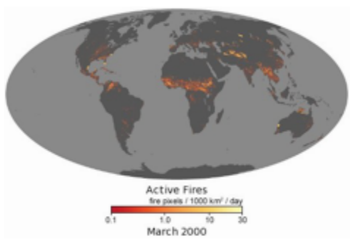
ANBI 141   Evolution of the Human Diet

Lecture 13: Fire on Demand

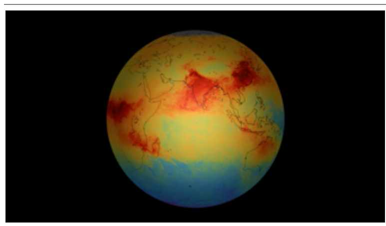
Pascal Gagneux   November 9, 2021

Global fires: ancient, but increasingly linked to humans



The fire maps show the locations of actively burning fires around the world on a monthly basis, based on observations from the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite. The colors are based on a count of the number (not size) of fires observed within a 1,000-square-kilometer area. White pixels show the high end of the count — as many as 30 fires in a 1,000-square-kilometer area per day. Orange pixels show as many as 10 fires, while red areas show as few as 1 fire per day.
Practice question: Which continent has no observed fires?
Antarctica

Global CO (Carbon Monoxide)

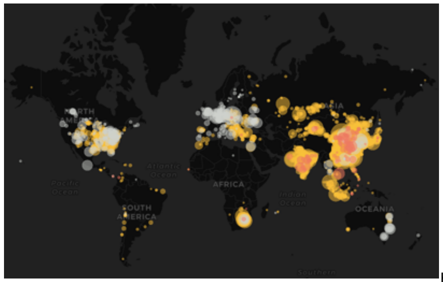


Visualizing the Anthropocene!

CO conc
https://www.nzz.ch/panorama/der-umweltsatellit-sentinel-5p-zeigt-luftverschmutzung-auf-der-erde-ld.1334755

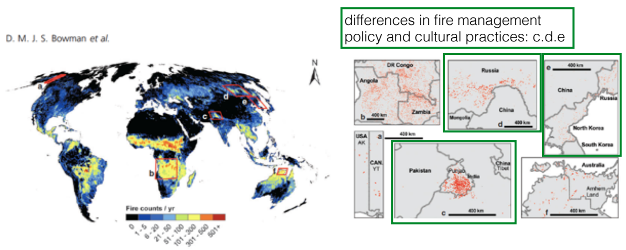
1 December 2017，Launched on 13 October, the Sentinel-5P satellite has delivered its first images of air pollution. Even though the satellite is still being prepared for service, these first results have been hailed as exceptional and show how this latest Copernicus satellite is set to take the task of monitoring air quality into a new era. This new mission promises to image air pollutants in more detail than ever before. And, while these first results demonstrate the sophistication of the satellite's instrument, they certainly bring the issue of air pollution sharply into focus. One of these first images shows nitrogen dioxide over Europe. Caused largely by traffic and the combustion of fossil fuel in industrial processes, the high concentrations of this air pollutant can be seen over parts of the Netherlands, the Ruhr area in western Germany, the Po Valley in Italy and over parts of Spain. Global carbon monoxide measured by Sentinel-5P。 Access the video：Some of the first data have been used to create a global map of carbon monoxide. The animation shows high levels of this air pollutant over parts of Asia, Africa and South America.

The world's coal power plants



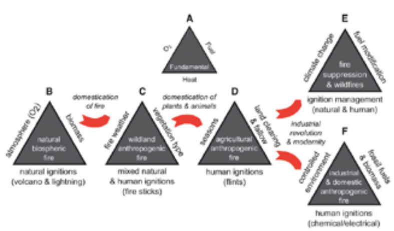
https://www.carbonbrief.org/

Global fires: ancient, but increasingly linked to humans



Global distribution of fires generated by human and natural causes, represented as active fire counts per year recorded with the MODIS sensor (Terra) between 2001 and 2007 (Giglio et al., 2006). Panels illustrate fire activity on selected cloud-free days at various locations spanning political boundaries where differences in fire management policy and cultural practices may (c, d, e) or may not (a, b, f) affect fire activity. Images were provided by the MODIS Rapid Response Team at NASA GSFC. http://lancedev.eosdis.nasa.gov/imagery/rapidresponse/.

global pyric phases



The human dimension of fire regimes on Earth ***Journal of Biogeography*** 2011

Schematic representation of the model of global pyric phases. The model is based on the classical fire triangle concept, which represents fire as a physiochemical process made up of three vital ingredients: oxygen, heat and fuel

(A). With the evolution of terrestrial vegetation, fire was able to become a biospheric phenomenon, given lightning and volcanic ignitions and sufficient oxygen in the atmosphere. Fire activity varied in response to oxygen levels and vegetation types

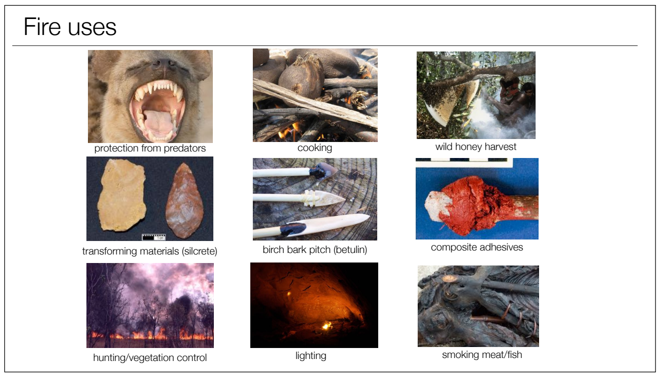
(B). Prehistoric humans domesticated fire, leading to modification of vegetation, by setting fires under suitable weather conditions. The motive for burning varied and included game and habitat management. These prehistoric traditions remain important in many contemporary wildlands, albeit in modified forms

