TECHNIQUES D’ANALYSE

INTRODUCTION

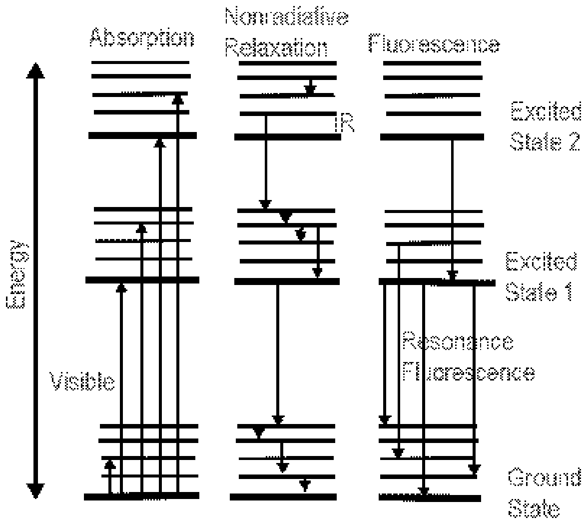
RELATION ENTRE LA MATIERE ET LA LUMIERE

Lumière et Matière

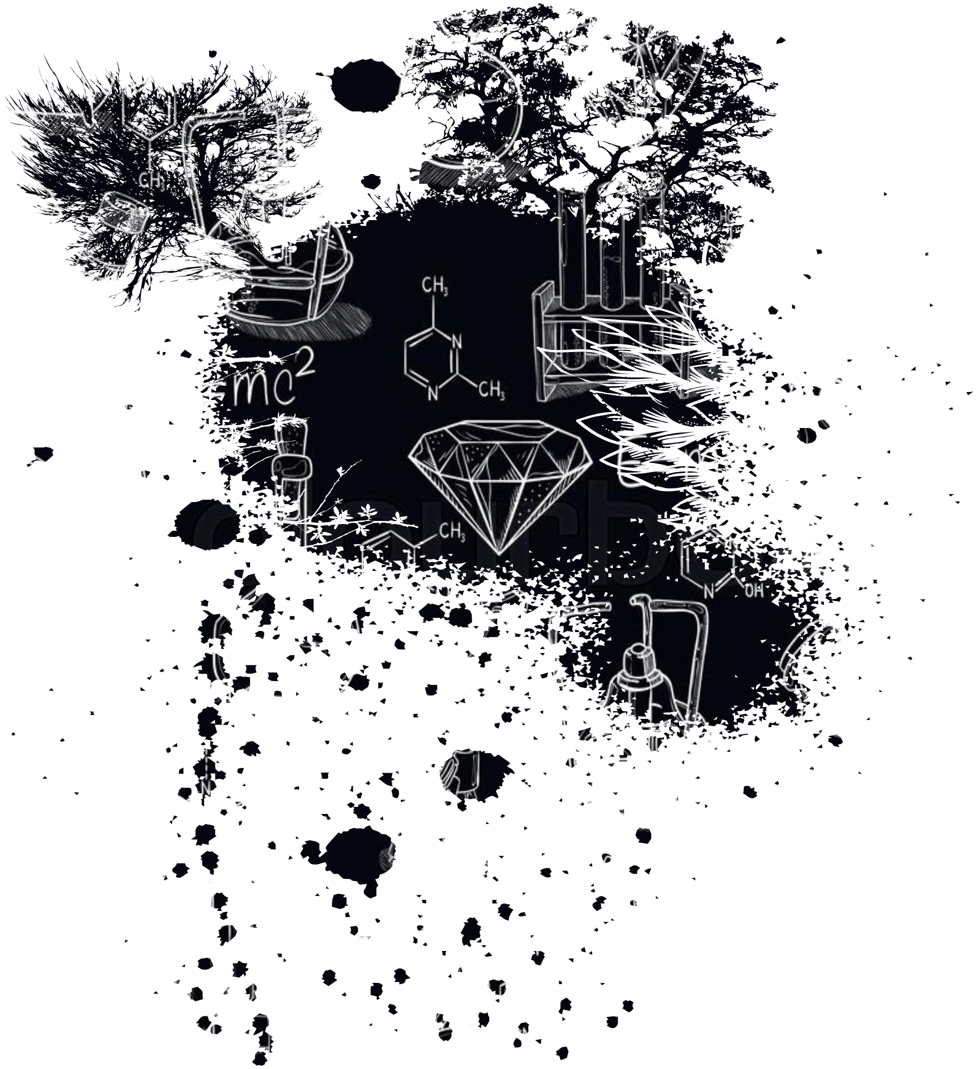
- Lumière et matière sont tous deux quantiques
- Elles se comportent comme des paquets de grains, les quanta
- L’interaction entre la lumière et la matière
- Notion de spectroscopie analytique

ENERGIE MOLECULAIRE

Mesure de l'énergie de la molécule, mesure de la lumière

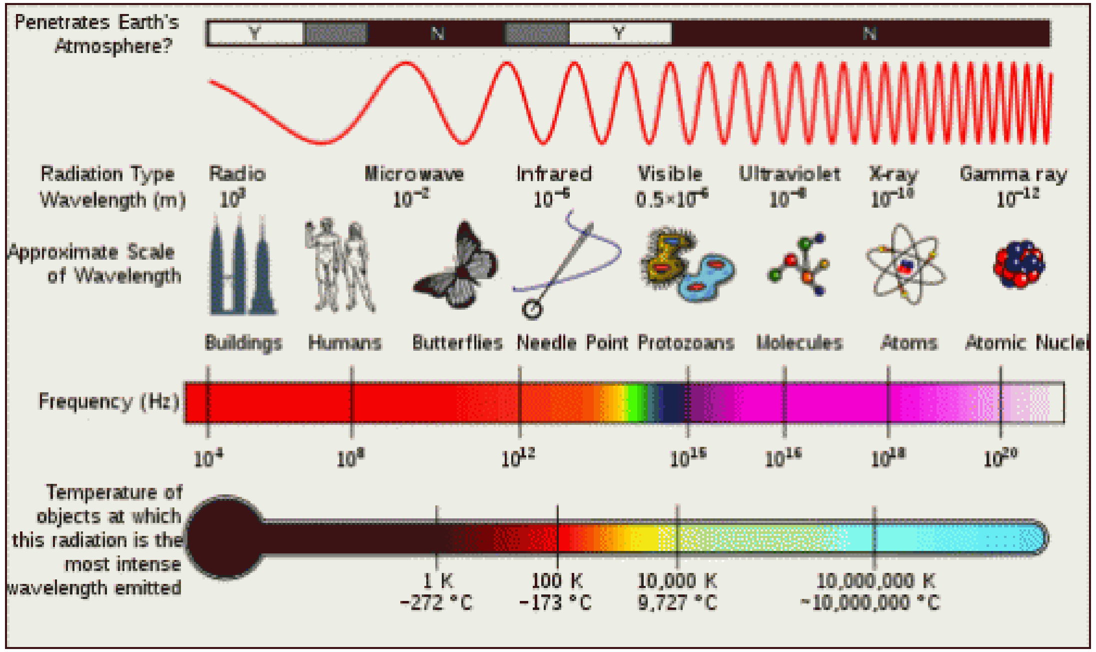


- Spectrocopie UV-Vis
- Spectrocopie Infrarouge
- Résonance Magnétique Nucléaire
- Fluorescence et Phosphorescence
- Autres spectroscopies



Spectre Électromagnétique

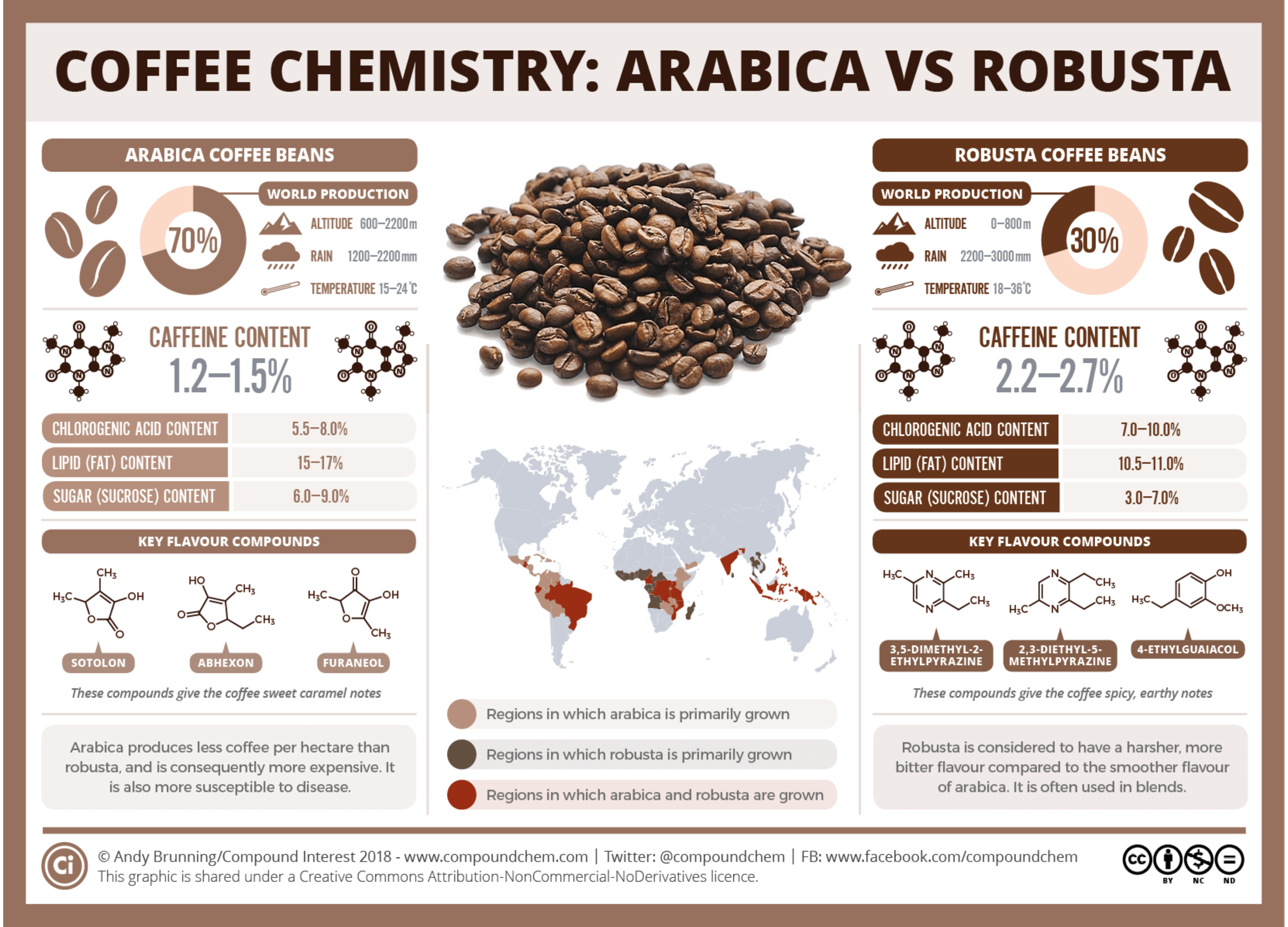
Mesure de l'énergie de la molécule, mesure de la lumière



CHIMIE DES ALIMENTS

COMMENT FAIRE PARLER LA CHIMIE D’UN ALIMENT

COMMENT MIEUX CONNAITRE UN ALIMENT ?


