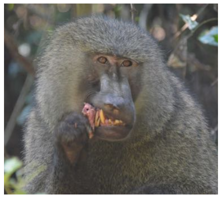
ANBI 141 Evolution of the Human Diet

Lecture 4: Dietary Adaptations



Pascal Gagneux

October 4, 2022

Adaptation?

Adaptation, in biology, the process by which a species becomes fitted to its environment; it is the result of **natural selection**'s acting upon **heritable variation** present in a population over several generations.

Organisms are adapted to their environments in a great variety of ways:

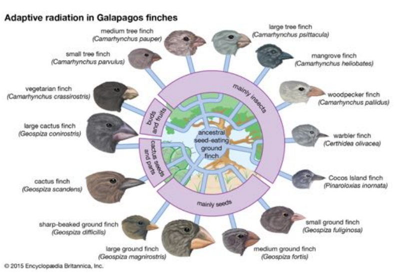
in their structure, physiology, and genetics,

in their locomotion or dispersal, in their means of defense and attack,

in their reproduction and development, and in other respects.

Food and Adaptation?

1.5 million years was enough to evolve 14 different species derived from one common ancestor founding population.

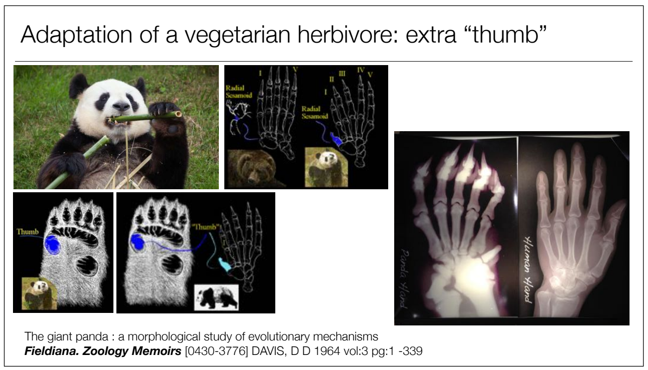


Fourteen of the currently recognized species evolved from a common ancestor in the Galápagos archipelago in the past 1.5 million years according to mitochondrial DNA (mtDNA) dating; a fifteenth species inhabits Cocos Island. The radiation proceeded rapidly as a result of strong isolation from the South American continent, generation of new islands by volcanic activity, climatic oscillations caused by the El Niño phenomenon, and sea level changes associated with glacial and interglacial cycles over the past million years that led to repeated alternations of island formation and coalescence

The best evidence for evolution that Darwin's team collected in the Galapagos were all the different tortoises (belonging to 13 sub-species). **They ate them** and threw their skeletons in the ocean……… It took many more years for Darwin to realize that the finches reflected recent evolution on those islands.

Practice question: What did the crew of the HMS Beagle do with the powerful evidence for evolution in the form of galapagos tortoise skeletons?

Answer: They ate the tortoises and threw the bones over board!

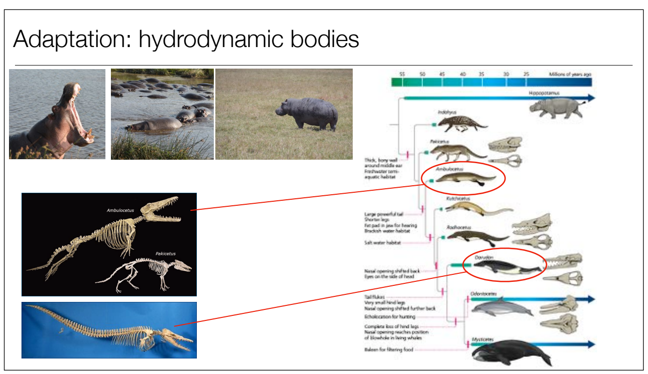


Giant pandas are close relatives of bears and all bears ar part of the carnivore group of animals. Their paws have 5 parallel claws.

Gina pandas secondarily evolved into highly specialized bamboo eating herbivores. They evolved a novel opposable thumb from a tiny sesamoid wrist bone that is present in the hand of all carnivores.

Practice question: What unusual adaptation is evident in the giant panda's front paws?

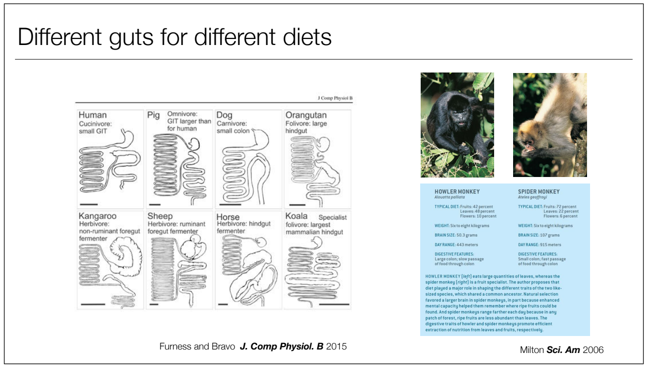
Answer: They evolved an extra digit to hold bamboo.



Whales and dolphins share a common ancestor with hippopotamuses. The hydrodynamic bodies of whales and dolphins are the result of dozens of millions of years of adaptation to life under water!

Good resource for evolutionary biology:

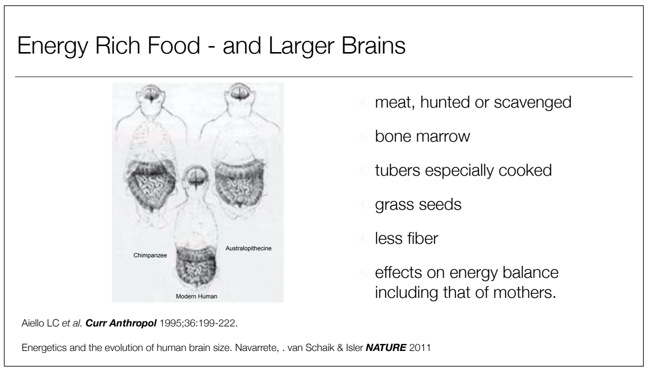
https://evolution.berkeley.edu/evolibrary/home.php



Mammalian gut morphology/anatomy is adapted to the dietary habits of each species.
Size of different gut segments: foregut, stomach, small intestine, and large intestine (hind gut/colon) as well as passage time of ingested food and composition of the gut microbiome are all adapted to the animal's dietary habit and shaped by int environments.

Practice question: Which diet is associated with larger relative brain size in non-human primates, leaf eating or fruit eating?

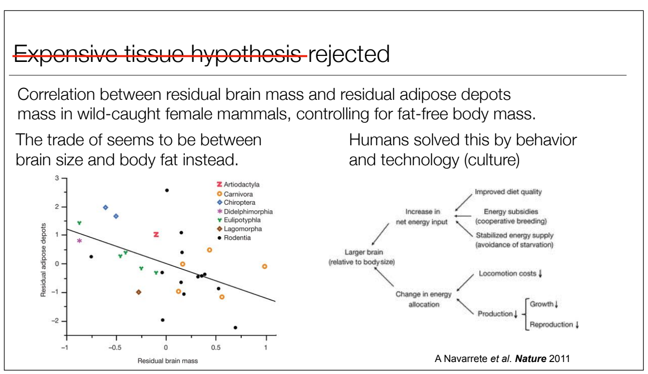
Answer: Fruit eating.



Gut brain size trade off? Not so simple.
Known as the "expensive tissue hypothesis" the proposal that primates balance the cost of digestion and brain function has ben shown to be too simplistic.

Practice question: What is the Expensive Tissue Hypothesis in the context for the evolution of the human diet?

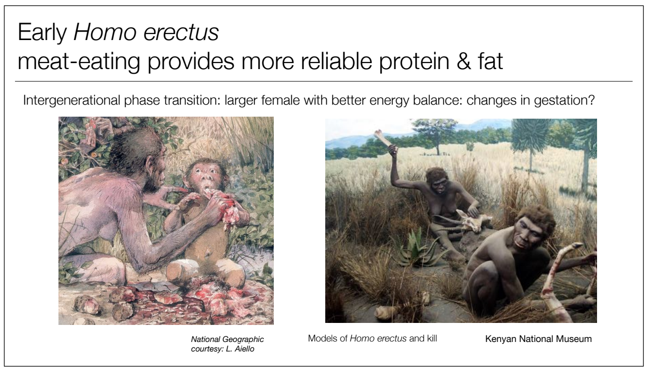
Answer: The idea that there exist a direct trade off between gut size and brain size..



