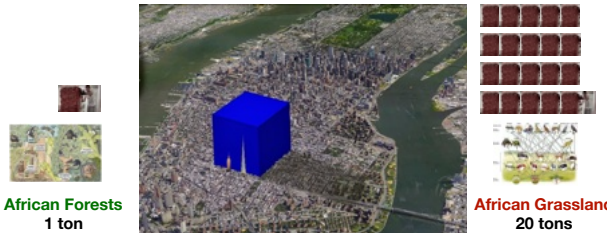


African Forests <<<<<<< African Savannah

1000 kg/km^2 20,000 kg/km^2

Landscapes with different plants carry very different densities of animals: tropical forests have much lower animal densities than savannas.

Meat per square km:



African Forests
1 ton

African Grassland
20 tons

https://kaiserscience.wordpress.com/

Grass, oh grass!!

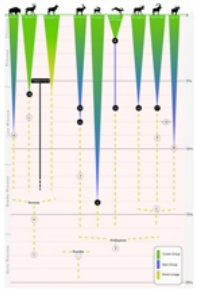


Wildebeest and African buffalo in Tanzania: rich grassland and even richer ruminant megafauna



Eland and Grant's gazelles in the Serengeti, the elands display an important anti-predator behavior: they are forming an alert circle.

Evolution of African Bovid Diversity



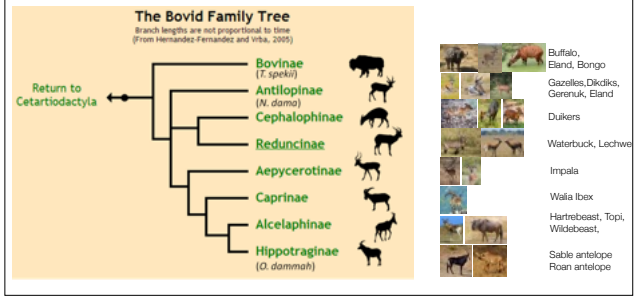
—> more grassland
—> more different bovid species since the late Miocene (10 mya)

70 new genera, 75 living species!

Bibi *et al.* ***Palaeo-electronica*** 2009: 3/169

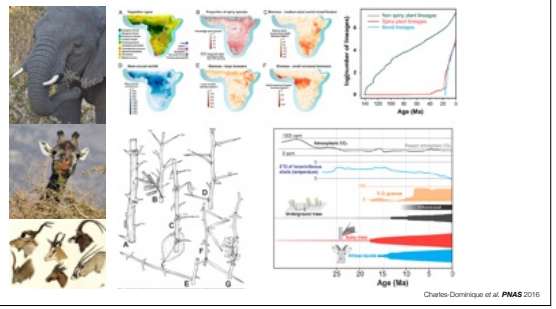
Diversification of bovid species in Africa over the last 10 million years.

Bovid (antilope radiation)



Over 75 species of bovids are alive in Africa (most of them are antelopes). They form the result of a **radiation of species**, adapted to growing grasslands.

Plants react: Bovids and Spiny plants



Unlike bovids, elephants, rhinos, zebra and giraffes are less bothered by spines. The number of spiny plants and bovid species in Africa have increased in parallel.

Exploiting of coastal resources, marine and fresh water

New opportunities for infection by water borne parasites



Olduvai, now and 2 million years ago

Reconstruction of Olduvai Gorge, 2 million years ago. Hominins used the rich resources near the water, but also payed steep prices in terms of predation by crocodiles.

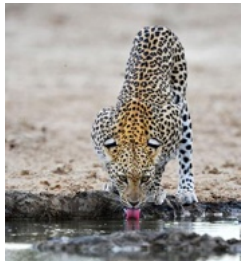
Water holes are dangerous

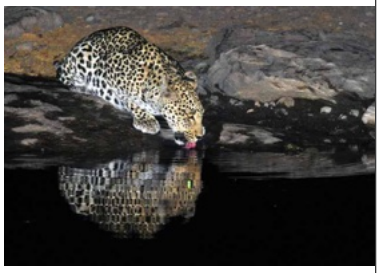


photo: John Mullineux

At a bend along Kruger National Park's Sweni River, a Nile crocodile (*Crocodylus niloticus*) lies in wait, hidden beneath the placid surface of the shallower-than-usual water. It's the spring of 2016, and the park's herbivores are suffering through the worst drought since official record-keeping began in 1904. Kruger's predators aren't having any trouble finding food, however. Emaciated, easy-to-catch prey abound, and the haggard animals are forced to congregate around the park's few remaining watering holes. It's with these circumstances in mind that photographer John Mullineux has trained his camera on the river bend, waiting with anticipation as a group of impala (*Aepyceros melampus*) approach to drink.

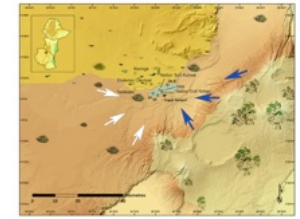
Water holes are dangerous

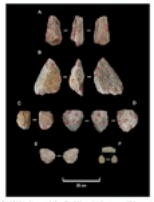


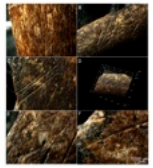


Large land predators also use water holes and are aware of the many opportunities for hunting there.

Homo erectus at Oldupai adapted to hyperarid landscape 1 mya?







Mercader et al. ***Communications Earth & Environment | (2025) 6:1***

A brand new study using archeology, geology and pollen analysis reveals that *H. erectus* were adapted to hyper arid steppe desret environment over 1 million year ago at Olduvai.

Confrontational scavenging?

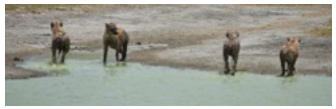


Homo erectus/ergaster scavenging and chasing a vulture and a jackal, diorama at the American Museum of Natural History, New York

---

Competition





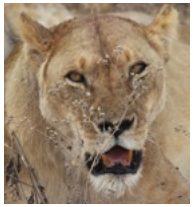




Other carnivores and scavengers such as sported hyenas are very quick to rush to any kill site. these strong and dangerous animals will steal kills from lions if they are in a big enough group.

Competition from other carnivores







Imagine having to walk past such a lion on the way to the wildebeest in the back! The spotted hyenas came up to about 15 feet from our camp fire…..

Competition from land and air



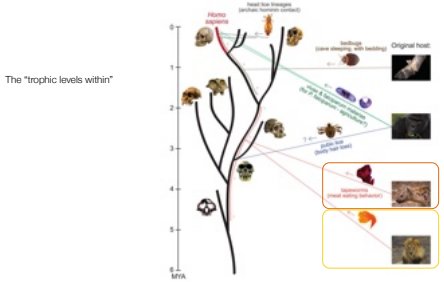
Two cheetah brother eating a grant's gazelle. They take turns eating as they need to keep an eye out for incoming thieves….. hyenas and vultures, lions will also steal their kill.

