ANBI 141 Evolution of the Human Diet

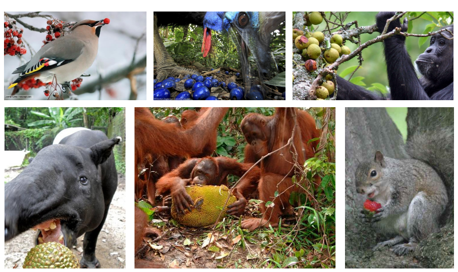
Lecture 15: The Story of Sugar

Pascal Gagneux

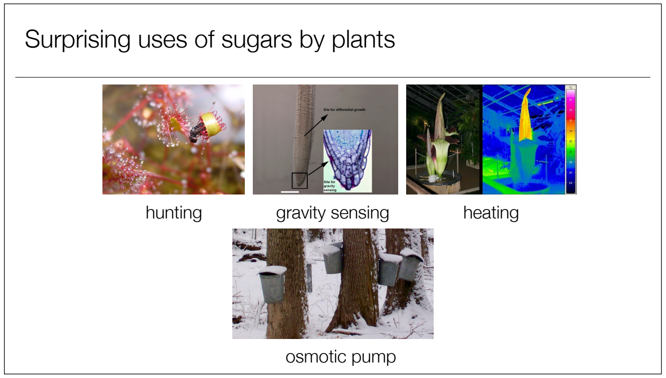
November 18, 2021

Plants deploy sugar to attract animal pollinators

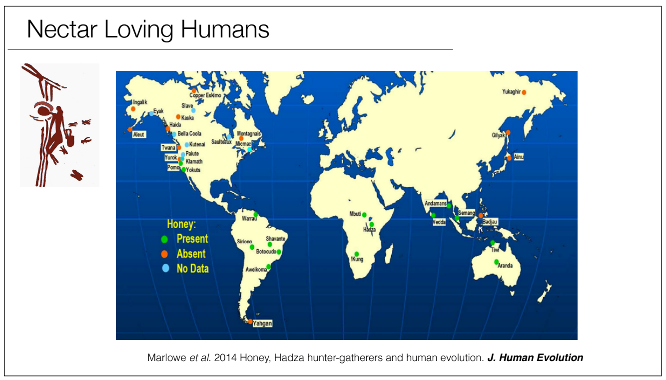
Plants use sugar to reward animal seed dispersers



Practice question: What functions other than structure and energy do plants use sugars for?
Answer: Attracting pollinators with nectar, rewarding seed dispersers with sweet fruit, catching insects and sensing gravity with starch granules.

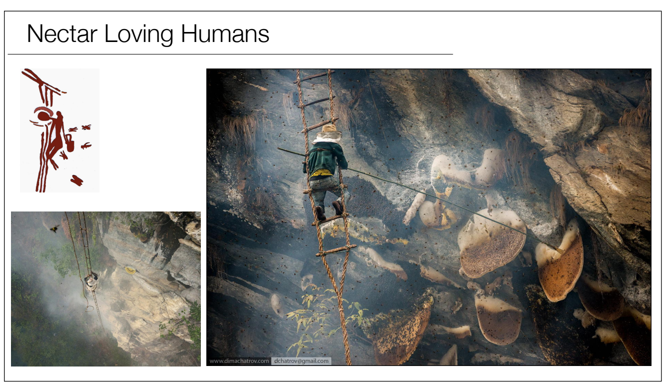


Practice question: Why is maple sap so sweet in spring?
Answer: Sugar maples use the sugar concentration in their trunks osmotically attract water from the ground.



Where humans have access to honey, they cherish it as one of their favorite foods.
Where honey is available, it is an important food for huntergatherers. Almost all warm-climate foragers in the Standard Cross Cultural Sample (SCCS) of traditional societies have honey in their diet (Fig. 1, Table 1). Of the 36 foraging societies in the SCCS by our definition of foragers, there are 29 with data on honey consumption.1 Fifteen of the 16 warm-climate societies (Effective Temperature 13 C) take honey, whereas none of the 13 cold-climate societies (ET < 13 C) (Table 1) take honey, or at least there is no mention of it. Of the 15 warm-climate societies, only the Badjau of the Philippines, who spend most of their time on boats, do not collect honey (Nimmo, 1964). It is clear that the cold weather explains why there is such a difference in honey consumption between the warm-climate and cold-climate foragers.

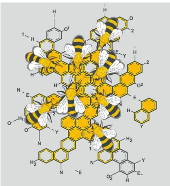
Practice question: What commonly explains the absence of honey as an important part of the diet in traditional societies?
Answer: Cold Climate and absence of honey bees.

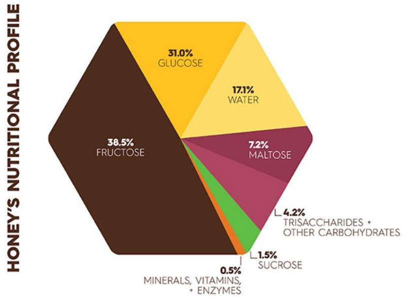


The Gurung or Tamu people of Nepal harvest honey from a large honey bee (Himalayan honey bee *Apis laboriosa* which is twice as large as the common honey bee and make giant combs hanging from cliffs . The honey is made from rhododendron nectar and contains the psychoactive toxin grayanatoxin.
Practice question: How can honey become toxic?
Answer: If bees collect nectar from plants that produce neurotoxins, such as rhododendron or brugmansia (angel trumpet).

Practice question: What would toxic honey fetch higher prices?
Answer: If bees collect nectar from plants that produce psychoactive toxins, some people may cherish a buzz.

Molecular Honey





Honey consist mostly of monosaccharides fructose and glucose.

Bees use enzymes to cleave the disaccharide sucrose.

Practice question:

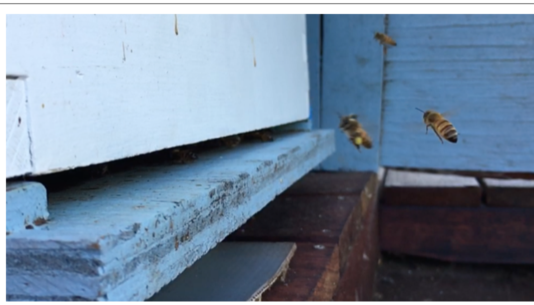
How can honey consist mostly of monosaccharides when most nectar contains the disaccharide sucrose?

Bees cleave the disaccharide sucrose into glucose and fructose using an enzyme in their gut.

Bee keeping

Capturing a bee swarm in Pacific Beach

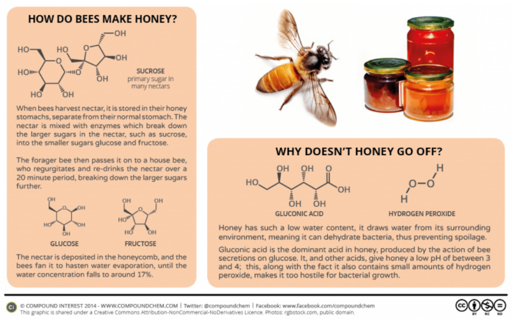
Bee keeping



Ladies coming back from harvest

Bee keeping

Honey Chemistry



Practice question:
What prevents honey from going bad?
The high concentration of sugars and low content of water.

First Alcohol? Mead (fermented honey water)

ጠጅ
Tej

Diluting honey with water will allow it to ferment with wild yeast and from mead (honey wine). Tej is the national drink of Ethiopia.

Practice question:
If honey is said to never go bad, how can people ferment it into mead?
Diluting the honey with water will allow yeasts to ferment it.

When fermenting diluted honey into mead, by adding yeast to honey water, the yeast generates alcohol and carbon dioxide. If fermented in a closed bottle: considerable pressure builds.
Practice question: Why would you dilute honey in water?
Answer: When separating the wax from the honey comp from honey and grubs, boiling the remainder of the combs allows the wax to float on top and all the honey to dissolve in the water.

History of sugar

a bee hive in a skep

Kristy Mucci
2017 ***Saveur***

Honey versus sugar

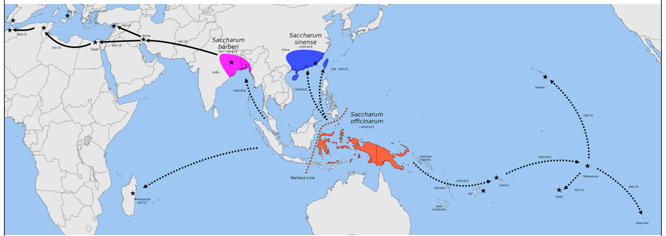
Sugar cane: *Saccharum officinarum,* a medicine in Roman and medieval times.