The human brain stands out among mammals by being unusually large. The expensive-tissue hypothesis explains its evolution by proposing a trade-off between the size of the brain and that of the digestive tract, which is smaller than expected for a primate of our body size.

Although this hypothesis is widely accepted, empirical support so far has been equivocal. Here we test it in a sample of 100 mammalian species, including 23 primates, by analysing brain size and organ mass data. We found that, controlling for fat-free body mass, brain size is not negatively correlated with the mass of the digestive tract or any other expensive organ, thus refuting the expensive-tissue hypothesis. Nonetheless, consistent with the existence of energy trade-offs with brain size, we find that the size of brains and adipose depots are negatively correlated in mammals, indicating that encephalization and fat storage are compensatory strategies to buffer against starvation. However, these two strategies can be combined if fat storage does not unduly hamper locomotor efficiency. We propose that human encephalization was made possible by a combination of stabilization of energy inputs and a redirection of energy from locomotion, growth and reproduction.

First, brains can get larger when energy inputs are stabilized on a higher level (higher total metabolic turnover) through an increase in mean dietary quality (for example, more animal fat and protein in early Homo), energy subsidies from other individuals (for example, cooperative breeding, allomaternal care) or by reducing fluctuations in energy inputs (for example, cognitive solutions, including culture). Second, at constant total energy intake, energy allocation to other functions may be reduced, such as locomotion (for example, efficient bipedalism) or production (for example, slower life history pace).

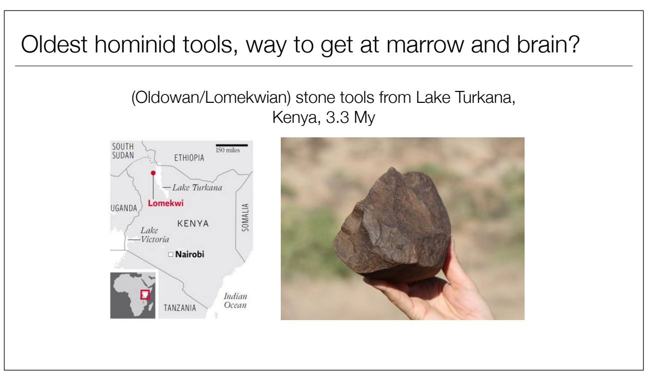


Bone marrow as weaning food?

Meat within bones is much safer to consume than muscle meat and organs.

Practice question: Why is meat inside bone safer to consume?

Answer: Much less exposure to microbes, takes much longer to get contaminated.



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.

Many Plants are well defended

physical defenses, anti-nutrients and toxins

Stinging nettles have microscopic needles made out of silicate (glass-like) material called trichomes, these break on contact forming a sharp edge that pierces the skin and introduces oxalic, formic and tartaric acids into the wound…..

Many cacti of the Americas and acacias of Africa and Asia have very sharp thorns.

Some acacia have evolved symbioses with ants that live inside their hollow thorns and attack any animal (from caterpillar to giraffe) that touch the plant.

Practice question: Name an example of plant insect symbiosis that improves plant protection from herbivores?

Answer: Ant-Acacias, where the plant houses and feeds the ants and the ants “earn their keep” by attacking any animals trying to feed on the trees.

Many Plants are well defended

physical defenses, anti-nutrients and toxins

Animals adapt physiologically and behaviorally!

Common milkweed, *Asclepias syriaca*, being fed upon by (A) the milkweed leaf beetle, *Labidomera clivicollis* (Coleoptera: Chrysomelidae) and (B) a larva of the monarch butterfly, *Danaus plexippus* L. (Lepidoptera: Nymphalidae). Note the latex exuding from where the beetle has severed the veins and where the caterpillar is notching the mid-vein. Photos taken by Pete Van Zandt.

Practice question: How can a plant eating insect adapt to sticky and toxic plant latex?

The Insect can drain the leaves of much of the noxious latex by severing major latex vessels before eating the leaf.

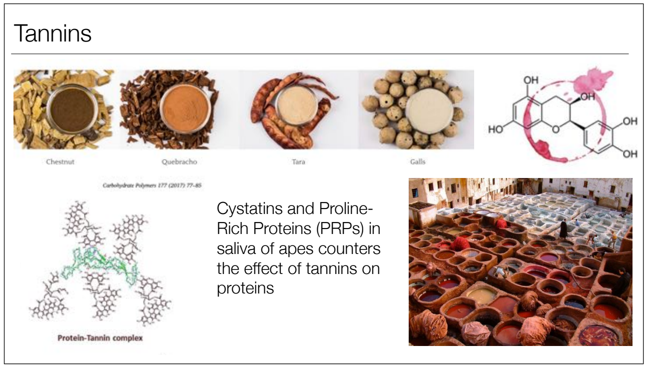
Co-evolution of plant defenses and herbivore teeth

Silicates in grass and horse teeth

Many grasses have evolved higher silica content, horses teeth have grown their crowns.

Practice question: How can a herbivore adapt to higher silicate content in grass that it eats?

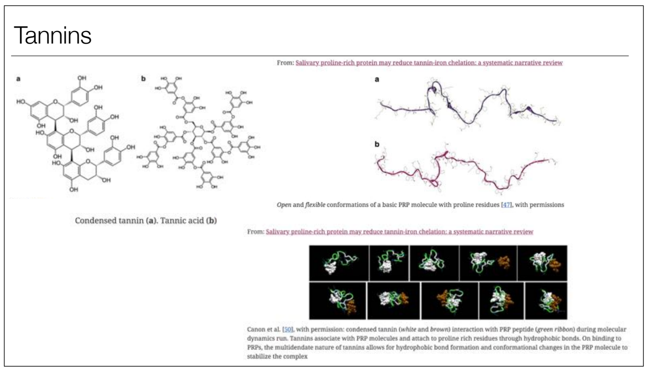
Answer: Evolving higher crowns on its teeth to protect against premature wear.



Tannins are named after leather tanning as seen on this slide in Marrakesh, Morocco

Practice question: What are tannins named after?

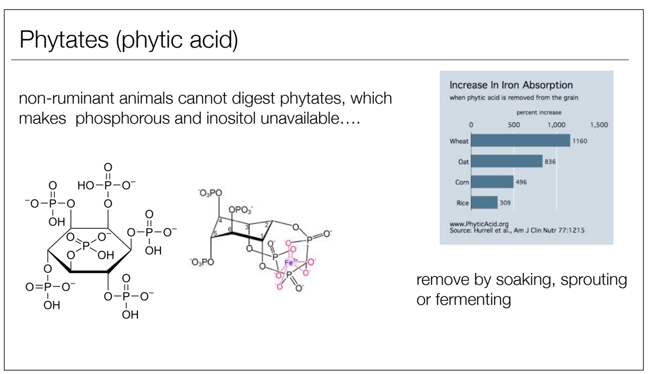
Answer: Tanning animal skin into leather.



Animal saliva contains special proteins, that can counteract the effect of tannins: Cystatins and proline-rich proteins.

Practice question: How can animal saliva counteract plant anti nutrients?

Saliva contains cystatin proteins that binds tannins to negate their effects.



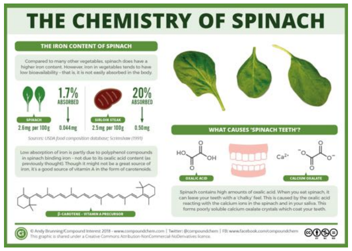
Phytic acid has a strong binding affinity to the dietary minerals, calcium, iron, and zinc, inhibiting their absorption. Phytochemicals like polyphenols and tannins also influence the binding.When iron and zinc bind to phytic acid, they form insoluble precipitates and are far less absorbable in the intestines. This process can therefore contribute to iron and zinc deficiencies in people whose diets rely on these foods for their mineral intake, such as those in developing countries and vegetarians.

Practice question: How do phytates act as anti-nutrients?

Answer: They sequester minerals, making them unavailable to animals.

Oxalates, oxalic acid

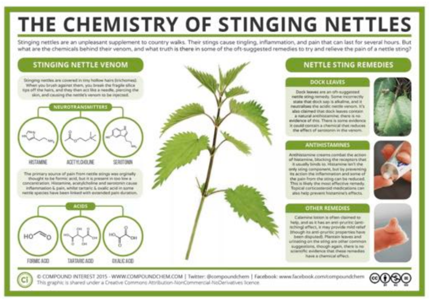
Bind to Calcium and magnesium



Oxalis triangular wood-sorrel

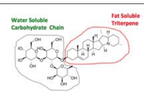
Oxalic acid, one of the main reasons children do not like many vegetables.