(C). Fire is an important tool for clearing land to establish fields and is incorporated into many agricultural systems to burn dead biomass in specific seasons to prepare fields for cultivation, remove post-harvest residues and stimulate pasture growth

(D). Industrialization has influenced landscape fire activity by changing ignition patterns, enabling the development of suppression technologies and causing climate change via greenhouse gas pollution

(E). Fossil fuels increasingly replaced biomass as an energy source following industrialization

(F). All phases remain on Earth, although comparative studies remain rudimentary.



Practice question:give four examples of fire use other than for cooking:
protection, light, landscape management, transforming materials.

Using a Home base, where a social group sleeps regularly and spends a lot of time, leaves trash and bodily wastes creates completely new opportunities for infectious diseases.

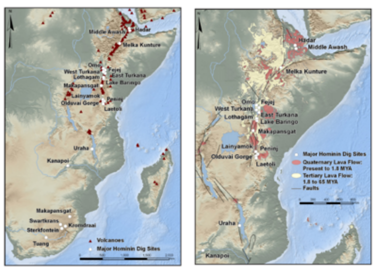
Practice question:What are the limitations in detecting ancient hearths?

Answer: Large trees burnt by natural fires can mimic a hearth.

A Hadza hut in 2018, Such a structure would leave almost no archeological traces!

African volcanic fire ecology: lava flows

Hominin Fossil Finds



Lava flows Quaternary (last 1.6 my) and Tertiary (65 to 1.6 my)

Medler: Effects of Fire and Lava Flows ***Fire Ecology*** 2011

Human evolution linked to tectonic activity and volcanism? Many of the most significant finds in hominid evolution are located in close proximity to lava flows.

Practice Question: What is the connection between lava flows and hominid fossil sites in East Africa?

They are found in similar regions.

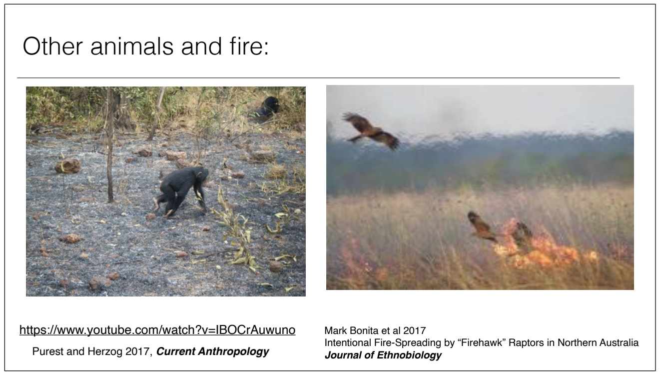
One massive volcanic eruption can ruin your entire day - and shape evolution

74 kya caused a six year nuclear winter and a 1000 year glaciation

Ambrose, ***J. Hum Evol.*** 2003

Punctuated natural disasters, such as the eruption of Mount Toba in South east Asia 74 ky ago, had the potential to influence the course early human history….. human life on the Indian subcontinent would likely have been wiped out…

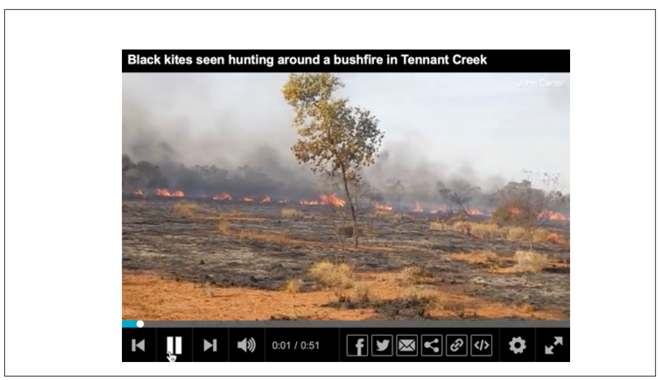
By then modern *H. sapiens* made and used fire routinely, and was about to spread all over Asia.



Chimpanzees in Fongoli, Senegal stay totally relaxed near brush fires. Black kites in Australia have been seen actively spreading fires! The only non-human species known to use fire!

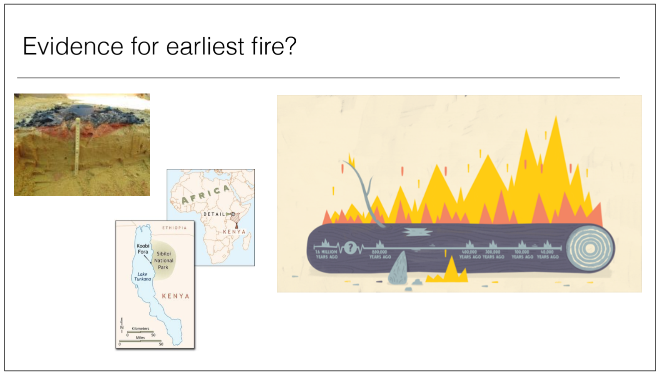
Practice question: Which species has been observed actively spreading fire?
Black kites in Australia.

Chimpanzees in Fongoli, Senegal, totally unimpressed by a wildfire.