The words “officinarum” or “officinalis” refers to the apothecary’s store room.

Human made Honey: Sugar

Boiling down sugar cane juice into jaggery, raw, evaporated cane sugar juice.

The spread of sugar cane

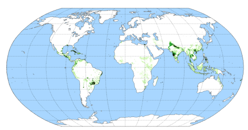


Daniels, Christian; Menzies, Nicholas K. (1996). Needham, Joseph (ed.). *Science and Civilisation in China: Volume 6, Biology and Biological Technology, Part 3, Agro-Industries and Forestry*. Cambridge University Press. pp. 177–185. ISBN 9780521419994.

From South East Asia, sugar cane spread North and West.
The Polynesian expansion took sugar cane all over the Pacific Ocean.

Practice question: Sugar cane did not exist first millennium Europe. What do you expect was the sweetener of choice in early recipes from Europe?
Answer: Dried fruit and honey.

Saccharum officinarum, aka sugar cane



Sugar Cane is a grass. In the western world, Alexander the Great reported about canes that produce sugar for the first time.
Practice question:
Why does the botanical name for sugar cane refer to an apothecary?
Sugar was considered a medicine.

First written recipes for sugar: India

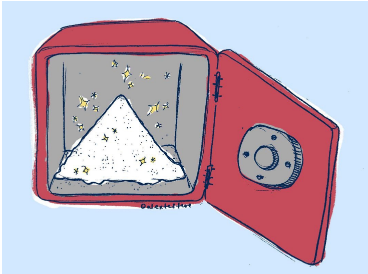
Atta Ladoo

1.Atta (wheat flour)- 1 1/2cup
2. Ghee- 1/2cup
3. Sugar- 1/2cup
4. Cardamom- 4 5.
Clove- 4

Preparation
1.Heat heavy bottom kadai add atta to it and dry roast it properly
2. It should be roasted up to a sweet aroma comes
3. Then add ghee to it and roast it for 5 mins more
4. Make powder out of green cardamom and clove and keep aside
5. Now add sugar to it and mix.
6. Now switch off the heat and remove from heat
7. Add powdered spices to it and mix properly
8. Let it cool down a bit. It should be enough hot to touch.
9. Then prepare ladoo out of the roasted atta

Year 400-350: Recipes call for sugar in the Mahabhashya of Patanjali. They include rice pudding with milk, sweet barley meal, and fermented drinks with ginger.
Year 327: Greeks and Romans learn about sugar during visits to India. Nearchus, Alexandria's general, writes of "a reed in India that brings forth honey without the help of bees, from which an intoxicating drink is made, though the plant bears no fruit." Small amounts are brought back to the Mediterranean and traded to physicians who use it for medical purposes.
Year 500-600 A.D.: Jundi Shapur, a university in Iran, becomes the meeting place for the world's scholars (at least those west of China). Greek, Christian, Jewish, and Persian scholars gather to create the first teaching hospital. They study texts from various cultures, and by 600 A.D. they are writing about a potent Indian medicine: sugar. They also develop better methods for processing sugar cane into crystallized sugar.

Arabic treasure



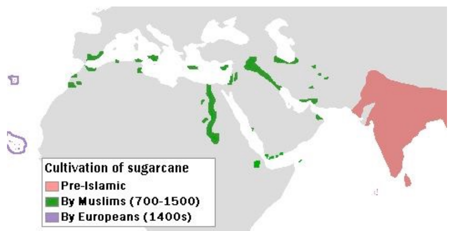
As armies of Muslims take over Egypt, Persia, India and the Mediterranean, they bring their knowledge of sugar with them. Many European doctors learn of the medicinal uses for sugar from Arab texts. Under Arab rule, Egyptians mastered the refining process and became known for making the purest, whitest sugar.

Practice question:

How did sugar cane get to southern Spain?

The Arabs and Moors brought it there when they civilized southern Spain in the 8th century.

The westward diffusion of sugarcane



The westward diffusion of sugarcane in pre-Islamic times (shown in red), in the medieval Muslim world (green), and in the 15th century by the Portuguese on the Madeira archipelago, and by the Spanish on the Canary Islands archipelago (islands west of Africa, circled by violet lines)

The westward diffusion of sugarcane

Salobreña in Andalucia

Mosque, now cathedral of Cordoba

Salobreña in Andalucia (formerly Al Andalus) with sugar cane fields

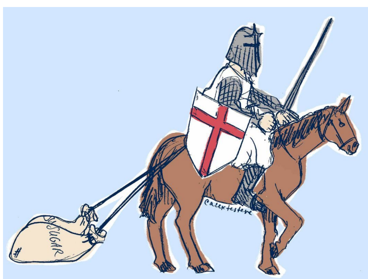
Arabic Sugar Tradition

Two treasures:
sugar & durum wheat

Circa Year 650: The Arabs were masters of growing, refining, and cooking with sugar; they begin to conceptualize it not just as a medicine or spice, but as a rare delicacy for royalty and the most wealthy. They combine it with ground almonds to create a moldable sweet still popular today—marzipan—and sugar sculptures become regular parts of lavish dinner parties.

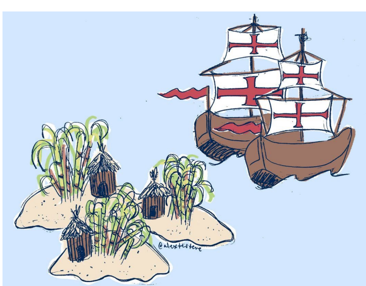
Practice question:
What do sugar and durum wheat have in common
Both were discovered by Europeans during the early crusades in the 11th century.

Year 1000: European crusade, taste for sugar!



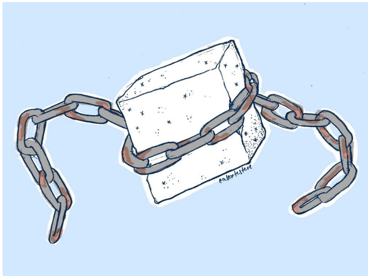
Year 1099: Europeans conquering Jerusalem learn the details of sugar production, which was a profitable business in the city at the time. When the soldiers return home, they bring sugar with them, sparking widespread demand across Europe.

European Conquest of Americas, bypassing the Ottoman Empire



Year 1402-1500: The Spanish colonize the Canary Islands, setting up sugar plantations and enslaving indigenous people to run the mills. Export back to Spain is up and running by 1500, though, when the islands become mostly deforested, the sugar industry falters. In 1493, Columbus brings sugar cane from the Canary Islands to Hispañola (Haiti and the Dominican Republic). By 1516, Hispañiola is the most important sugar producer in the New World.
The Ottoman Empire Pushes Sugar Westward Mediterranean sugar production faces many challenges: a diminished labor pool, a climate that isn't ideal for growing cane, and depleted soil and deforestation. Importing sugar is easier than growing and producing it. When the Ottoman Turks conquer Constantinople in 1453, the Middle East, North Africa, and Eastern Europe, they also take control of, and disrupt, the major trade routes. Looking for ways to circumvent the Turks and Arabs, Europeans take to the seas to find new lands on which to grow their own sugar.
1500: Pedro Cabral of Portugal lands on Brazil by accident and establishes sugar plantations there. Portuguese growers make technological advances in sugar production: a new mill design that could be powered by animals, water, or even wind, and a new method for refining sugar that allows them to operate on a larger scale. Brazilian sugar production eventually dominates the industry.

American Sugar and Slavery

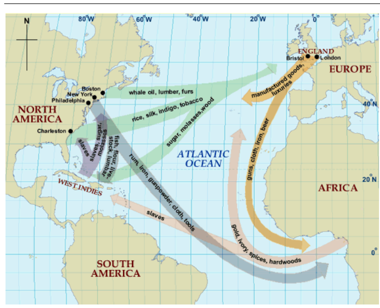


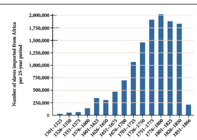
The arrival of the Spanish in the Americas caused The biggest epidemic in human history. Millions of native Americans died in many waves of infectious diseases brought by the Europeans.Cheap labour was needed for the sugar cane fields and sugar production in the the Americas: 1583: São Tomé, a Portuguese colony that can't keep up with Brazil's rate of sugar production, starts exporting slaves to Brazil and other New World islands to work on sugar plantations. It's a profitable business. By the late 16th century, Brazil out-produces all of the New World colonies and the Mediterranean. The Mediterranean sugar industry collapses.