Oxalates, oxalic acid

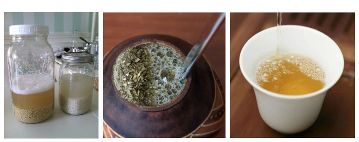


Saponins

The name ‘saponin’ is derived from the Latin word sapo which means ‘soap’, because saponin molecules form soap-like foams when shaken with water.



Saponins are surfactants: they change the surface tension of liquid and can dissolve membranes.

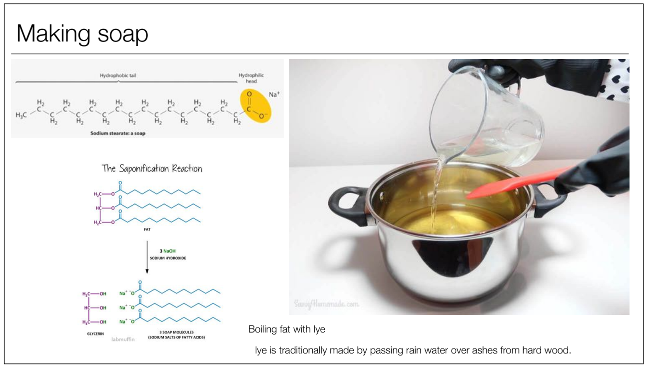


Quinoa saponins | Yerba mate saponins | Tea saponins

They are structurally diverse molecules that are chemically referred to as triterpene and steroid glycosides. They consist of nonpolar aglycones coupled with one or more monosaccharide moieties. This combination of polar and non-polar structural elements in their molecules explains their soap-like behavior in aqueous solutions.

Practice question: What are saponins named after?

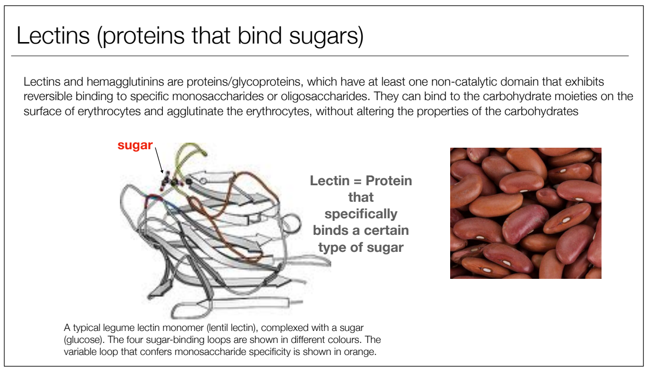
Answer: soap, because they are detergents/surfactants.



Modern lye, (Sodium hydroxide or NaOH) is made by applying electric currents to brine (solution of NaCl in H2O): this results in the “splitting” of water and produces NaOH and hydrogen gas (H2).

Practice question: How is soap made traditionally?

Answer: Cooking a combination fats with lye (a watery solution of pot ash)..



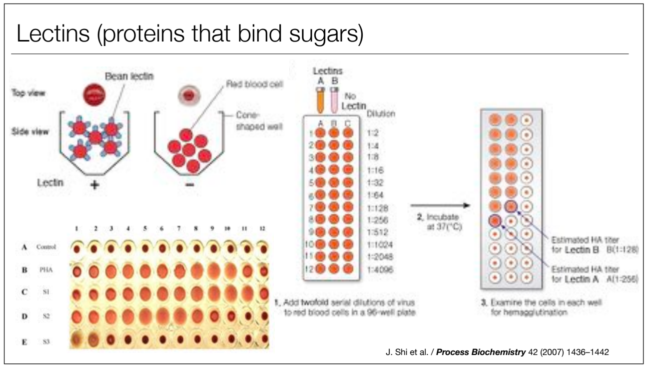
Hemagglutination activity of lectin in samples extracted from raw red kidney beans (S1 and S2) and crude extract of canned red kidney beans (S3). PHA (phytohemagglutinin) from Sigma 1 mg/mL (B) was used as the positive control. Negative control (A) contained buffer only. Each well of the microtiter plate contained 75 mL of sample or its dilution and 75 mL of 4% suspension of human erythrocytes. The agglutinated RBCs form a carpet that covers the whole well; where no agglutination occurs, red blood cells form a button at the bottom of the well. Picture was taken after 2 h.

Practice question: What is a lectin?

Lectins are proteins that can bind sugars (glycans = mono, oligo- or polysaccharides).

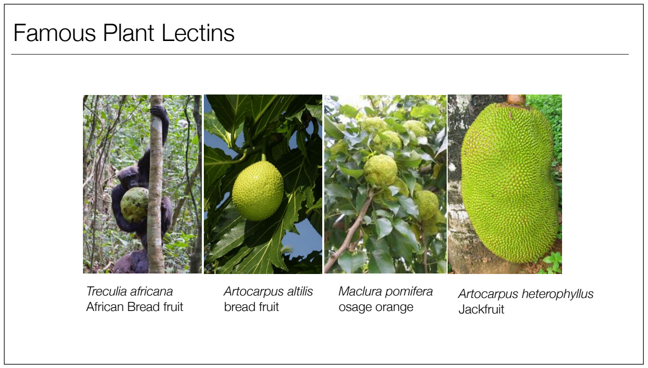
Practice question: Where are lectins found in nature?

Lectins are found in plants, animals, fungi, bacteria, archaea, and even viruses.

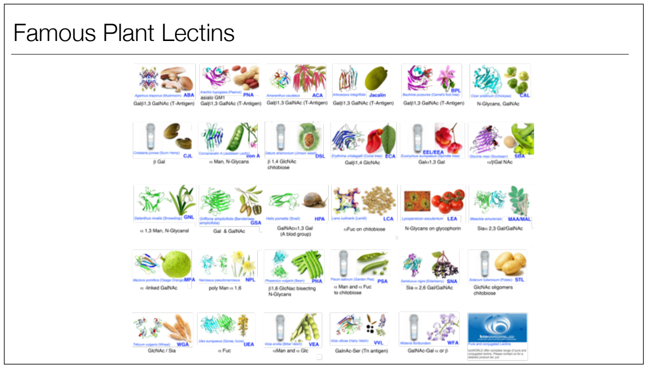


Practice question: What does the term hemagglutinin mean?
Answer: A molecule that causes red blood cells to stick together (heme=blood; agglutinate=stick together)

Practice question: How does hemagglutination look in a round bottom test tube, compared top control blood that is not treated with a lectin?
Answer: Hemagglutinated red blood cells remain in suspension (pink), while non-hemagglutinate red blood cells sink to the bottom and appear as a dark red dot.

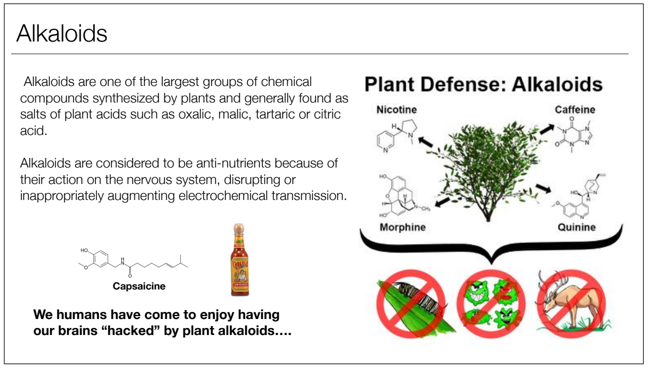


All plants belonging to the Moraceae family (named after mulberries) have lectins: Bread fruit (Polynesia), African bread fruit (Africa), osage orange (North America), and Jackfruit (Southeast Asia).



Panel of plant lectins sold commercially for biological research.
Quack alert!!!! Dr. Gundry's No Lectin diet and Dr Dadamo's ABO blood type diet: both multi-million dollar scams!
Practice question: What are lectins used for in biology labs?
Answer: Staining different cell and tissue types in basic and biomedical research (histology and pathology).

