Institute of Food Research

Taste and Flavour

For Teachers

The information and lessons on these pages will introduce pupils to the science of the sensation of taste. This has links to a variety of areas of the curriculum and subjects including chemistry, biology and food science, covering topics such as the nervous system, healthy eating, genetics, anatomy, molecular biology and organic chemistry. The activities are kinaesthetic and multisensory with some numeracy tasks.

Each section contains; Learning objectives, Keywords, Background, Activity, What you will require, Health and Safety and Further reading. There are also curriculum and web links as well as recommended suppliers. It is recommended that the background and health and safety sections are read carefully before carrying out these activities. For more detailed further reading and primary references see the researchers guide.

Activities take between *10 and 30 minutes* depending on the age and ability of the pupils.

The activities outlined below can be carried out in lessons with a small number of easy to obtain food items (see list below), some of these may be available from a food technology department in your school, magnifiers or digital microscopes, cotton buds, gloves, plastic cups or bowls, a mirror, spoons, knives and chopping boards, flavourings and genetic taste strips. Flavourings can be obtained from Sigma-Aldrich and genetic taste test strips from Blades Biological Ltd.

- Lemon juice or citric acid
- Sugar
- Salt
- Tonic water
- Coffee
- Monosodium Glutamate
- Tabasco sauce or other chilli sauce
- Mints
- Onions
- Parma violets
- Lemon jelly
- Red and Blue food colouring
- Marmite
- Honey or Maple syrup
- Glucose
- Table sugar (sucrose)
- Maltose
- Lactose
- Genetic taste test strips

Optional

- Bag of jelly beans or highly flavoured sweets
- Vinegar
- Soy Sauce
- Clear still flavoured
- Flavouring solutions dissolved in propan-1,2-diol:
    - ethyl butanoate (1%)
    - 4-hydroxy-2,5-dimethyl-3(2*H*)-furanone (3%)
    - methyl 3-phenylpropenoate (0.03%)
    - 5-hexyloxolan-2-one (0.02%)

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You will need to supply water for mixing taste solutions.

Health and Safety

Risk assessments should be carried out for all activities and it is recommended that CLEAPPS guidelines are followed.

Food and drink should not be consumed in science laboratories and therefore it is recommended that if the investigations are carried out in school an alternative location such as food technology department or school canteen is used.

It is important that you check before carrying out these activities for any medical conditions such as diabetes, allergies or intolerances that young people or members of the public may have. It is essential that good food handling and preparation hygiene measures are employed. It is recommended that pupils are made to wash their hands at the start and end of activities.

Further reading

CLEAPPS guidelines 3.014 (Eating and Tasting), 3.022 (Handling Food), 3.021 (Purchase and Selection of Food) (COSHH Regulations)
CLEAPPS laboratory handbook – section 15.3
CLEAPPS Guidance G5p – pages 41 (food colouring), 67 (sugar, sweetness and threshold tests), 68 (bitter coffee taste test).
CLEAPPS HAZCARD 35 (PTC papers)

ASE Be safe 4th Edition, 2011, page 15.
ASE Safeguards in the school laboratory 11th edition, 2006.

Key words/ Word cloud

taste, gustation, flavour, tongue, taste bud, smell, senses, perception, sensation, receptor, bitter, salty, sweet, umami, sour, fatty, metallic, glucose, sucrose, fructose, lactose, maltose, solution, water, acid, ion, genetic, gene, allele, olfactory, temperature, texture, nervous system, brain

Summary of activities

Taste Basics:
Pupils 'taste' a set of compounds that represent the five basic tastes; sweet, salty, sour, umami and bitter. The taste solutions used are sugar, salt, citric acid, monosodium glutamate and flat tonic water. Subjects should be able to identify these equally well with or without holding the nose, because these flavours do not depend on smell.

The Taste map myth:
Pupils identify their own taste zones and compare their experiences to the taste map.

Taste and Flavour:
Pupils are given parma violets to demonstrate the involvement of smell in flavour perception.
They will also be invited to sniff four individual chemicals, and then the four mixed together. The sniff solutions are ethyl butanoate (1%), 4-hydroxy-2,5-dimethyl-3(2H)-furanone (3%), methyl 3-phenylpropenoate (0.03%) and 5-hexyloxolan-2-one (0.02%) dissolved in propan-1,2-diol.
They will be asked to describe the smells and suggest the smell they would produce if mixed together.
Pupils then smell the four mixed together and describe the smell before it's supposed smell and use is described (artificial strawberry).

Taste Buds:
Pupils identify taste buds by applying blue food colouring to their tongue to reveal their 'taste buds', which they can view in a mirror or on a TV monitor via a flexicam.

Taste and Temperature:
Pupils compare the sense of taste with warm and cool water.
There will be some Tabasco Sauce and some peppermint to demonstrate false hot and cold stimulation of the trigeminal nerve.

Taste and Colour:
Pupils will taste 3 jellies, yellow, orange and red describing the flavour. Pupils will then taste clear and coloured drinks once again describing their flavour before the actual flavour is revealed.

Taste Genetics:
Pupils will be able to test their genetic sense of taste with, Phenylthiocarbamide, Thiourea and Sodium Benzoate taste test papers. The categorization as tasters, non-tasters or super-tasters will be recorded and the percentage proportions of each group calculated and compared to the general population.
Compare the members of the class who dislike marmite with the numbers who are super tasters.

Taste Basics

Learning objectives: Recognise the five basic tastes
Describe the five basic tastes
Distinguish between tastes
Give examples of foods with the five basic tastes
Describe tastes other than the five basic tastes

Key words/ Word cloud

taste, bitter, salty, sweet, umami, sour, fatty, metallic, taste bud

Background

Basic tastes are detected by taste receptor cells or 'Taste Buds' on your tongue, throughout your mouth. Each taste bud has 50-150 taste receptors sensitive to certain chemicals. When these chemicals dissolve in the saliva in your mouth, a signal is sent straight to your brain.