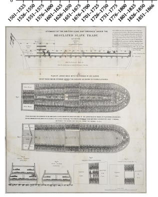
1600s: At this point, coffee, tea, and chocolate have made their way to Europe. Their arrival drastically increases sugar consumption, making sugar more popular than alcohol ever did, and increasing demand—with lower prices—means a greater reliance on slavery. During the 17th century alone, over half a million African slaves are shipped to Brazil and other New World colonies to work on sugar plantations.1791: The British Parliament fails to pass the Slave Trade Abolition Bill, which leads to an abstention movement. Abolitionists boycott slave-grown sugar, and the movement increases the demand for slave-free sugar grown in India. American abolitionists also try to avoid Caribbean-grown sugar, turning instead to the maple sugar industry. In 1789, some residents of Philadelphia agree to buy certain amounts at fixed prices in hopes of helping the industry take off. The U.S. government urges Americans to make maple syrup at home and to avoid sweets sold in shops.

1807: Thomas Jefferson signs a bill that prohibits importing slaves to the U.S. Shortly after, the British House of Lords passes an act for the abolition of the slave trade. But slavery remains a widespread practice, continuing in: the British West Indies until 1834, the French colonies until 1848, the U.S. until 1866, Cuba until 1886, and Brazil until 1888

Triangle trade

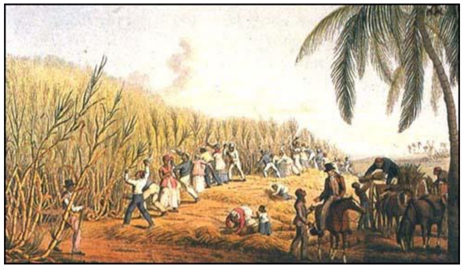






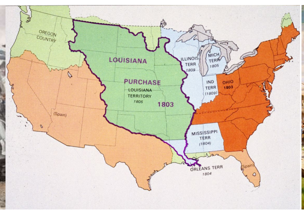
The massive production of sugar cane in Brazil and the Caribbean was a key drive for the trans-atlantic slave trade, as sugar cane production requires an immense amount of labor. ~ 10 million people were enslaved, many of them perishing on the cross-atlantic voyage.

Caribbean Sugar and Slavery



A sugar plantation in 1823

Haiti and the making of the USA

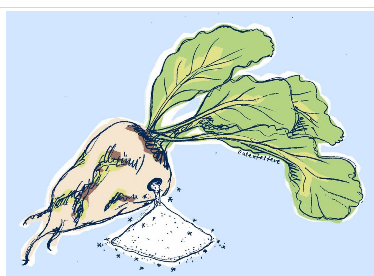


Haiti Revolution: 1791–1804
first nation to ban slavery
Sainte Domingue

Sugar and slavery and slave uprisings in Haiti:
directly contributing to the making of the USA?

Practice question" What is the link between the slave revolt /successful revolution in Haiti and the United States?
It contributed to the Louisiana purchase, the transfer of a huge stretch of territory from France to the US.

European sugar: Sugar Beet

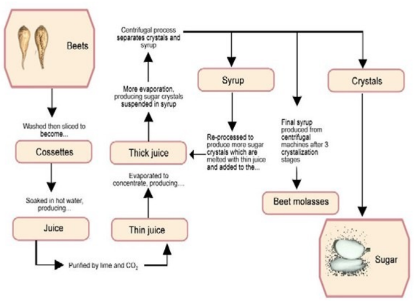


1747: Prussian chemist Andrea S. Margraff discovers that sucrose can be derived from beets.
1801: Franz Carl Achard, a student of Margraff, is credited as the first person to extract sugar from beets on a commercial level.
1815 The beet sugar industry thrives in Europe through the Napoleonic Wars, though Napoleon is the subject of much ridicule for supporting the industry. When the wars end, cheap Caribbean sugar is once again exported to Europe, severely damaging the sugar beet business.
1837: Vilmorin, a French seed company, creates the sugar beet, which has a high sucrose content and a structure designed for optimal sugar extraction. As slavery dies out in the Caribbean, European governments enact policies to support their beet growers. With governmental support, the European beet sugar industry expands through the 20th century.

European sugar: Sugar Beet

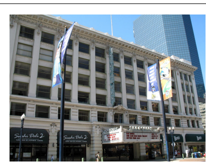
Beet sugar production began in Europe in the 19th century following the Continental Blockade instituted during the Napoleonic wars, thus preventing the importation of cane sugar. After sugar cubes were put on the market at the turn of the 20th century, sugar loaves were no longer used on a daily basis, but were kept in reserve in case of shortages.

European sugar: Sugar Beet



Modern sugar beets date back to mid-18th century Silesia where the king of Prussia subsidised experiments aimed at processes for sugar extraction. In 1747, Andreas Marggraf isolated sugar from beetroots and found them at concentrations of 1.3–1.6%. He also demonstrated that sugar could be extracted from beets that was identical with sugar produced from sugarcane. His student, Franz Karl Achard, evaluated 23 varieties of mangelwurzel for sugar content and selected a local strain from Halberstadt in modern-day Saxony-Anhalt, Germany. Moritz Baron von Koppy and his son further selected from this strain for white, conical tubers. The selection was named “weiße schlesische Zuckerrübe”, meaning white Silesian sugar beet, and boasted about a 6% sugar content.This selection is the progenitor of all modern sugar beets

Global sugar production



By 1907 ASRC controls 97% of all American sugar production. 1906: C&H sugar company is formed by Claus Spreckles, a German immigrant who ran a beet sugar factory in California (C&H stands for California and Hawaii). Spreckles dominates sugar production in Hawaii until the 1930s, when sugar plantations are converted for other uses. Today C&H is part of Domino Sugar, and there are no more sugar factories or mills in operation on Hawaii.

1864: The largest and most technologically advanced sugar refinery in the world opens in Williamsburg on Long Island. With improvements in manufacturing, the production of American sugar increases and drives down the prices.
1887: Lower prices mean less profit, so in 1887, eight leaders in the American sugar industry form the American Sugar Trust with the intention of reducing production to increase prices and profits for all of their companies. After acquiring more companies, they change their name to The American Sugar Refining Company (ASRC). They close facilities they deem inefficient and combine others with ones they already own, essentially fixing the price of refined sugar. 1900: The ASRC creates the Domino Sugar brand to market all of the sugar they produce under one name. By 1907 ASRC controls 97% of all American sugar production. 1906: C&H sugar company is formed by Claus Spreckles, a German immigrant who ran a beet sugar factory in California (C&H stands for California and Hawaii). Spreckles dominates sugar production in Hawaii until the 1930s, when sugar plantations are converted for other uses. Today C&H is part of Domino Sugar, and there are no more sugar factories or mills in operation on Hawaii.

Sugar Power

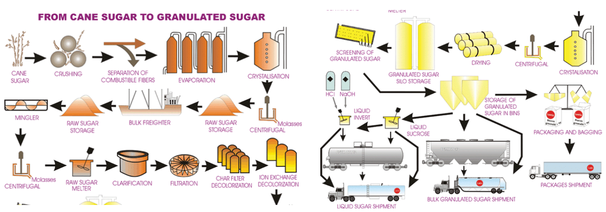

NEW YORK JOURNAL

HAWAIIAN ISLANDS OURS BY SENATE'S VOTE.

Newlands Resolutions Passed Yesterday by Exactly a Two-thirds Majority, and Only the President's Signature Is Needed Now.

Sugar Topples the Hawaiian Throne In 1875, the Reciprocity Treaty between Hawaii and the US permits duty-free importation of Hawaiian sugar. In 1887, American sugar interests force the king of Hawaii to agree to a constitution that gives them significant power in the the kingdom. By 1893, they overthrow the Hawaiian monarchy and pressure the US Congress to annex Hawaii.

Sugar production from cane



The process of turning sugar cane juice into refined sugar is long!