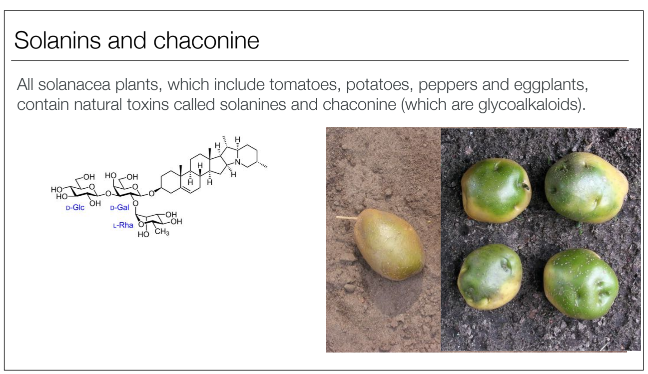
Practice question: Name an infamous lectin that is a lectin.
Answer: Ricin, extracted from castor bean seeds.



More than 3,000 different types of alkaloids have been identified in a total of more than 4,000 plant species. In general, a given species contains only a few kinds of alkaloids, though both the opium poppy (*Papaver somniferum*) and the ergot fungus (*Claviceps purpurea*) each contain about 30 different types. Certain plant families are particularly rich in alkaloids; all plants of the poppy family (*Papaveraceae*) are thought to contain them, for example. The *Ranunculaceae* (buttercups), *Solanaceae* (nightshades), and *Amaryllidaceae* (amaryllis) are other prominent alkaloid-containing families. A few alkaloids have been found in animal species, such as the New World beaver (*Castor canadensis*) and poison-dart frogs (*Phyllobates*). Ergot and a few other fungi also produce them. The function of alkaloids in plants is not yet understood. It has been suggested that they are simply waste products of plants' metabolic processes, but evidence suggests that they may serve specific biological functions. In some plants, the concentration of alkaloids increases just prior to seed formation and then drops off when the seed is ripe, suggesting that alkaloids may play a role in this process. Alkaloids may also protect some plants from destruction by certain insect species or fungi.

Practice question: What are alkaloids?

Secondary products made mostly by plants that have many biological activity including causing pain and stimulating the nervous system.



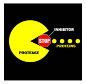
While levels are generally low, higher concentrations are found in potato sprouts and bitter-tasting peel and green parts, as well as in green tomatoes. The plants produce the toxins in response to stresses like bruising, UV light, microorganisms and attacks from insect pests and herbivores. To reduce the production of solanines and chaconine it is important to store potatoes in a dark, cool and dry place, and not to eat green or sprouting parts.

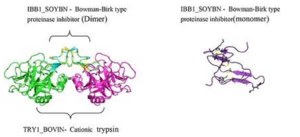
Practice question: Why should we avoid eating green potatoes?

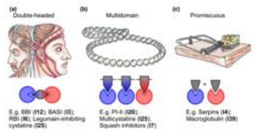
Answer: The green tissue of potatoes contains toxic alkaloid (solanine) that is heat stable and thus resistant to cooking.

Protease inhibitors

Protease inhibitors are the most commonly encountered class of anti-nutritional factors of plant origin.
Protease inhibitors have the ability to inhibit the activity of proteolytic enzymes within the gastrointestinal tract of animals.







Three classes of multifunctional protease inhibitors. BBI, Bowman–Birk inhibitor; BASI, barley a-amylase/subtilisin inhibitor; RBI, ragi bifunctional inhibitor; PI II, potato peptidase inhibitor II; MEROPS families are given in brackets. Many are proteins, but plants also make non-protein protease inhibitors.

Practice question: What are protease inhibitors?

Answer: Molecules that block proteases (enzymes = biocatalytic proteins) from cutting other proteins.

Examples of Protease inhibitors and their effects

Int. J. Mol. Sci. 2019, 20, 1345

Table 1. Plant protease inhibitors with potential application in agriculture and molecular farming.

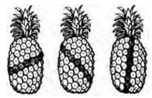
SPI Name	Origin	Role and Function	Biotechnology Application	References
A. thaliana Kunitz trypsin inhibitors (AtKTI4, AtKTI5)	*Arabidopsis thaliana*	Inhibitory activity against serine and cysteine protease; effect on mite performance (fecundity and mortality)	Protection against spider mite	[42]
Atserpin1	*Arabidopsis thaliana*	Inhibition of digestive protease activity; inhibition of larval growth; inhibition of RD21 activity	Protection against insect disease	[47,103]
Kunitz type protease inhibitor (AtWSCP)	*Arabidopsis thaliana*	Inhibition of cysteine RD21 activity; controlling cell death	Protection against herbivore attack	[45,47]
Potato type I inhibitors	*Solanum tuberosum*	Differential expression pattern after wounding and nematode infection	Protection against nematodes	[68]
Bowman-Birk-type inhibitor	*Oryza sativa*	Arrest fungal invasion; inhibition of fungal growth	Protection against fungal disease	[69]
Phloem serpin-1 (CmPS-1)	*Cucurbita maxima*	Inhibition of elastase activity; increase of the aphid mortality	Protection against insect disease	[73,74]
Cowpea trypsin inhibitor gene (CPTI)	*Vigna unguiculata*	Inhibition of larval growth	Protection against insect disease	[78,79,83]
Potato carboxypeptidase inhibitor (PCI)	*Solanum tuberosum*	Antifungal activity; inhibition of larval growth	Protection against fungal and insect disease	[80,81]
Maize proteinase inhibitor (mPI)	*Zea mays*	Inhibition of digestive serine proteinases; inhibition of larval and fungal growth	Protection against fungal and insect disease	[81,86]
Soybean Kunitz inhibitor (SKTI)	*Glycine max*	Inhibition of digestive proteases present in insects and parasites	Protection against parasitic and insect disease	[83,84,85]
Soybean Bowman-Birk inhibitor (SbBBI)	*Glycine max*	Inhibition of digestive protease activity; inhibition of aphid growth	Protection against aphid parasitoids	[83]
Poplar Kunitz trypsin inhibitor	*Populus trichocarpa x Populus deltoides*	Inhibition of midgut protease present in lepidopteran pests	Protection against insect disease	[86]
Passion fruit Kunitz type inhibitors (PfKI)	*Passiflora edulis* Sims	Inhibition of midgut proteases present in lepidopteran and coleopteran pests and *Aedes aegypti*	Protection against insect disease and Control of vectors of neglected tropical diseases	[87]
Kunitz trypsin inhibitor (ApKTI)	*Adenanthera pavonina*	Inhibitory activity against trypsin and papain proteases; inhibition of midgut proteases and larval growth	Protection against insect disease	[88,89]
Unusual serine protease inhibitor (UPI)	*Arabidopsis thaliana*	Chymotrypsin inhibitory activity; effect on the fungal and larval growth	Protection against fungal and insect disease	[91]
Serine proteinase inhibitor (BvSTI)	*Beta vulgaris*	Trypsin inhibitor activity; effect on larval weights	Protection against lepidopteran insect disease	[92]
Serine protease inhibitor CMe (BTI-CMe)	Barley (*Hordeum vulgare*)	Inhibition of midgut protease activity; effect on larval growth and survival of insects	Protection against insect disease	[94,101,102]
Potato type I (StPin1A) inhibitor/Potato type II (NaPI) inhibitor	*Solanum tuberosum* *Nicotiana alata*	Protease inhibitory activity; effect on larval growth	Protection against *Helicoverpa* spp.	[97]

Many protease inhibitors directly target insect herbivores.

Cutting a pineapple following the Fibonacci spirals.

Fibonaci series and plant growth

The geometry of plant growth. defined by: 1 1 2 3 5 8 13 **21**



The Fibonacci sequence is represented when each number is created by adding together the previous two, so starting from 1 1 2 3 5 8 13 21… it continues to infinity. The Fibonacci sequence is ubiquitous in nature making it hard to find a plant or fruit structure that does not conform to it. For example, the placement of leaves along a stem follows the Fibonacci sequence, ensuring that each leaf has maximum access to key vertically delivered resources: sunlight, and rain. It is an example of optimally evolved packaging or placement in nature.

Know your 21 herbs

Rosemary
Bay leaf
Curry leaf
Siam ginger (Galangal, kha)
Turmeric
Cardamon
Mint
Peppermint
Siam basil
Genovese basil
Lavender

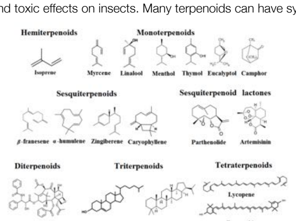
Cilantro (coriander leaves)
Lemon verbena
Lemon balm
Thyme
Sage
Oregano
Italian Parsley
Shiso
Lemon grass
Kaffir Lime leaves

San Diego has the perfect climate for growing many aromatic herbs and spices. Even ginger, turmeric and galangal (kha;siam ginger) grow here in summer.
Chilies also grow very well.