The basic tastes are the commonly recognized tastes that you will be familiar with including bitter, salty, sour, sweet, and a fifth taste termed umami Taste is detected by sensory organs called taste buds, found on the upper surface of the tongue and other parts of the mouth. Umami (the flavour of certain glutamates, variously described as savoury, meaty, or brothy) has long been known in Asian cooking, but has only recently been found to have its own taste receptors.

Receptors that recognise a large number of specific chemicals have been identified. The specific chemicals that can be detected include sodium, potassium, chloride, glutamate and adenosine.

There is scientific debate concerning the existence of basic tastes as identified by chemical reactions between receptors for individual molecules and the perception of taste as a combination of experience, cultural expectations and psychological states.

The final 'flavour' experienced by an individual may be somewhat different to the biochemical stimulus that an individual is exposed to.

The sense of taste is termed gustation.

There are Five basic Tastes

Salt
The taste of salt is due to sodium chloride (and to a lesser degree other salts). Sodium (Na^+) and other salt ions can pass through ion channels in the membranes of taste receptor cells on the tongue. This triggers an action potential leading to an electrical signal along a sensory nerve fibre. The taste of salt can be blocked by an ion-channel inhibitor called amiloride, indicating that this is the biochemical basis of the taste of salt. The sensitivity to the taste of salt can differ depending on factors such as salt depletion and dehydration. Salt can also modify other senses of taste increasing their potency. This explains why

tomatoes have a ‘fuller’ flavour with the addition of salt.

Sour
The taste of sour is due to acids like vinegar, lemon juice or malic acid found in ‘sour sweets’. Sour tastes are detected by ion channels similar to those for the taste of salt. Hydrogen ion channels detect the concentration of acids or hydrogen ions (H^+ ions) in food. Hydrogen ions are capable of passing through the amiloride-sensitive sodium channels, but they can also inhibit potassium channels and prevent hyperpolarisation of taste receptor cells. The combination of depolarisation by passage through the ion channels as well as the inhibition of potassium channels causes the sensation of sourness.

Sweet
The sensation of sweetness is produced by sugars, sugar substitutes and some proteins. Aldehydes and ketones are also often found to be sweet. These substances are detected by receptors that are joined to the G protein gustducin, found on the taste buds. There are a variety of similar receptors for sweetness and more than one type needs to be activated to perceive the sweet taste.

The lowest concentration of sugars that can normally be detected are about 10 millimoles per litre for sucrose and 30 millimoles per liter for lactose (see activity Taste Threshold).

Bitter
Bitter tastes are initially unpleasant and often require a period of exposure to ‘acquire a taste’ for foods that are very bitter such as beer, coffee or quinine found in tonic water.

Bitter tastes may indicate toxins or spoiled food. Most toxic plants and many poisons taste bitter and evolutionary biologists think that a dislike of bitter tastes evolved as a defence against accidental poisoning. There are many bitter foods and beverages are not at all harmful and even healthy, such as brussel sprouts, but their taste is off-putting to many people.

There are 25 different types of ‘bitter’ receptors. Research has shown that TAS2Rs (taste receptors, type 2) coupled to the G protein gustducin are responsible for the human ability to taste bitter substances (see activity Taste Genetics). They are identified not only by their ability to taste for certain "bitter" ligands, but also by the morphology of the receptor itself (surface bound, monomeric).

The bitterest substance known is a synthetic chemical called denatonium. It is often added to toxic substances to prevent accidental ingestion. It is odourless but creates a strong taste response that may even lead to vomiting creating the added benefit of stimulating the regurgitation of any consumed toxins.

Savouriness or Umami
The taste of savoury foods is the ‘fifth’ taste and is produced by free glutamates (forms of the glutamic amino acid). These glutamates are often found in protein rich foods such as meats and mushrooms as well as fermented and aged products such as soy sauce and parmesan.

In Japanese, the term *umami* (旨味, うまみ) is used for this taste sensation, whose characters literally mean "delicious flavour." Umami is now the commonly used term by

taste scientists.

Not every glutamate produces a savoury-like taste sensation and there is continuing investigation into the exact mechanism of how the savoury taste sensation is produced. Glutamate binds to a variant of G protein coupled glutamate receptors. Recently it has been discovered that the savoury taste is produced by interaction of NMDA and mGluR4, mGluR1 and taste receptor type 1(TRT1) receptors.

The additive monosodium glutamate (MSG), which was developed as a food additive in 1907 by Dr Kikunae Ikeda at the Imperial University of Tokyo, produces a strong savoury taste. Savoury is also provided by the nucleotides disodium 5'-inosine monophosphate (IMP) and disodium 5'-guanosine monophosphate (GMP). These are naturally present in many protein-rich foods. Together in certain quantities these three glutamates act to produce an even stronger umami taste.

The glutamate taste sensation is most intense in combination with sodium. This is one reason why tomatoes exhibit a stronger taste after adding salt. The molecular gastronomist Heston Blumenthal, along with Scientists at Nottingham University have even studied the relative distribution of umami taste in different parts of the tomato.

There may also be other basic tastes

Fatty
Fat is mainly detected by it's texture. The taste of triglycerides (dietary fat molecules) may be due to fatty acids that are produced when the lipase enzyme in the mouth breaks down the triglycerides. A potential taste receptor called the CD36 receptor reacts to fatty acids and maybe a de facto fat receptor. CD36 has been found in mice, but probably exists in humans and other mammals as well. Mice with a genetic defect that prevents the CD36 receptor from working do not show the same urge to consume fatty acids as normal mice. They also do not release gastric juices in their digestive tracts in preparation of digesting fat. A better understanding of the biochemical activity of this receptor may lead to an understanding of cravings for fat and treatments for obesity.

Metallic
Scientists have found receptors for calcium and are searching for others. If you've ever put a cut finger in your mouth or bitten your lip you may have experienced a metallic taste in your blood.

Water
The taste of water can be hard to test for as most taste sensations are caused by substances in solutions and the presence of saliva. Water may have a sweet taste as a phenomenon known as "sweet water after-taste" occurs when the receptors that normally detect sweetness are blocked and water is tasted.

Polysaccharides
Molecules such as starch are detected by different receptors to those for sweet tastes.

It should be emphasized that there are no more than 5 distinctive tastes: salty, sour, sweet, bitter, and umami.