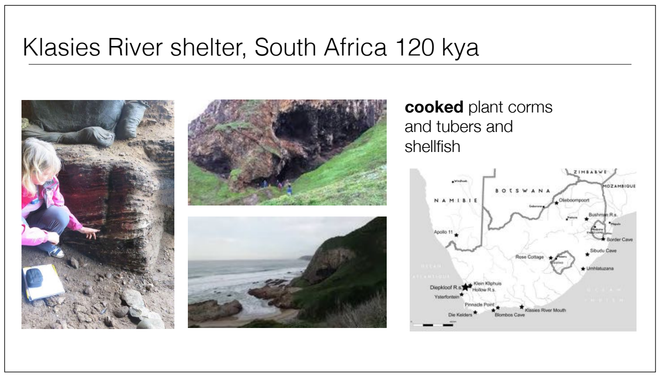


Black kites interacting with fires in Australia.

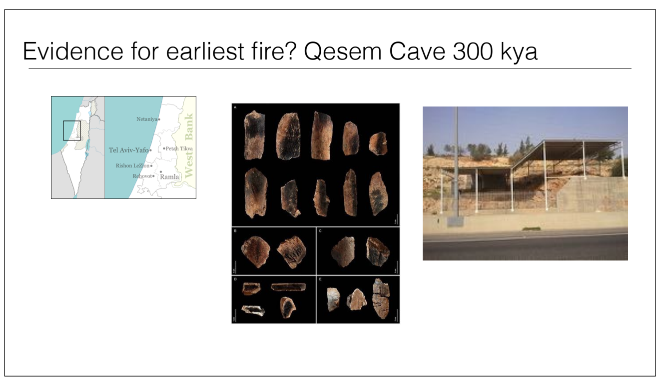
Practice question: What do some Australian aboriginal cultures believe black kites taught humans?
Hunting with fire.



Experiments show that fires leave behind evidence—charcoal, ash, and burned artifacts—that gets buried under layers of sediment. These layers accumulate over time, leaving a record that can persist for many thousands of years.



Archaeologist Cynthia Larbey, shown here at the Klasies River Cave in South Africa, studies the presence of early modern humans in the region. Wits University



Qesem Cave in Israel, where these charred bits of animal bones were found, is one of the earliest known sites showing somewhat persistent fire usage by humans. Ruth Blasco/Wikimedia Commons

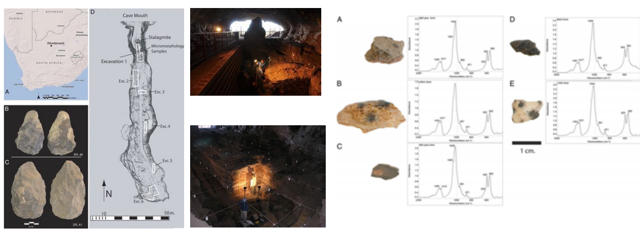
Gesher Benot Ya‘aqov, Israel, 780 kya

Homo erectus roasted plant material including nuts and tubers.

Melamed et al. 2016 ***PNAS***

Food plant remains from GBY.
(A) Quercus sp., young cupule (layer II-6 L1);
(B) *T. natans* water calthrop, upper tip of nut (layer III-7);
(C) *Nuphar luteum*, cow/water lilly seed (layer II-7);
(D) *B. umbellatus*, flowering rush, seed (layer III-4);
(E) *Scirpus lacustris*, lakeshore bulrush seed (layer II-9); and
(F) *Vitis sylvestris*, wild grapevine , pip (layer IV-7).

Wonderwerk Cave, SA, 1 my old burnt animal bones



burnt anima 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.

How old is fire use?

Table 1. List of sites before 400 kya with evidence of fire

Location	Period	Evidence of fire
Africa:		
Koobi Fora, FxJj20, Kenya[a]	1.5–1.6 Mya	Burned lithics, reddened sediment
Chesowanja, GnJi1/6E, Kenya[a,b]	1.42 Mya	Reddened sediment
Gadeb, Ethiopia[a]	.7–1.5 Mya	Burned lithics
Swartkrans, South Africa[c,d]	1.0 Mya	Burned bones
Wonderwerk, South Africa[e]	1.0 Mya	Ash, charcoal, burned bone
Southwest Asia:		
Gesher Benot Ya'aqov, Israel[f]	780 kya	Burned lithics, charcoal, burned seeds
Qesem Cave, Israel[g]	400–200 kya	Hearths, ash, burned bone
Tabun, Israel[h]	350 kya	Hearth, ash, phytoliths
Hayonim, Israel[i]	250–100 kya	Ash, charcoal, phytoliths
Europe:		
Atapuerca, Spain[j]	1.2–.780 Mya	Dispersed charcoal
Isernia, Italy[j]	606 kya	Burned bone, burned sediment
Boxgrove, England[j]	MIS 13	Charcoal
Highlodge, England[j]	MIS 13	Charcoal
Beeches Pit, England[j,k]	MIS 11	Burned lithics, burned bone, burned sediment, hearth
Vertesszöllös, Hungary[j]	MIS 9–11	Burned bone, hearth
Bilzingleben, Germany[j]	MIS 9–11	Charcoal, burned lithics, burned bone
Terra Amata, France[j]	380–239 kya	Charcoal, burned lithics, burned bone, hearth
Orgnac, France[j]	MIS 9–8	Burned bone, ash
Petit Bost, France[j]	MIS 9/8	burned lithics