Force of the pride



Pride with four lion brothers totally controlling access to adult male giraffe kill.

Parasites and carnivory



Parasite host species transfers inform hominin evolutionary history -
Figure 1 from Perry 2014 ***Evol Anth*** 23:218-28.

Parasite host species transfers inform hominin evolutionary history. The timing of selected parasite host species transfers and their potential proxy significance (in parentheses), superimposed on an approximate hominin phylogeny. Original hosts are shown at right. The original host for human Plasmodium vivax may have been either gorilla or chimpanzee; for simplicity, only gorilla is shown. All fossil, parasite, and original host depictions were modified from images on Wikimedia Commons.

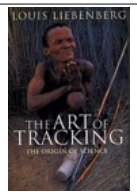
Hunting techniques: start early and practice a lot



Young Hadza practicing bow and arrow making and using.
(notice the real arrows with the poison tips stashed high on pegs against a baobab tree).
Use of bow and arrows is extremely gendered in the Hadzabe, only males make and use them, there are strong taboos against women handling bows and arrows as the Hadza believe such contact would abolish the effect pdf the arrow poison.

Do other species read tracks?





No!

Why not!

Sikwezi a Hadza man reading tracks of his tribe member Philemon and inferring correctly that he must have hunted a zebra, before the local Datoga pastoralists came through with their cattle.

Tracking prey



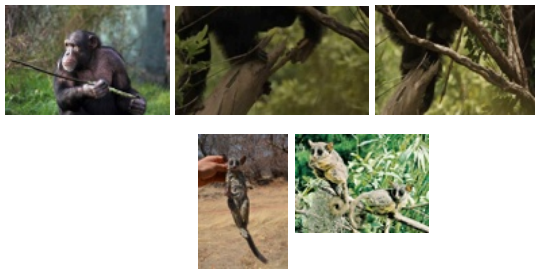
Hadzabe (Hadza people) tracking an impala shot with a poison arrow. Much discussion about which set of tracks to follow, small droplets of blood verify the assumption.

Example of hunting with ancient but complex technology



The Last Whalers: Three Years with an Ancient Tribe and a Vanishing Way of Life, chronicles three years in the life of the Lamalerans, an indigenous Indonesian tribe that hunts sperm whales with bamboo harpoons and wooden boats for its living. All photos on this website are © Doug Bock Clark.

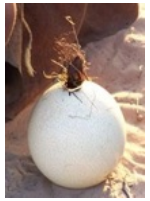
Prosimian extraction by chimpanzees using “spears”



In Fongoli, Senegal, chimpanzee females have been observed using sticks to injure and dislodge bush babies (galagos) which they then capture and eat.
My friend Paco Bertolani made this observation and does not really consider it “spear use”…..

Transporting water?

technical solution to get water on demand…..







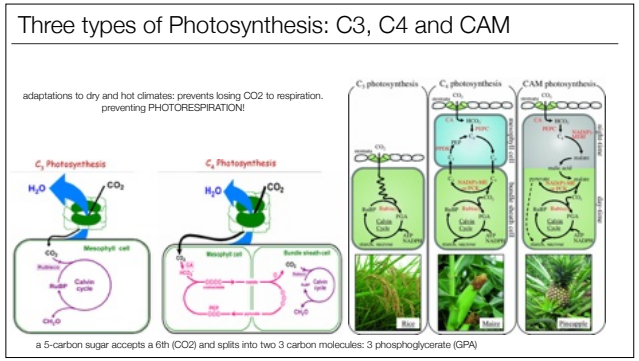




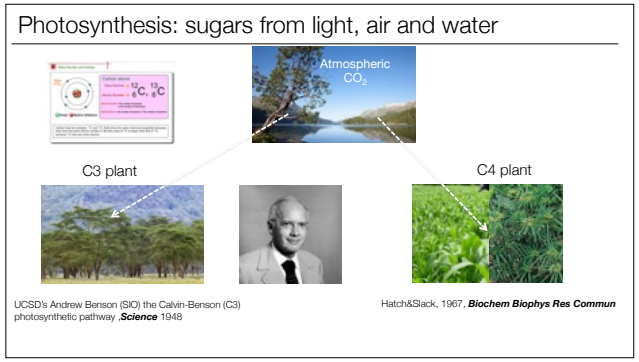
Ostrich eggs and bottle gourds

Bottlegourds (genus *Lagenaria*) are among the earliest domesticated plants in Africa. The plants floated across the Atlantic where it established and patiently “waited” a second domestication by humans who arrive there in the last 15 thousand years only!



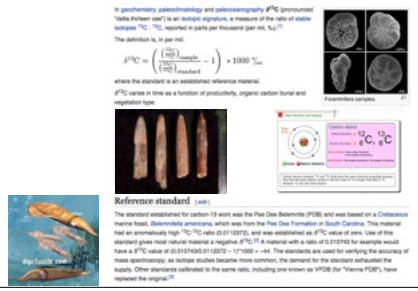


A schematic diagram of C3 and C4 photosynthesis.
Ribulose-1,5-bisphosphate carboxylase/oxygenase, commonly known by the abbreviations RuBisCO is an enzyme involved in the first major step of carbon fixation, a process by which atmospheric carbon dioxide is converted by plants and other photosynthetic organisms to energy-rich molecules such as glucose, via a three-carbon precursor 3 phosphoglycerate (GPA). The first product in in C3 is 3 Phosphoglycerate (GPA, C3), in C4 photosynthesis iot is ocaloacetate (C4). CAM photyocynthesis evolved i many desert plant is a second C4 type photosyntesis that allows plants to store CO2 during the night, the first product there is malate (C4).



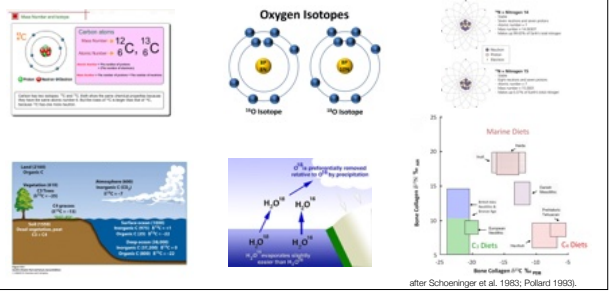
Two types of photosynthesis incorporate different rations of stable carbon isotope. C3 photosynthesis is more ancient and C4 phototsynthesis is thought to have evolved as an adaptation to warmer/drier climate and higher O2 pressure.

The PeeDee Belemnite (PDB) standard



Those comparisons rely on well-established standards, such as the PeeDee belemnite standard, from a Cretaceous marine fossil in South Carolina.