Practice question:
List 18 different herbs:
see above

Terpenoids

The most diverse class of bioactive natural products in plants is terpenoids, with approximately 40,000 structures. Terpenoids are synthesized from acetyl-CoA and play a role in plant defense, can act like active compounds in resin or as volatiles, repellents, and toxins, or can modify development in herbivores. Another characteristic in monoterpenes and sesquiterpenes is its ability to form essential oils, like limonene in citrus plants; these essential oils have repellent and toxic effects on insects. Many terpenoids can have synergistic effects upon release.



Terpenoids: terpentine, menthol, latex etc.

Practice question:
Name two famous plant products that are terpenoids:
Latex rubber (polyisoprene) and menthol (monoterpenoid).

Turpentine (including terpene)

Jeffrey pines in California have occasionally been mistaken for **Ponderosa pines** by people trying to make turpentine.
Turpentine is made by distilling pine sap. However, Jeffrey pine sap leads to massive explosions when heated…..

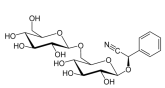
Pine nuts

Torrey pines in California have large edible seeds (piñones). Piñon pine, the state are of New Mexico is *Pinus exults.* These are very important traditional foods that have been exploited by local indigenous people for thousands of years. The seeds of almost all pine trees around the world are edible. *Pinus armandi* (华山松) from China contains bitter chemicals that can give you "pine mouth" or worse pine nut syndrome.
These seeds are not "defended chemically" but rather by a hard shell that also has "wings" allowing the mature seeds to "fly" a certain distance as they drop to the ground.
Practice question: What protects pine seeds from predation?
Tough pine cones, that only open up shortly before the seeds are ready to spread and a hard other shell.

Cyanogenic glycosides

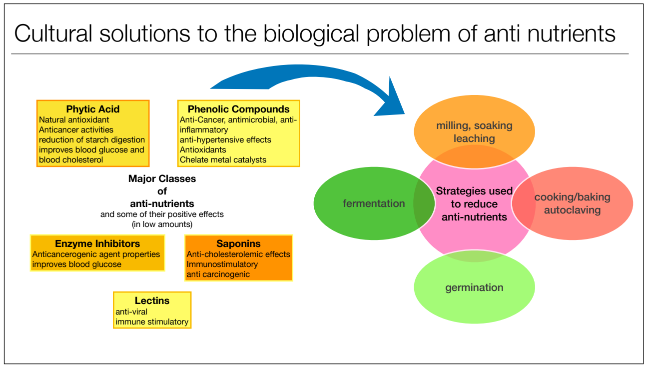
The cyanogenic glycosides belong to the products of secondary metabolism, to the natural products of plants. These compounds are composed of an a-hydroxynitrile type aglycone and of a sugar moiety (mostly D-glucose).

Cyanogenic glucosides (a-hydroxynitrile glucosides) are derived from the five protein amino acids Val, Ile, Leu, Phe and Tyr and from the nonproteinogenic amino acid cyclopentenyl glycine. Although derived from six different building blocks, they constitute a very small class with around 50 different known structures. A number of plant species produce hydrogen cyanide (HCN) from cyanogenic glycosides when they are consumed.



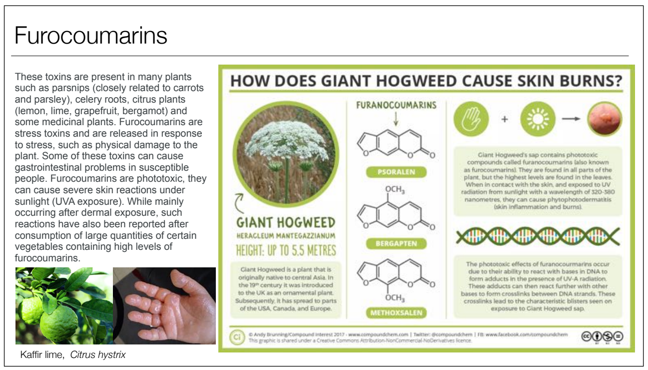
amygladin
a cyanogenic glycoside found in bitter almonds

https://www.theguardian.com/science/blog/2017/jun/22/cassava-deadly-food-venezuela
Cyanogenic glycosides are phytotoxins (toxic chemicals produced by plants) which occur in at least 2000 plant species, of which a number of species are used as food in some areas of the world. Cassava, sorghum, stone fruits, bamboo roots and almonds are especially important foods containing cyanogenic glycosides. The potential toxicity of a cyanogenic plant depends primarily on the potential that its consumption will produce a concentration of cyanide that is toxic to exposed humans. In humans, the clinical signs of acute cyanide intoxication can include: rapid respiration, drop in blood pressure, dizziness, headache, stomach pains, vomiting, diarrhea, mental confusion, cyanosis with twitching and convulsions followed by terminal coma. Death due to cyanide poisoning can occur when the cyanide level exceeds the limit an individual is able to detoxify.



Practice Question: Mention four different ways in which anti-nutrients can be reduced in food plants.

Answer: leaching, cooking, fermenting, and germinating.



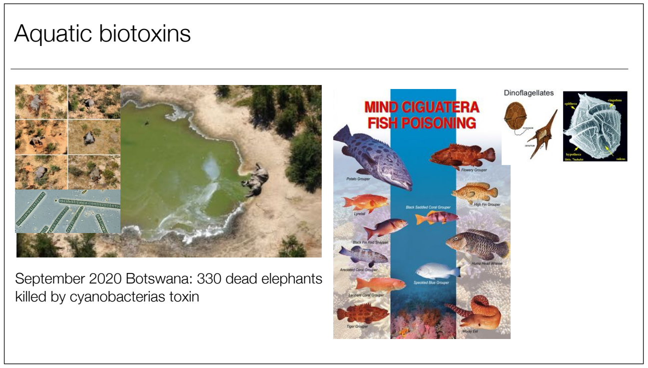
Some plant toxins are activated by the sun! E.g furanocoumarins from hogweed and kaffir lime. These can cause phytodermatitis.

Mycotoxins are naturally occurring toxic compounds produced by certain types of moulds. Moulds that can produce mycotoxins grow on numerous foodstuffs such as cereals, dried fruits, nuts and spices. Mould growth can occur before harvest or after harvest, during storage, on/in the food itself often under warm, damp and humid conditions.

Most mycotoxins are chemically stable and survive food processing. The effects of food-borne mycotoxins can be acute with symptoms of severe illness and even death appearing quickly after consumption of highly contaminated food products. Long term effects on health of chronic mycotoxin exposure include the induction of cancers and immune deficiency.

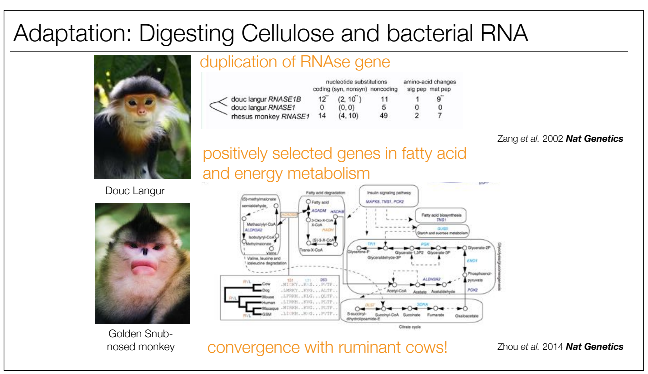
Practice question: Give an example of a mycotoxin.

Answer: Aflatoxin from Aspergillus fungus.