COFFEE CHEMISTRY: ARABICA VS ROBUSTA
ARABICA COFFEE BEANS
70%
WORLD PRODUCTION
ALTITUDE 600–2200m
RAIN 1200–2200mm
TEMPERATURE 15–24°C
CAFFEINE CONTENT
1.2–1.5%
CHLOROGENIC ACID CONTENT 5.5–8.0%
LIPID (FAT) CONTENT 15–17%
SUGAR (SUCROSE) CONTENT 6.0–9.0%
KEY FLAVOUR COMPOUNDS
SOTOLON
ABHEXON
FURANEOL
These compounds give the coffee sweet caramel notes
Arabica produces less coffee per hectare than robusta, and is consequently more expensive. It is also more susceptible to disease.
Regions in which arabica is primarily grown
Regions in which robusta is primarily grown
Regions in which arabica and robusta are grown
ROBUSTA COFFEE BEANS
WORLD PRODUCTION
ALTITUDE 0–800m
RAIN 2200–3000mm
TEMPERATURE 18–36°C
30%
CAFFEINE CONTENT
2.2–2.7%
CHLOROGENIC ACID CONTENT 7.0–10.0%
LIPID (FAT) CONTENT 10.5–11.0%
SUGAR (SUCROSE) CONTENT 3.0–7.0%
KEY FLAVOUR COMPOUNDS
3,5-DIMETHYL-2-ETHYLPYRAZINE
2,3-DIETHYL-5-METHYLPYRAZINE
4-ETHYLGUAIACOL
These compounds give the coffee spicy, earthy notes
Robusta is considered to have a harsher, more bitter flavour compared to the smoother flavour of arabica. It is often used in blends.
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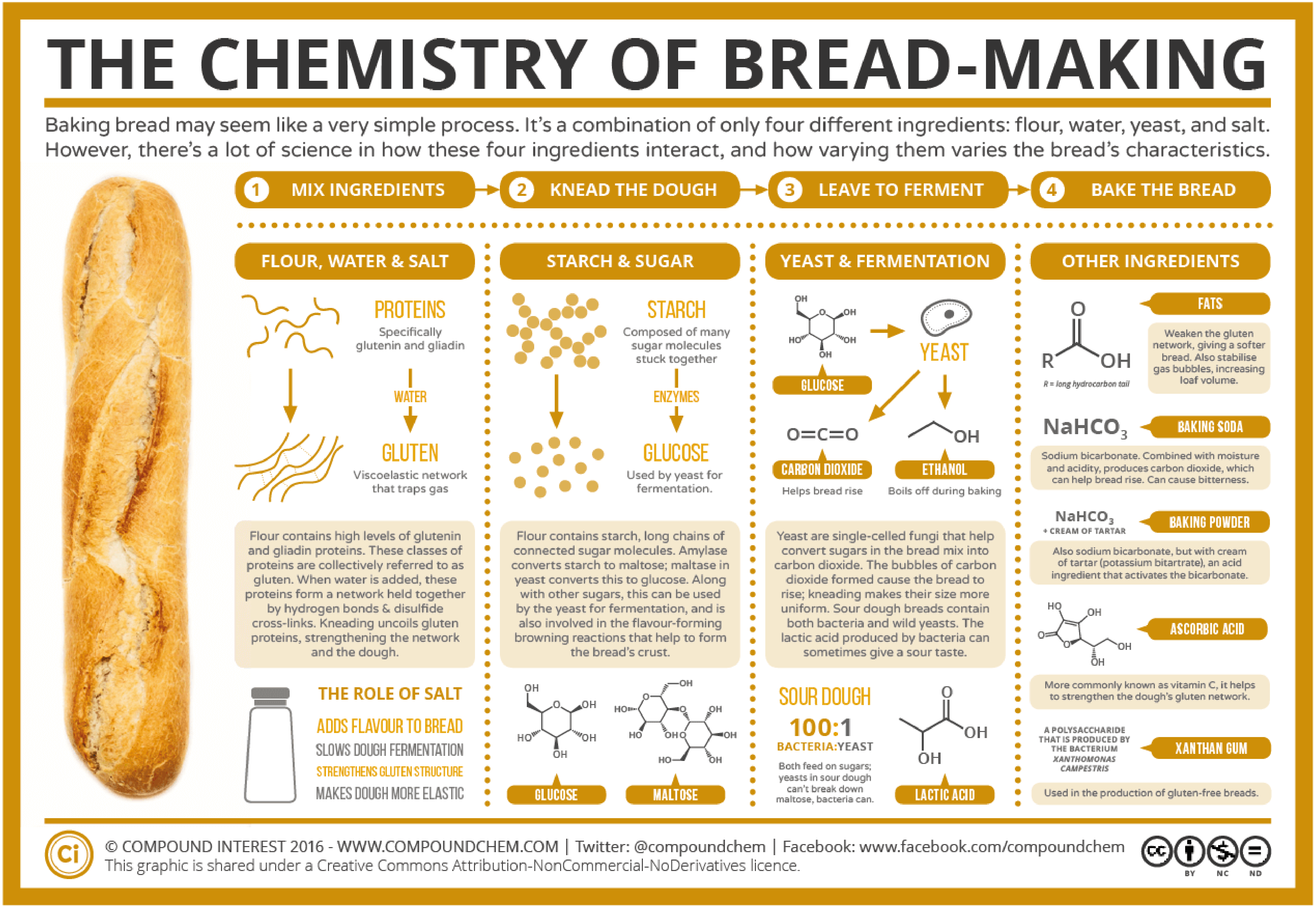

THE CHEMISTRY OF BREAD-MAKING
Baking bread may seem like a very simple process. It's a combination of only four different ingredients: flour, water, yeast, and salt. However, there's a lot of science in how these four ingredients interact, and how varying them varies the bread's characteristics.
1 MIX INGREDIENTS
2 KNEAD THE DOUGH
3 LEAVE TO FERMENT
4 BAKE THE BREAD
FLOUR, WATER & SALT
PROTEINS
Specifically glutenin and gliadin
WATER
GLUTEN
Viscoelastic network that traps gas
Flour contains high levels of glutenin and gliadin proteins. These classes of proteins are collectively referred to as gluten. When water is added, these proteins form a network held together by hydrogen bonds & disulfide cross-links. Kneading uncoils gluten proteins, strengthening the network and the dough.
THE ROLE OF SALT
ADDS FLAVOUR TO BREAD
SLOWS DOUGH FERMENTATION
STRENGTHENS GLUTEN STRUCTURE
MAKES DOUGH MORE ELASTIC
STARCH & SUGAR
STARCH
Composed of many sugar molecules stuck together
ENZYMES
GLUCOSE
Used by yeast for fermentation.
Flour contains starch, long chains of connected sugar molecules. Amylase converts starch to maltose; maltase in yeast converts this to glucose. Along with other sugars, this can be used by the yeast for fermentation, and is also involved in the flavour-forming browning reactions that help to form the bread's crust.
GLUCOSE
MALTOSE
YEAST & FERMENTATION
GLUCOSE
YEAST
O=C=O
OH
CARBON DIOXIDE
Helps bread rise
ETHANOL
Boils off during baking
Yeast are single-celled fungi that help convert sugars in the bread mix into carbon dioxide. The bubbles of carbon dioxide formed cause the bread to rise; kneading makes their size more uniform. Sour dough breads contain both bacteria and wild yeasts. The lactic acid produced by bacteria can sometimes give a sour taste.
SOUR DOUGH
100:1
BACTERIA:YEAST
Both feed on sugars; yeasts in sour dough can't break down maltose, bacteria can.
LACTIC ACID
OTHER INGREDIENTS
R = long hydrocarbon tail
FATS
Weaken the gluten network, giving a softer bread. Also stabilise gas bubbles, increasing loaf volume.
NaHCO3
BAKING SODA
Sodium bicarbonate. Combined with moisture and acidity, produces carbon dioxide, which can help bread rise. Can cause bitterness.
NaHCO3
+ CREAM OF TARTAR
BAKING POWDER
Also sodium bicarbonate, but with cream of tartar (potassium bitartrate), an acid ingredient that activates the bicarbonate.
ASCORBIC ACID
More commonly known as vitamin C, it helps to strengthen the dough's gluten network.
A POLYSACCHARIDE THAT IS PRODUCED BY THE BACTERIUM XANTHOMONAS CAMPESTRIS
XANTHAN GUM
Used in the production of gluten-free breads.
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Aroma Chemistry

THE AROMA OF FRESH-BAKED BREAD

WHAT CREATES BREAD'S AROMA?

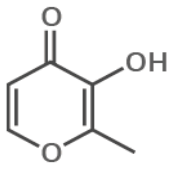
INGREDIENTS

FERMENTATION

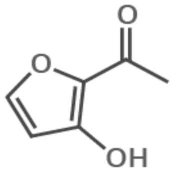
BAKING

The compounds that help to generate baked bread's aroma are influenced by the ingredients of the bread, and also by compounds generated during the fermentation process. Caramelisation and non-enzymatic Maillard reactions during baking help produce characteristic aroma compounds.

A SELECTION OF SIGNIFICANT AROMA COMPOUNDS FROM BAKED BREAD

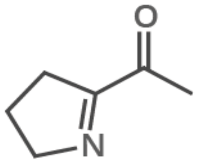


MALTOL



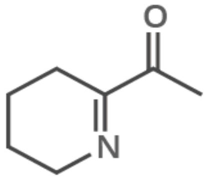
ISOMALTOL

Both formed from D-fructose. Well-known contributors to bread and bread crust flavour and aroma.



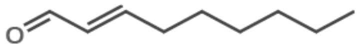
2-ACETYL-1-PYRROLINE

Key odorant in wheat-bread crust, responsible for cracker-like properties.

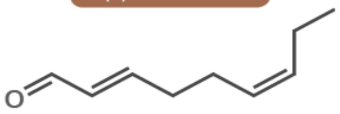


2-ACETYLTETRAHYDROPYRIDINE

Also a significant crust odorant. It and 2-acetyl-1-pyrroline are both have low odour thresholds.

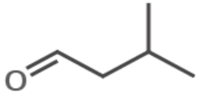


(E)-2-NONENAL



(E,Z)-2,6-NONADIENAL

Amongst the key odorants of bread crumb; also found in the crust. Weirdly enough, these are also key odorants of cucumber.



3-METHYLBUTANAL

METHIONAL

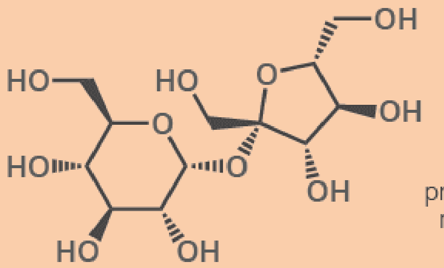
3-methylbutanal (malty), found in the crust, has a significantly higher value in the crust of rye breads, as does methional (also a key odorant in the crumb). Diacetyl adds buttery notes.

IN SHORT

No one compound conjures up the smell of baked bread; instead a mixture of compounds are responsible. 2-acetyl-1-pyrroline is a significant contributor to the crust aroma.

THE CHEMISTRY OF HONEY

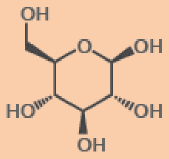
HOW DO BEES MAKE HONEY?



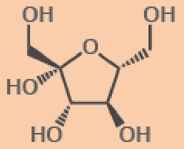
SUCROSE
primary sugar in many nectars

When bees harvest nectar, it is stored in their honey stomachs, separate from their normal stomach. The nectar is mixed with enzymes which break down the larger sugars in the nectar, such as sucrose, into the smaller sugars glucose and fructose.

The forager bee then passes it on to a house bee, who regurgitates and re-drinks the nectar over a 20 minute period, breaking down the larger sugars further.



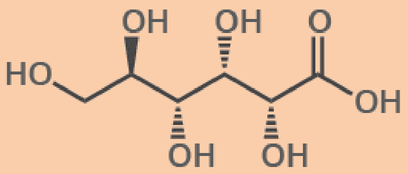
GLUCOSE



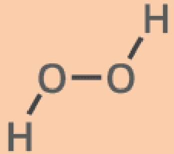
FRUCTOSE

The nectar is deposited in the honeycomb, and the bees fan it to hasten water evaporation, until the water concentration falls to around 17%.

WHY DOESN'T HONEY GO OFF?



GLUCONIC ACID



HYDROGEN PEROXIDE

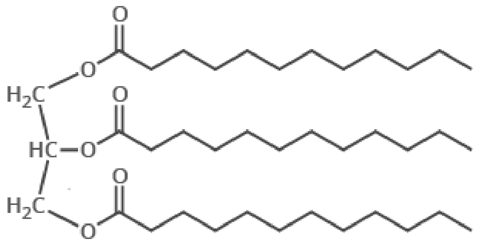
Honey has such a low water content, it draws water from its surrounding environment, meaning it can dehydrate bacteria, thus preventing spoilage.