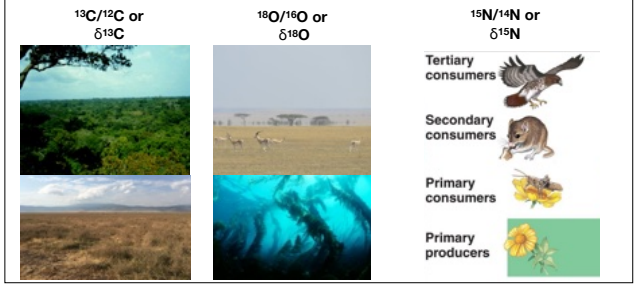
Stable Isotopes (non radioactive variants of the same atom)



Carbon, Oxygen and nitrogen stable isotopes…..
Important indicators of diet and climate and placement in the food pyramid

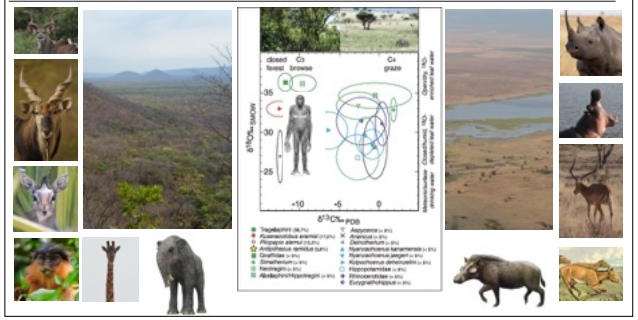
---

Stable Isotope Analysis : Types of foods and ecology



Stable isotopes in animal bones/teeth can be used to reconstruct past climate, vegetation and trophic levels.

Stable Isotopes (carbon and oxygen) & paleoecology



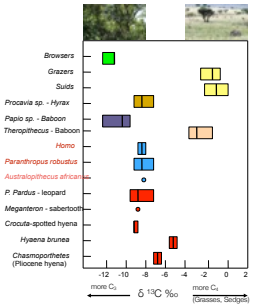
The stable isotope profile of *Ardipihtecus ramidus*, 4.6 million year old hominin from Ethiopia. Oxygen and carbon stable isotopes indicate that this short bipedal hominin fed on mostly C3 plants, or animals that consumed C3 plants, unlike later hominins, where one sees a shift to C4, probably due to the consumption of grazing antelopes.

Wooded Savannah Ugalla, Tanzania



Wooded savannah in Tanzania, a present day landscape where chimpanzees live, that is not unlike the paleolandscape reconstructed for ***Ardipithecus ramidus***.

Plio-Pleistocene Hominin Diet: Stable Isotopes

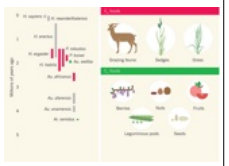


" It now seems inescapable that all hominid species inhabiting the S. African landscape from the late Pliocene to the early Pleistocene exploited foods of C_4 grass origin and were very likely all omnivorous."

Lee-Thorp J *et al.* ***J Human Evol*** 2000;39:565-76



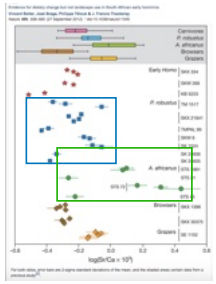
Sponheimer M *et al.* ***Science*** 1999;283:368-70



Margaret J. Schoeninger ***Nature*** 2012

Robust australopithecines committed to C4 plants, our ancestors ate mixed C3 and C4 foods.

Stable Isotopes (Strontium/Calcium) : dietary breadth?



laser ablation of enamel in bovids and hominids

Sr/Ca decreases with trophic level

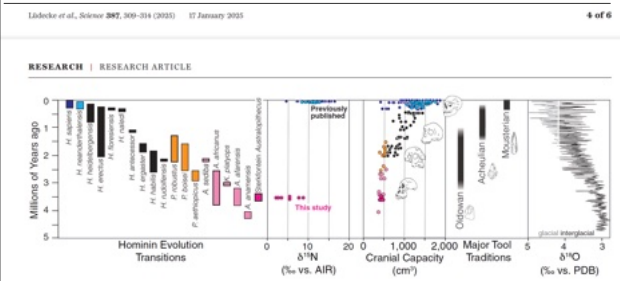
same landscape, differential food plant use?

Balter *et al.* ***Nature*** 2012

The dichotomy between early *Homo* and *Paranthropus* is justified partly on morphology. In terms of diet, it has been suggested that early *Homo* was a generalist but that Paranthropus was a specialist. However, this model is challenged and the issue of the resources used by Australopithecus, the presumed common ancestor, is still unclear. Laser ablation profiles of strontium/calcium, barium/calcium and strontium isotope ratios in tooth enamel are a means to decipher intra-individual diet and habitat changes. Here we show that the home range area was of similar size for species of the three hominin genera but that the dietary breadth was much higher in Australopithecus africanus than in *Paranthropus robustus* and early Homo. We also confirm that *P. robustus* relied more on plant-based foodstuffs than early Homo. A South African scenario is emerging in which the broad ecological niche of Australopithecus became split, and was then occupied by Paranthropus and early Homo, both consuming a lower

---

Not much meat for *A. africanus!*

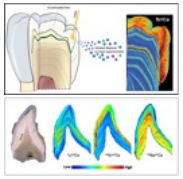


How long did *A. africanus* suckle?

Barium/Strontium and Lithium in tooth enamel

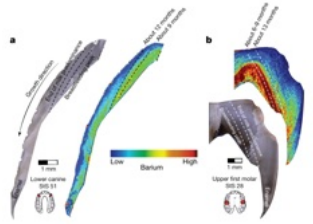


Kennis & Kennis Paleo reconstructions



Australopithecus africanus, ~ 2 mya

Several years of breastfeeding after initial weaning at age 1!



Joannes-Boyau, R, *et al.* Elemental signatures of *Australopithecus africanus* teeth reveal seasonal dietary stress. ***Nature*** *2019*

Measuring elements in fossil teeth of > 2my old *Australopithecus africanus*. (a, Section of enamel of the lower canine of StS 51, and associated 138Ba/43Ca elemental mapping. b, Section of the enamel of the upper first molar of StS 28, and associated 138Ba/43Ca elemental mapping. The dotted lines indicate the beginning of enamel calcification, the time at which the breastfeeding peaked and the date at which the infant A. africanus breast milk intake decreased with respect to solid food intake. A period of approximately 12 and 13 months for StS 51 and StS 28, respectively, for predominant breastfeeding was estimated using the distance between the identified lines and the average rate of calcification of the species (5.5 µm d−1). Schematic diagram of the use of laser ablation analysis to map the concentration of strontium and uranium within a tooth. Renaud Joannes-Boyau, Author provided *Australopithecus africanus* canine showing a first period of nursing behavior followed

by a cyclical signal in the lithium, strontium and barium distribution. Renaud Joannes-Boyau
Strontium isotopic ratio along the growth axis of an *Australopithecus africanus* tooth.