Cane Sugar varieties:

granulated, pearl, confectioners, turbinado, molasses

coarse, liquid, demara style, organic, evaporated cane juice

superfine sugar, liquid invert, muscovado, golden syrup, jaggery

Sugar is produced into a variety of products, refined granulated sugar being the most common.

Jaggery production in India

Jaggery from Sanskrit Sarkara is traditionally produced raw sugar from boiled down cane juice. It contains minerals and vitamins, unlike refined sugar!

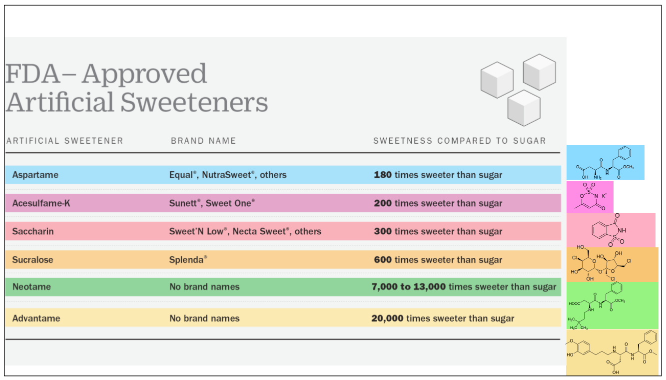
Practice question:
What is jaggery
evaporated cane juice, produced by boiling unfiltered cane juice.

Global sugar production

1942: The American Medical Association's Council on Food and Nutrition suggests that it "would be in the interest of the public health for all practical means to be taken to limit consumption of sugar in any form in which it fails to be combined with significant proportions of other foods of high nutritive quality."
1966: Medical professionals recommend a decrease in sugar intake, noting new studies that correlate sugar consumption with diabetes and other diseases. These studies, and the increasing rates of diabetes and obesity, spark an interest in sugar substitutes.
1980: The FDA considers fat a greater villain than sugar, driving a trend of reduced-fat (but high-sugar) manufactured food. Sugar-related health issues continue to rise.

Artificial sweeteners

1879: A graduate student at Johns Hopkins refines saccharin, a crystalline powder 300 to 500 times sweeter than sugar but with no calories. It doesn't see widespread use until World War I, when sugar was subject to strict rationing; once sugar became available again, saccharine was shunted to diet foods. A 1977 study reports that saccharin caused cancer in test animals, causing the FDA to place a moratorium on saccharine use, which is only lifted in 1991.
1952: Calcium cyclamate starts appearing in diet sodas. Studies in the 1960s show that it's likely carcinogenic, and the FDA bans the sweetener in 1970.
1965: Aspartame (a.k.a. NutraSweet and Equal) is invented in 1965, and by the late 1970s is used in diet sodas.
1967: High-fructose corn syrup hits the scene.
1998: Sucralose, which goes by the brand name of Splenda and is a whopping 600 times sweeter than sugar, is approved for use in the U.S. Artificial sweeteners supplement or replace sugar in all kinds of food products, but have yet to prove rigorously measurable health benefits.

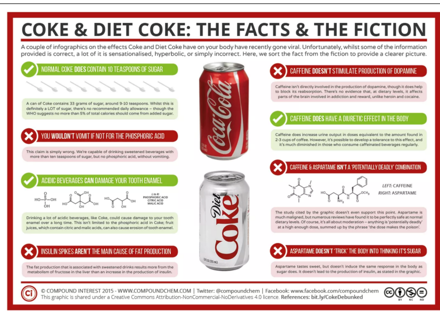


FDA– Approved Artificial Sweeteners

ARTIFICIAL SWEETENER	BRAND NAME	SWEETNESS COMPARED TO SUGAR
Aspartame	Equal®, NutraSweet®, others	**180** times sweeter than sugar
Acesulfame-K	Sunett®, Sweet One®	**200** times sweeter than sugar
Saccharin	Sweet'N Low®, Necta Sweet®, others	**300** times sweeter than sugar
Sucralose	Splenda®	**600** times sweeter than sugar
Neotame	No brand names	**7,000 to 13,000** times sweeter than sugar
Advantame	No brand names	**20,000** times sweeter than sugar

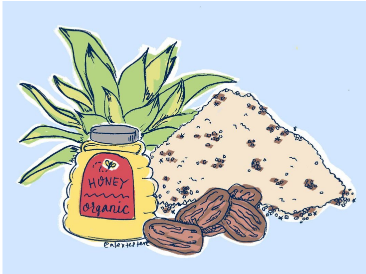
It didn't take long for food makers to swarm to saccharin, since it was cheaper, sweeter and more reliable to make in the lab than sugar, which needed to be harvested and shipped. Other versions followed, and while some, like aspartame, contain about 4 calories per gram, others boasted fewer or no calories at all, making them a staple of the new diet-conscious culture that emerged in the 1950s and 1960s, and became a foundation of most weight loss efforts.There are now six high-intensity sweeteners approved by the Food and Drug Administration (FDA), increasingly sprinkled into a surprising number of foods on supermarket shelves, from diet sodas to frozen meals and savory snacks. Among more than 85,000 commonly purchased foods, 1% contain non-caloric sweeteners and 6% contain a combination of both sugar and non calorie sweeteners. But to find them, you need higher order chemistry knowledge. Unlike fats, which are broken down into saturated, trans and cholesterol on nutrition labels, sugars are listed in one sweet lump, combining both naturally occurring forms such as sucrose (sugar cane), fructose (from fruit) and dextrose (from corn) as well as the lower calorie substitutes like aspartame, saccharin, sucralose (Splenda), stevia (Truvia), acesulfame potassium (Sunett, Sweet One, Ace K), neotame (Newtame) and advantame. To find the latter agents, you'll have to hunt in the lengthy list of ingredients on the label. Many of these substances now end up in waste water.

Sugar and other taste receptors



Artificial sweeteners are mostly safe, but do not seem to have turned around the trend of us getting heavier!

Nothing beats the classics



2000s: As artificial sweeteners fall out of vogue, ancient forms of sugar make a major comeback: agave nectar, stevia, dates, and of course honey, which is delicious, shelf-stable, and linked to many health benefits. Nothing beats the classics.

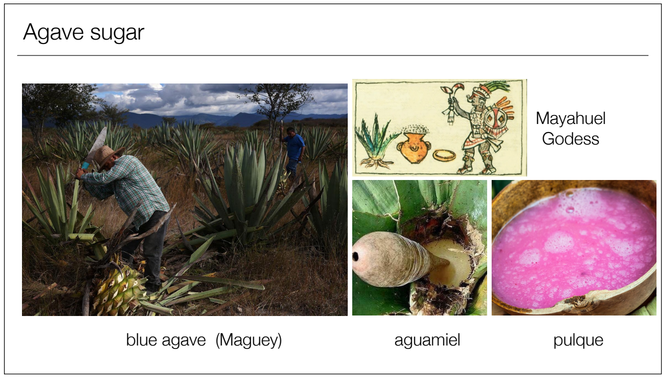
pie crust
wheat flour, butter, sugar, cold water and salt

combining fats with starch and sugar……tasty!

Palm Sugar

Borassus (palmyra) palm
Date palm
Nipa palm (Asia)
Sugar (Arenga) palm (Asia)
Coconut palm (Asia)

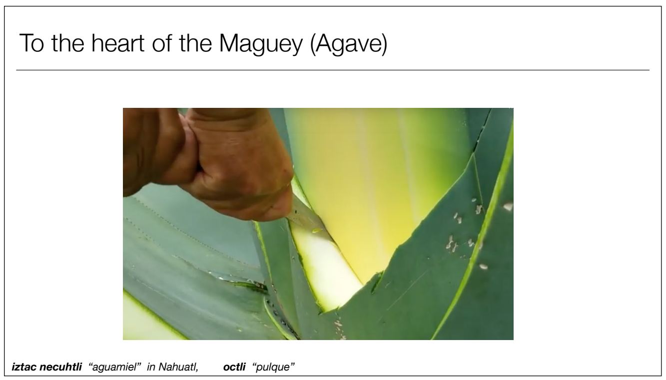
Palm sugar is produced by boiling collected sap until it thickens. The boiled sap can be sold as palm syrup. It is sold in bottles or tins and tends to thicken and crystallize over time. The boiled sap can also be solidified and sold in the form of bricks or cakes.