Gluconic acid is the dominant acid in honey, produced by the action of bee secretions on glucose. It, and other acids, give honey a low pH of between 3 and 4; this, along with the fact it also contains small amounts of hydrogen peroxide, makes it too hostile for bacterial growth.

A GUIDE TO THE DIFFERENT TYPES OF FAT

Fat is an essential part of our diets, and has a number of important roles in the body. However, there are different types, and there are health concerns surrounding eating too much of some types of fat. Here, we look at what distinguishes different types of fat, and their effects on the body.

TRIGLYCERIDES & FATTY ACIDS

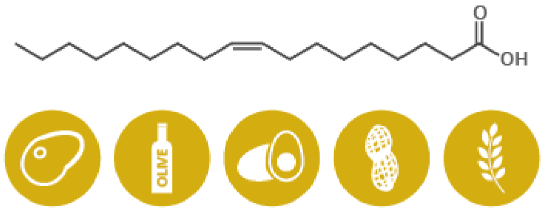


Triglycerides account for around 95% of the fat in our diet, and are formed from the combination of glycerol and three fatty acid molecules. The three fatty acids are often different, and the chemical structures of these fatty acids defines the type of fat. Cholesterol is made in the liver, and transported around the body by low density lipoproteins (LDL) and high density lipoproteins (HDL). Different fats affect LDL and HDL differently.

SATURATED FATS

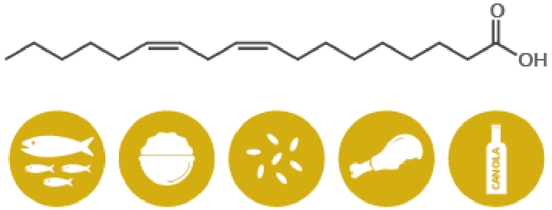
Contain no carbon-carbon double bonds. Saturated fats are solids at room temperature. They increase levels of LDL in the bloodstream. They have previously been associated with heart disease, though more recent studies and reviews have called this association into question.

MONOUNSATURATED FATS



Contain one carbon-carbon double bond. They are liquids at room temperature, but solidify when chilled. They reduce levels of LDL in the bloodstream, thereby decreasing the total cholesterol to HDL ratio (HDL helps take cholesterol back to the liver where it can be disposed of).

POLYUNSATURATED FATS



Contain two or more carbon-carbon double bonds. They are liquids at room temperature, but they start to solidify when chilled. They are split into omega-3 and omega-6 fatty acids. Polyunsaturated fats help reduce LDL levels, decreasing the total cholesterol to HDL ratio.

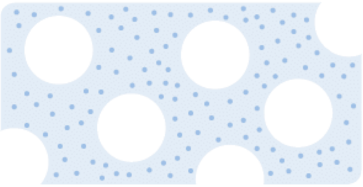
TRANS FATS

Contain carbon-carbon double bonds in a *trans* rather than *cis* configuration. Formed artificially, via a process called hydrogenation; also found naturally in small amounts in meat and dairy products. They raise LDL, and are associated with heart disease. Many countries are phasing them out.

THE CHEMISTRY OF COW'S MILK

MILK'S COMPOSITION

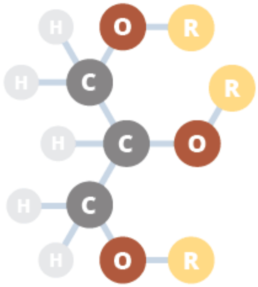
Milk is an emulsion of fat in water. It is also a colloidal suspension of proteins. Other compounds, including lactose and minerals, are fully dissolved in the solution.



WATER	87.5%
FAT	3.9%
PROTEINS	3.4%
LACTOSE & MINERALS	5.2%

FATS IN MILK

Droplets of fat in milk have an average size of 3–4 micrometres. They consist mainly of triglycerides, and also contain fat-soluble vitamins.



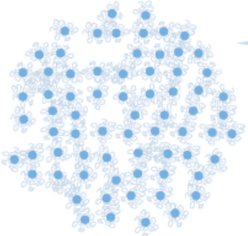
TRIGLYCERIDE

R = FATTY ACID MOLECULES

PALMITIC ACID	23.6–31.4%
OLEIC ACID	14.9–22.0%
STEARIC ACID	10.4–14.6%
MYRISTIC ACID	9.1–11.9%

WHY IS MILK WHITE?

Milk contains hundreds of types of protein, of which casein is the main type. The milk proteins form micelles. These micelles scatter light, causing milk to appear white.



CASEIN MICELLES

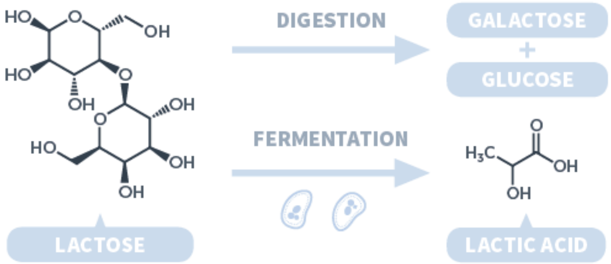
There are several models of casein micelle structure. This diagram shows the supramolecular structure.

CASEIN PROTEINS

CALCIUM PHOSPHATE CLUSTER

LACTOSE & MILK

Lactose is a sugar found in milk. People who are lactose intolerant are unable to digest it. Lactose can be fermented by microorganisms to form lactic acid, causing the milk to sour.



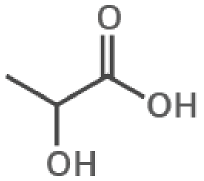
THE CHEMISTRY OF CAMEMBERT

Camembert is a surface-ripened cheese made from cow's milk. What's behind its strong smell and gooey texture? This graphic takes a look.

WHY DOES CAMEMBERT SOFTEN AS IT RIPENS?

LACTIC ACID

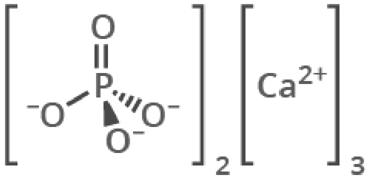
Formed by the breakdown of lactose in the cheese



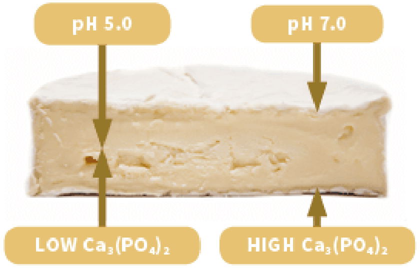
pH 4.5 → **pH 7.0**

As the lactic acid is broken down by the surface mould, the acidity of the cheese decreases.

Lactic acid is formed by the breakdown of lactose in the cheese. The surface mould that forms on the camembert, called *penicillium camemberti*, can then break down this lactic acid into carbon dioxide and water. This raises the pH of the cheese, from around 4.5 to 7.0.

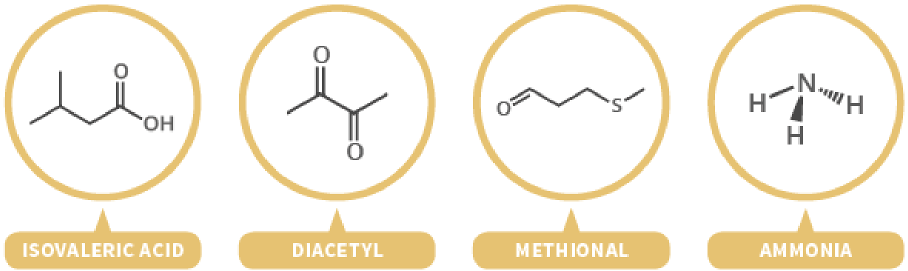


CALCIUM PHOSPHATE



Calcium phosphate helps hold casein protein micelles together in the cheese. As lactic acid is broken down and pH increases, calcium phosphate becomes less soluble, and precipitates on the cheese's surface. This draws the calcium phosphate from the cheese's centre, making it soften.

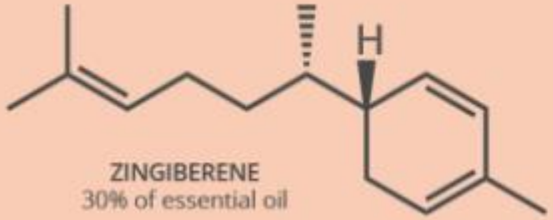
WHAT MAKES CAMEMBERT SMELL SO STRONG?



A range of compounds contribute to camembert's aroma. These include isovaleric acid, which smells of feet, diacetyl, which has a buttery aroma, and methional, which smells like boiled potatoes. Other compounds are 1-octen-3-one (mushroom), methanethiol (cabbage) and butyric acid (sweaty). The smell of ammonia increases as the cheese ripens and amino acids are deaminated.

THE CHEMISTRY OF GINGER

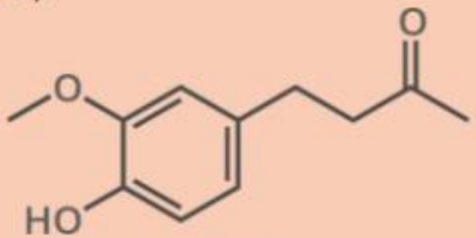
FLAVOUR, AROMA & PUNGENCY



ZINGIBERENE
30% of essential oil

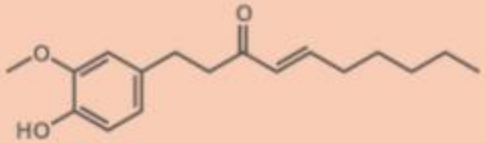
Ginger's flavour is influenced by a number of compounds. The pungency of fresh ginger comes from gingerol, whilst flavour also comes from zingiberene.

Cooking ginger breaks down gingerols into the compound zingerone, which is less pungent, and a significant contributor to ginger's flavour. Another class of compounds formed during cooking are the shogaols, which also contribute to flavour & pungency.

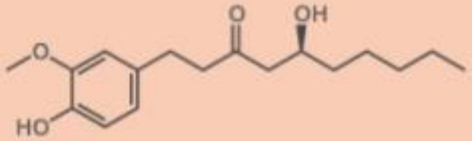


ZINGERONE
Formed when ginger is cooked

POTENTIAL HEALTH BENEFITS OF GINGER



SHOGAOL
Produced when ginger is dried/cooked

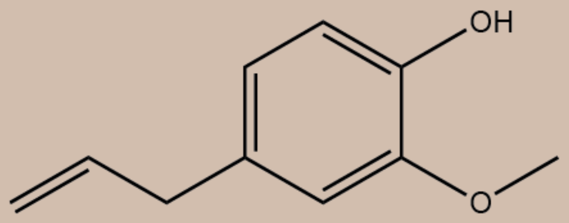


GINGEROL
Active constituent of fresh ginger

A number of the compounds in ginger are bioactive. Shogaol has a strong anti-coughing effect, whilst gingerol has anti-inflammatory & analgesic properties. Studies have also suggested that [6]-gingerol inhibits production of new blood vessels, which may make it useful in the treatment of tumours. Ginger has additionally been found to be more effective than a placebo for treating nausea during pregnancy and chemotherapy.

THE CHEMISTRY OF CLOVES

WHY DO CLOVES HELP TOOTHACHE?



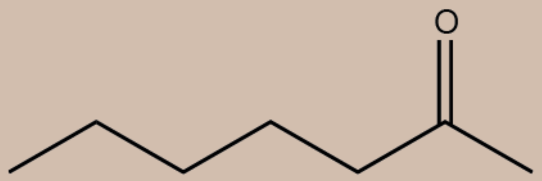
EUGENOL

The essential oil of cloves is often touted as a remedy for dental pain; it is composed mainly of 70-85% eugenol, 15% eugenyl acetate, and 5-10% ß-caryophyllene.

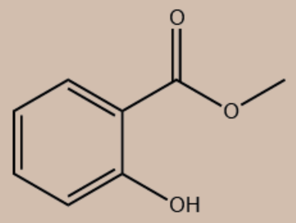
Eugenol has antiseptic and anti-inflammatory properties. As well as this, it has anaesthetic properties, due to its ability to inhibit movement of sodium ions in peripheral nerves. Additionally, it can act as an antifungal and antibacterial agent. However, the FDA believes there is currently not enough evidence of its effectiveness for it to be recommended in treating tooth pain - though some research has shown it may be of use in creams for the treatment of premature ejaculation.