The 10,000 different scents which humans usually recognize as 'tastes' are often actually 'flavour' (see activity Taste and Flavour), which many people, who can smell, confuse with taste.

Activity
Pupils will be given a ‘taste’ of compounds that represent the five basic tastes. Sweet, salty, sour, umami and bitter. The taste solutions used are sugar, salt, citric acid, monosodium glutamate and flat tonic water. Pupils can test their sense of the five basic tastes by placing some of each solution on their tongue with a cotton bud. Subjects should be able to identify these equally well with or without holding the nose, because these flavours do not depend on smell.
They will all react differently to umami – some may hate it others may not be able to taste it at all and the taste will range from salty, meaty, fishy or vinegary and several other things too! This is not unusual we don’t all have the same ability to taste, and some of the differences between us are due to our genes. You could do a survey here and present the results.

What you will require
- cotton buds
- gloves
- plastic cups or bowls
- Lemon juice or citric acid
- Sugar
- Salt
- Tonic water or Coffee
- Monosodium Glutamate

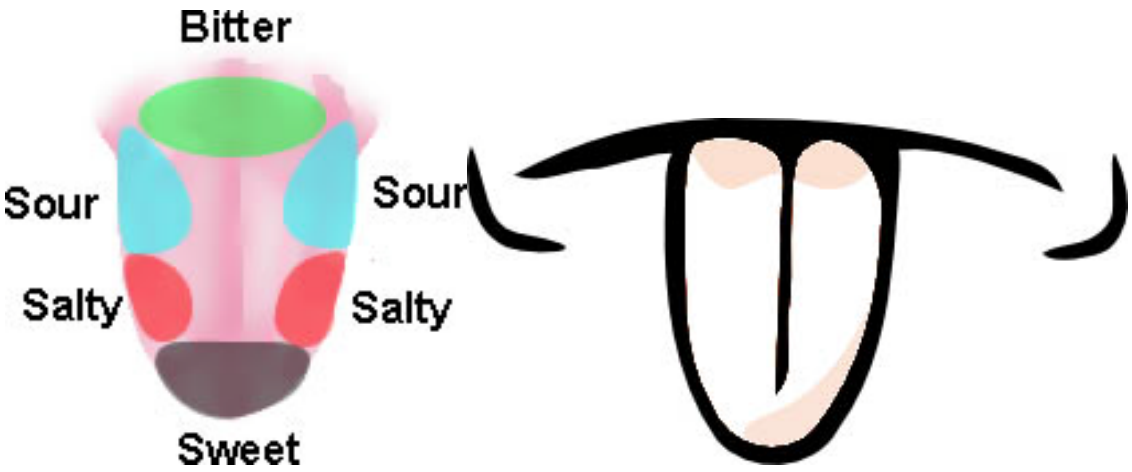
Health and Safety

The taste solutions should be made up at a weak concentration. When carrying out taste tests cotton buds are recommended for applying taste solutions to the tongue. It is IMPORTANT to stress that people should not put cotton buds that have been in their mouths back into the taste solutions to prevent cross contamination. If the solutions are applied by a teacher or assistant they should wear rubber nitryl gloves to maintain hygiene and prevent allergic reactions.

The 'Taste' map myth

Background

It is a commonly held myth that there are specific areas on your tongue for the separate taste buds and it is common to see diagrams showing the bitter, sweet, salty and sour zones of the tongue. The taste map originated in 1901 when a German PhD thesis by D.P. Hanig was mistranslated and misinterpreted**.** It entered common folklore and was not debunked until 1974, though tongue maps still appear in textbooks and on websites.



While this is partially true it is now known that the sensation of taste is far more complicated with different taste receptor cells (see activity Taste Buds), variation amongst people and taste buds that change with age. All taste buds detect all tastes though there are different types of taste buds located around the oral cavity.

Activity

Pupils test themselves against the traditional taste map and see if they can draw their own taste zones. It will help pupils if they have mirrors so they can see where they are touching on their tongues.

Dispel the tongue map myth – this can be done by placing a 'sweet' cotton bud to the back or side of the tongue, as the map says you only taste sweet at the tip OR place a small amount of salt on the very tip of your tongue.

What you will require

- The five basic tastes; sweet (sugar solution), salty (salt solution), sour (citric acid solution or lemon juice) and bitter (flat tonic water or coffee). It is important to use flat tonic water as carbonation changes the taste.
- Mirrors
- Diagrams of the tongue to label.

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Health and Safety
Ideally pupils would have their own taste samples for this activity to reduce the chance of cross contamination. If this is not possible ensure that cotton buds are not placed back in taste solutions.

Further reading and links

BBC Science and Nature taste information and animation
http://www.bbc.co.uk/science/humanbody/body/factfiles/taste/taste_animation.shtml

Taste science at Cornell University
http://www.tastescience.com

Neuroscience for kids - Taste
http://faculty.washington.edu/chudler/taste.html

New Scientist. Does anything eat wasps? Pages 114-115. Ed. Mick O'Hare, 2005, Profile Books Ltd.

Neuroscience for kids - Test your taste lesson
http://faculty.washington.edu/chudler/pdf/tastetg.pdf

BBC Science and Nature lemon juice experiment
http://www.bbc.co.uk/science/humanbody/mind/articles/personalityandindividuality/lemons.shtml

Tongue map: myth or reality?
http://thetastytongue.weebly.com/

Naked Scientists – Carbonation taste
http://www.thenakedscientists.com/HTML/content/news/news/1832/

New Scientist. Do Polar Bears Get Lonely? Pages 16-17. Ed. Mick O'Hare, 2008, Profile Books Ltd.

Taste and Flavour

Learning objectives: Identify tastes and flavours
Provide examples of tastes and flavours
Distinguish between taste and flavour
Explain the difference between taste and flavour

Key words: smell, flavour, aroma, olfactory, epithelium, volatile, pungent, chemesthesis

Background

The *flavour* of food depends more on its *smell*, than on its *taste*, and we can recognise a very large number of different odours indeed. What you think of as taste, is more likely to be aroma. That's why food seems so tasteless when you have a cold. When you have food in your mouth, as you breathe molecules of the food that come off into the air (volatile chemicals) pass over a part of your nose called the *olfactory epithelium*.