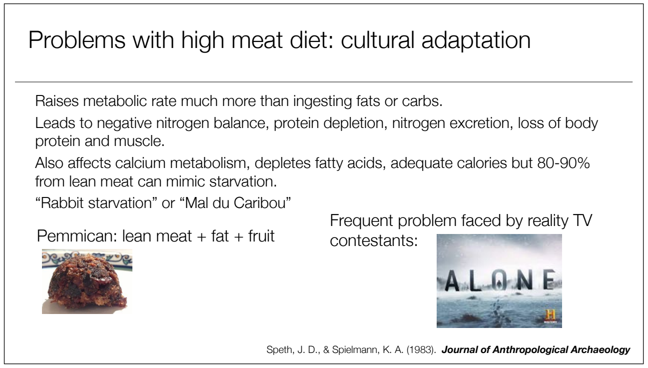
Toxins formed by algae in the ocean and fresh water are called algal toxins. Algal toxins are generated during blooms of particular naturally occurring algal species. Shellfish such as mussels, scallops and oysters are more likely to contain these toxins than fish. Algal toxins can cause diarrhea, vomiting, tingling, paralysis and other effects in humans, other mammals or fish. The algal toxins can be retained in shellfish and fish or contaminate drinking water. They have no taste or smell, and are not eliminated by cooking or freezing.
Another example is ciguatera fish poisoning (CFP) which is caused by consuming fish contaminated with dinoflagellates that produce ciguatoxins. Some fish known to harbour ciguatoxins include barracuda, black grouper, dog snapper, and king mackerel. Symptoms of ciguatera poisoning include nausea, vomiting, and neurologic symptoms, such as tingling sensation on fingers and toes. There is currently no specific treatment for ciguatera poisoning.

Practice question: give an example of an aquatic biotoxin:
Answer: algal toxin from cyanobacteria.



The insertion of Alu elements (“selfish DNA element”) in primate genomes and the adaptive evolution of golden snub nosed monkey (GSM). Enrichment for positively selected genes: genes evolved in parallel and expanded gene families that function in fatty acid and energy metabolism. The positively selected genes in GSM are shown in purple, the genes from expanded families in GSM are shown in light blue and the genes evolved in parallel in GSM and cattle are shown in orange.

Practice question: Apart from sugars freed from cellulose, what other molecules do foregut fermenting leaf eating monkeys obtain from their gut bacteria?
Answer: They obtain nucleic acids (DNA and RNA) from the bacteria that the monkeys also digest.



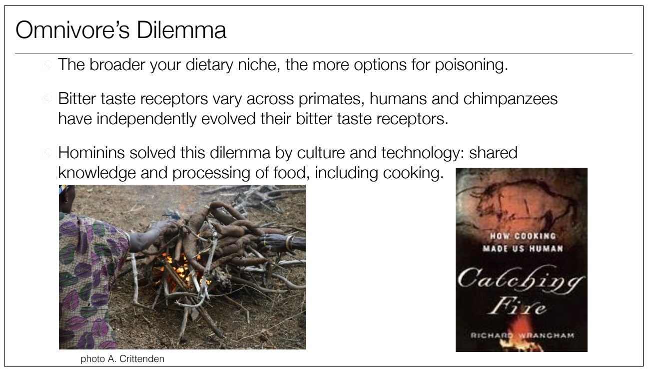
Lean meat diets are not sustainable.

Practice question: What is pemmican?

Answer: A nutritious traditional blend of lean meat, fat and dried fruit.

Practice question: What is rabbit starvation?

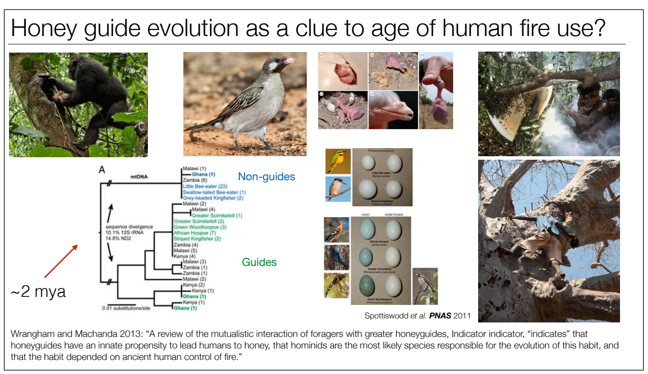
Answer: A life threatening condition due to a diet too rich in lean meat.



Processing food by heat, only possible after our distant ancestors discovered the use of fire, has profound effects on food safety, food digestibility and food storage.

Practice question: Which is older, our species *Homo sapiens* or the use of fire?

Answer: The use of fire.

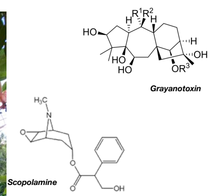


Mitochondrial and nuclear DNA relationships among honeyguides using different host species. (A) Mitochondrial phylogeny based on partial 12SrRNA gene sequences. Genetic divergence for the ND2 gene was measured for a representative sample of individuals with divergent 12S sequences. The lineages that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

Practice question: What can honey guide bird 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 of fire use by humans.

Honey (melivory) toxic honey plant diterpene


scopolamine from plants can render honey toxic.

Grayanotoxin diterpene can bind to activated sodium channels in neurons and prevent their de-activation.

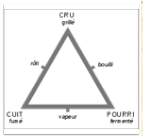
two different plant toxins that can make it into honey

Psychoactive honey is harvested as a specialty in the mountains of Nepal.

Practice question: How could honey become toxic?

Answer: If bees collect nectar from flowers of toxic plants.

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 Levi-Strauss, the late famous French Anthropologist get really wrong about cooking and biology?

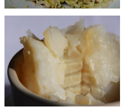
Answer: That cooking had little or no biological effects.

Putrid meat and fish - Key part of ancient diets?

Stinkhead

cheese

Sauerkraut



Lutefisk

John Speth ***PaleoAnthropology*** 2017: 44–72.

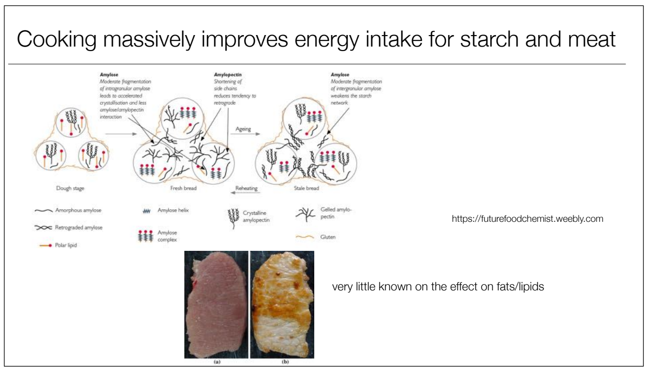
Other ways to preserve and alter animal and plant food is fermentation/putrification….

Practice question: Give two example of how protein rich food can be treated other than cooking with heat.

Answer: Rotting/putrification and fermentation.

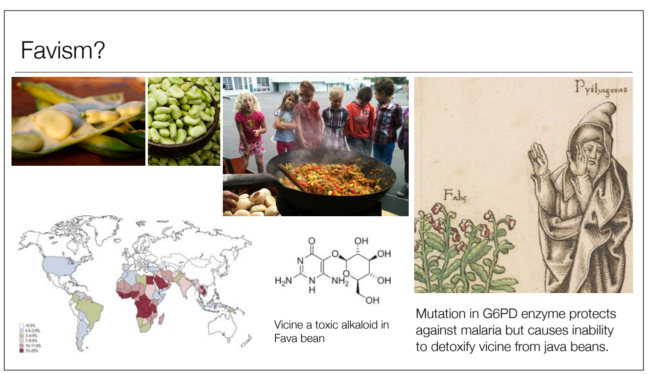
Cooking as a massive **niche broadening technology**, better digestion, less chewing, detoxification, conservation etc.. of much larger number of food items.

Practice question: Why can cooking be considered as a niche-broadening technology?
Answer: Better digestion, less chewing, detoxification, conservation of much larger number of food items to chose from.



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….

Practice question: What happens to starches and proteins during cooking?
Answer: Starches gelatinize and proteins denature, they both become easier to digest.

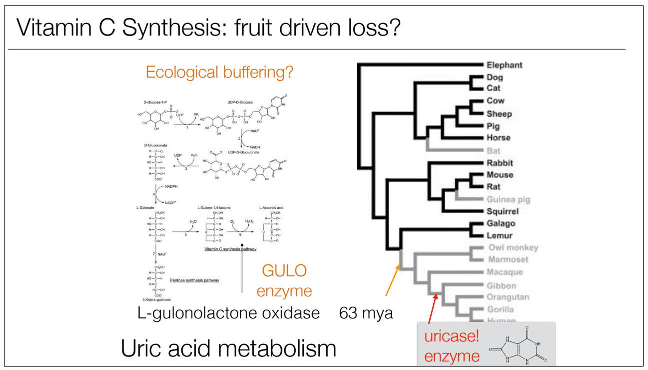


At the biochemical level, the glucose-6-phosphate dehydrogenase enzyme (G6PD) converts glucose-6-phosphate into 6-phosphoglucono-δ-lactone and is the rate-limiting enzyme that maintains the supply of NADPH. This cofactor, in turn, maintains the level of reduced glutathione in the cells that scavenges free radicals to prevent oxidative damage to the cell. The G6PD/NADPH pathway is the only source of reduced glutathione (GSH) in erythrocytes. Lack of adequate GSH in erythrocytes puts them at high risk of damage by oxidative stress, which may lead to hemolytic anemia .
Oxidative stress factors include infection, chemicals, medicines, and certain foods such as fava/broad beans (*Vicia faba*), which contain a high level of the glycoalkaloids vicine and 6-hyroxy vicine (covicine) and the corresponding aglycons, divicine and isouramil. All these compounds are harmful oxidative agents. Heating fava/broad beans to relatively high temperatures is not effective in reducing the concentrations of these glycosides. However, the concentration of

vicine and covicine and their corresponding aglycons can be greatly reduced in fava/broad bean food preparations by enzymatic hydrolysis.