Agave sugar was traditionally made from the sap of the inflorescence of agave plants, 12 to 14 year old plants are used to produce large quantities of aguamiel. The center of the plant is cut back deep into the base of the meristematic tissue, the plant is then left alone for several months, before the pit is cleaned out and collection of the sap begins for several weeks. A plant can give a much as 10 liter so aguamiel per day. the liquid is sucked out with a large gourd. The sap can be fermented with wild yeasts into pulque, an alcoholic drink. Another method is to harvest the center (pina) and press out all the sap.

Practice question: What is pulque?
Answer: A traditional alcoholic drink in Central America made from fermented agave sap.

Practice question: What is the principal sugar in agave juice?
Answer: Fructose and polyfructose (fructan).



https://www.therecipehunters.com/maguey

practise question:

What is the difference between harvest from agave (Maguey) for aguamiel and for the production of tequila?

Answer: Only the sap is used for aguamiel/pulque , but the whole base of the plant (pina with sap and starch) is used for making tequila.

The ancient disappearing art of Maguey:
Agave americana and several other species of agave, desert adapted succulents that can provide precious nutrition!

Practice question: What plant does the word maguey refer to?
Answer: Agave

Fermenting plant sap: palm wine

The some palm wines are harvested without felling the palm.
Palm wine in Malaysia has been a source of Nipah virus infection. The virus comes from bats that shed it while drinking palm wine at night!
Practice question: Which non-human animals also enjoy palm wine?
Answer: chimpanzees and bats.

Fermenting plant starches:

requires **malting**: enzymatically cleaving the long starch polysaccharides into much shorter, fermentable oligosaccharides.

requires **mashing**: extracting the cleaved starches with hot water.

requires alcoholic **fermentation** with yeast: yeasts metabolize the malts into alcohol.

malting

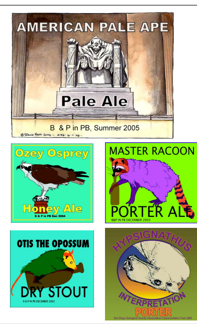
mashing

fermenting

To ferment starch from grain or tubers, the starch has to be enzymatically cleaved into short, fermentable sugars first. This can be done with human saliva amylase (chweing cooked grain and spitting back into a container, or by awakening the grain by soaking and sprouting (malting). The embryo of the grain will express enzymes that can turn starch into sugar. These enzyme will survive kilning/roasting and drying!
Mashing allows the enzymes to act on more starch and produces a very sweet/malted water solution, which can then be fermented with yeast.

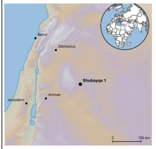
Practice question: What steps are required for fermenting starch from grain, tubers of fruit into alcoholic beverages?
Answer: Malting, and mashing.

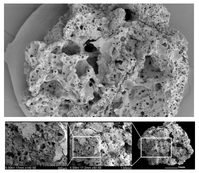
Brewing Beer at home:



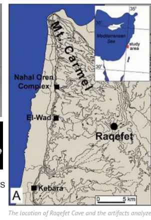
Beer fermenting right now in our kitchen in PB (November 2021
During top fermentation, there is a “storm” in the large glass carboy.
One of my favorite parts of making beer is to make labels….

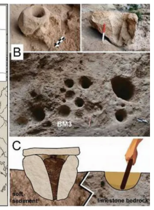
Liquid bread 13kya, or solid bread 14 kya?





Dorian Fuller and colleagues





A bit of 14,400-year old charred bread, about 2 millimeters in size. Note the bubbles from kneading. Like matza, it was not leavened

Use-wear and residue analyses of three stone mortars from a Natufian burial site at Raqefet Cave, Israel (13,700–11,700cal. BP). The results of the analyses indicate that the Natufians exploited at least seven plant taxa, including wheat or barley, oat, legumes and bast fibers (including flax). They packed plant-foods, including malted wheat/barley, in fiber-made containers and stored them in boulder mortars. They used bedrock mortars for pounding and cooking plant-foods, including brewing wheat/barley-based beer likely served in ritual feasts ca. 13,000years ago. These innovations predated the appearance of domesticated cereals by several millennia in the Near East.

Fermenting unusual plant starches:

requires alcoholic **fermentation** with yeast: yeasts metabolize the malts into alcohol.

Chicha (Peru):
human spit, salivary enzymes (amylases) cleave the corn starch into fermentable sugars

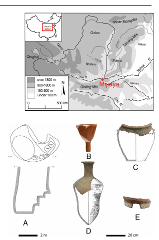
Mbege (Tanzania):
malted (sprouted) millet used to cleave banana starch, wild yeasts in fermented banana porridge produce alcohol.

Pombe (across Africa):
malted (sprouted) millet used to produce alcohol.

To ferment starch from grain or tubers, the starch has to be enzymatically cleaved into short, fermentable sugars first. This can be done with human saliva amylase (chewing cooked grain and spitting back into a container, or by awakening the grain by soaking and sprouting (malting). The embryo of the grain will express enzymes that can turn starch into sugar. These enzyme will survive kilning/roasting and drying! Mashing allows the enzymes to act on more starch and produces a very sweet/malted water solution, which can then be fermented with yeast.

Practice question: What steps are required for fermenting starch from grain, tubers of fruit into alcoholic beverages?
Answer: Malting, and mashing.

Millet, rice, sorghum, barley, fermentation and distillation



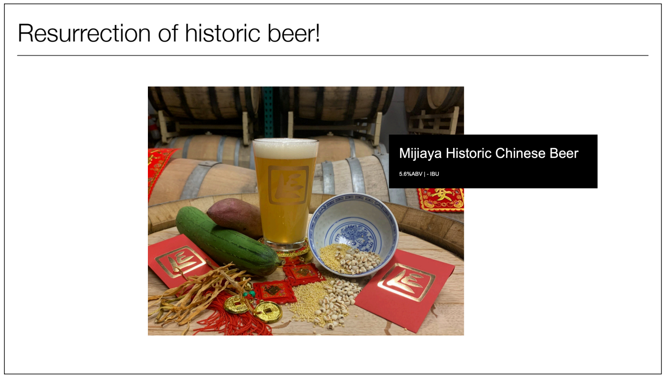
白酒　燒酒

5000 year old Beer in Mijiaya, China

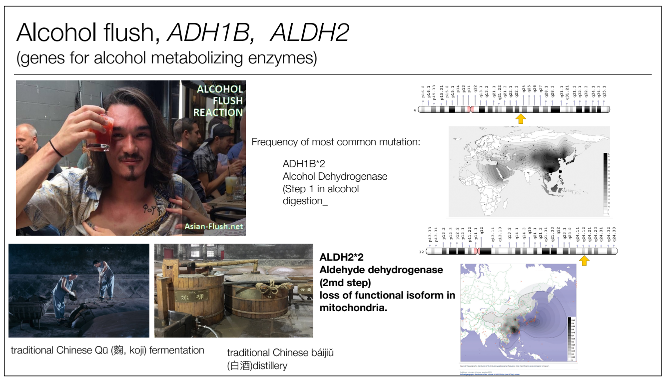
Chinese "wines were more similar to beer, as these were mostly produced from grains. The yeast used is very different from *Saccharomyces* brewer's yeast as it is an *Aspergillus* species. Chinese alcohol predates recorded history. Dried residue extracted from 9,000-year-old pottery implies that early beers were already being consumed by the neolithic peoples in the area of modern China. Made from rice, honey, grapes, and hawthorn, it seems to have been produced similarly to that of Mesopotamia and Ancient Egypt.

Research revealed a 5,000-y-old beer recipe in which broomcorn millet, barley, Job's tears, and tubers were fermented together. The data provide the earliest direct evidence of in situ beer production in China, showing that an advanced beer brewing technique was established around 5,000 y ago. Scientists were able to identify the presence of barley in archaeological materials from China by applying a recently developed method based on phytolith morphometrics, predating macrobotanical remains of barley by 1,000 y. The method successfully distinguishes the phytoliths of barley from those of its relative species in China.

Practice Question: what is a SCOBY?
Symbiotic Community of Bacteria and Yeast, e..g. Qu or Koji, used to directly ferment (without the need for mashing) any starch in East Asia.