Your olfactory epithelium is the super star of food flavour sensation!

You have about 350 different types of odour receptor, each one works like a lock and key to detect a particular set of scent molecules. The individual receptors work together in combinations to produce the sensation of smell. It is like the letters of a giant alphabet and the smells we perceive are the words made up from a 350 letter alphabet. Your memory recognizes the smell and tells you what it is.

The 10,000 different scents which humans usually recognize as 'tastes' are often actually 'flavour' (see activity Taste and Flavour), which many people who can smell confuse with taste. This sense of 'flavour' is greatly diminished by a loss of the sense of smell, often causing those with sudden onset anosmia (loss of the sense of smell) a great deal of concern when all food suddenly loses its flavour. Congenital anosmics often have a much more developed sense of taste than those who could smell at some point in their lives, and can enjoy food just as much as someone who could smell.

The olfactory bulb can detect around 3,000 compounds, which when combined together with the 5 tastes will make between 10,000 and 100,000 recognisable flavours.

Sensations other than taste that contribute to our sense of flavour are termed chemesthesis.

Activity

Ask the question "What is the difference between taste and flavour?"

Do the parma violet or jelly bean test. Ask the student to hold their nose and start to suck the parma violet or chew the jelly bean. Ask if they can tell what flavour it is and what they can taste. They will probably only say it is something sweet, which is the sugar taste in the parma violet or jelly bean. Now tell them to let go of their nose and they will get a sudden rush of the flavour and be able to tell you what it is. This demonstrates that it is smell which gives it flavour. Just like when you have a cold you can not "taste" your food properly.

Invite pupils to sniff four individual chemicals, and then the four mixed together. The sniff solutions are ethyl butanoate (1%), 4-hydroxy-2,5-dimethyl-3(2H)-furanone (3%), methyl 3-phenylpropenoate (0.03%) and 5-hexyloxolan-2-one (0.02%) dissolved in propan-

1,2-diol. Flavouring solutions should be made up before hand in suitable containers and diluted as indicated.

They will be asked to describe the smells and suggest the smell they would produce if mixed together.

Pupils then smell the four mixed together and describe the smell before it's supposed smell and use is described (artificial strawberry).

Extension activity

The ability to distinguish between apple and pear can be tested by chopping or grating the two fruits and tasting one while smelling the other.

What you will require

- Jelly beans or parma violets
- Flavouring solutions dissolved in propan-1,2-diol (aka propylene glycol):
  - ethyl butanoate (1%) - fruity
  - 4-hydroxy-2,5-dimethyl-3(2*H*)-furanone (3%) - candy
  - methyl 3-phenylpropanoate (0.03%) - balsamic
  - 5-hexyloxolan-2-one (0.02%) - creamy

Health and Safety

Do not handle sweets without washing your hands or wearing gloves if pupils are eating them. Check for diabetes or use sugar free sweets. Instruct pupils to put sweets in the bin straight away if they do not like the taste to prevent the spread of germs.

Flavouring solutions should be handled with care and diluted to the indicated concentrations due to their potency and potential hazards at full strength. The flavourings are used in a variety of foods and fragrances and are safe at recommended dilutions. The % concentrations are recommended fragrance concentrations and pupils should not taste the solutions. Hazard indication of undiluted chemicals; Ethyl butanoate (irritant), 4-hydroxy-2,5-dimethyl-3(2H)-furanone (harmful), methyl 3-phenylpropenoate (irritant), 5-hexyloxolan-2-one (irritant). It is recommended that the fragrances are applied to an absorbent material such as cotton wool to prevent spillage.

Further reading

Neuroscience for kids - Taste
http://faculty.washington.edu/chudler/taste.html

Neuroscience for kids - Test your taste lesson
http://faculty.washington.edu/chudler/pdf/tastetg.pdf

New Scientist. How To Fossilise Your Hamster – and other amazing experiments for the armchair scientist. Pages 60-61. Ed. Mick O'Hare, 2007, Profile Books Ltd.

Taste Buds

Learning Objectives Identify taste buds.
Recognise different types of taste buds
Describe the shapes of taste buds
Suggest reasons for different shaped taste buds

Key words: taste bud, receptor, papillae, tongue, nervous system

Background

Basic tastes are detected by taste receptor cells or 'Taste Buds' on your tongue, throughout your mouth. Each taste bud has 50-150 taste receptors sensitive to certain chemicals. The taste buds are clustered in papillae.

Taste buds can be seen as non-staining regions on the tongue when food colouring is added. The non-staining regions are called papillae and they are the structures on your tongue that hold your taste buds. Non- and medium- tasters look as though they have polka dots on their tongues. Supertasters have a tiled effect on theirs, and the papillae will be edge to edge on the tip of the tongue.

There are 3 different types of papillae; fungiform (because they look like mushrooms), foliate (leaf shaped found on the sides of the tongue) and vallate papillae (large dome shaped 'taste buds' towards the back of the tongue. Taste buds are also found in the roof of the mouth (palate) and the back of the throat (including the oropharynx, larynx, epiglottis and upper oesophagus).

Activity

Swab the blue colouring on your tongue. Make sure that you cover the tip. If you look in the mirror, you should see little pink circles that don't stain.

What you will require

- blue food colouring
- a cotton bud or cotton wool
- Magnifying glasses
- Mirrors

Optional

- Flexi cam or digital microscope (such as a dinolite®) and monitor

Health and Safety

Try to ensure a natural blue food colouring is used.

Further reading

Test your taste buds
http://www.bbc.co.uk/science/humanbody/body/articles/senses/tongue_experiment.shtml

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Taste and Temperature

Learning objectives: Recognise other senses that contribute to perception of food.
Give examples of foods and drinks that taste differently at different temperatures.
Describe how chemicals can create a sense of hot or cold.
Distinguish between sensing temperature and sensing chemicals in the mouth.

Key words: Trigeminal nerve, hot, cold, temperature, menthol, sorbitol, chilli, capsaicin, Scoville

Background

Temperature

Temperature is an essential element of human taste experience. Food and drink which — within a given culture — is considered to be properly served hot is often considered distasteful if cold, and *vice versa*.