Practice question: What is favism?

Answer: Disease resulting from inability to degrade toxin in fava bean due to adaptation to malaria.

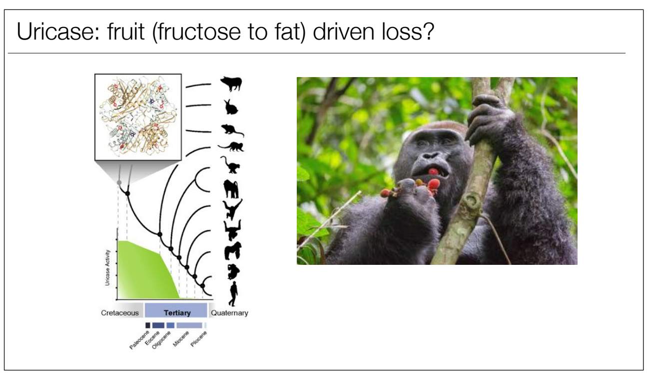


Eating fruit seems to have allowed for the loss of vitamin C synthesis genes. An ancestry without much meat consumption, allowed the loss of the uricase gene.

Loss of uricase gene: more efficient fat from fructose metabolism?

Practice question: Why have monkeys and apes and humans lost the ability to make their own vitamin C?

Answer: Fruit-rich diets over million of years, have buffer the inability to make the vitamin.



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

Practice question: What is the connection between fruit eating and uric acid metabolism in apes and humans?

Answer: Adaptation fruit eating in these species led to the loss of the uricase enzyme, leading to risk of disease (gout) in humans consuming too much meat.

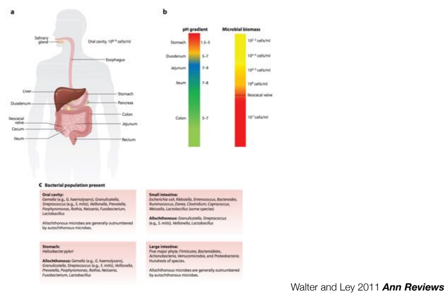
Gout

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

Practice question: Why was gout mostly a disease of the rich until very recently?

Answer: Only the rich could afford a lot of meat in their diets.

Microbial assistants



Walter and Ley 2011 ***Ann Reviews***

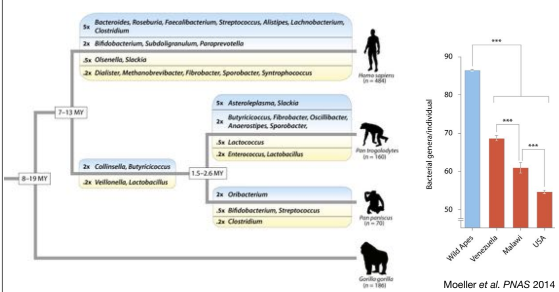
Characteristics of the major habitats of the human gastrointestinal tract and their inhabitants.

(a) The major sections of the gastrointestinal tract.

(b) Bars in the center indicate pH levels moving from the stomach to the distal gut (left) and biomass levels (right).

(c) Boxes indicate the dominant types of microbes either allochthonous or autochthonous to those habitats.

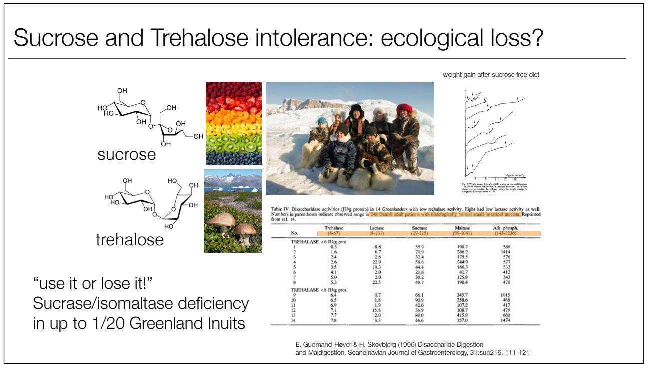
Microbiome



Moeller *et al.* *PNAS* 2014

Overall, humans appear to have lost microbial diversity compared to the great apes.

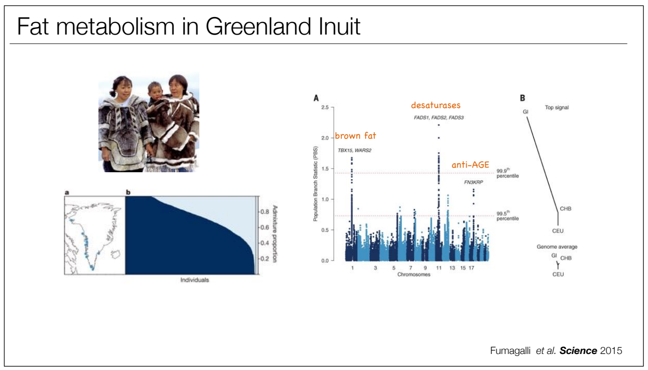
Especially city dwelling humans in the USA and other industrialized countries.



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.

Practice question: What evolutionary process is the loss of sucrase/isomaltase enzyme in Inuit populations an example of?

Answer: “Use it or lose it”.

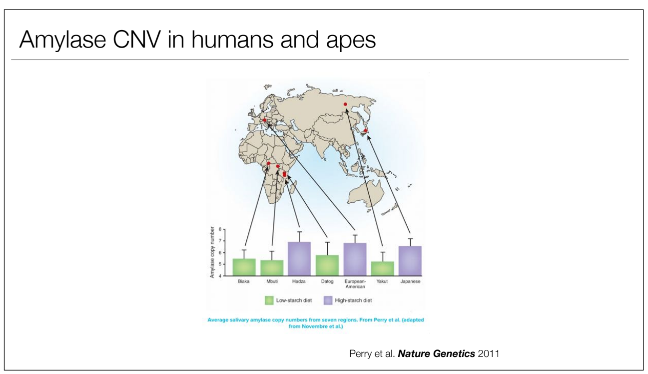


a, Sampling locations in Greenland.

b, Estimated admixture proportions of Inuit and European ancestry. The admixture proportions were estimated assuming two source populations (K = 2). The estimates are both for the 2,733 individuals in…

A Genes identified to be associated with local population variants

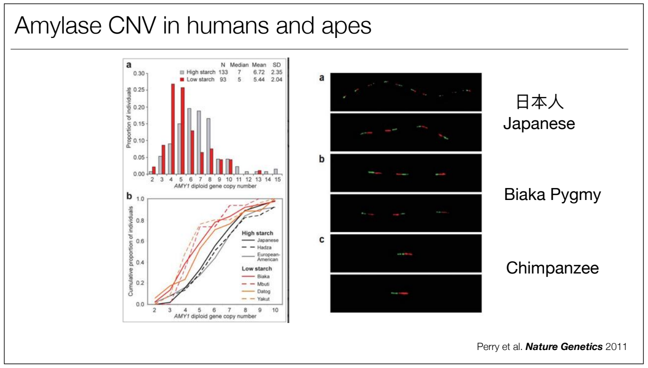
B Population clusters for Greenland Inuit (GI), Chines Han (CHB), and Central Europeans (CEU)



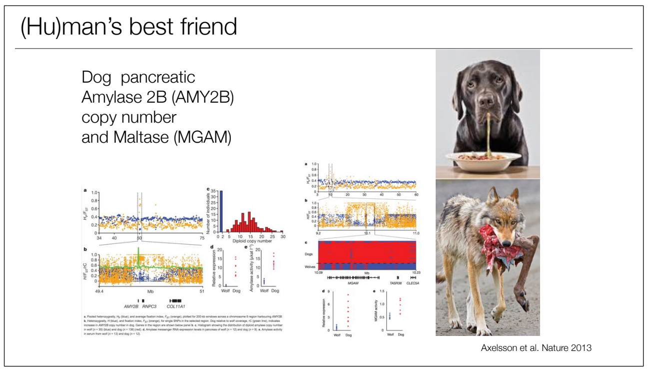
Differences in salivary amylase gene copy number exist between present day humans populations. They correlate with the history of grain or tuber use.