Named after the 5,000 year-old Mijiaya archaeological site in Shaanxi, Northern China. We brewed this special Chinese New Year release based on the starch and grains found in various brewing vessels excavated from the dig site. Brewed with barley, Job's tears, millet, Chinese squash, lily flowers, and yam, the resulting beer is flowery, light, and clean.

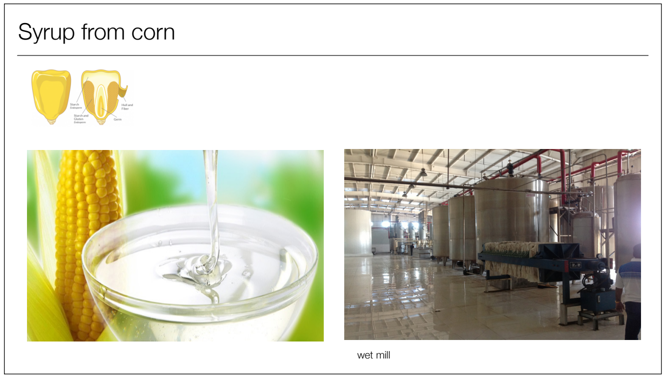


Alcohol is a natural toxin produced as a waste product when yeast ferment sugars. Humans have fermented sugars (diluted honey) or malted grain since more than 10 thousands of years to make alcohol. Genetic variation at two genes coding for alcohol metabolism alcohol dehydrogenase 1b that turns alcohol to acetaldehyde and aldehyde dehydrogenase 2 that turns acetaldehyde into acetate can strongly affect an individual's ability to metabolize alcohol and in doing so limit the toxic effect of alcohol.

These genes act in a **co-dominant manner**: one allele of a poorly active enzyme reduces metabolism, two copies lead to much stronger effect: individuals with two copies of inactive/or slowly active enzyme get classical facial flushing after just a small amount of alcohol. The reasons for the high frequency of these alleles in East Asia are not understood, but could include ***social selection*** against alcoholism, known to be very costly to societies. East Asia, where distillation was wide-spread early in history. East Asian populations have lower rates of alcoholism than many other populations.

Practice Question: How is the East Asian variant of aldehyde dehydrogenase acting in a co-dominant manner?

Answer: One copy of the variant reduces the person's ability to metabolize alcohol, two copies reduce it further.



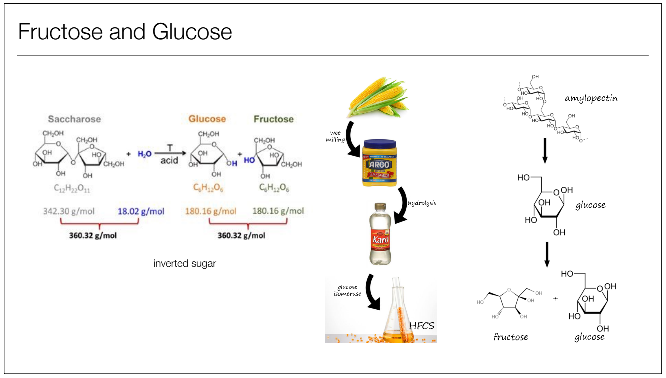
Corn has become a source of glucose and fructose, using wet mill technology.

Practice question:
How can corn starch give rise to glucose and fructose corn syrup?
By the use of enzymes that cleave the starch and change glucose into fructose.

The explosives industry of WWII became the fertilizer industry post-War
New corn varieties that require much more nitrogen fertilizer were favored and led to a huge increase in corn.

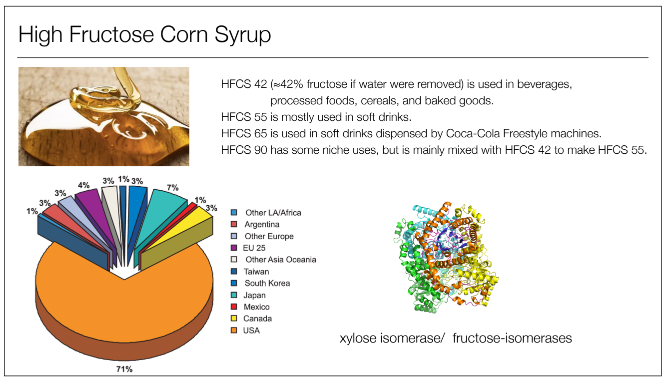
Practice question:
What is the link between explosives and fertilizers?
Both are based on industrial nitrogen fixation.

Flow chart for wet milling, from corn meal to a variety of mixes of pure glucose and sucrose.

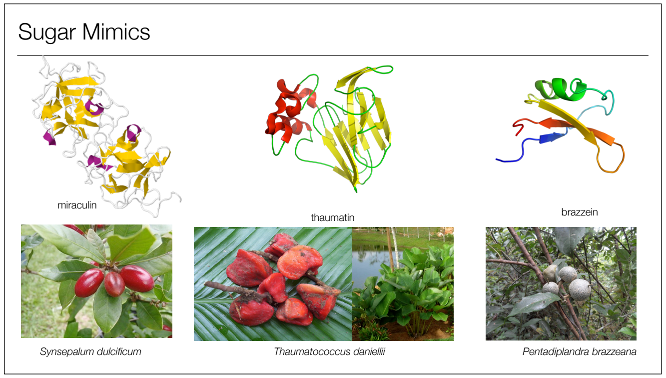


The inversion of beet or cane sugar is the chemical conversion of saccharose in solution into glucose and fructose.
This process is enhanced by acids and high temperatures. The angle of rotation of polarized light sent through the solution changes during the process of inversion.
Inverted sugar is used in sweets and pastry and has a consistence similar to honey.

Practice question:
Why is hydrolyzed sucrose called inverted sugar?
Fructose rotates light the opposite way than sucrose does.



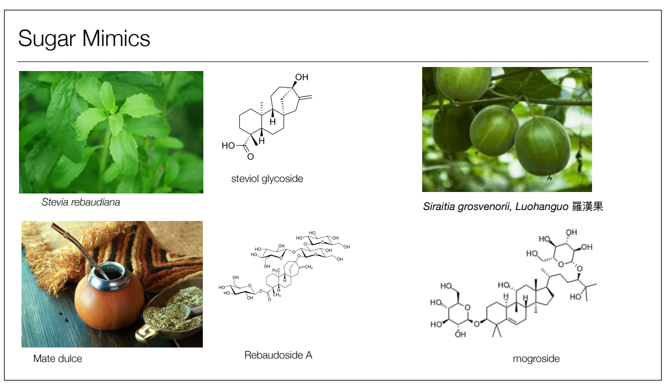
In the contemporary process, corn is milled to extract corn starch and an "acid-enzyme" process is used, in which the corn-starch solution is acidified to begin breaking up the existing carbohydrates. It is necessary to carry out the extraction process in the presence of mercuric chloride (0.01 M) in order to inhibit endogenous starch-degrading enzymes. High-temperature enzymes are added to further metabolize the starch and convert the resulting sugars to fructose.The first enzyme added is alpha-amylase, which breaks the long chains down into shorter sugar chains – oligosaccharides. Glucoamylase is mixed in and converts them to glucose; the resulting solution is filtered to remove protein, then using activated carbon, and then demineralized using ion-exchange resins. The purified solution is then run over immobilized xylose isomerase, which turns the sugars to ~50–52% glucose with some unconverted oligosaccharides and 42% fructose (HFCS 42), and again demineralized and again purified using activated carbon. Some is processed into HFCS 90 by liquid chromatography, and then mixed with HFCS 42 to form HFCS 55. The enzymes used in the process are made by microbial fermentation.
Composition and varieties
HFCS is 24% water, the rest being mainly fructose and glucose with 0–5% unprocessed glucose oligomers.
The most common forms of HFCS used for food and beverage manufacturing contain fructose in either 42% ("HFCS 42") or 55% ("HFCS 55") amounts, as described in the US Code of Federal Regulations (21 CFR 184.1866).