MIS: marine isotope stage
MIS13 500 kya

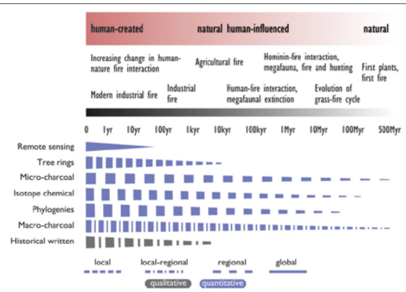
Hlubik et al. Nature of Fire at FxJj20 AB, Koobi Fora, Kenya

a Clark and Harris 1985.
b Gowlett et al. 1981.
c Brain 1993.
d Gibbon et al. 2014.
e Berna et al. 2012.
f Alperson-Afil and Goren-Inbar 2010. g Shahack-Gross et al. 2014.
h Albert et al. 1999.
i Shahack-Gross, Bar-Yosef, and Weiner 1997.
j Roebroeks and Villa 2011.
k Preece et al. 2006.

Geography of early fire

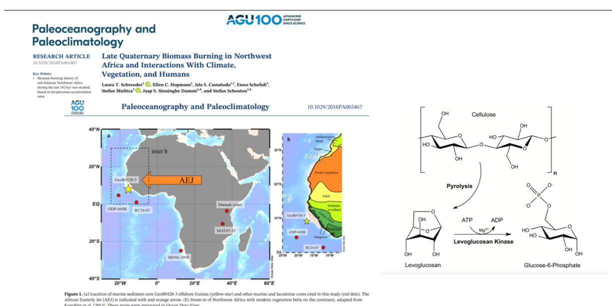
Fire use predates the origin of modern humans and could be as old as the first *Homo erectus* 2 million years ago.

Summary of the available historical sources and palaeoecological proxies to reconstruct fire regimes



Summary of the available historical sources and palaeoecological proxies to reconstruct fire regimes, spanning the period from the advent of fire on Earth in deep time to the modern industrial period characterized by fossil fuel combustion. The spatial and temporal resolution of all these approaches varies and decays with increasing time depth, constraining our understanding of fire regimes, especially before the Industrial Revolution.

New molecular markers for fire? Levoglucosan?



Peaks between 60 and 50,000 years ago, coinciding with human arrivals in West Africa?

friction fire

Hadza man (named Janjako) making a friction fire to light an herbal jazz cigarette.

Making a hand fire drill

dry hard wood and grass as tinder

Carving the adapter bit to turn a poison arrow into a fire stick. the wood used for the drill bit and the bottom to be drilled are both cut from dry *Commiphora africana* trees. the knife is a Norwegian Helle Knive that Janjako borrowed from me.

More fire-making techniques

fire thong, rattan

https://www.youtube.com/watch?v=_yieVOvk7Kc&NR=1&feature=endscreen

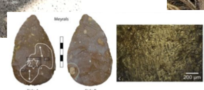
More fire-making techniques

fire plow

https://www.youtube.com/watch?v=aSpioDPX3ic

More fire-making techniques

Starting a fire with flint hand axe and pyrite



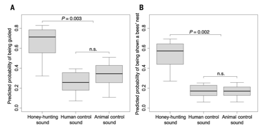
Flint and pyrite?

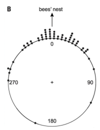
Sorensen *et al.* ***Scientific Reports*** 2018

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.
Practice question: Give four different methods of making fire on demand:
hand drill, bow drill, fire thong/belt, flint and pyrite.

Greater honey guide (Indicator indicator) on a baobab tree in Southern Tanzania, Lake Eyasi region.

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.

Honey Guide in action

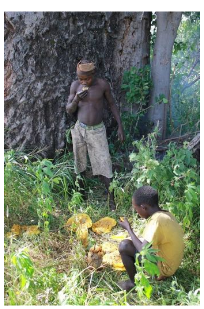
honey guide

risky honey

https://www.youtube.com/watch?v=6ETvF9z8pc0

https://www.youtube.com/watch?v=j3IAZq-mGwY

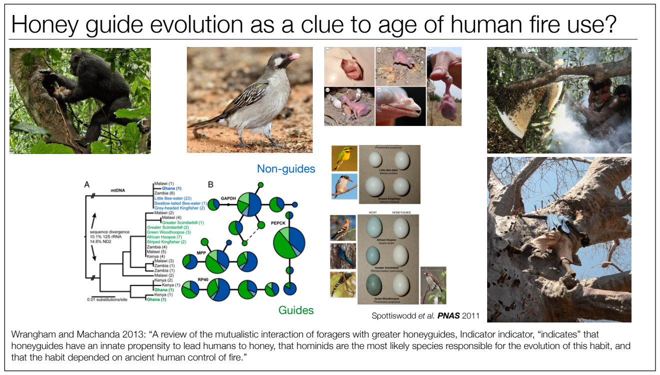
Paying the Honey Guide?



https://vimeo.com/72279587

Brian Wood, UCLA

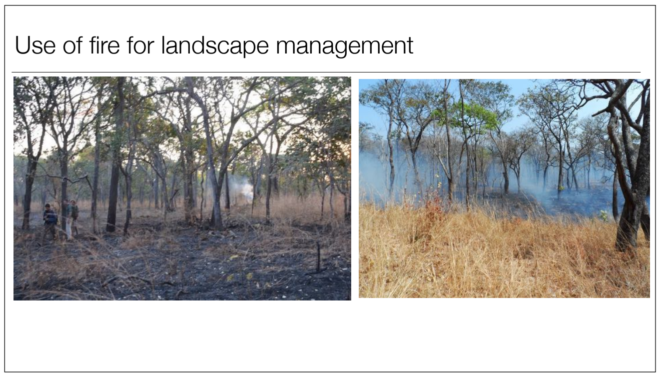
Brian Wood (UCLA) reporting on Hadza burning or burying extra honey comb!…. To prevent the honey guide from getting "lazy"!!