Practice question: What could explain why the Hadza, who are foragers and do not farm have higher numbers of gene copies of salivary amylase than Biaka pygmies?

Answer: Unlike the Biaka, the Hadza eat a lot of starchy wild tubers.



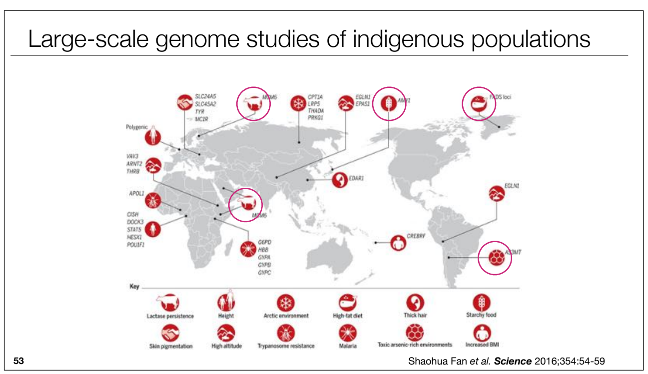
Different number of copies of the salivary amylase gene in the genomes of humans and chimpanzees. These copies can be fluorescently stained on prepared chromosomes.



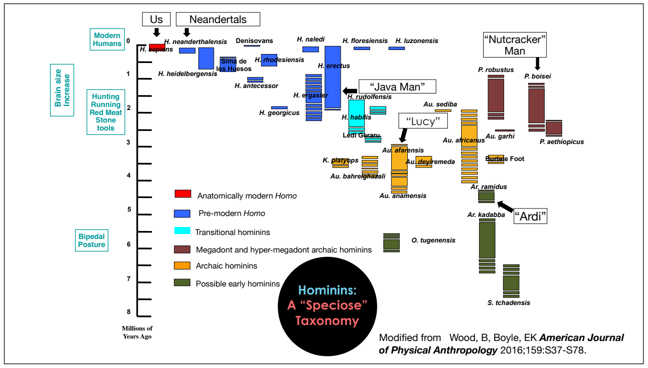
Domestic dogs have evolved pancreatic amylase, wild wolves do not have this enzyme.

Practice question: How come dogs can digest starch in human leftovers, but wolves cannot?

Answer: Domestic dogs evolved a high number of amylase gene copy numbers in their pancreas.

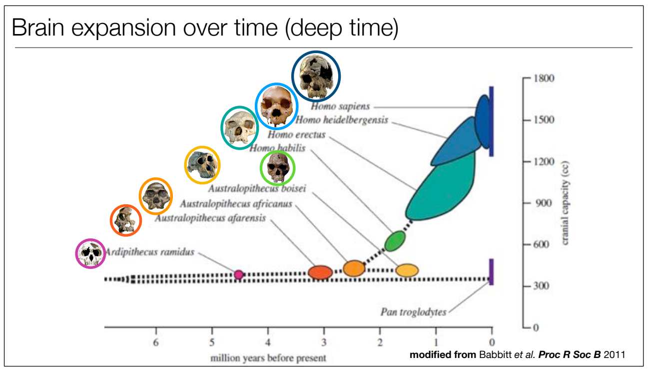


Examples of human local adaptations, each labeled by the phenotype and/or selection pressure, and the genetic loci under selection.

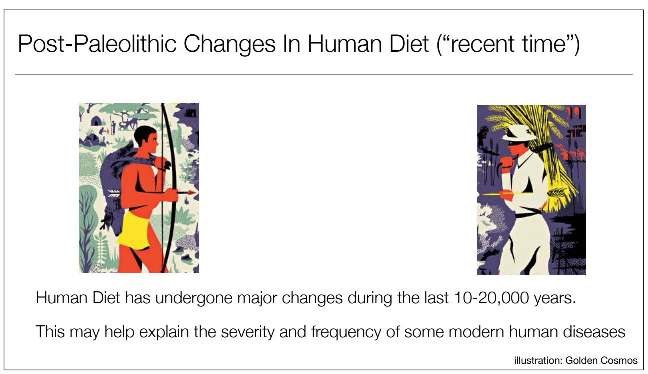


Summary of human fossil record:

Brain size increase and tooth size decrease in the last 2 million years……cooking, novel food, processing of food before eating????



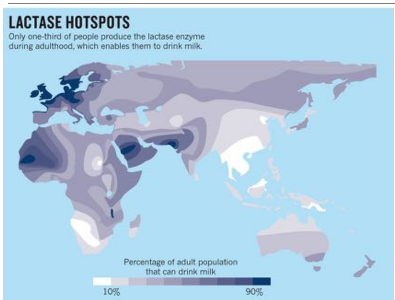
Was this brain expansion driven by novel foods or by novel behavior an associated cognitive demands?



Examples Of Changes Disease, Modern Lifestyle & Biology

Item	Change	Pro	Con
Milk Drinking after infancy	Increased (Lactose Tolerance)	Source of Many Nutrients, e.g. Calcium	Rich source of Saturated Fat
Mother/Infant Co-Sleeping	Decreased	Father Does More?	Increased "Sudden Infant Death"?
Dietary Soluble Fiber	Reduced	Chewing Easier Food Tastier	Irritable Bowel Colon Cancer
Toughness of Food	Reduced	Chewing Easier Less Gingivitis	Dental Crowding Impacted Molars
Consumption of Red Meat	Marked Increase	Nutritious, Satisfying	Carcinomas Atherosclerosis
Consumption of starch	Marked Increase	Nutritious, Satisfying	Insuline resistance
Excessive Focus on Near Objects	Marked Increase Reading/Computers	Cognitive Benefits	Myopia
Gut Bacteria/Worms	Reduction	Lower parasite burden	Crohn's Disease?
Hygiene	Improved	Protection from Infections	Increase in Allergies?

Keeping Lactase On.



Animal milk use allows you to outcompete your neighbors

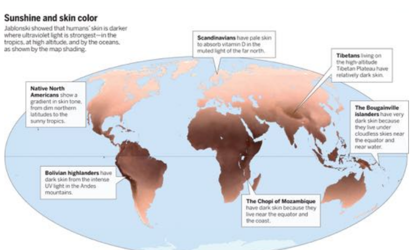
Tanzania: Hadza foragers

Datoga pastoralists

Curry. A. Archaeology: The milk revolution. ***Nature***. 2013;500:20–22.

Why would mammals evolve to stop the production of the enzyme lactase around weaning age? Is it economy of investment or does it reflect parent-offspring conflict?

Human skin color??



A. Gibbons. ***Science***. 2014;346:934-936

Darker skin is clearly adaptive for life in the tropics, high elevation and near water. Is the loss of melanin in some human populations a case of use it or lose it? or is it an adaptation to less sunshine? Could the loss of melanin have come under different types of selection? e.g. sexual selection?

Likely all of the above, a common phenomenon in biology, where "YES, AND" is more common than "YES, BUT".

Summary

Animals adapt to their ecological and dietary niches.

Humans are flexible omnivores who became top predators.

Modern humans in opulent societies can choose countless different diets based on countless motivations.

Human adaptations are both biological and cultural/technical.

Like all animals, humans rely on their symbiotic microbes for optimal nutrition.

Plants have many components that are toxic or act otherwise as anti-nutrients: tannins, phytic acid, alkaloids, saponins, furanocoumrins, oxalic acid, and enzyme inhibitors etc.

Food and water can become toxic due to algal or dynoflagellate toxins.

Current diets range from almost all plants (Indian vegetarians, Chinese buddhist vegans) to almost all animal (Arctic Inuit).

Human cultural niches likely promoted brain growth and was made possible by much richer diets starting 2 million years ago.

Fire and cooking are enormously important, but their precise age remains uncertain.

The flexible cultural and technical packages of modern humans have allowed our species to survive in most environments.

Expansion of modern humans into temperate zones was accompanied with reduction of melanin, and contributed to the large phenotypic diversity of modern humans.