The perception of taste is influenced by the temperature of foods. In some people, stimulation of the tongue with different temperatures can produce different tastes. Warming the front of the tongue produces a sweet sensation, while cooling can produce a salty or sour sensation. Our taste sensitivity is enhanced with increased temperature explaining why warm beer tastes bitterer and warm cola is sweeter. The flavour of foods is also enhanced with increasing temperature as more volatile chemicals are released to be detected by the olfactory system.

Many of the sensations that affect taste are detected by the trigeminal nerve including substances, temperature and texture.

Coolness

Some sugar substitutes cause cooling as they dissolve in solution e.g. saliva. Sorbitol, xylitol and mannitol often found in mint sweets or chewing gum not only stimulate sweet receptors but also cause a cooling sensation detected by temperature receptors.

Some substances activate taste cell receptors connected to the trigeminal nerve. These receptors respond to substances found in spearmint, menthol, ethanol or camphor producing a cool sensation referred to as "fresh" or "minty". The substances in the food activate the TRP-M8 ion channel on nerve cells that signal cold. This receptor is also known as the cold and menthol receptor 1 (CMR1) and as the name suggests it senses both temperature and menthol molecules.

There are therefore two forms of cold sensation, that caused by a change in temperature and that caused by chemicals such as menthol.

Spiciness or 'heat'

Substances such as chilli and capsaicin activate a different receptor connected to the trigeminal nerve, TRP-V1. This is a nerve cell ion channel that is also activated by heat. The burning sensation, usually referred to as "hot" or "spicy", is a notable feature of Mexican, Indian, Tex-Mex, Szechuan, Korean, and Thai cuisine.

The two main plants providing this sensation are chilli peppers (those fruits of the Capsicum plant that contain capsaicin) and black pepper. Spicy foods are measured on the Scoville scale in Scoville heat units. This scale was developed in 1912 and involved a panel of tasters, nowadays the concentrations of 'heat' inducing chemicals can be measured with high-performance liquid chromatography (HPLC).

The Trigeminal (or cranial V) nerve endings in the tongue, mouth and nose are stimulated by a variety of chemical 'irritants' including chillis. The receptors detect 'pungent' chemicals that give sensations of

Heat – Chilli, Pepper, Mustard, horseradish
Astringency – Onion, Garlic
Coolness –Mint
Alcohol – Vodka, Absinthe

The trigeminal nerve carries signals to and from the face. There are trigeminal nerve endings that detect irritation to the eyes such as chopped onion and in the nose, for example causing a sneezing response to sniffing pepper.

Activity

Prepare cool and warm water and ask pupils to compare their sense of taste with the five basic tastes. This can be done by pupils dipping their tongue in warm water for a few seconds and then after a short break to let the tongue return to body temperature repeating it with cold water. Not all pupils will experience a thermal taste response, though sweetness is most common among those that do.

After this introduction to the effect of temperature, the effect of chemicals inducing sensations of hot and cold can be investigated.

Pupils can choose to taste Tabasco Sauce and some peppermint to demonstrate false hot and cold.

Extension activity: Pupils can then try chopping onions to see if they are sensitive to eyes watering and then compare their results later with the results of their genetic taste tests. Ask pupils to formulate a hypothesis about the relationship between trigeminal nerve sensitivity and genetic super tasters.

What you will require

- Tabasco sauce or chilli sauce
- Mint
- Cups
- Drinking water

Optional

- Chopping boards
- Knives
- Onions

Health and Safety

Ensure the temperature of water for tasting is not so cold or hot as to cause discomfort. Provide pupils with individual receptacles for tasting water. Make sure pupils do not have too much Tabasco as they are often unaccustomed to the strength and are more sensitive than adults. Also make sure there is water available to drink straight away.

Further reading

New Scientist. Why Don't Penguins Feet freeze? Pages 113-114. Ed. Mick O'Hare, 2006, Profile Books Ltd.

New Scientist. Do Polar Bears Get Lonely? Pages 12-13. Ed. Mick O'Hare, 2008, Profile Books Ltd.

Taste and Colour

Learning objectives: Describe unusually coloured foods
Give examples of foods and their expected colour
Distinguish the taste of a food and the perceived flavour
Give examples of poisonous foods that can be identified from their colour
Suggest explanations for the appeal or aversion to certain food colours

Key words: Perception, synthaesia, evolution, toxin, poisonous

Background

Our aversion to blue or black coloured foods is thought to be a protective mechanism we have evolved to avoid poisonous or rotten foods. Birds have been shown to avoid reds and yellows. These are colours likely to be displayed by poisonous insects as a warning not to eat them.

Which foods and drinks we buy depends on the colour. Researchers found that the colour of orange juice was more important in perception of taste than branding as premium or budget quality. Pepsi produced clear cola but it's appeal didn't last long.

Some people literally see taste as colours. Synthaesthesia causes the senses to interpret stimuli differently. People with synaesthesia have reported chocolate tasting deep purple. In some cases words can stimulate the sense of taste in one case an individual reported that the word blue provokes an 'inky' taste.

Would you eat unusually coloured food if it was better for you? Scientists at the John Innes centre have produced purple tomatoes that contain more of the colourful antioxidant – anthocyanin.

Activity

Pupils taste 3 jellies, yellow, orange and red describing the flavour. Lemon Jelly coloured with varying amounts of red food dye seem most effective. Pupils will then taste clear and food dye coloured drinks once again describing their flavour before the actual flavour is revealed. Choosing a still clear flavoured drink and adding a variety of food colourings can produce a range of interesting results. Commonly pupils will be strongly influenced by other pupils suggested flavours and a peer effect can be very strong. Black food colouring can also be purchased and added to lemonade or other clear fruit flavoured drinks, while pupils are asked to suggest the brand of cola. The power of branding, advertising and anticipation can also be discussed with this activity.

What you will require

- Lemon jelly
- Food dye
- Clear still flavoured drinks
- Cups or small bowls

- Spoons

Optional

- Spaghetti
- Food dye
- Bird table

Extension activity

Pupils can carry out their own experiment on food choice and colour by dying spaghetti different colours with food dye and then counting how much of each colour is eat by birds from a feeding table. See the Survival Rivals Webpage (**www.survivalrivals.org**) for more details.