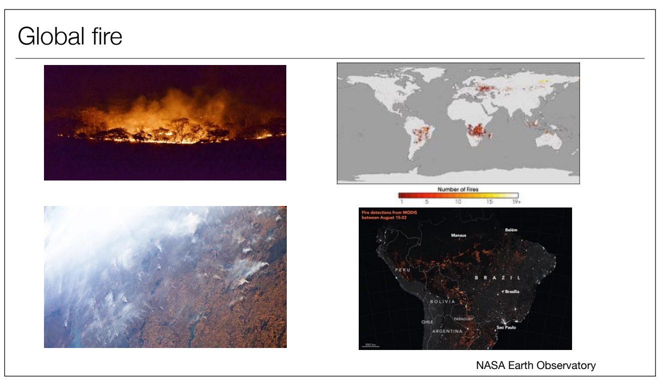
Mitochondrial and nuclear DNA relationships among honeyguides using different host species. (A) Mitochondrial phylogeny based on partial 12SrRNA gene sequences. Genetic divergence for the ND2 gene was measured for a representative sample of individuals with divergent 12S sequences. The lineages that 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?

Practice question: What can honey guide genetics teach us about human fire use?

The ancient divergence between bird lineages that do or do not interact with humans, point to the deep age (~2 my) of fire use by humans.



Burnt landscape are much easier to travel through.



The Amazon has been particularly hard hit with human made fires recently. the populist Jair Bolsanero places cattle production over the protection of biodiversity.

Bush Fires

Many bush fires travel rapidly and do not burn most of the mature trees.

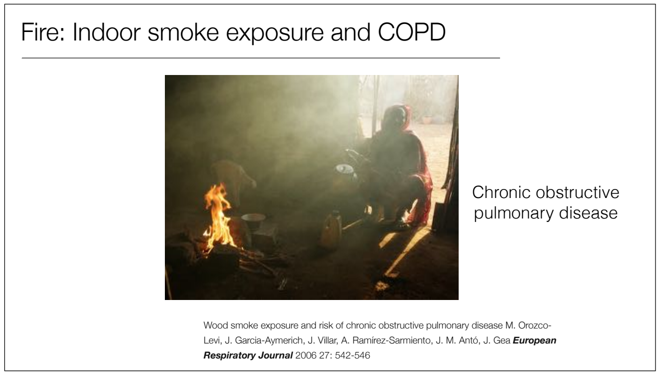
Use of fire by pastoralists

Burning pasture can fertilize the ground and cause fresh new grass to sprout.

Practice: What are three advantages of burning landscapes?
Hunting is easier, travel is easier, and new grass attracts prey.

Changing landscapes and homes

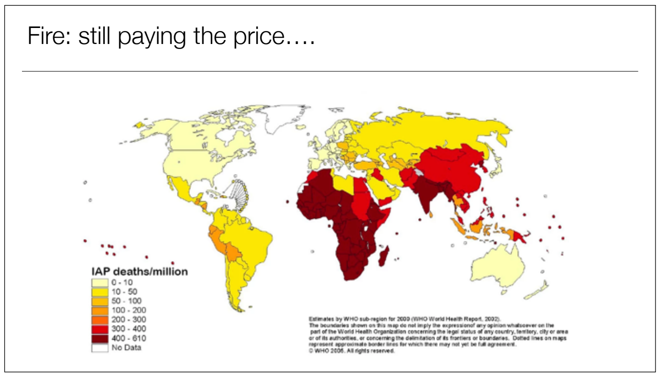
Unburnt and burnt savannah grass land in southern Tanzania
Kitchen in field research Camp in Tanzania, open fire kitchens generate much smoke.



COPD continues to be a huge problem in poorer countries where people cook indoors using wood or coal.

Practice question: What does COPD stand for?

Answer: Chronic Obstructive Pulmonary Disease.



Practice question:

Where are people still most affected from indoor fire smoke inhalation?

Africa and India, South East Asia.

Fire use might have sparked novel social behavior by bringing people together. It also damages a lungs and might be part of the ancient history of TB.

Practice question:

How might the regular use and fire and tuberculosis be related?

Answer: Fire damages lungs and brings people together.

How fire creates flavor in food

A soufflé: egg cheese mixture baked golden brown……

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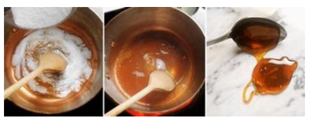
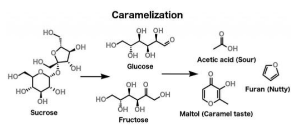
burnt sugar: caramel



sugar heated to 160 °C or 320 F



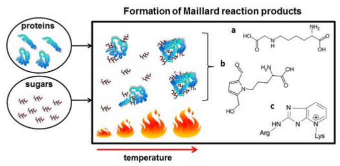
Caramelization is the removal of water from a sugar, proceeding to isomerization and polymerization of the sugars into various high-molecular-weight compounds. Compounds such as difructose anhydride may be created from the monosaccharides after water loss. Fragmentation reactions result in low-molecular-weight compounds that may be volatile and may contribute to flavor. Polymerization reactions lead to larger-molecular-weight compounds that contribute to the dark-brown color.