Eugenol can also have toxic side effects in larger quantities - as little as 5-10 ml of undiluted essential oil could cause these. It can damage the liver and respiratory system.

WHAT GIVES CLOVES THEIR AROMA?



2-HEPTANONE



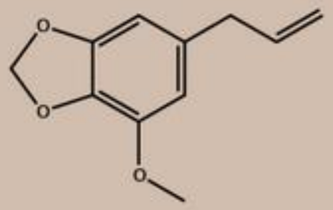
METHYL SALICYLATE

The aroma of cloves is partly influenced by eugenol, but minor compounds such as 2-heptanone and methyl salicylate are also significant contributors. Interestingly, 2-heptanone is also a compound secreted by honeybees; they secrete it when biting intruders in their hives, and the anaesthetic effect paralyses the intruding creature and allows it to be removed.

The Hallucinogen in Your Kitchen – The Chemistry of Nutmeg

THE CHEMISTRY OF NUTMEG

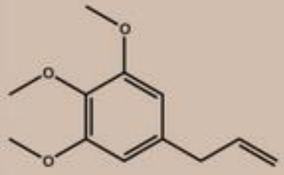
WHY IS NUTMEG HALLUCINOGENIC?



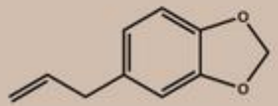
MYRISTICIN

Nutmeg contains compounds that lend it a hallucinogenic effect in larger quantities than those usually used in cooking. Around a tablespoon is enough to produce mild effects.

One of the main compounds responsible for this effect is myristicin, which accounts for up to 1.3% of raw nutmeg. The exact manner in which myristicin induces these effects is unclear, however, and the same effects are not observed with ingestion of pure myristicin, suggesting other compounds, such as elemicin & safrole, must also contribute.

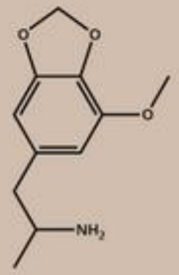


ELEMICIN



SAFROLE

WHAT ARE THE ADVERSE EFFECTS?



MMDA

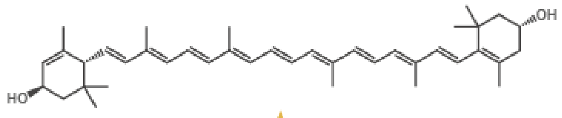
In large doses, nutmeg can cause nausea, vomiting, flushing, an elevated heart rate, euphoria and hallucinations. A dose of 10-15g is required before acute intoxication occurs, and the side effects can last for several days after ingestion.

It has been suggested that nutmeg's hallucinogenic properties could be the result of myristicin being broken down into MMDA, a compound similar to Ecstasy, in the liver. However, this has only been observed in rats, and there has been no proof of this breakdown occuring in humans.

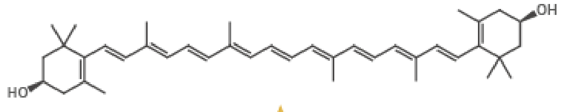
THE CHEMISTRY OF EGGS & EGG SHELLS

Eggs are one of the most versatile kitchen ingredients; there are numerous ways of cooking them on their own, and they can also be used to help create a range of other foods. Here, we take a look at what they're made of, and how they change during cooking.

EGG COLOUR & COMPOSITION



LUTEIN



ZEAXANTHIN

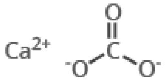
The yellow colour of egg yolks is due to the presence of the carotenoid pigments lutein and zeaxanthin. Artificial additives aren't permitted, but additives such as beta-carotene and marigold petals can be added to chicken feed to influence the yolk's colour.

EGG WHITE PROTEINS

OVALBUMIN	CONALBUMIN	OVOMUCIN	OTHERS
54%	12%	2%	32%

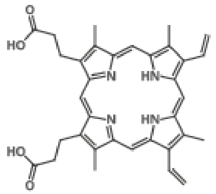
About 90% of the egg white is water; the rest of its mass is mostly protein. Ovalbumin's purpose is thought to be nutrition for the developing chick; Ovomucin helps thicken the egg white; and conalbumin binds iron & guards against infection.

EGG SHELL COMPOSITION



CALCIUM CARBONATE

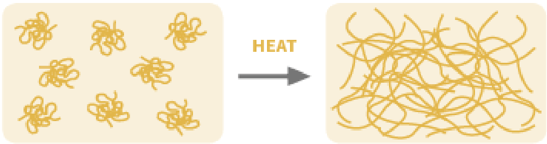
Calcium carbonate is the main component of eggshells. Nanoparticles of calcium carbonate are arranged into ordered crystals by proteins, forming a calcite shell. The colour of the eggshell comes from porphyrin pigments on the shell's surface.



PROTOPORPHYRIN IX

Brown pigment; the presence of the pigment oocyanin causes eggs to have a blue or green colouration.

COOKING EGGS



BEFORE COOKING | AFTER COOKING

Egg proteins begin in the raw egg as folded chains, but as they are heated they begin to denature and unfold. Interactions between the unfolded proteins create a three-dimensional network, trapping the water and causing the egg to solidify.

H_2S — HYDROGEN SULFIDE

FeS — IRON (II) SULFIDE

Hydrogen sulfide, formed by the reaction of sulfur-containing proteins in the albumen, is the compound that gives cooked eggs their characteristic smell. When eggs are cooked for a long time it can react with iron in the yolk, forming iron sulfide, and giving a green hue to the yolk surface.

7.6 — ALBUMEN pH OF FRESHLY LAID EGG

9.2 — pH AFTER SEVERAL DAYS OF STORAGE

Albumen pH increases as CO_2 diffuses out through the shell. Albumen adheres more strongly to the shell at lower pH, making it harder to peel boiled eggs.

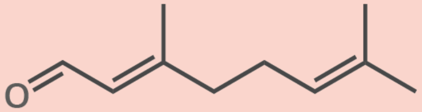
THE CHEMISTRY OF TOMATOES

SHOULD TOMATOES BE STORED IN THE FRIDGE?

(Z)-3-HEXENAL
Significant volatile compound in tomatoes

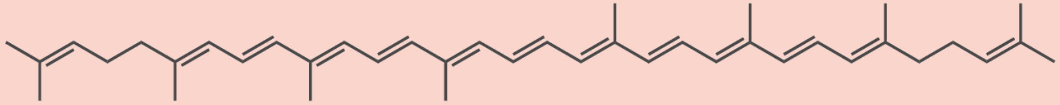
Chilling damages cell membranes in tomatoes, and inhibits enzyme activity, which can lead to a drastic loss of volatile compounds. Some of these, such as the C6 (six carbon) volatiles, do not contribute significantly to flavour, but others, such as geranial, have a noted impact on factors such as sweetness.

Taking tomatoes out of the fridge for 24 hours can lead to some recovery of volatile compounds, however, though only within a week of fridge storage. It's also worth noting that storing ripe tomatoes in the fridge can obviously be beneficial, to stop them from going off!



GERANIAL
Contributor to sweetness of tomatoes

WHAT CAUSES THE COLOUR OF TOMATOES?



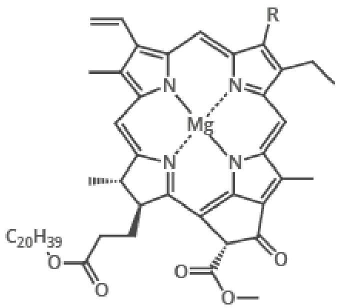
LYCOPENE
Absorbs all but the longest wavelengths of visible light

Green tomatoes are so coloured because of the presence of chlorophyll. As they ripen, the pigment lycopene develops; this compound absorbs light across most of the visible light spectrum, except the red portion, causing the tomato to appear red. It absorbs most visible light as a result of its highly conjugated structure - that is to say, it has lots of alternating double and single bonds.

THE CHEMISTRY OF BELL PEPPERS

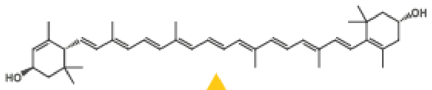
Bell peppers go through a spectrum of colours as they ripen – here we look at the compounds behind their colour, aroma, and flavour.

BELL PEPPER COLOUR CHEMISTRY

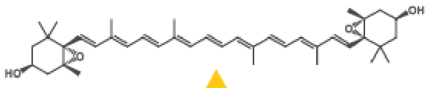


CHLOROPHYLL

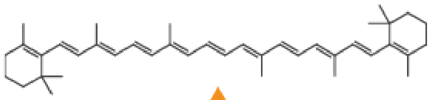
CHLOROPHYLL A: R = $-CH_3$
CHLOROPHYLL B: R = –CHO



LUTEIN

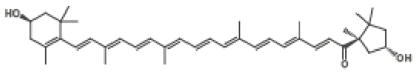


VIOLAXANTHIN

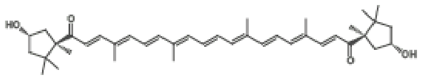


β-CAROTENE

Chlorophyll, used by plants for photosynthesis, gives bell peppers their initial green colour. As the pepper ripens, these are decomposed, and a range of carotenoid pigments appear. These include lutein, violaxanthin, and beta-carotene, which give yellow and orange hues. Eventually red carotenoid pigments including capsanthin and capsorubin appear. These red pigments are almost exclusively found in peppers.

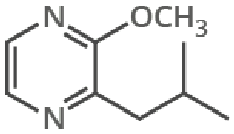


CAPSANTHIN

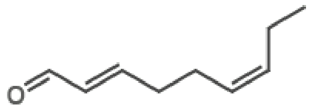


CAPSORUBIN

BELL PEPPER AROMA



BELL PEPPER PYRAZINE



CUCUMBER ALDEHYDE

(E)-2-HEXENAL

The aroma of bell peppers also develops as they ripen. In green peppers, the characteristic smell is largely due to a single chemical, 2-methoxy-3-isobutylpyrazine ("bell pepper pyrazine"). Other minor contributors include (E,Z)-2,6-nonadienal ("cucumber aldehyde"). The concentrations of most volatile compounds drop during ripening, with the exception of (E)-2-hexenal and (E)-2-hexenol, lending a sweeter, fruitier note to the aroma.

THE CHEMISTRY OF SPINACH

THE IRON CONTENT OF SPINACH

Compared to many other vegetables, spinach does have a higher iron content. However, iron in vegetables tends to have low bioavailability – that is, it is not easily absorbed in the body.

SPINACH

2.6 mg per 100 g

1.7% ABSORBED

0.044 mg

SIRLOIN STEAK

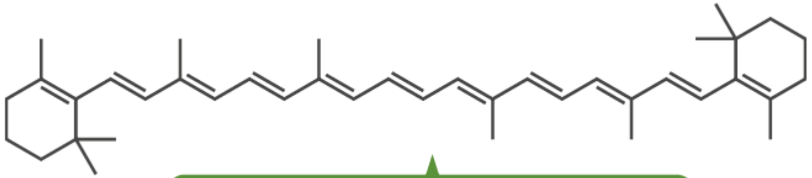
2.5 mg per 100 g

20% ABSORBED

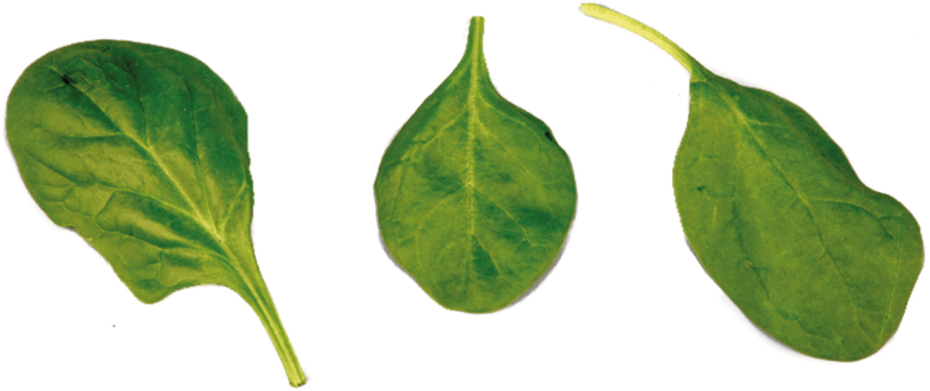
0.50 mg

Sources: USDA food composition database; Scrimshaw (1991)

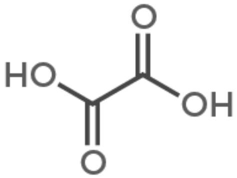
Low absorption of iron is partly due to polyphenol compounds in spinach binding iron – not due to its oxalic acid content (as previously thought). Though it might not be a great source of iron, it's a good source of vitamin A in the form of carotenoids.