Further reading

Survival Rivals I'm a worm get me out of here
http://survivalrivals.org/i-am-a-worm-get-me-out-of-here/about

Taste Genetics

Learning objectives: Recognise that some people are more sensitive to bitter tastes than others
Give examples of foods with bitter tastes that some people dislike
Explain why some people are able to taste bitter compounds but others are not
Describe the inheritance of the PTC tasting trait (TAS2R38 gene)
Suggest reasons for populations with different numbers of supertasters

Key words: evolution, homozygous, dominant, allele, genotype, phenotype

Background

There is a single gene that codes for a protein (receptor) found in our taste buds known as taste receptors, type 2 (TAS2R38). If a person has this protein receptor then they are able to detect the bitter taste of a chemical called phenylthiocarbamide (PTC). PTC can bind to the receptor and the person will be able to taste the chemical. If the individual does not have the gene, and hence the protein is not present, PTC cannot bind to the taste buds and the person cannot taste it.

Research has shown that TAS2Rs are coupled to the G protein gustducin. Researchers use two synthetic substances, phenylthiocarbamide (PTC) and 6-*n*-propylthiouracil (PROP) to study the genetics of bitter perception. PTC and PROP can taste very bitter to some people, but are virtually tasteless to others. Among the tasters, some are so-called "supertasters" to whom PTC and PROP are extremely bitter. The variation in the ability to taste substances amongst people has been determined to be a genetic trait. This has led to great interest from geneticists and anthropologists investigating diverse groups around the world.
It is also of interest to evolutionary biologists and nutritionists since many naturally bitter compounds also happen to be toxic but so too are foods high in antioxidants such as broccoli or coffee. Those individuals with the ability to taste PTC may have acquired this trait through an evolutionary protective mechanism that now puts them off healthy foods such as green vegetables.

Being able to taste PTC is a dominant trait. About 2/3 to 3/4 of people in western cultures are able to taste it, while 1/3 to 1/4 will not. Individuals who are homozygotes for the dominant allele are commonly described as “supertasters”. Having two copies of the gene means that they produce more proteins or more binding sites for PTC.

The proportions of tasters and ‘non-tasters’ varies in different parts of the world. It has been reported that 100% of Native Americans, about 70% of westerners, and 50% of Aboriginal peoples are tasters and supertasters are more likely to be African-American, Asian or female.

A wide variety of responses to PTC have been described and may elicit tastes such as sour, sweet, salty and occasionally more obscure tastes.

Tasters are more likely to avoid bitter foods such as green vegetables, coffee and tea as well as smoking

There are about 30 genes in total that code for different bitter taste receptors in mammals.

Phenylthiourea papers, taste bitter to seven out of ten people, and sodium benzoate papers taste sweet, salty, bitter, or tasteless to different people.

Activity

Tongue rolling starter

The ability to roll the tongue is a genetic trait and this is commonly used in class to start topics on genetics. It is a good way to start this lesson to introduce the topic of genetics to pupils or remind pupils about what they know and elicit their level of knowledge. It's not just the way you roll your tongue that is decided by your genetics, your sense of taste is determined by the genes you inherit from your parents.

Genetic taste test strips

4 Test strips are available

- Control
- PTC
- Thiourea
- Sodium Benzoate

Pupils should each be provided with a control strip first. This will enable pupils to distinguish between the residual taste of the paper strips and the potential taste of the test substances. Results of the taste tests should be collated either on a whiteboard or flipchart so that pupils can calculate the percentage of tasters or super tasters in the class. This data can then be compared to the results found in different ethnic groups, genders or in the results from other investigations.

Do not inform pupils of the possible taste prior to the test as suggestion and prior expectations can have a strong influence on the perceived taste. It is also beneficial, if possible, that all pupils try the taste strips at the same time and do not react too strongly to any tastes they experience as this may put off other pupils from even trying the strips. Despite this some people find the tastes extremely strong and it is also wise to ensure that there are sweet flavoured drinks or water on hand for those pupils who have a strong taste sensation. One end of the taste test strips should be placed in the middle of the tongue. Saliva is often required and there is often a delay before pupils will be able to taste the strips, if at all.

Dispense taste test strips while wearing gloves to prevent any transmission of germs and as with all lab activities involving food ensure pupils wash their hands prior to the activity (not just after the activity). Pupils should record the intensity of the taste as none, weak or strong as well as describing the taste according to one of the five basic tastes, sweet, sour, salty, bitter or umami.

Repeat with PTC, thiourea or sodium benzoate.

Pupils can be classified as non tasters if they did not taste anything with PTC. Weak tasters or supertasters according to the strength of their reaction.

Ask pupils if their results correlate with the number of papillae (taste buds) they could locate on their tongue (see activity Taste Buds).

Confirm with pupils who could not taste PTC that they had identified taste buds on their tongue and then enquire of the class possible reasons for some individuals not being able to taste PTC yet having taste buds (if required hint back to the starter activity).

At this point you can provide more information about the genetic traits of supertasters and the response to PTC.

Depending on the age and ability of the pupils you may want to ask them to draw conclusions from the results about the type of genes or alleles associated with the supertaster trait.

Assessment
What might be the genetic advantage or disadvantage of being a super-taster?

Extension activity
Is being a 'supertaster' related to liking or disliking marmite?
Are 'supertasters' more sensitive to stimulation of the trigeminal nerve by chopping onions?

Health and Safety Information
It is recommended by CLEAPSS that pupils do not taste more than two PTC strips.

Ethical Information
It is strongly recommended that children and their parents do not participate in this activity together.

The ability to taste PTC is a trait which is inherited from parents.

The results of the taste tests could lead to anxiety to parents and children who participate together in this activity. As a dominant trait, and one that can produce a strong reaction in homozygous individuals, a lack of response in either parent or adult and a strong response in the other could be interpreted as a lack of relatedness. This assumption may not take into account other genetic variations including in TASR38, age or lifestyle such as smoking.