Practice question why does white sugar turn brown when caramelized?

Answer: Sugar molecules combine into aromatic molecules that absorb light.

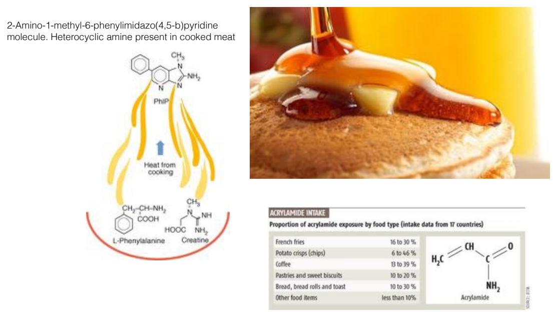
making caramel filling for walnut cake

proteins reacting with sugars: flavor and color!

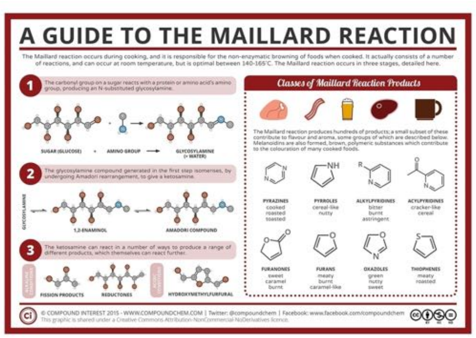


Practice question: What are the two reagents forming Maillard reaction products?
Answer: Sugars and proteins.

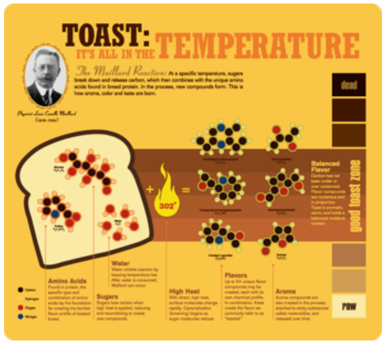
How heat from cooking forms PCAH compounds



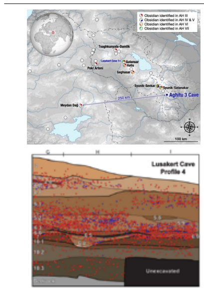
Heating organic matter (including food) will cause the formation of polycyclic aromatic hydrocarbons. These tend to be colorful ranging from yellow to brown to black. They also can be very tasteful.
The Maillard Browning reaction can also create acrylamide, less tasty but more carcinogenic…..most roasted foods including drinks like coffee (roasted coffee beans) and beer (roasted malted grain) contain some…. heavy PCAH require heat of 600° C plus, characteristic of fires made in hearths.

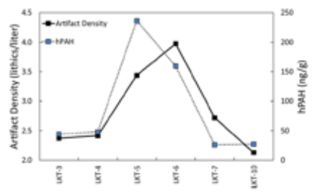


Maillard Reaction named after a French chemist is one of the sources of all good flavors…. Sugar reacts with amino groups of amino acids in proteins and generates browning reaction products, many of them very flavorful, not all healthy. Our bodies also slowly brown, even under much lower temperature than cooking. The products are called advanced glycation end products (ACE). The higher levels of glucose in diabetics increase the formation of ACE, with detrimental health effects. Caramelization in contrast is a form of pyrolysis, as the disaccharide sucrose falls apart into glucose and fructose and these two sugars then form a large number of further compounds.



Neanderthal fire: Lusakert Cave,Armenia (300 -40 kya)



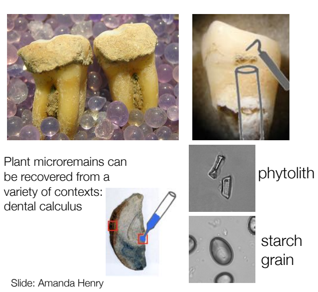


low molecular weight (four or fewer rings) versus high molecular weight (five or more rings) polycyclic hydrocarbons (require 600 to 1000 C heat)

Alex Brittingham et al. Geochemical Evidence for the Control of Fire by Middle Palaeolithic Hominins, ***Nature Scientific Reports*** 2019

Distribution of measured lithic (red circles) and faunal remains (blue circles) excavated by stratigraphic unit from LKT1 during the 2008–2011 field seasons. 1 meter excavation squares (G, H and I) are labeled. Sedimentary units are labeled in white.
Artifact density of plotted lithic artifacts and high molecule weight polycyclic aromatic hydrocarbons (hPAH) concentrations of each layer at LKT1. Average hPAH concentrations of subunits are nested into their unit designations.

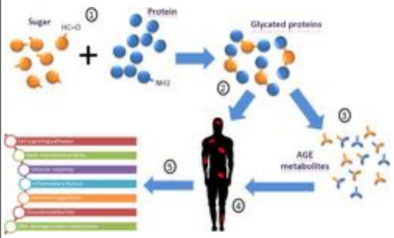
Evidence for cooked plant foods in Neanderthals?



Slide: Amanda Henry

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.

AGE (advanced glycation end products)



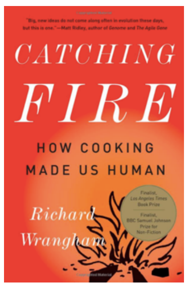
Our bodies slowly undergo non-enzymatic glycation (slow motion maillard reaction) and generate advanced glycation end products. These can be involved in disease but are cleared by special receptors: RAGEs

Our bodies slowly undergo non-enzymatic glycation (slow motion maillard reaction) and generate advanced glycation end products. These can be involved in disease but are cleared by special receptors: RAGEs

Practice question: What are the parallels between Maillard reaction products and advanced glycation end products (AGE)?