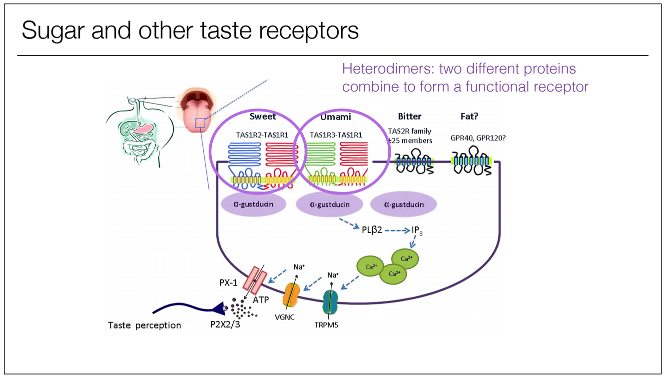
The Oubli plant (from which the protein was isolated) grows in Gabon and Cameroon, where its fruit has been consumed by the apes and local people for a long time. Due to brazzein and pentadin, the berries of the plant are incredibly sweet. African locals call them "Oubli" (French for "forgot") in their vernacular language because their taste is said to encourage nursing infants to forget their mother's milk,as once they eat them they are said to forget to come back to the village to see their mother.

On a weight basis, brazzein is 500 to 2000 times sweeter than sucrose, compared to 10% sucrose and 2% sucrose solution respectively.

Most primates have a genotype of the taste receptor protein, taste receptor type 1 member 3 (TAS1R3), that enables them to taste the protein, brazzein.To humans, the fruit is intensely sweet, but provides few calories. Such proteins may imitate sweetness to lure wild animals to eat the berries and disperse the seeds. Western lowland gorillas (Gorilla gorilla), however, have two mutations in the TAS1R3 gene, and although its diet contains a high proportion of fruit, scientists have not witnessed gorillas consuming P. brazzeana berries If factual, this avoidance behavior and the taste gene mutations may indicate a counter-adaptation to deter gorillas from foraging for low-calorie foods.

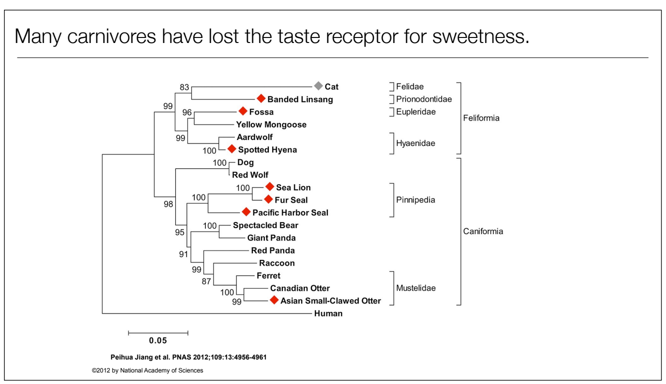


Diterpene glycosides from Stevia (sun flowers family) and from luohanguo (gourd family), each hundreds of time as sweet as sugar.



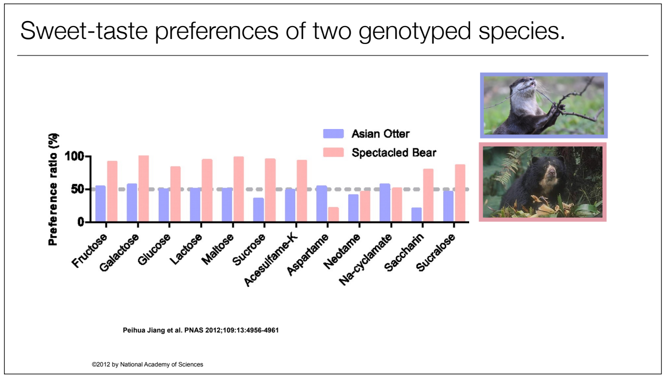
Simplified model of the taste GPCR signalling pathways involved in chemosensing by taste cells of the tongue. Subtypes of the TAS1R family heterodimerize to detect sweet (TAS1R2-TAS13) and umami (TAS1R1-TAS1R3) while bitter is detected by 25 subtypes of the TAS2R family.
Medium-chain and long-chain fatty acids are detected by FFAR1 and GPR120. Taste receptor binding leads to activation of gustatory G-proteins,
release of intracellular Ca2+, activation of TRPM5, depolarisation, activation of voltage-gated Na+ channels (VGNC) and release of ATP which activates purinergic receptors on afferent nerve fibres leading to taste perception. ATP, adenosine triphosphate; FFAR1, free fatty acid receptor 1; GPCR, G-protein coupled receptor; GPR120, G-protein coupled receptor 120; PX-1, pannexin 1-hemichannel; TAS1R, taste receptor type 1; TAS1R1, taste receptor type 1 member 1; TAS1R2, taste receptor type 1 member 2; TAS1R3, taste receptor type 1 member 3; TAS2R, taste receptor type 2; TRPM5, transient receptor potential cation channel M5; VGNC, voltage-gated Na+ channel.

Practice question:
What is a heterodimer as seen in taste receptors?
A heterodimer is the combination of two different proteins to form a single functional unit.



An evolutionary tree of Tas1r2 gene from 18 species within Carnivora. The evolutionary history is inferred by using the maximum-likelihood method based on the Tamura–Nei model (37) implemented in MEGA5. The tree is drawn to scale, with branch lengths measured in the number of substitutions per site. Species with a pseudogenized Tas1r2 are marked with a diamond (red and gray depict species characterized in this study or previously, respectively). The human Tas1r2 is used as the outgroup for the analysis.

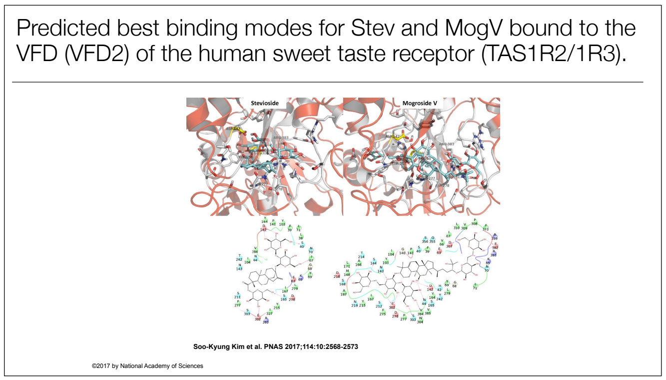
Practice question: Why would carnivores have lost functional sweetness receptors during evolution?
Answer: Their diets do not include fruit or honey. There was no evolutionary disadvantage for mutations that inactivated the receptor proteins.



Sweet-taste preferences of two genotyped species. Two Asian otter and four spectacled bears were tested behaviorally for their preferences for sweeteners using a two-bowl preference setup. One bowl contained sweetener solution and the other contained plain water. Dashed line indicates no preference (50%). Sweeteners were tested at the following concentrations: fructose (0.8 M), galactose (0.8 M), lactose (0.5 M), maltose (0.7 M), sucrose (0.5 M), acesulfame-K (6.0 mM), aspartame (10 mM), neotame (10.5 mM), saccharin (6.2 mM), and sucralose (5.0 mM).

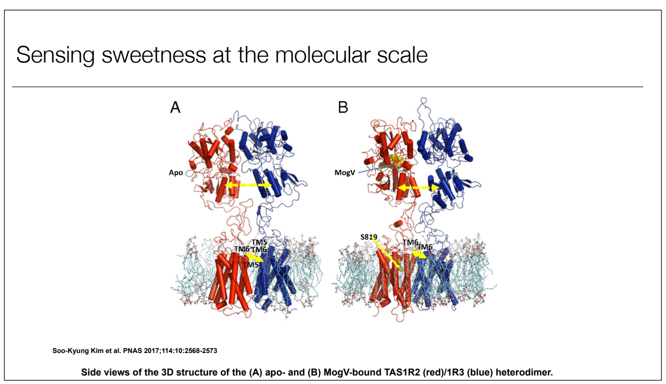
Practice question: Otters and bears are both in the order carnivora. How do spectaled bears and otter differ in their ability to sense sugars?

Answer: spectacled bears are omnivores and sense most sugars, while otters don’t.



Predicted best binding modes for Stev and MogV bound to the VFD (VFD2) of the human sweet taste receptor (TAS1R2/1R3). The predicted pharmacophore is at the bottom.

Scientists are trying to understand the molecular nature of sweetness.