Early *Homo erectus*
meat-eating more reliable protein & fat

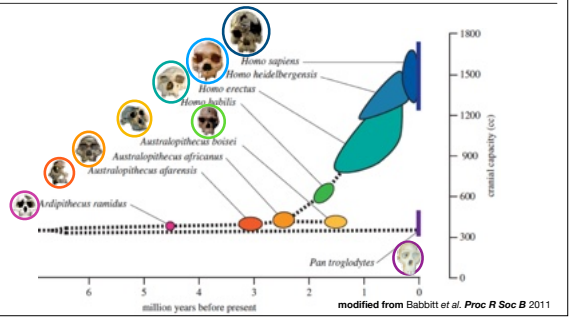
Intergenerational phase transition: larger female with better energy balance: changes in gestation?



National Geographic
courtesy: L. Aiello

Bone marrow as weaning food?

Brain expansion over time: Adaptation to Culture?

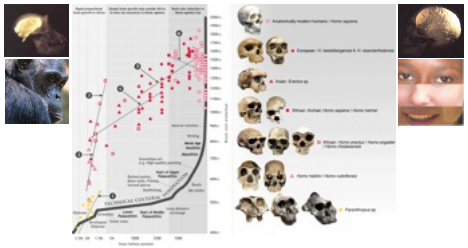


modified from Babbitt *et al.* ***Proc R Soc B*** 2011

Ancient adaptation to culture or driven by culture or both?

Brain expansion over time

Driven by culture and/or driving culture?



Bradshaw Foundation adapted from Steven Oppenheimer, 2012 Out of Eden

Brain size tripled along the human lineage in the last 2 million years? How we went from an ancestor with a chimp-sized 400 cc brain to a modern 1500cc brain and the technology accompanying, driving it?
A part fro brain size, there must have been countless changes in how these brains were connected, with the emergence of novel networks that support language acquisition and social behavior.

Extractive Technology



Chimpanzees in West Africa are known to use hammers (stone or hard wood) to extract nutritious seeds nuts from several species of trees.
During nut cracking season, these chimpanzees can satisfy their dietary needs in less than 3 hours. They then have time to laze around and play, even the adults.

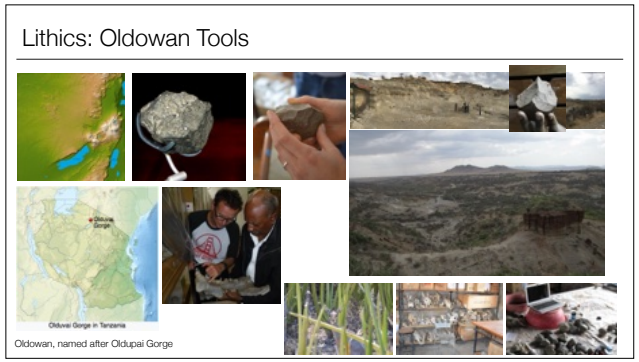
Oldest hominid tools, way to get at marrow and brain?

(Oldowan) stone tools from Lake Turkana, Kenya, 3.3 My





Such stone tools would allow easy access to bone marrow and brain, two fat rich resources that remain uncontaminated by bacteria for extended time in an animal carcass.





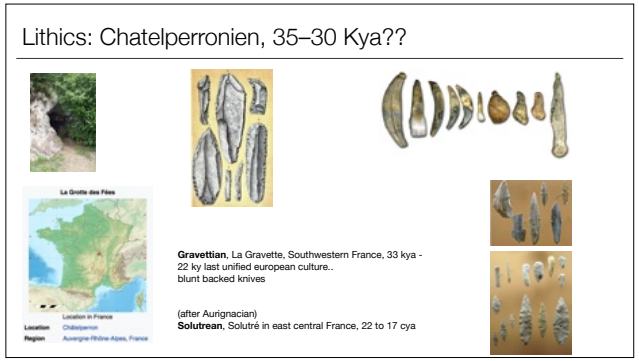
With a French name, most people forget that this “Swiss Army Knife” of human evolution is an African invention.



Levallois cores allowed for there rapid production of “pre-sharpened” blades.

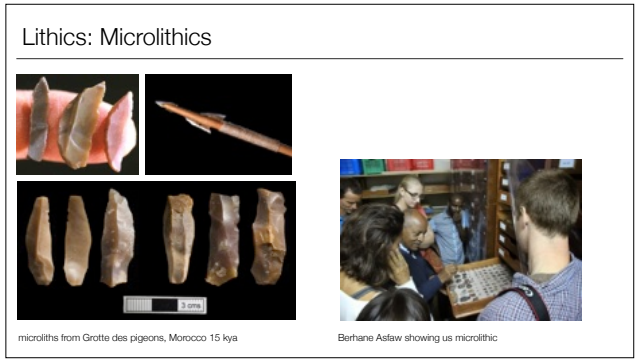


Tools made out of bones and teeth, including ivory, became rather common. These do not preserve as well over longer periods of time though and might already have existed much earlier, but without persisting into the archeological record.



Around 40,000 years ago, modern humans made their way into Europe, sweeping through the continent and, eventually, driving to extinction our close relatives, the Neanderthals. Exactly how that process took place is still up for debate. Tangled up in that conversation are questions about the sophistication of Neanderthals, including whether they were capable of artistic expression, or made jewelry or complex stone tools.

Archaeologists agree that hand axes and scrapers were definitely part of the Neanderthal toolkit, and modern humans are credited with developing points made of bone and antler, as well as flint blades. But in between these two types of technology, chronologically, are the so-called Châtelperronian tools, characterized by sawtooth edges and knives with convex backs. Researchers are still unsure which hominin was responsible for them.



Lithics (Stone Tools)

Oldowan (Mode 1): Stone tools characterized as simple flakes struck off an unmodified core, most commonly as "choppers" for pounding, breaking, and bashing.
from 2.6 - 1.7 million years ago.



Acheulean (Mode 2): Stone tools characterized by distinctive oval and pear-shaped bifaced "hand-axes."
from 1.6 to 200,000 years ago.