Answer: Both are products of reactions between sugars and proteins.

Fire and cooking



Treating food with heat massively broadens feeding opportunities and improves caloric intake.

Cooked food represent clumped resources that can be stolen and need to be defended.

Genetic adaptation to cooking?

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

Feeding experiments in mice combined with comparative primate genomics:
Consumption of a cooked diet influences gene expression and affected genes show signals of positive 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.
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.

Carmody *et al.* ***Genome Biol. Evol.*** 2016

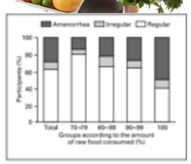


Fig. 4. Classification of menstruation occurrence in groups according to the amount of raw food consumed (n = 145).

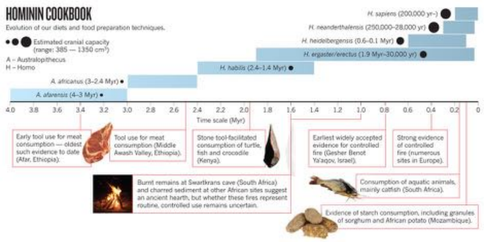
Koebnick *et al.* ***Nutrition and Metabolism.*** 1999

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 >40% of adult women on raw food diet stopped ovulating. One of the strongest evidence that humans have become biologically dependent on cooking.

Practice question: What is the evidence that humans are biologically "addicted" to cooking their food?

Raw food eating females loose fertility, all known human societies cook.

Hominin Dietary Changes Over Deep Time

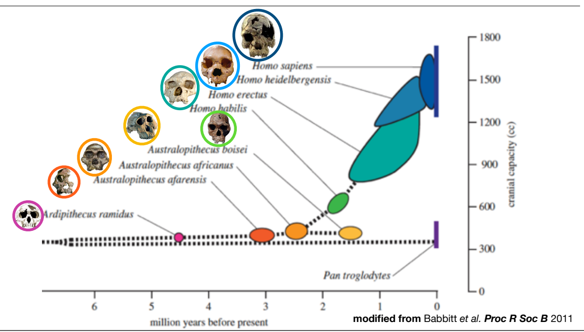


Many details still controversial: "The Cooking Hypothesis" "Meat and Potatoes"

Eisenstein, M. Evolution: The First Supper. *Nature*. 2010;468,S8-S9. COMSTOCK IMAGES; D. STELLER /ISTOCKPHOTO; J. READER/SCIENCE PHOTO LIBRARY; UP THE RESOLUTION; A. DICKOV/ISTOCKPHOTO

Dietary changes have also had both immensely positive and very negative effects on human health.

Brain expansion over time



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

Did fire use usher in the increase in brain size?

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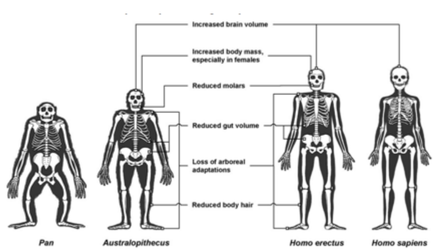
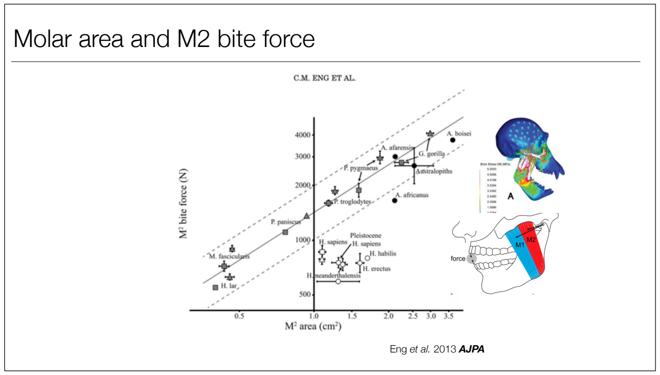
fire and anatomical change

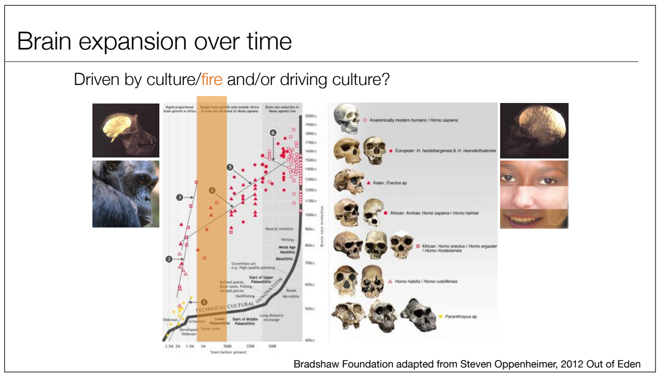


Wrangham and Carmody ***Evol. Anthropol.*** 2010

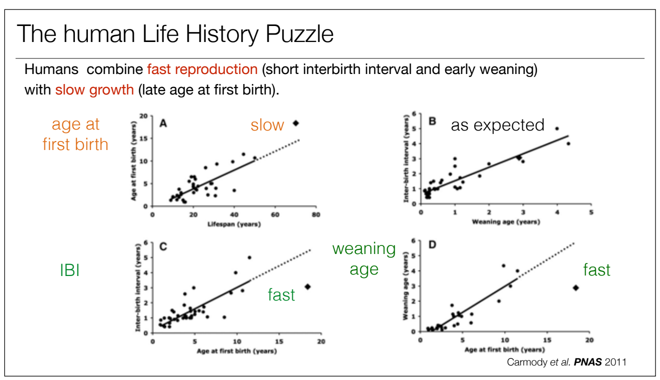
Practice question: Give three examples of human anatomical adaptation to cooked food. Small teeth, low bite force, small gut.