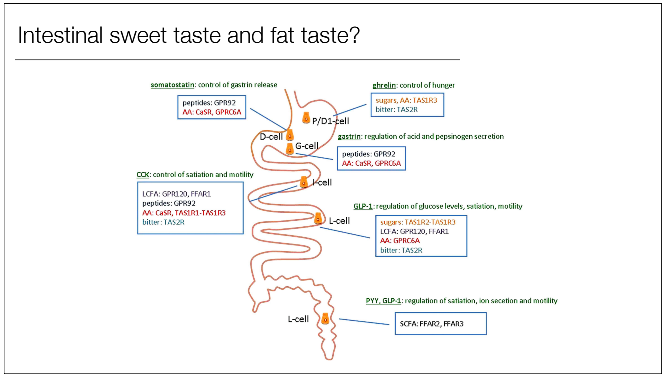


Structural biology of sweetness: modeling the 3D structure of sweetness receptor to study their interactions with sweet molecules.

Side views of the 3D structure of the (*A*) apo- and (*B*) MogV-bound TAS1R2 (red)/1R3 (blue) heterodimer. The MogV agonist is shown in VFD2 as a yellow space-filling model, whereas the S819 agonist modulator is the yellow structure at the EC part of TMD2. *SI Appendix*, Fig. S2 shows a more detailed binding site for the S819 allosteric agonist. The yellow arrows between VFD2 and VFD3 show the separation (Å) between the geometric center of lower VFD2 and lower VFD3 (VFD2–VFD3 in Table 1), whereas yellow arrows between TMD2 and TMD3 show the distance (Å) between the closest Cα of TM6/TMD2 with a Cα of TM6′/TMD3 (Dist TM6-6′ Cα in Table 1). These numbers are in *SI Appendix*, Table S13 for all 11 cases.

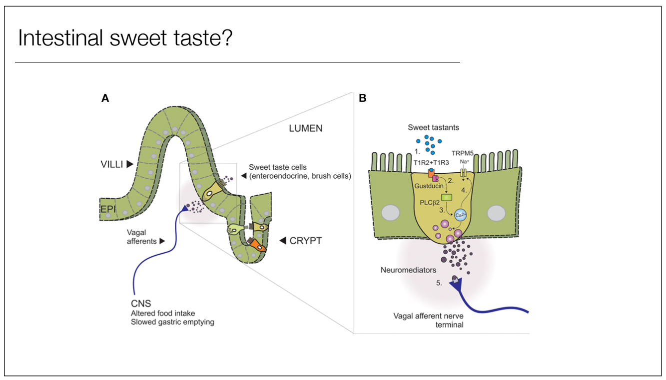
Practice question: How can scientists understand sweetness detection by our bodies.

Answer: Through studies of the cell surface receptors (proteins), their 3-dimensional organization and their interactions with sweet molecules at the molecular level.

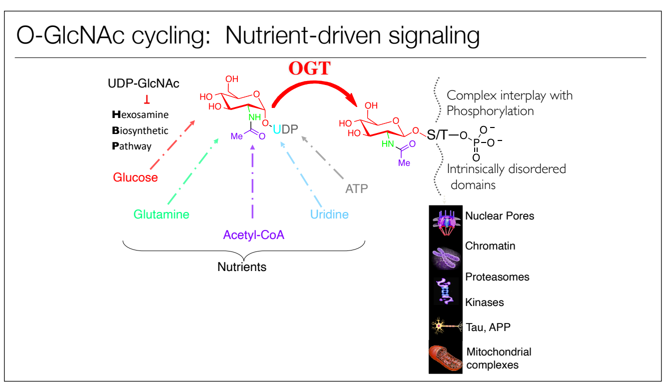


Schematic overview of the expression of taste receptors in different type of endocrine cells along the gut that control the release of hormones in response to nutrients. CaSR, calcium sensing receptor; FFAR1, free fatty acid receptor 1; FFAR2, free fatty acid receptor 2; FFAR3, fatty acid receptor 3; GPR92, G-protein coupled receptor 92; GPRC6A, G-protein coupled receptor family C group 6 member A; LCFA, long-chain fatty acids; TAS1R1, taste receptor type 1 member 1; TAS1R2, taste receptor type 1 member 2; TAS1R3, taste receptor type 1 member 3; TAS2R, taste receptor type 2.

Practice question: What tissues in your body carry taste receptors?
Answer: Your tongue and much of your digestive tract.



Model of intestinal sensing by sweet taste cells and mucosal vagal afferents (adapted, with permission, from Bertrand, 2009). (A) Intestinal wall showing villus–crypt and location of sweet taste cells. Different sweet taste cells are shown within the epithelial layer (EPI, alternate colors) indicating the range of intestinal enteroendocrine and brush cells identified with sweet taste machinery. Vagal afferent nerve terminals are shown adjacent the basolateral membrane where they can be activated in response to paracrine signaling (neuromediators), triggering nutrient reflexes that alter behavior (food intake) and slow gastric emptying. (B) Expanded schematic of boxed area in (A), showing key components of the intestinal sweet taste signaling pathway proposed to operate in an enteroendocrine sweet taste cell; (1) Heterodimeric sweet taste receptors comprising the GPCR T1R2 and T1R3 detect a wide range of sweet tastants in the intestinal lumen, (2) Upon GPCR binding, the taste-specific G-protein Gustducin is activated, liberating Gα and Gβ3 and Gγ13-subunits which are thought to activate PLCβ2, (3) leading to the release of intracellular calcium from IP3-sensitive stores. Gα-gustducin may also reduce intracellular levels of cAMP via activation of phosphodiesterases (not shown), (4) Rising intracellular calcium can then gate the taste-specific cation channel TRPM5, leading to Na+ influx, membrane depolarization, neuromediator release, and (5) nerve terminal activation.

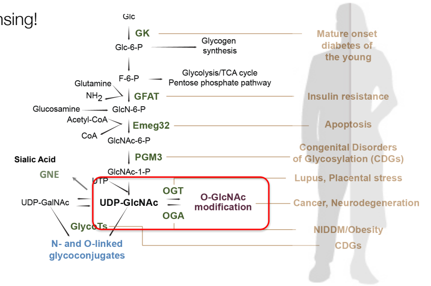


As I mentioned earlier, UDP-GlcNAc levels are sensitive to nutrient flux due to the variety of metabolites that are used for its synthesis. The sugar nucleotide UDP-GlcNAc is second only to ATP as the body'e high energy donor! The enzyme OGT transfers O-GlcNAc onto serine and threonine resides contained in numerous proteins within the cell (read). Because it occurs at the same site as phosphorylation, there exists a dynamic and complex interplay between these two post-translational modifications much of this work comes from Jerry Harts Lab.

Practice question:
What is UDP-GlcNAc?
An important sugar donor nucleotide (Uridine diphosphate N-Acetylglucosamine) providing the single sugar (GlcNAc) for an enzyme that modifies many important proteins by adding this sugar to serine or threonine amino acids. This regulates the activity of these proteins inside cells.

Hexosamine Signaling: Links to Human Disease

Nutrient Sensing!



Glucose can be used for energy or it can enter the hexosamine pathway giving rise to UDP-GlcNAc.
UDP-GlcNAc can be used to add N-Acetyl glucosamine to sugar chains on glycoproteins outside cells or it can be used by OGT enzyme to modify thousands of key proteins inside the cells, thus regulating gene expression, enzyme activity and mitochondrial function! Altering levels of glucose modify all of these processes!

Summary

Plants make sugar as structural building blocks and source of energy (including storage).

Plants use sucrose to attract pollinators and reward seed dispersers.

We are primates with a taste for sweet milk, sweet fruit and honey.

Honey is highly sought after by humans wherever bees live (honey bees and other bees, e.g. sweat bees)

With cooking, humans figured out ways to concentrate sugar containing plant juices: they invented sugar.

Diluted honey and sweet plant juices spontaneously ferment and turn into “wines”. Humans realized and made all kinds of alcoholic beverages. In the Americas, the agave plants were important sources of aguamiel and pulque. Across the tropics, palm sap is also collected and fermented. Fermenting starches requires the extra steps of malting and mashing.

The history of the sugar cane is old, colorful and cruel.

The sugar beet in Europe and syrups from corn provided novel sources of sucrose, glucose and fructose.

These new sources broke the tropical monopoly on sugar allowing modern societies to “swim” in sugar!

Many plants have evolved ways to “hack” animal sweetness receptors with super sweet protein and glycoside mimics of sucrose.

Many carnivore mammals have lost the receptors for sweetness.

The gut is full of sweetness- and fat-sensing “taste receptors”, maybe why artificial sweeteners have failed to prevent obesity.

Sugar is key to nutrient-sensing, many processes are directly affected by sugar levels, from hunger to gene expression.