Mousterian (Mode 3): Stone tools characterized by Levallois Technique (prepared core technology) to form handaxes, scrapers, triangle points, and denticulates.
Modern humans and Neanderthals, from **160,000 BP to 40,000 BP.**



Aurignacian (Mode 4): Worked bone and antler points with grooves cut in the bottom, as well as fine stone blades and bladelets struck from prepared cores.
Associated with the earliest modern humans in Europe and their migration from the Near East –**43 -23 kya.**



Microlithic (Mode 5): Small blades or points, called microliths, typically used in composite tools, such as an arrow point fastened to a haft.
-**35 kya - 3 kya.**



Problems with high meat diet: cultural adaptation

Raises metabolic rate much more than ingesting fats or carbs.

Leads to negative nitrogen balance, protein depletion, nitrogen excretion, loss of body protein and muscle.

Also affects calcium metabolism, depletes fatty acids, adequate calories but 80-90% from lean meat can mimic starvation.

"Rabbit starvation" or "Mal du Caribou"

Pemmican: lean meat + fat + fruit



Frequent problem faced by reality TV contestants:

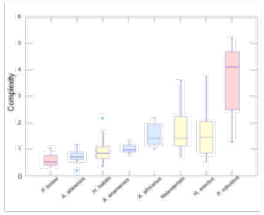


Speth, J. D., & Spielmann, K. A. (1983). ***Journal of Anthropological Archaeology***

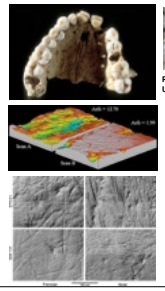
Lean meat diets are not sustainable.

Microwear on Neanderthal tooth surfaces indicates plant-eating

Zaatari *et al.* 2011 ***Journal of Human Evolution*** 61:411-424



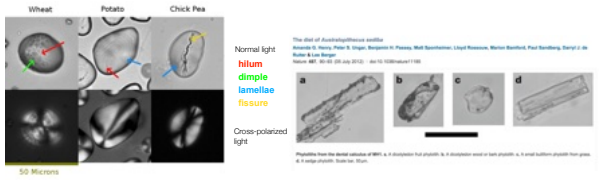
Scott et al. 2006 JHE





Peter Ungar
U. of AK website

Extinct plant diets?



Slide: Amanda Henry

Different plant species produce starch granules of distinctive shape and structure! Can be used to identify ancient foods trapped on dental calculus.

Homo erectus, 600-200 kya Europe



Atapuerca Cave, Northern Spain

430,000 year old ancient DNA was extracted from these fossils and yielded sequence data published in 2016

Nuclear DNA sequences from the Middle Pleistocene Sima de los Huesos hominins Matthias Meyer t al. Nature ,volume 531, pages 504–507 (24 March 2016)

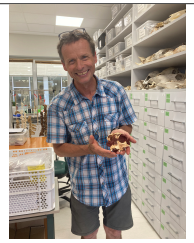
Homo heiderlbergensis/neanderthalensis, 430 kya Europe



Atapuerca Cave, Northern Spain, Sima de los Huesos contianing bones from 30 individuals. 430,000 year old ancient DNA was extracted from these fossils and yielded sequence data published in 2016
Nuclear DNA sequences from the Middle Pleistocene Sima de los Huesos hominins. Matthias Meyer *et al.* ***Nature*** ,volume 531, pages 504–507.
Paleomagnetism dating of sand stone and sediment bearing the fossils.
Early Neanderthal, with at least some mitochondrial DNA of Denisovan nature.

Homo antecessor,1.2 million to 800-kya Europe





New facial bones: maxilla from Sima del Elefante: 1.4 mya, announced in July 2022!







J.M. Parés, L. Arnold, M. Duval, M. Demuro, A. Pérez-González, J.M. Bermúdez de Castro, E. Carbonell, J.L. Arsuaga,
Reassessing the age of Atapuerca-TD6 (Spain): new paleomagnetic results, ***Journal of Archaeological Science***, Volume 40, Issue 12, 2013, Pages 4586-4595,

---

Cannibalism in Europe

35,000 to 120,000 years old:

Krapina, Croatia: cut marked and scattered remains of 20 neanderthal individuals. Goyet, Belgium (45,000 kya, 99 neanderthal remains, many with cut marks)



Atapuerca, Spain
800 kya



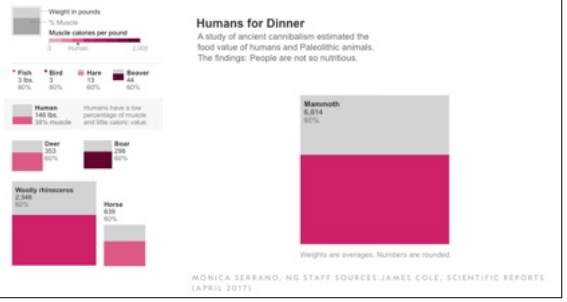
Rougier *et al* 2016 ***Nature Scientific Reports***

Retouching marks (b1,b2) and cutmarks (c1,c2) present on the Goyet Neandertal bones (example of femur III). (a) femur III in anterior view; (b1,c1) close-up photos; (b2,c2) images obtained using a minidome

Overview of the anthropogenic modifications observed on the Neandertal remains from the Troisième caverne of Goyet (Belgium). See Supplementary Fig. S8 for individual Neandertal bones with anthropogenic modifications. Skeleton diagrams modified from https:// en.wikipedia.org/wiki/File:Human_ skeleton_front_en.svg and

---

Cannibalism: energetically not worth it?



The energetic value of human bodies is not particularly high, but they would contain all the nutrients we need.

Cannibalism: Real and Not always a colonialist myth

Thousands years of evidence from all contents:
contexts:

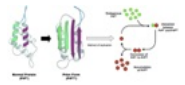
famine (great famine in Europe 1315; Jamestown, 1609, Russia 1920, Ukraine famine 1932)
crime (long list in Europe, Americas, Asia)

paraphilia (kink including autocannibalism) (long list)

warfare (Croatia, Liberia, Angola, Congo, Burma, China, Siberia, Iran, Japanese Army in Papua during WW2 German prisoners of war in Siberia)

ritual (Papua New Guinea, Sierra Leone, Ivory Coast, Caribbean).

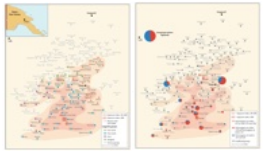
Genetic Adaptation to Kuru? Novel protective protein variant



Adaptation to cannibalism?:
Prion protein polymorphisms providing protection?
Mead *et al* 2003 ***Science***: yes
Soldevilla *et al* 2006 ***Genome Research***: no
Mead *et al*. 2009 ***NEJM***: yes



Fore people in PNG, 20th century



Cannibalism has also been documented for chimpanzees. It has been linked to neurodegenerative disease Kuru in Papua New Guinea. The disease more widely known as spongiform encephalopathy (in English: “disease inside your head caused by sponge like brain tissue” also occurs in hospital settings where the toxic proteins are passed on by contaminated surgical tools.