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.



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



The human life history puzzle. In most species, different life history parameters are consistent in their pace, as illustrated here for nonhuman primate species (solid circles) by correlations among four life history variables. Unusually, hunter-gatherers (large diamond) are slow in two variables (life span, age at first birth), but fast in two others (weaning, interbirth interval).

A: Nonhuman primates with long maximum life span tend to have late age of first birth (r2 1/4 0.56, n 1/4 36, p < 0.001). Humans are here assigned a conservative estimateof 70 years for maximum life span, following Harvey, Martin, and Clutton-Brock, and fall close to the primate line.

B: Nonhuman primates with later weaning have longer interbirth intervals (r2 1/4 0.80, n 1/4 36, p < 0.001). Hunter-gatherers conform to the primate trend.

C: Nonhuman primates with a late age of first birth tend to have long interbirth intervals (r2 1/4 0.61, n 1/4 41, p < 0.001); however, hunter-gatherers have shorter interbirth intervals than expected.

D: Nonhuman primates with a late age of first birth tend to wean later (r2 1/4 0.82, n 1/4 29, p < 0.001), but hunter-gatherers have an earlier weaning age than expected. Number of hunter-gatherer societies contributing to mean values: age at first birth, n =6; interbirth interval, n=9; weaning age, n=18.

Practice question: what aspects of human life history are particularly puzzling?

Answer: Early weaning, shorter IBI.

Cooking, no biological effects?

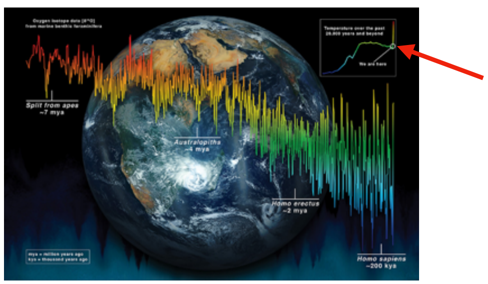
Claude Lévi-Strauss, one of the most influential Anthropologists of all times published on cooking, but strongly doubted that cooking would have a biological effect!

Sociocultural anthropology can be as blind to biology as biology is to human culture……

Practice question: What did Claude Lévi-Strauss think about the biological impact of cooked food?

Answer: He believed that cooking had no biological impact.

Our species as climate driver



The human who first started that friction fire would never have imagined that burning stuff would eventually change the global climate.

Summary

Natural fires are frequent and old, charcoal records dating back 400 million years!

Humans are now a big part of global fire.

Large fires are both dangerous and needed, unnatural and natural…..

Humans promote and try to prevent fires.

When humans began using fire at will, remains unknown, but could be older than 1 million years ago.

Volcanoes and early hominins were neighbors.

Almost no other animals use fire, but chimpanzees seem somewhat fire wise…..and do not panic.

Fires change the ground on which they burn and leave tell-tale signs.

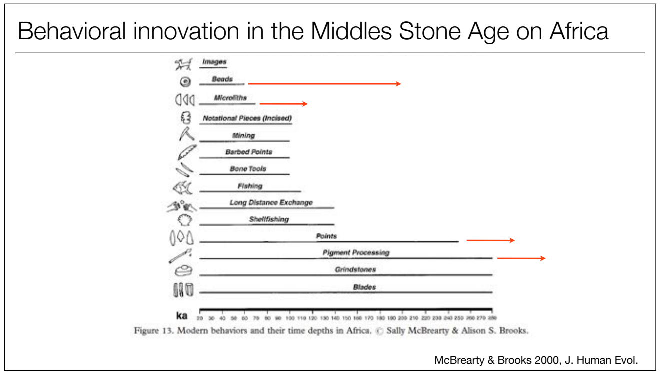
Humans' symbiosis with the greater honey guide might point to very old use of fire to get honey from bees.

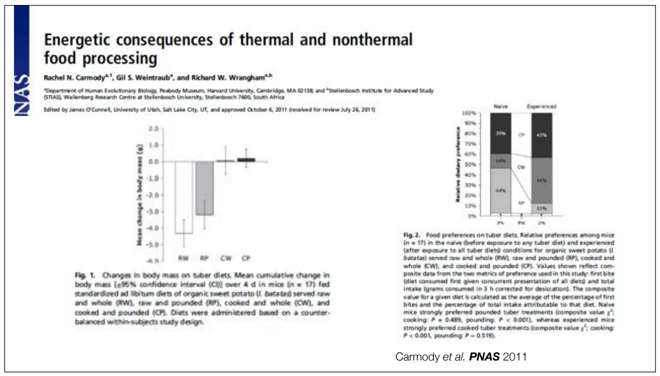
Several techniques can be used to make friction fire or to generate hot sparks.

Fire has profound effects on human health, with good and bad (warmth and nutrition vs TB and lung disease)

Fire transform food and creates flavors and colors.

Human biology and life schedules (life history) have become dependent on fire use.





Many exciting recent discoveries of fossils and artifacts, 2 million year old tools in North Africa, 50 thousand year old art in Borneo.

Human made Honey: Sugar

Nectar Loving Humans