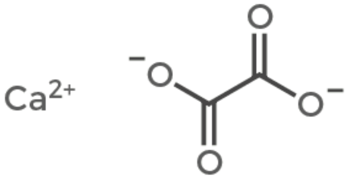
β-CAROTENE – VITAMIN A PRECURSOR



WHAT CAUSES 'SPINACH TEETH'?



OXALIC ACID



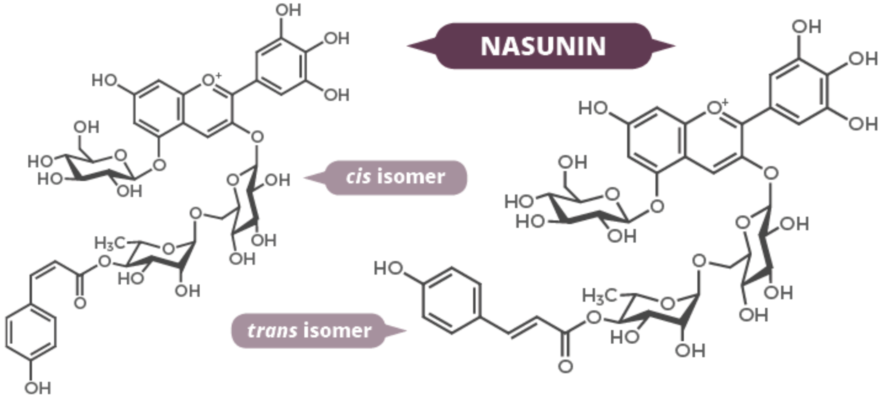
CALCIUM OXALATE

Spinach contains high amounts of oxalic acid. When you eat spinach, it can leave your teeth with a 'chalky' feel. This is caused by the oxalic acid reacting with the calcium ions in the spinach and in your saliva. This forms poorly soluble calcium oxalate crystals which coat your teeth.

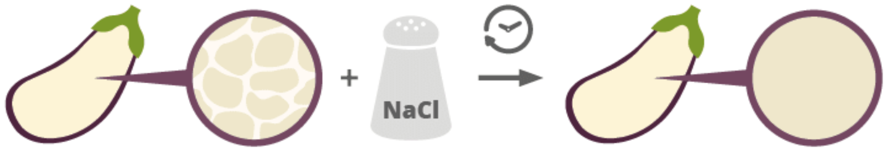
THE CHEMISTRY OF AUBERGINES

THE COLOUR AND TEXTURE OF AUBERGINES

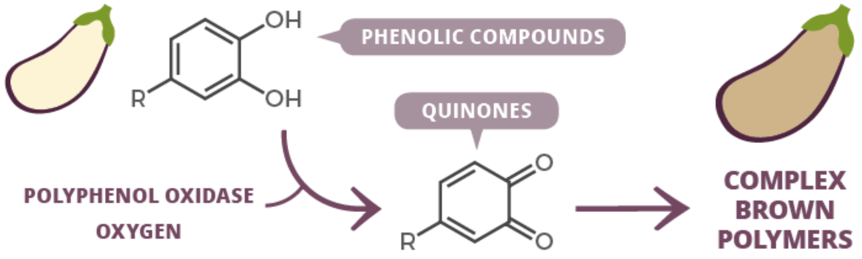
The purple colour of aubergines comes from anthocyanin pigments. The main anthocyanin present is nasunin, named after the Japanese name for aubergine ('nasubi'). It is present as a mix of *cis* and *trans* isomers; the *trans* isomer is the more stable of the two.



Aubergines have a spongy texture, caused by many tiny air pockets between cells. This is why they shrink when cooked, and also soak up cooking oil. The latter can be prevented by pre-cooking or adding salt to draw out water into the air pockets, collapsing the structure.



BITTER FLAVOUR AND BROWNING

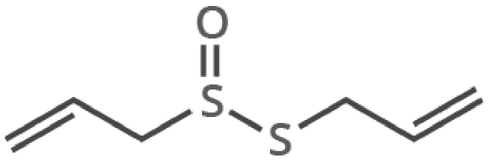


Phenolic compounds cause the bitter flavour of aubergines. These compounds also explain their browning when cut. Cutting releases polyphenol oxidase enzyme from cells; it oxidises phenolic compounds, leading to the eventual formation of brown polymers.

THE CHEMISTRY OF GARLIC

WHAT CAUSES GARLIC BREATH?

There are four major volatile organic compounds responsible for 'garlic breath': diallyl disulfide, allyl methyl sulfide, allyl mercaptan, and allyl methyl disulfide. None of these compounds are present in garlic until it is crushed or chopped.



ALLICIN

ALLYL METHYL SULFIDE

When garlic is mechanically damaged, enzymes convert the compound alliin to allicin (which gives chopped garlic its aroma). This is broken down further into the afore-mentioned volatile compounds.

Allyl methyl sulfide is broken down in the body more slowly than the other three compounds, so it is the primary volatile responsible for garlic breath. It is excreted via sweating, breathing, and through the urine, and its effects can last up to a day!

A few foods have been shown to have some effect on reducing garlic breath, including parsley & milk.

GARLIC'S ANTIBACTERIAL PROPERTIES

DIALLYL SULFIDE

DIALLYL DISULFIDE

DIALLYL TRISULFIDE

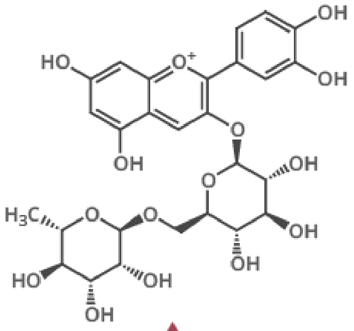
Sulfur-containing organic compounds give garlic antibacterial properties. Antimicrobial effects have been shown to increase as the number of sulfur atoms in the compounds increases.

The organosulfur compounds can penetrate the cell membranes of bacteria cells, and combine with certain enzymes or proteins to alter their structure, injuring the cells. Allicin, formed initially when garlic is crushed, also has antibacterial properties.

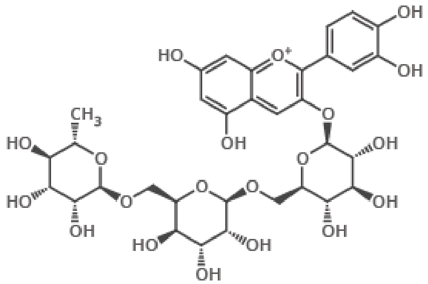
THE CHEMISTRY OF CHERRIES

Cherries are a popular summer fruit, and come in both sour and sweet varieties. Here we look at the chemical differences between the two.

SWEET CHERRIES AND SOUR CHERRIES

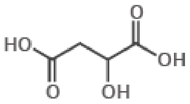


CYANIDIN-3-O-RUTINOSIDE



CYANIDIN-3-GLUCOSYLRUTINOSIDE

Cherry colour is due to the presence of compounds called anthocyanins. Sweet and sour cherries usually contain both of the compounds shown, but sweet cherries contain primarily cyanidin-3-o-rutinoside, whereas in sour cherries cyanidin-3-glucosylrutinoside is more abundant. Sour cherries also contain anthocyanins in greater concentrations.



MALIC ACID

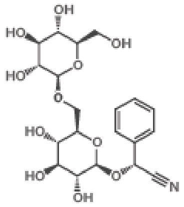
Sour cherries: 1.2–1.9%
Sweet cherries: 0.7–0.9%

Sour: pH 3.1-3.6

Sweet: pH 3.7-4.5

The tart flavour of sour cherries is due to the presence of a greater amount of malic acid. They have a titratable acidity of 1.2–1.9% of malic acid. Sour cherries also contain less sugar than sweet cherries.

POISONOUS PITS



AMYGDALIN

HYDROGEN CYANIDE

H—C≡N

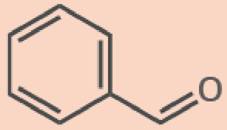
BLACK CHERRY
~2.7mg/g

RED CHERRY
~3.9mg/g

Cyanogenic glycosides are found in the seeds of a number of fruits, including apples and apricots, and cherries are no exception. Their pits contain amygdalin, a compound which, when broken down during digestion, releases poisonous hydrogen cyanide. While a large number of the pits would need to be eaten by humans to see toxic effects, much less is needed for animals. Other parts of the cherry tree, including the leaves, are also toxic to animals.

THE CHEMISTRY OF PLUMS & PRUNES

PLUM AROMA & WAX BLOOM



BENZALDEHYDE

LINALOOL

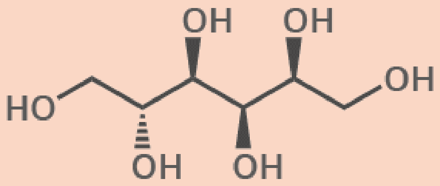
γ-DECALACTONE

The aroma of plums is down to a number of volatile compounds, which include benzaldehyde, linalool, ethyl nonoate, methyl cinnamate, & γ-decalactone. Several six-carbon alcohols, aldehydes, and esters also contribute.

The dusty white coating visible on many plums is referred to as a 'wax bloom'. This bloom consists of long chain alkanes and alcohols (mainly those containing 29 carbon atoms), and adds to the flavour of the plum by trapping compounds such as nonanal.

NONANAL

WHY DO PRUNES HELP WITH CONSTIPATION?



SORBITOL

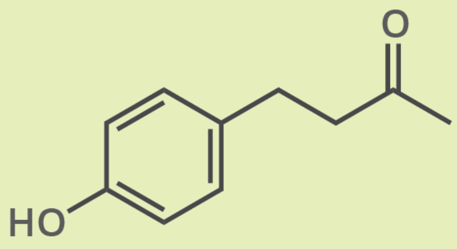
PRUNES		CHEWING GUM
15g	VS	30g

(SORBITOL CONTENT PER 100 GRAMS)

Prunes are dried plums, and are often cited as a home remedy for constipation. This is due to their relatively high natural levels of the known laxative compound sorbitol (approximately 15g per 100g). Sorbitol is also responsible for the laxative effect of some chewing gums. Phenolic compounds, such as neochlorogenic acids, and the high fibre content of prunes may also aid the laxative effect.

THE CHEMISTRY OF RASPBERRIES

THE AROMA OF RASPBERRIES



RASPBERRY KETONE
4-(4-hydroxyphenyl)butan-2-one

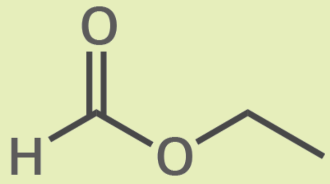
The chemical compound commonly referred to as 'raspberry ketone' is the primary compound responsible for the aroma of raspberries. Around 1 to 4 milligrams of the compound can be extracted from a kilogram of raspberries.

Raspberry ketone, also found in cranberries and blackberries, is commonly used as an aroma compound in perfumes, as well as in cosmetics and in small amounts as a food additive. Because it occurs in quite low amounts, natural raspberry ketone is an expensive additive, though synthetic versions of the compound are cheaper.

Studies in rodents have suggested that raspberry ketone may have an anti-obesity effect, but there is currently no reliable scientific evidence for this effect being observed in humans.

IS THE GALAXY RASPBERRY-FLAVOURED?

Ethyl formate is one of a number of chemicals that contribute towards the flavour of raspberries. In 2009, astronomers detected ethyl formate molecules at the centre of our galaxy, prompting a spate of news articles proclaiming that the galaxy tastes of raspberries. Other simple molecules, such as methanol, have also been detected, however, so the notion that the galaxy tastes of raspberries is something of a romanticised one!