However, as this activity could cause undue distress it is recommended that situations that could lead to parents and children both taking part are avoided. It is also sensible to take precautions against pupils taking the taste test strips home.

Further reading
Survival Rivals - A question of taste
http://survivalrivals.org/a-question-of-taste/about

DNA learning centre - Using a single-nucleotide polymorphism to predict bitter tasting ability
http://bioinformatics.dnalc.org/ptc/animation/ptc.html

Feedback

We would welcome any comments you have on the usefulness or otherwise of these lessons so we can improve them in future. We would also like to hear about how you have taught some of the topics covered here. You can email any feedback to **ifr.communications@bbsrc.ac.uk**

Thank you.

Were there any problems? If so, please briefly explain what these were.

Were the instructions clear?

Are the resources required cheap and easy to obtain?

What did the students enjoy doing most in the exercise?

Were the additional notes of use?

Did any health and safety issues arise that should be highlighted?

Suggestions for activities?

Suggestions for assessment activities?

Suggestions for extension activities?

Any other comments?

Curriculum links

Key Stage 1

Personal, social and health education (PSHE)

Developing a healthy, safer lifestyle

a. how some diseases spread and can be controlled
b. the names of the main parts of the body
c. that all household products, including medicines, can be harmful if not used properly

Science

Sc1 Scientific Enquiry

Ideas and evidence in science

1 That it is important to collect evidence by making observations and measurements when trying to answer a question.

Investigative skills

Planning

b use first-hand experience and simple information sources to answer questions

Obtaining and presenting evidence

e follow simple instructions to control the risks to themselves and to others
f explore, using the senses of sight, hearing, smell, touch and taste as appropriate, and make and record observations and measurements

Considering evidence and evaluating

i compare what happened with what they expected would happen, and try to explain it, drawing on their knowledge and understanding

Sc2 Life Processes and living things

Humans and other animals

b that humans and other animals need food and water to stay alive
c that taking exercise and eating the right types and amounts of food help humans to keep healthy
g about the senses that enable humans and other animals to be aware of the world around them.

Variation and classification

a recognise similarities and differences between themselves and others, and to treat others with sensitivity

Sc3 Materials and their properties

Grouping materials

a use their senses to explore and recognise the similarities and differences between materials

Breadth of study

Health and safety

b recognise that there are hazards in living things, materials and physical processes, and assess risks and take action to reduce risks to themselves and others.

Key Stage 2

Personal, social and health education (PSHE)

Developing a healthy, safer lifestyle

3. Pupils should be taught:

a. what makes a healthy lifestyle, including the benefits of exercise and healthy eating, what affects mental health, and how to make informed choices
b. that bacteria and viruses can affect health and that following simple, safe routines can

reduce their spread

Science
Sc1 Scientific Enquiry
Ideas and evidence in science
1 That it is important to test ideas using evidence from observation and measurement.
Investigative skills
Planning
b consider what sources of information, including first-hand experience and a range of other sources, they will use to answer questions
Obtaining and presenting evidence
e use simple equipment and materials appropriately and take action to control risks
Sc2 Life Processes and living things
Humans and other animals
Nutrition
b about the need for food for activity and growth, and about the importance of an adequate and varied diet for health
Breadth of study
Health and safety
b recognise that there are hazards in living things, materials and physical processes, and assess risks and take action to reduce risks to themselves and others.

Key Stage 3
Science
Sc1 Scientific Enquiry
Ideas and evidence in science
That it is important to test explanations by using them to make predictions and by seeing if evidence matches the predictions
Investigative skills
Planning
b decide whether to use evidence form first-hand experience or secondary sources
Obtaining and presenting evidence
f use a range of equipment and materials appropriately and take action to control risks to themselves and others
Sc2 Life Processes and living things
Cells and cell functions
e to relate cells and cell functions to life processes in a variety of organisms.
Humans as organisms
Nutrition
a about the need for a balanced diet containing carbohydrates, proteins, fats, minerals, vitamins, fibre and water, and about foods that are sources of these
b the principles of digestion, including the role of enzymes in breaking down large molecules into smaller ones
Variation, classification and inheritance
Variation
a about environmental and inherited causes of variation within a species
Breadth of study
Health and safety
b recognise that there are hazards in living things, materials and physical processes, and

assess risks and take action to reduce risks to themselves and others.

Design and Technology
Pupils should be taught: about the working characteristics and applications of a range of modern materials, including synthetic flavours.

Key Stage 4
How Science Works
Data, evidence, theories and explanations
d that there are some questions that science cannot currently answer, and some that science cannot address
Applications and implications of science
c how uncertainties in scientific knowledge and scientific ideas change over time and about the role of the scientific community in validating these changes.
Organisms and health
c the ways in which organisms function are related to the genes in their cells
d chemical and electrical signals enable body systems to respond to internal and external changes, in order to maintain the body in an optimal state
e human health is affected by a range of environmental and inherited factors, by the use and misuse of drugs and by medical treatments
Chemical and material behaviour
c new materials are made from natural resources by chemical reactions

WJEC – Design and Technology GCSE – Food Technology
MATERIALS AND COMPONENTS
(b) know how materials can be combined and processed to create more useful properties, and how these materials are used in industry;
Candidates should have a working knowledge of the properties of a wide range of food materials and components.
• Select materials and components, combining where appropriate, to improve, for example the nutritional content, appearance, texture, taste and aroma of a food product.
(d) sensory characteristics;
• Candidates should be able to describe how foods are selected in a product because they impart a desired organoleptic quality, including flavour, aroma, mouthfeel and visual qualities (colour, surface texture, shape).

iGCSE 21st Century
Module C3 Food matters
C3.2 Why are chemicals deliberately added to food.
1. Recall that food colours can be used to make processed food look more attractive
2. recall that flavourings enhance the taste of food
3. understand that artificial sweeteners help to reduce the amount of sugar in processed foods and drinks

2011 Draft GCSE curriculum links
AQA GCSE Biology and Science A
Unit 1 Biology
B1.2.1 The nervous system
b) Cells called receptors detect stimuli (changes in the environment).