The Kuru-Exposed Region in Detail, Showing Areas of High Exposure and Persons with the 127V Allele.
We divided the kuru region into three zones of increasing exposure: villages with at least one recorded case of kuru but an exposure index of 30 or less (low-exposure group); a zone with an exposure index of more than 30 to 200; and a high-exposure zone, with an exposure index of more than 200. Red dots show the locations of persons with the 127V allele. The Purosa valley includes the villages of Purosa-Takai, Ketabi, Ai, and Mugaiamuti. The figure is adapted from a figure in Collinge et al.,26 which shows the location of all villages with a history of kuru.

friction fire



honey guide

https://www.youtube.com/watch?v=6ET-z7Ra8ps0

risky honey

https://www.youtube.com/watch?v=3l5DZo-mGeY

Hadza man (named Janjako) making a friction fire to light a joint.

Evidence for plant foods in Neanderthals?





Plant microremains can be recovered from a variety of contexts: dental calculus





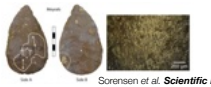
phytolith



starch grain



Starting a fire with flint hand axe and pyrite

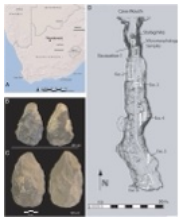


Slide: Amanda Henry

Sorensen *et al.* ***Scientific Reports*** 2018

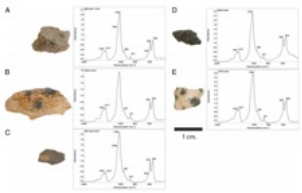
Calculus from Neanderthal teeth contains starch granules and phytoliths. Neanderthal had fire, using pyrite and flint to strike long glowing sparks into dry mushroom tinder.

Wonderwerk Cave, SA, 1 my old burnt animal bones









burnt animal bones

Berna et al. 2012 ***PNAS***

Selection of bone fragments recovered close to wood ash identified in thin section (excavation 1, stratum 10, square R28, elevation from top of stratum 10 of 15–20 cm) and their representative FTIR spectra. Gray and black bones (samples A, C, and D) show the presence of IR absorptions at 630 cm−1 and 1,090 cm−1 characteristic of bone mineral heated to more than 400 °C (32). Yellow (B) and white bone (E) fragments show IR spectral pattern characteristic of unheated bone or heated below 400 °C. The circular and irregular opaque nodules are composed of Fe and Mn oxides and a result of diagenetic impregnation.

Geography of early fire: older than our species!





Fig. 2 - A map of Plio-Pleistocene sites in Africa, Asia and Europe where evidence for hominin use

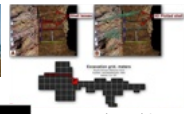
Attwell *et al.* 2015 ***J. of Anthropol. Sci.***

Fire use predates the origin of modern humans and could be as old as the first Homo erectus 2 million years ago.

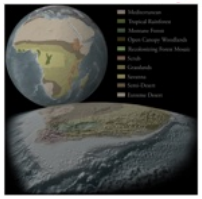
Coastal resources ?



Pinnacle Point cave, SA







easy protein and fats

good fats DHA (PUFAs)

evidence from S. Africa middle stone age ~ 280 kyat to 50 kyat

<— African vegetation during Marine Isotope stage 6 191 kyat



Marean ***JHE*** 2014

Pinnacle Point Cave SA, large accumulations of shellfish remains. Clear evidence of there importance of coastal resources.

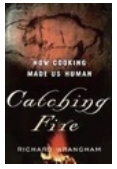
Docosahexaenoic acid (DHA) is an omega-3 fatty acid that is a primary structural component of the human brain, cerebral cortex, skin, sperm, testicles and retina ...

Omnivore's Dilemma

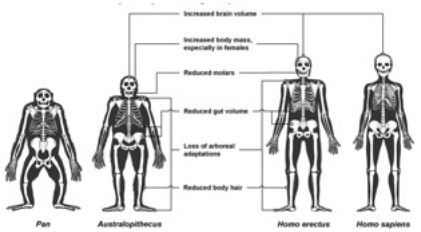
- The broader your dietary niche, the more options for poisoning.
- Bitter taste receptors vary across primates, humans and chimpanzees have independently evolved their bitter taste receptors.
- Hominins solved this dilemma by culture and technology: shared knowledge and processing of food, including cooking.



photo A. Crittenden



Fire and anatomical change



Carmody et al. PNAS 2011

Use of fire for landscape management

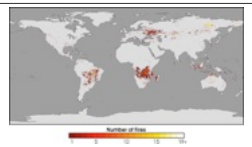




Burnt landscape are much easier to travel through.

Global fire



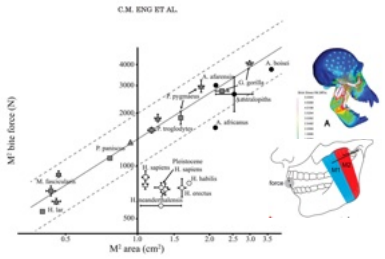






NASA Earth Observatory

Molar area and M2 bite force



Eng *et al.* 2013 ***AJPA***

Compared to other primates, humans and our extinct relatives have remarkably low bite force! Logarithmic plot of M2 molar area and M2 bite force. Bite forces have been calculated from skeletal data and estimates of jaw muscle architecture, and related to actual measurements in modern humans and non-human primates. Note that the human difference from other primates preceded the dates of well documented use of cooking.

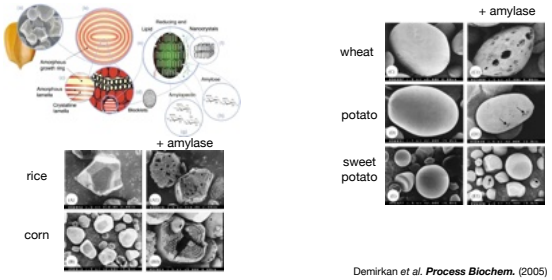
Gritty Tubers?



brief cooking allows pealing, detoxifies anti-nutrients and gelatinizes starch

Eating cooked tubers would not impact teeth with grit from the soil, as pealing is easy after cooking, also nutrients are more accessible and toxins largely detoxified…

Starch Granules



Demirkan *et al.* ***Process Biochem.*** (2005)

Scanning electron microscopy of untreated and treated raw starch granules by alpha-amylase of *B. amyloliquefaciens* mutant type. The A, B, C, D and E and A1, B1, C1, D1 and E1 micrographs show amylase untreated and treated starch granules with enzyme, respectively. A: rice, B: corn, C: wheat, D: potato, E: sweet potato.

Honey guide evolution as a clue to age of human fire use?