ETHYL FORMATE
Tastes of raspberries, smells like rum

THE CHEMISTRY OF WATERMELON

COLOUR & AROMA

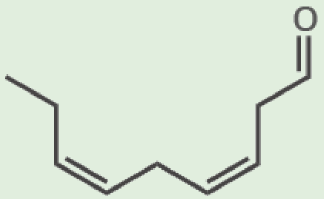
LYCOPENE

Pigment that causes watermelon's pink colour, also found in tomatoes

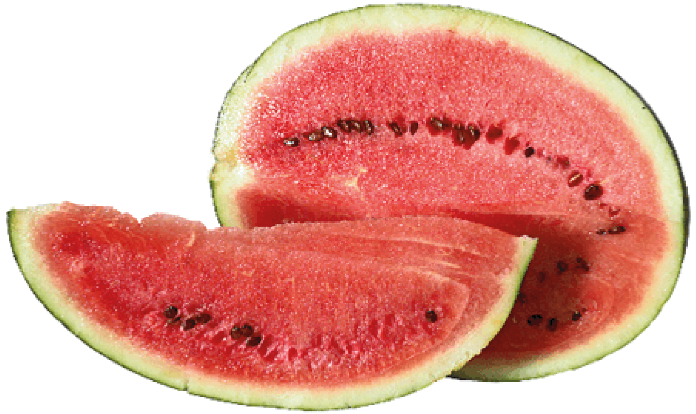
The pink colouration of red watermelon flesh is due to the presence of lycopene. This compound is also responsible for the colour of tomatoes, but it is found in even higher levels in watermelon.

The aroma of watermelon is contributed to by a variety of chemicals, generated by enzymatic oxidation of fatty acids when the watermelon is cut. The primary aroma-impact compounds are thought to be C_6 and C_9 aldehydes.

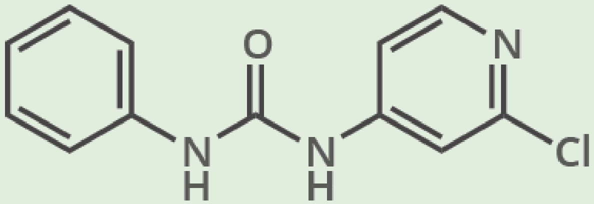
The aldehyde (Z,Z)-3,6-nonadienal is of particular significance, and is often itself described as having a fresh, watermelon-like odour. (Z)-3-hexenal, another aldehyde present, also contributes to the smell of fresh-cut grass.



LEFT: (Z,Z)-3,6-NONADIENAL
ABOVE: (Z)-3-HEXENAL



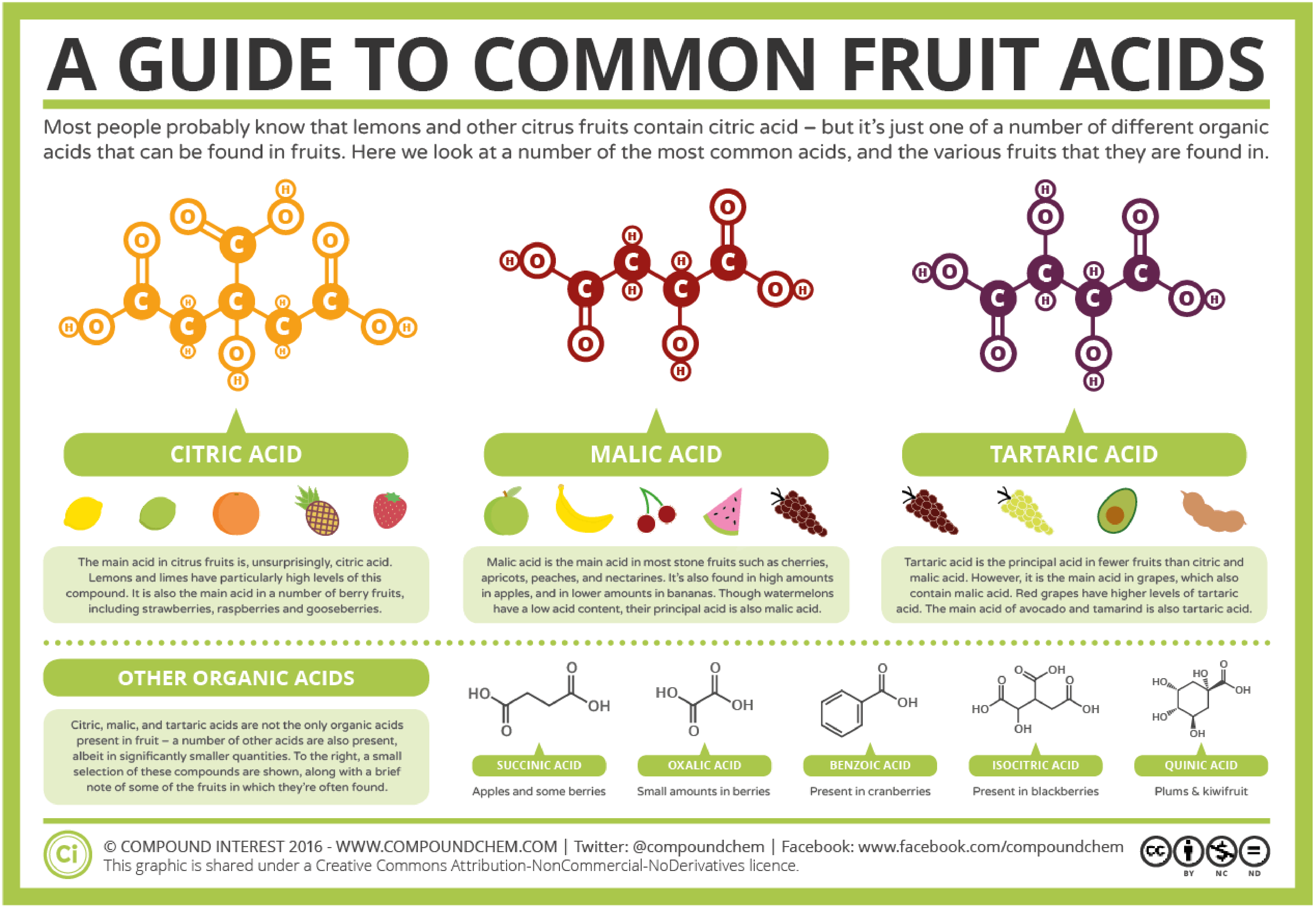
EXPLODING WATERMELONS



FORCHLORFENURON

A growth-promoting chemical approved in the US for use on kiwi fruits, raisins, and grapes. It is normally used in low quantities.

In 2011, farmers in Eastern China were hit by a spate of exploding watermelons. This was a result of their treatment with forchlorfenuron, a plant growth regulator. Forchlorfenuron acts with plant auxins, naturally present hormones that play an important role in plant growth, to promote cell division and growth. It was suggested that overuse of forchlorfenuron during wet weather resulted in the exploding watermelons, affecting an area of approximately 115 acres.


A GUIDE TO COMMON FRUIT ACIDS
Most people probably know that lemons and other citrus fruits contain citric acid – but it's just one of a number of different organic acids that can be found in fruits. Here we look at a number of the most common acids, and the various fruits that they are found in.
CITRIC ACID
The main acid in citrus fruits is, unsurprisingly, citric acid. Lemons and limes have particularly high levels of this compound. It is also the main acid in a number of berry fruits, including strawberries, raspberries and gooseberries.
MALIC ACID
Malic acid is the main acid in most stone fruits such as cherries, apricots, peaches, and nectarines. It's also found in high amounts in apples, and in lower amounts in bananas. Though watermelons have a low acid content, their principal acid is also malic acid.
TARTARIC ACID
Tartaric acid is the principal acid in fewer fruits than citric and malic acid. However, it is the main acid in grapes, which also contain malic acid. Red grapes have higher levels of tartaric acid. The main acid of avocado and tamarind is also tartaric acid.
OTHER ORGANIC ACIDS
Citric, malic, and tartaric acids are not the only organic acids present in fruit – a number of other acids are also present, albeit in significantly smaller quantities. To the right, a small selection of these compounds are shown, along with a brief note of some of the fruits in which they're often found.
SUCCINIC ACID
Apples and some berries
OXALIC ACID
Small amounts in berries
BENZOIC ACID
Present in cranberries
ISOCITRIC ACID
Present in blackberries
QUINIC ACID
Plums & kiwifruit
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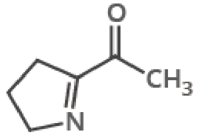
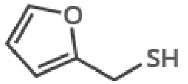
THE CHEMISTRY OF POPCORN

POPCORN FLAVOUR & AROMA COMPOUNDS



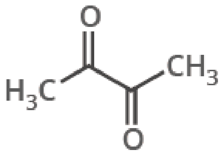
2-ACETYL-1-PYRROLINE



2-FURFURYLTHIOL

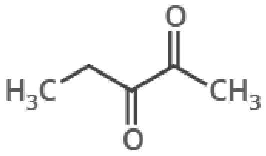
(*E,E*)-2,4-DECADIENAL

Many aroma compounds are given off by freshly prepared popcorn. Some of the most significant are 2-acetyl-1-pyrroline (which is a contributor to the roasty, popcorn-like aroma), (*E,E*)-2,4-decadienal (which has a fatty, fried aroma) and 2-furfurylthiol (which in isolation has a roasted coffee-like aroma). A range of other pyrazine, pyridine, and phenol compounds also contribute to flavour and aroma.