Receptors and the stimuli they detect include:

- receptors on the tongue and in the nose that are sensitive to chemicals and enable us to taste and to smell

OCR GCSE
Module B6: Beyond the Microscope
Item B6g: enzymes in action
Describe everyday uses of enzymes:

- altering the flavour of food products.

Key Stage 5
Scottish Qualifications Authority (SQA)

Higher Biology
Unit 1: Cell Biology
d) Synthesis and release of proteins (ii) DNA: structure
Unit 2: Genetics and Adaptation
b) Selection and speciation 1 Natural selection

Advanced Higher Biology
Unit: Cell and Molecular Biology
b) Structure and function of cell components (iv) Nucleic Acids , Structure of DNA
d) Applications of DNA technology (i) The human genome project (iii) Forensic uses

Higher Human Biology
Unit 1: Cell Function & Inheritance
b) Protein synthesis 2 (i) DNA structure
f) Inheritance 1 Chromosomes as vehicles of inheritance
2 Monohybrid inheritance
3 Mutations & chromosome abnormalities

GCE in Design and Technology – Food Technology
Unit 2 Design and Technology in Practice
2.3 Materials, components/ingredients and working properties
1 Carbohydrates
a) The chemical name, nature and basic characteristics of the following carbohydrates. Students do not need to know the chemical structures and complex formulae.
b) Fundamental working properties of carbohydrates:
sweetening: comparison of the sweetness level of sugars compared with sucrose
4 Other components and additives
a) Sensory characteristics
Name, nature, functional properties and use of the following additives which affect the characteristics of foods under the following.
(i) Colours: artificial, natural pigments.
(ii) Flavours: natural, spices and herbs, nature identical,synthetic flavour enhancers/modifiers:monosodium glutamate (MSG).

AQA GCE Biology
AS level
Unit 2 BIOL2 - The variety of living organisms
3.2.1 Living organisms vary and this variation is influenced by genetic and environmental factors

- Causes of variation

3.2.2 DNA is an information-carrying molecule. Its sequence of bases determines the structure of proteins, including enzymes.

- Genes and polypeptides

3.2.3 Similarities & differences in DNA result in genetic diversity

- Genetic diversity

3.2.9 Originally, classification systems were based on observable features but more recent approaches draw on a wider range of evidence to clarify relationships between organisms

- Genetic comparisons
- DNA
- Proteins

A2 Level
Unit 4 BIOL4 - Populations and environment
3.4.8 Genetic variation within a species and genetic isolation leads to the accumulation of different genetic information in populations and the potential formation of new species

- Inheritance
- Selection

Unit 5 BIOL5 - Control in cells and organisms
3.5.6 The sequence of bases in DNA determines the structure of proteins, including enzymes

- Gene mutation

AQA GCE Human Biology
AS level
Unit 2 HB102- Humans - their origins & adaptations
3.2.1 The information of Life

- Nucleic acids - the keys to life

3.2.4 Adaptations to a way of Life

- Humans have evolved adaptations that increase survival

A2 Level
Unit 4 HBIO4 - Bodies & Cells in and out of control
3.4.2 Growing up, growing old and passing on your genes

- Mendelian inheritance
- Where variation comes from

3.4.3 The management structure of cells

- DNA and protein synthesis

Unit 5 HBIO5 - The air we breathe, the water we drink, the food we eat
3.5.1 Human impacts on evolution

- Evolution

OCR GCE Biology
AS Level
Unit F212 - Molecules, biodiversity, food and health

Module 1 Biological Molecules
2.1.2 Nucleic acids
Module 3 Biodiversity and evolution
2.3.3 Evolution
A2 Level
Unit F215 - Control, genomes and environment
Module 1 Cellular control and variation
5.1.1 Cellular control
5.1.2 Meiosis and variation
Module 2 Biotechnology and gene technologies
5.2.3 Genomes and gene technologies

OCR GCE Human Biology
AS Level
Unit F222 - Growth, development and disease
Module 1 The developing cell
2.1.1 Mitosis as part of the cell cycle
A2 Level
Unit F225 - Genetics, control and ageing
Module 1 Genetics in the 21st century
5.1.1 Inheritance of human genetic disease
5.1.2 Genetic techniques

Edexcel GCE Biology
AS Level
Unit 1 - Lifestyle, transport, genes & health
1.4 Topic 2: Genes and health
Unit 2 - Development, plants and the environment
2.1 Topic 3: The voice of the genome

WJEC GCE Biology
AS Level
Unit BY1 - Basic biochemistry and cell structure
1.6 Nucleic acids
Unit BY2 - Biodiversity and physiology of body systems
2.1 All organisms are related through their evolutionary history
A Level
Unit BY5 - Environment, genetics & evolution
5.1 The genetic code and cell function
5.4 Inheritance
5.5 Variation & evolution
5.6 Applications of reproduction & genetics

WJEC GCE Human Biology
AS Level
Unit BY1 - Basic biochemistry and cell structure
1.6 Nucleic acids
Unit HB2 - Biodiversity and physiology of body systems
2.1 All organisms are related through their evolutionary history

A Level
Unit BY5 - Environment, genetics & evolution
5.1 The genetic code and cell function
5.4 Inheritance
5.5 Variation & evolution
5.6 Applications of reproduction & genetics

Links

http://www.ifr.ac.uk/info/science/NaturalProducts/
Institute of Food Research Plant Natural Products and Health group

http://www.reading.ac.uk/food/shortcourses/foodbio-teachersday.aspx
A one day course for teachers at Reading University's Food and Nutritional Sciences department.

http://www.reading.ac.uk/food/shortcourses/foodbio-sixthform.aspx
A 3 day summer school for A-level pupils A at Reading University's Food and Nutritional Sciences department.

http://www.nottingham.ac.uk/biosciences/outreachactivities/summerschools.aspx
Summer school in Food Sciences for GCSE students at University of Nottingham.

http://www.monell.org/
Monell Chemical Senses Centre

http://www.cardiff.ac.uk/biosi/staffinfo/jacob/teaching/sensory/taste.html
Summary of recent research from Cardiff University

Suppliers

Sigma-Aldrich
http://www.sigmaaldrich.com/united-kingdom.html

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