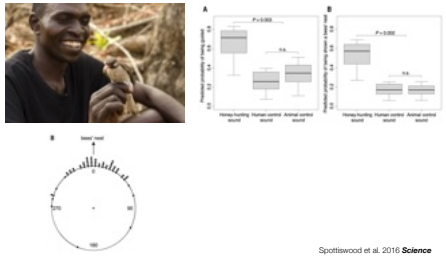


Spottiswoodd *et al.* ***PNAS*** 2011

Wrangham and Machanda 2013: "A review of the mutualistic interaction of foragers with greater honeyguides, Indicator indicator, "indicates" that honeyguides have an innate propensity to lead humans to honey, that hominids are the most likely species responsible for the evolution of this habit, and that the habit depended on ancient human control of fire."

Mitochondrial and nuclear DNA relationships among honeyguides using different host species. (A) Mitochondrial phylogeny based on partial 12SrRNA gene sequences. Genetic divergence for the ND2 gene was measured for a representative sample of individuals with divergent 12S sequences. The lineages that interact with humans diverged from those not interacting about 2 million years ago. Interaction with humans is contingent on humans using fire to harvest bee hives…….does this indicate that human fire use is 2 million years old?

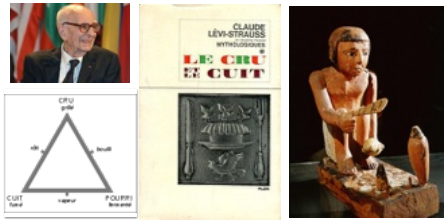
Yao people in Mozambique



Spottiswood et al. 2016 ***Science***

(A) A Yao honey-hunter and a wild, free-living honeyguide. (This bird was captured using a researcher's mist-net and is neither tame nor habitually captive.) (B) Accuracy of honeyguide initial guiding behavior in relation to direction of successfully located bees' nests. Points represent the difference in bearing between initial guiding trajectory over the first 40 m of travel and the ultimate direction of the bees' nest (here set at 0) and are binned into 5° intervals. Each point represents a journey (n = 58 journeys) to a separate bees' nest that was at least 80 m away from the point where guiding began. Sometimes a honeyguide led humans to more than one nest consecutively (n = 50 guiding events). The circular distribution is unimodal (Rayleigh test, $P < 0.001$) with a mean of 1.7° (95% confidence interval includes zero: 352.3° to 11.1°), showing that honeyguide behavior offers reliable directional information to humans.

Cooking, no biological effects?



Claude Lévi-Strauss, one of the most influential Anthropologists of all times published on cooking, but strongly doubted that cooking would have a biological effect!
Sociocultural anthropology can be as blind to biology as biology is to human culture……

genetic adaptation to cooking?

Mice fed raw or cooked tubers or meat, effects on their liver gene expression:



Controlled feeding experiments in mice with comparative primate genomics to show that consumption of a cooked diet influences gene expression and that affected genes bear signals ofpositive selection in the human lineage. Liver gene expression profiles in mice fed standardized diets of meat or tuber were affected by food type and cooking, but not by caloric intake or consumer energy balance. Genes affected by cooking were highly correlated with genes known to be differentially expressed in liver between humans and other primates, and more genes in this overlap set show signals of positive selection in humans than would be expected by chance.

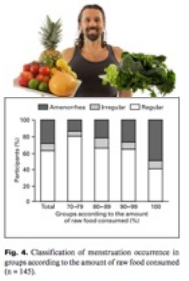


Fig. 4. Classification of menstruation occurrence in groups according to the amount of raw food consumed (n = 145).

Carmody *et al.* ***Genome Biol. Evol.*** 2016 Koebnick *et al.* ***Nutrition and Metabolism.*** 1999

Lab mice prefer cooked meat and tubers. Fed such a diet, the genes changing expression in the mice's livers, when examined in primates, appear to have been under natural selection in humans compared toothier primates. One study of raw foods in Germany reported that 30% of adult women on raw food diet stopped ovulating. One of the strongest evidence that humans have become biologically dependent on cooking.

Humans as cucinivores?



smoking meat/fish



cooking



wild honey harvest



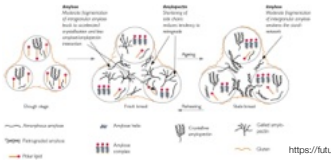
roasting



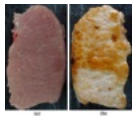
boil

Cooking as a massive niche broadening technology, better digestion, less chewing, detoxification, conservation etc..

Cooking massively improves energy intake for starch and meat



https://futurefoodchemist.weebly.com



very little known on the effect on fats/lipids

Starches and proteins, both become much easier to digest after cooking. Little is known about the effects of cooking on fats (lipids). Cooking of course allows one to extract fat from bone (boiling bone in water), allowing to get such fat without having to chew the bones into powder, like the hyenas….

Cooking Culture



Cuisines are ways in which human cultures define themselves. Differences in cuisines are used for cultural pride and prejudice alike…..

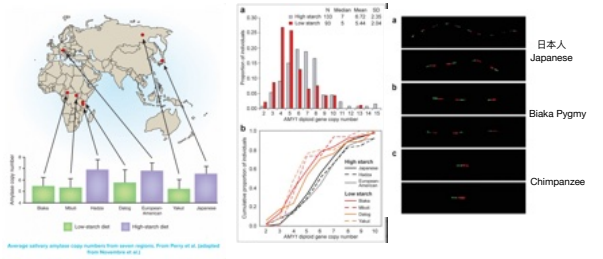
---

12 /40 ways of cooking Chinese food



Chinese culture prides itself in the multitude of culinary approaches to food preparation!

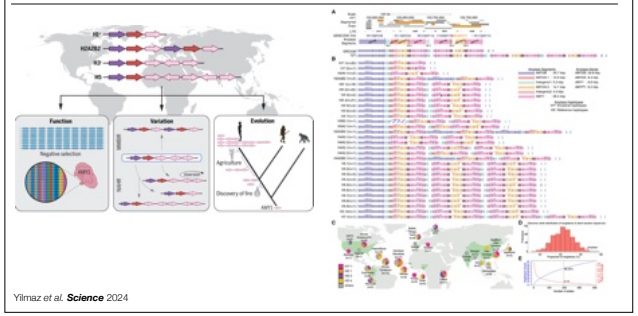
Amylase CNV in humans and apes



Perry et al. ***Nature Genetics*** 2011

Differences in salivary amylase gene copy number exist between present day humans populations. They correlate with the history of grain or tuber use.
Different number of copies of the salivary amylase gene in the genomes of humans and chimpanzees. These copies can be fluorescently stained on prepared chromosomes.