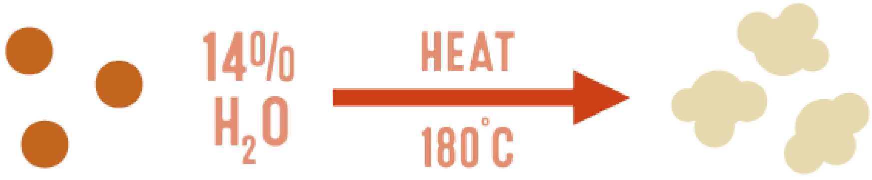
2,3-BUTANEDIONE

2,3-PENTANEDIONE

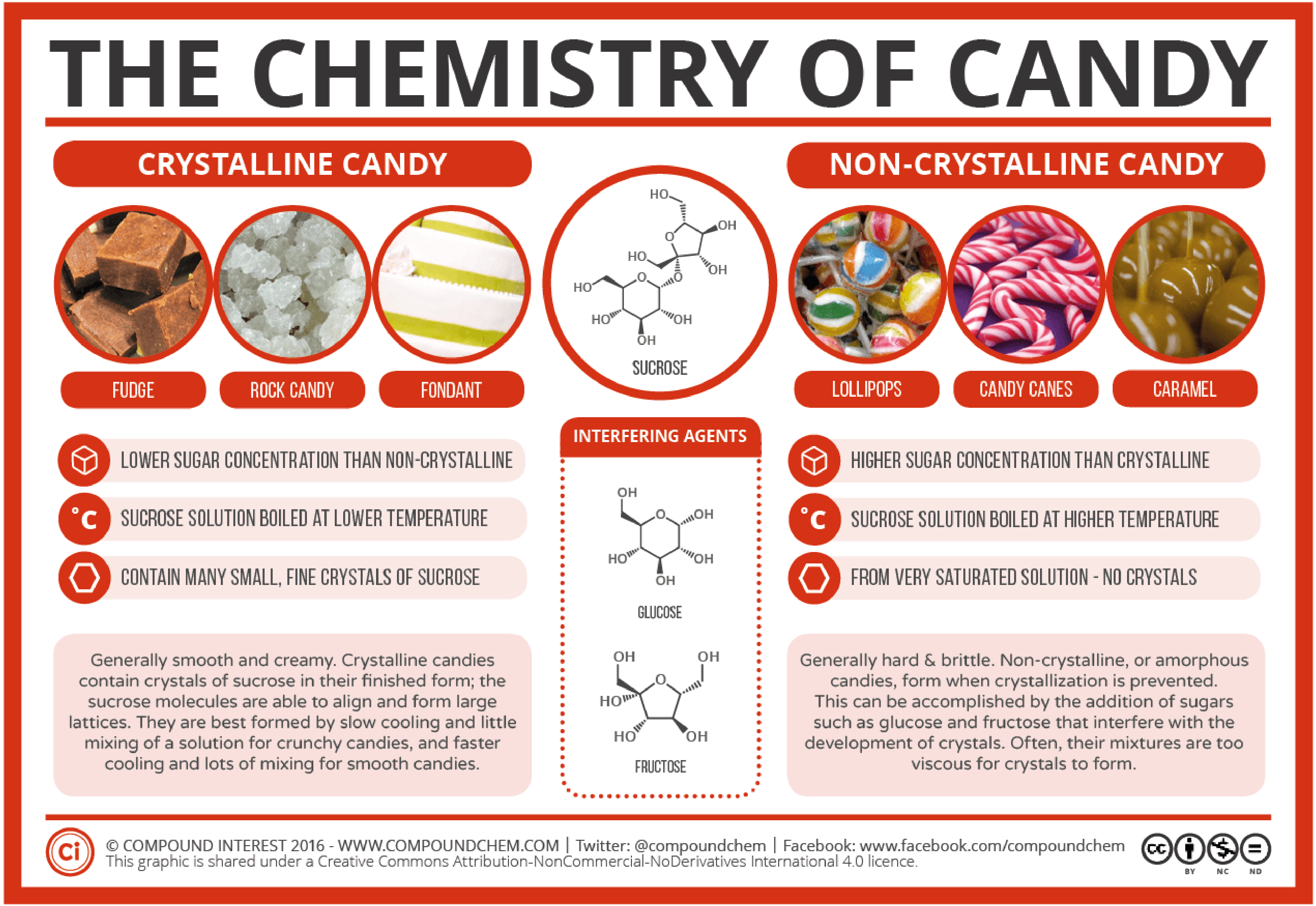


Flavourings added to popcorn can also contribute to the aroma. For example, butter-flavoured popcorn can include the compounds 2,3-butanedione (diacetyl) or 2,3-pentanedione. These compounds can cause respiratory problems in workers that inhale them while manufacturing the flavourings – the condition they can cause is known as 'popcorn lung'.

WHAT MAKES POPCORN POP?



The content of popcorn kernels is about 14% water. When the kernels are heated, this turns into water vapour at water's boiling point. However, it is trapped by the kernel's shell until the pressure builds up enough to crack through. The 'pop' is due to the escape of this pressurised water vapour, rather than the cracking of the kernel's shell. The molten starch bursts through the shell then rapidly cools, giving popcorn its fluffy appearance.


THE CHEMISTRY OF CANDY
CRYSTALLINE CANDY
NON-CRYSTALLINE CANDY
HO
OH
O
HO
OH
O
HO
O
HO
OH
OH
SUCROSE
FUDGE
ROCK CANDY
FONDANT
LOLLIPOPS
CANDY CANES
CARAMEL
INTERFERING AGENTS
LOWER SUGAR CONCENTRATION THAN NON-CRYSTALLINE
SUCROSE SOLUTION BOILED AT LOWER TEMPERATURE
CONTAIN MANY SMALL, FINE CRYSTALS OF SUCROSE
HIGHER SUGAR CONCENTRATION THAN CRYSTALLINE
SUCROSE SOLUTION BOILED AT HIGHER TEMPERATURE
FROM VERY SATURATED SOLUTION - NO CRYSTALS
OH
O
OH
HO
OH
OH
GLUCOSE
OH
OH
O
HO
HO
OH
FRUCTOSE
Generally smooth and creamy. Crystalline candies contain crystals of sucrose in their finished form; the sucrose molecules are able to align and form large lattices. They are best formed by slow cooling and little mixing of a solution for crunchy candies, and faster cooling and lots of mixing for smooth candies.
Generally hard & brittle. Non-crystalline, or amorphous candies, form when crystallization is prevented. This can be accomplished by the addition of sugars such as glucose and fructose that interfere with the development of crystals. Often, their mixtures are too viscous for crystals to form.
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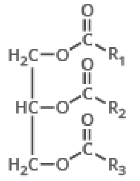
BY NC ND

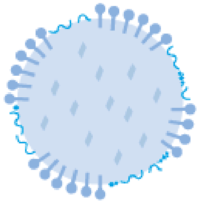
THE CHEMISTRY OF ICE CREAM

Ice cream is a combination of air, ice crystals, fat globules, and a liquid syrup. These are combined to make a colloid, a solution with very small insoluble particles suspended in it. This graphic looks in detail at the components of this colloid, and some molecules that produce ice cream flavours.

FATS, PROTEINS, & EMULSIFIERS



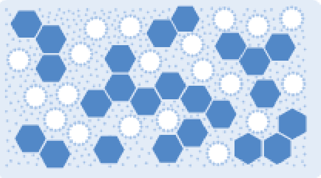
FAT (TRIGLYCERIDE)
R = fatty acids



- LIQUID FAT
- EMULSIFIER MOLECULES
- MILK PROTEINS
- FAT CRYSTALS

Fats are important for the creaminess of ice cream. Proteins from milk form a membrane around the fat droplets, making it harder for them to come in contact with each other. Emulsifiers replace some milk protein on the surface of the fat droplet. As ice cream is made, some of the fat in the droplet solidifies, and the fat 'needles' that form help droplets to partially cluster. These clusters, along with milk proteins, help stabilise air bubbles in the ice cream.

THE STRUCTURE OF ICE CREAM

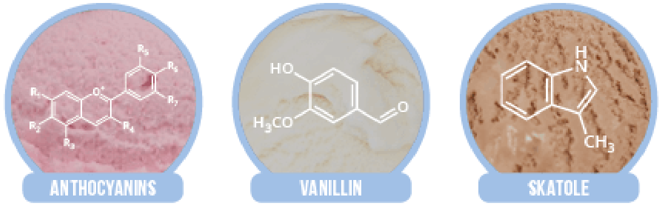


Component	%
ICE CRYSTALS	30%
AIR BUBBLES	50%
FAT DROPLETS	5%
LIQUID SYRUP	15%

% by volume for typical composition

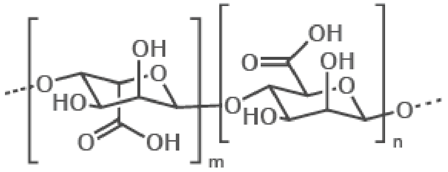
During freezing, most water is frozen into ice. Small ice crystals are needed for smooth ice cream. Beating and aeration occur at the same time as freezing to form small air bubbles, stabilised by de-emulsified fat. Air makes up 30-50% of ice cream's final volume. Sugar sweetens the ice cream, and lowers the freezing point of water, reducing the amount of ice. Soft ice cream contains less ice.

FLAVOURS AND COLOURS



Natural ice cream flavours contain a number of flavour-contributing compounds. Flavouring can also be achieved artificially. Artificial vanilla flavouring is often simply vanillin; other artificial flavours are more complex. Other compounds can be used as flavour enhancers – an unusual example is skatole, also found in faeces, but which has a floral odour at lower concentrations. Colours can be added artificially; anthocyanins from plants are amongst the colouring agents used.

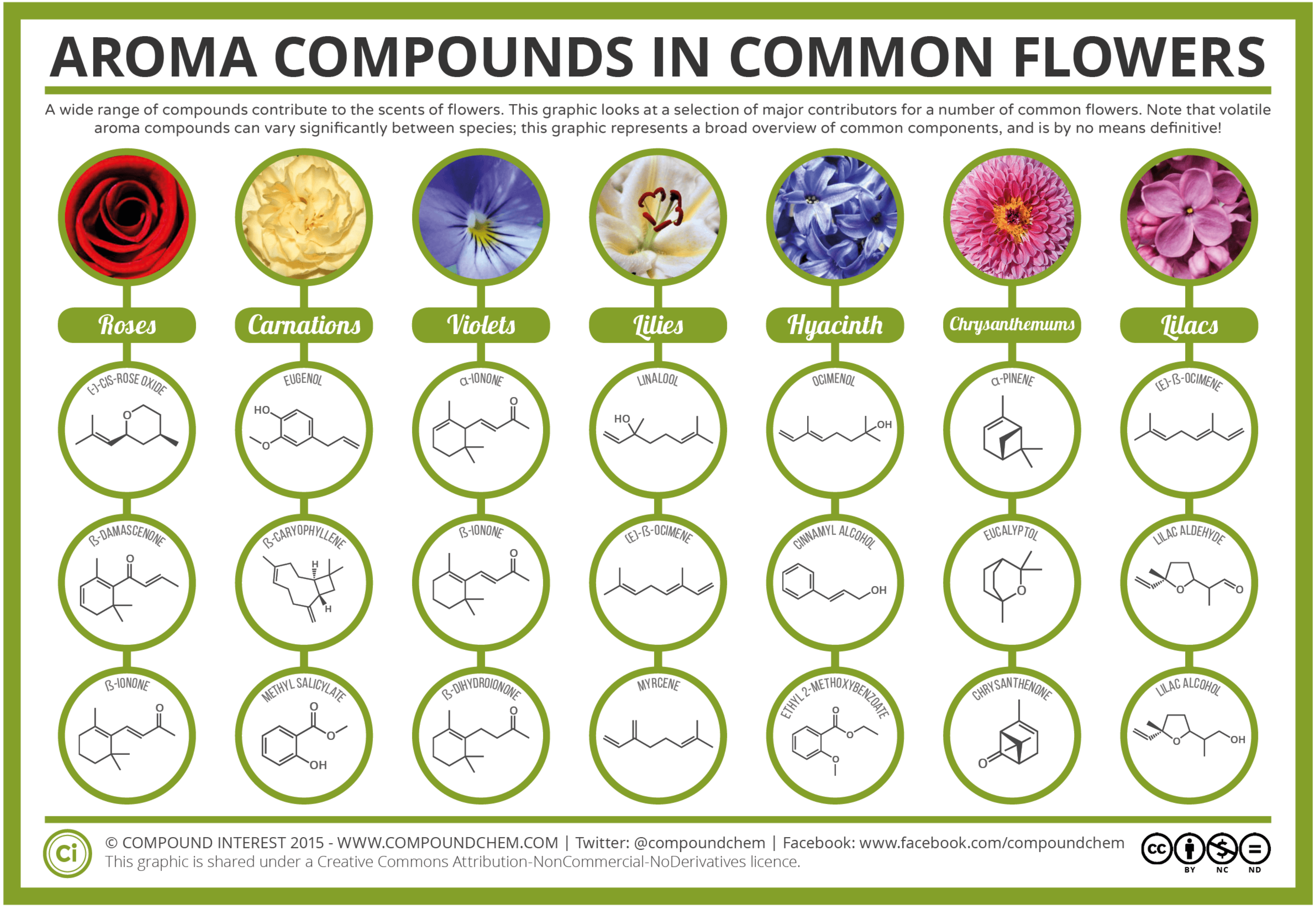
STABILISERS



ALGINIC ACID

Sodium alginate is the sodium salt of alginic acid. Another stabiliser that can be obtained from seaweed is carrageenan.

Stabilisers are added in small amounts (~0.2%) to ice cream. Often extracted from plants, a common example is sodium alginate, the sodium salt of alginic acid, extracted from brown seaweeds. Stabilisers reduce the rate at which ice cream melts, add smoothness, and increase the viscosity of the liquid phase of ice cream. Use of multiple stabilisers can produce synergistic effects.


AROMA COMPOUNDS IN COMMON FLOWERS
A wide range of compounds contribute to the scents of flowers. This graphic looks at a selection of major contributors for a number of common flowers. Note that volatile aroma compounds can vary significantly between species; this graphic represents a broad overview of common components, and is by no means definitive!
Roses
(-)-CIS-ROSE OXIDE
O
ß-DAMASCENONE
O
ß-IONONE
O
Carnations
EUGENOL
HO
O
ß-CARYOPHYLLENE
H
H
METHYL SALICYLATE
O
O
OH
Violets
α-IONONE
O
ß-IONONE
O
ß-DIHYDROIONONE
O
Lilies
LINALOOL
HO
(E)-ß-OCIMENE
MYRCENE
Hyacinth
OCIMENOL
OH
CINNAMYL ALCOHOL
OH
ETHYL 2-METHOXYBENZOATE
O
O
O
Chrysanthemums
α-PINENE
EUCALYPTOL
O
CHRYSANTHENONE
O
Lilacs
(E)-ß-OCIMENE
LILAC ALDEHYDE
O
O
LILAC ALCOHOL
O
OH
Ci
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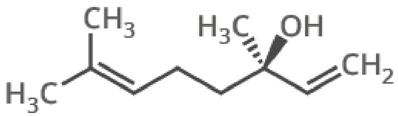
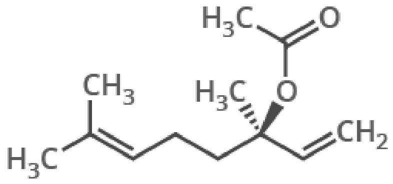
THE CHEMISTRY OF LAVENDER

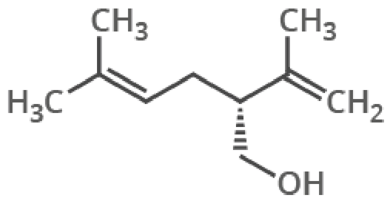
LAVENDER AROMA COMPOUNDS



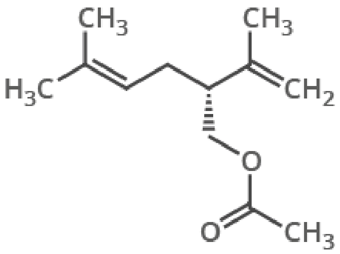
(R)-LINALOOL



LINALYL ACETATE



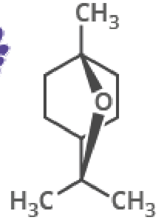
(R)-LAVANDULOL

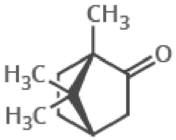


LAVANDULYL ACETATE

The primary compounds that contribute to the scent of lavender are linalool and linalyl acetate. Linalool is often used as a fragrance in consumer products. Other compounds that contribute include lavendulol and lavandulyl acetate, as well as a selection of other terpenoid compounds.

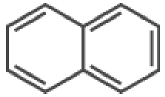
LAVENDER AND MOTHS

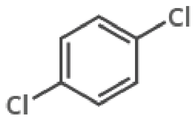




L: 1,8-CINEOLE
R: CAMPHOR

NAPTHALENE
1,4-DICHLOROBENZENE

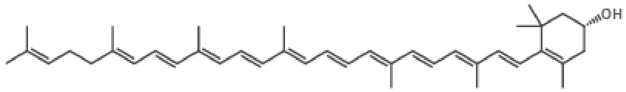




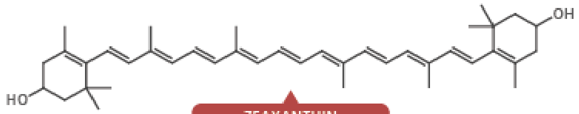
People often put bags of dried lavender with stored clothes to repel moths. 1,8-cineole and camphor, both present in lavender, have insecticidal and repellent activities. Mothballs can also be used to repel moths, and usually contain either naphthalene or 1,4-dichlorobenzene, but there are some health concerns regarding their use.

THE COLOUR AND AROMA OF ROSES

THE COLOURS OF ROSES



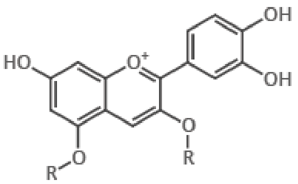
RUBIXANTHIN



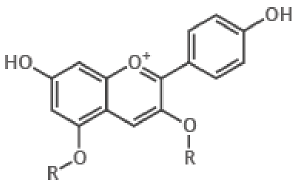
ZEAXANTHIN

Other carotenoids include lutein, lycopene, beta-carotene, taraxaxanthin, and rosaxanthin

Roses come in a variety of colours, and different chemical pigments are responsible for the different shades. A large variety of carotenoids (above) give yellow and orange hues, while a smaller number of anthocyanins (below) give the more typical reds. Combinations of compounds from the two classes of pigments give the variety of different shades of these colours.



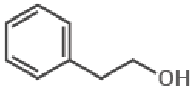
CYANIN



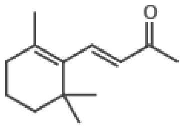
PELARGONIN

R groups = glucose (in both molecules)

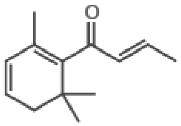
THE AROMA OF ROSES



2-PHENYLETHANOL

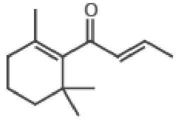


β-IONONE

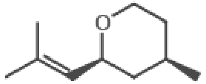


β-DAMASCENONE

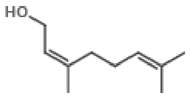
The aroma of roses is contributed to by a number of different chemical compounds; some key contributors are shown here. Their contribution to the aroma varies and isn't tied to their concentrations; in fact a number of them have very low concentrations! Important contributors are rose ketones (including damascenones, damascones, and ionones) and (-)-*cis*-rose oxide.



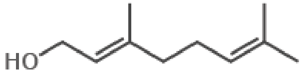
β-DAMASCONE



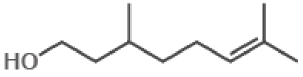
(-)-*cis*-ROSE OXIDE



NEROL



GERANIOL



CITRONELLOL

A BRIEF GUIDE TO

• TYPES OF ORGANIC FORMULAE •

A GUIDE TO THE DIFFERENT WAYS ORGANIC COMPOUNDS CAN BE REPRESENTED IN CHEMISTRY

MOLECULAR FORMULA

The molecular formula of an organic compound simply shows the number of each type of atom present. It tells you nothing about the bonding within the compound.

$C_4H_8O_2$

EMPIRICAL FORMULA

The empirical formula of an organic compound gives the simplest possible whole number ratio of the different types of atom within the compound.

C_2H_4O

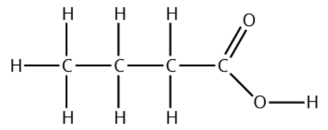
CONDENSED FORMULA

The condensed formula is also text-based; here, each carbon atom is listed separately, with atoms attached to it following. An exception is cyclic parts of molecules, e.g. benzene, where the carbons are grouped.

$CH_3CH_2CH_2COOH$

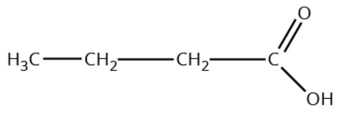
DISPLAYED FORMULA

A displayed formula shows all of the atoms and all of the bonds present in an organic compound. The bonds are represented as lines.



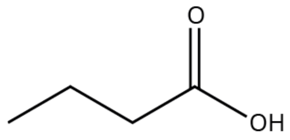
STRUCTURAL FORMULA

Similar to displayed formula - not all bonds are shown, although all atoms are still indicated using subscript numbers. Carbon hydrogen bonds are often simplified.



SKELETAL FORMULA

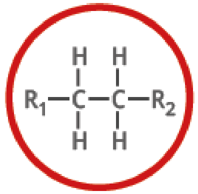
In a skeletal formula, most hydrogen atoms are omitted, and line ends or vertices represent carbons. Functional groups and atoms other than carbon or hydrogen are still shown. Easiest to draw & commonly used.



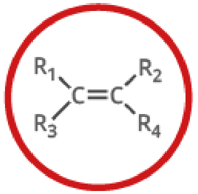
FUNCTIONAL GROUPS IN ORGANIC CHEMISTRY

FUNCTIONAL GROUPS ARE GROUPS OF ATOMS IN ORGANIC MOLECULES THAT ARE RESPONSIBLE FOR THE CHARACTERISTIC CHEMICAL REACTIONS OF THOSE MOLECULES. IN THE GENERAL FORMULAE SHOWN BELOW FOR EACH FUNCTIONAL GROUP, 'R' REPRESENTS THE REST OF THE MOLECULE, AND 'X' REPRESENTS ANY HALOGEN ATOM.

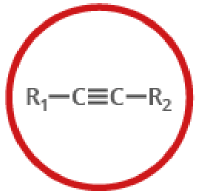
HYDROCARBONS · SIMPLE OXYGEN HETEROATOMICS · HALOGEN HETEROATOMICS · CARBONYL COMPOUNDS · NITROGEN-BASED · SULFUR-BASED · AROMATIC



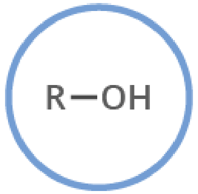
ALKANE
Naming: -ane
e.g. ethane



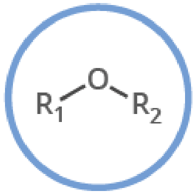
ALKENE
Naming: -ene
e.g. ethene



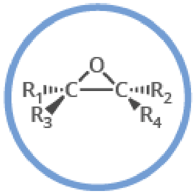
ALKYNE
Naming: -yne
e.g. ethyne



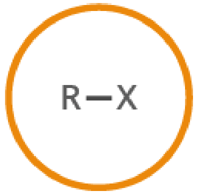
ALCOHOL
Naming: -ol
e.g. ethanol



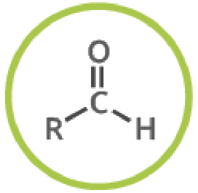
ETHER
Naming: -oxy -ane
e.g. methoxyethane



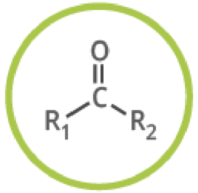
EPOXIDE
Naming: -ene oxide
e.g. ethene oxide



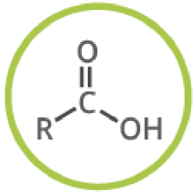
HALOALKANE
Naming: halo-
e.g. chloroethane



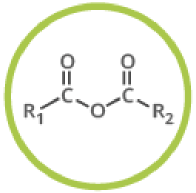
ALDEHYDE
Naming: -al
e.g. ethanal



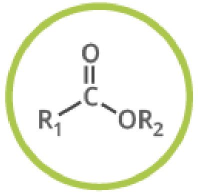
KETONE
Naming: -one
e.g. propanone



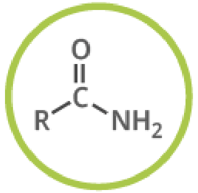
CARBOXYLIC ACID
Naming: -oic acid
e.g. ethanoic acid



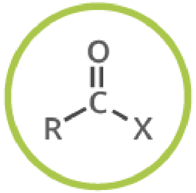
ACID ANHYDRIDE
Naming: -oic anhydride
e.g. ethanoic anhydride



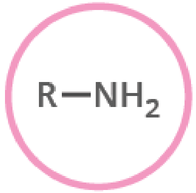
ESTER
Naming: -yl -oate
e.g. ethyl ethanoate



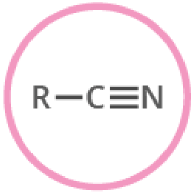
AMIDE
Naming: -amide
e.g. ethanamide



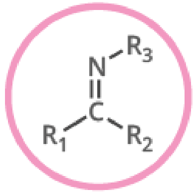
ACYL HALIDE
Naming: -oyl halide
e.g. ethanoyl chloride



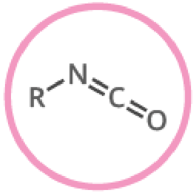
AMINE
Naming: -amine
e.g. ethanamine



NITRILE
Naming: -nitrile
e.g. ethanenitrile

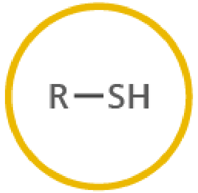


IMINE
Naming: -imine
e.g. ethanimine

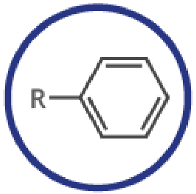


ISOCYANATE
Naming: -yl isocyanate
e.g. ethyl isocyanate

AZO COMPOUND
Naming: azo-
e.g. azoethane



THIOL
Naming: -thiol
e.g. methanethiol



ARENE
Naming: -yl benzene
e.g. ethyl benzene


the Better
Smile
Thank you