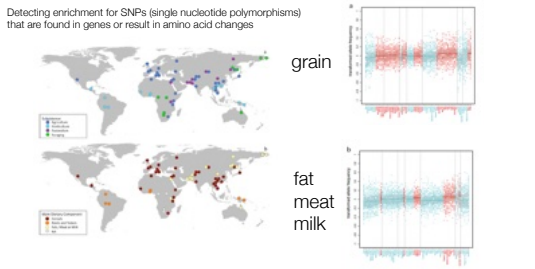
Amylase CNV in humans



Yilmaz *et al.* ***Science*** 2024

Complex evolution amylase locus reveals ancient duplications seeding modern-day variation. The shift to cooked foods, allowing access to to starches tubers and seeds detoxified by heat, and later the shift to grain agriculture, with were accompanied by massive expansions in amylase gene copy numbers.

Genomics of Dietary Adaptation



Hancock *et al.* ***PNAS*** 2010

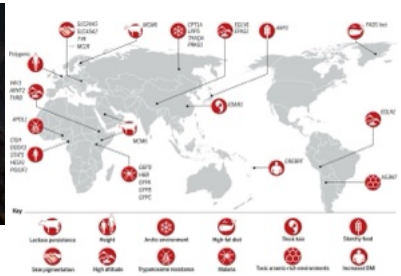
Transformed allele frequency plotted against population for two main dietary component variables: (A) cereals, and (B) fats, meat, and milk. Single nucleotide polymorphisms (SNPs) were polarized based on the relative difference between the two categories in the first region where both were present; then, transformed allele frequencies were computed by subtracting the mean allele frequency across populations. SNPs with ranks less than 10−4 are included in the plots. Vertical lines separate populations into seven major geographic regions (sub-Saharan Africa, Middle East, Europe, West Asia, East Asia, Oceania, or the Americas). Red denotes populations that are members of the category being tested, and all other populations are blue. Lines are drawn through the mean for the set of populations in a given region that are part of the category of interest, and gray shading denotes the central 50% interval.

---

large-scale genome studies of indigenous populations



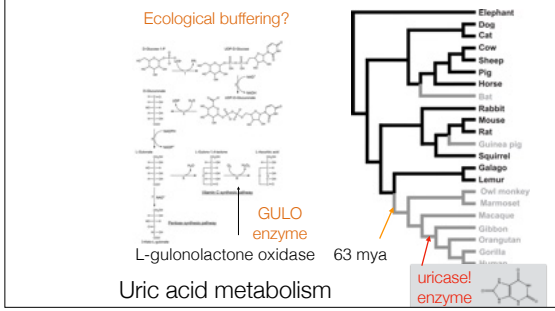
Cheddar Man, 9.5000 year old skeleton from Somerset, UK with ancient DNA



Shaohua Fan *et al.* ***Science*** 2016;354:54-59

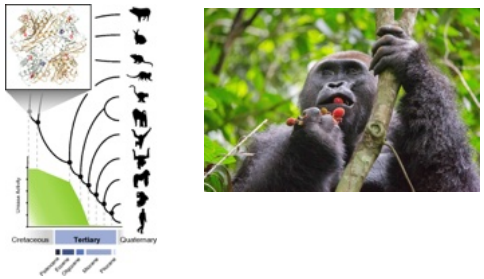
Examples of human local adaptations, each labeled by the phenotype and/or selection pressure, and the
genetic loci under selection.
Examples of adaptive traits reflected in the genome of modern humans.
Disease resistance, ecological adaptation (temperature, UV radiation, altitude), diet and toxins.

Vitamin C Synthesis: fruit driven loss?



Eating fruit seems to have allowed for the loss of vitamin C synthesis genes. An ancestry without much meat consumption, allowed the loss of the uricase gene.

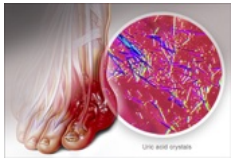
Uricase: fruit (fructose to fat) driven loss?



Uricase enzyme may have been lost as part of the adaptation to make fat from fructose (found mainly in fruit).

Gout



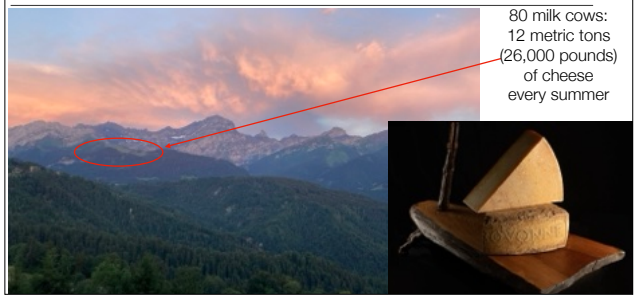


Incidence of gout, globally:
higher in meat consuming societies.



Gout is a disease caused by the accumulation of uric acid crystal in joints, when too much meat is consumed.

Cheese: turning grass into fat and proteins



View from my late grandmother's home in the Swiss Alps. Area in red is a summer grazing ground for 80 cows, which generate enough milk every summer to make 12 tons of cheese!, it takes 10 liters of milk to make 1 kg of hard cheese, so that means this patch of high alpine grazing ground generates one 120,000 liters of milk or ~ 32,000 gallons. In winter there is precious little food at these altitudes, so no wonder people evolved to digest lactose.

Sucrose and Trehalose intolerance: ecological loss?



"use it or lose it!"
Sucrase/isomaltase deficiency in up to 1/20 Greenland Inuits

E. Gudmand-Høyer & H. Skovbjerg (1996) Disaccharide Digestion and Maldigestion, Scandinavian Journal of Gastroenterology, 31:sup216, 111-121

The absence of plant sugars (sucrose) and fungi sugars (trehalose) in the arctic ecology, has contributed to the recent loss of digestive enzymes for both of these disaccharides in the Inuit population.
"Use it or lose it"

Diet and Nutrition

Animals reflect the plants they eat, directly or indirectly.

Plants and animals co-evolve.

Plants are well protected, they produce anti-nutrients in roots, bark, leaves and seeds, but not in ripe fruit.

Trends to frugivory: trichromatic vision, loss of GULO gene (uricase), sweet taste.

Animals adapt to anti-nutrients through physiology or behavior: detox with clay, detox with enzymes, fermentation with micro biome, external fermentation, coprophagy, chemical treatment, leaching and cooking.

Hominin transition from (C3) trees (leaves and fruits) and weeds to (C4) grass and sedges and tubers , or to prey feeding on such plants?

C4, direct and indirect via consumption of ruminants on grass lands. 70 new genera rapidly appearing around 10 mya (late Miocene)

Top scavenger/predator, weapons, tools and cooking, transport of food, risk of disease through meat (toxins, pathogens and parasites e.g. cestodae)

Coastal resources DHA from shellfish and fish, fat and ochre?

Fire was a massive game changer