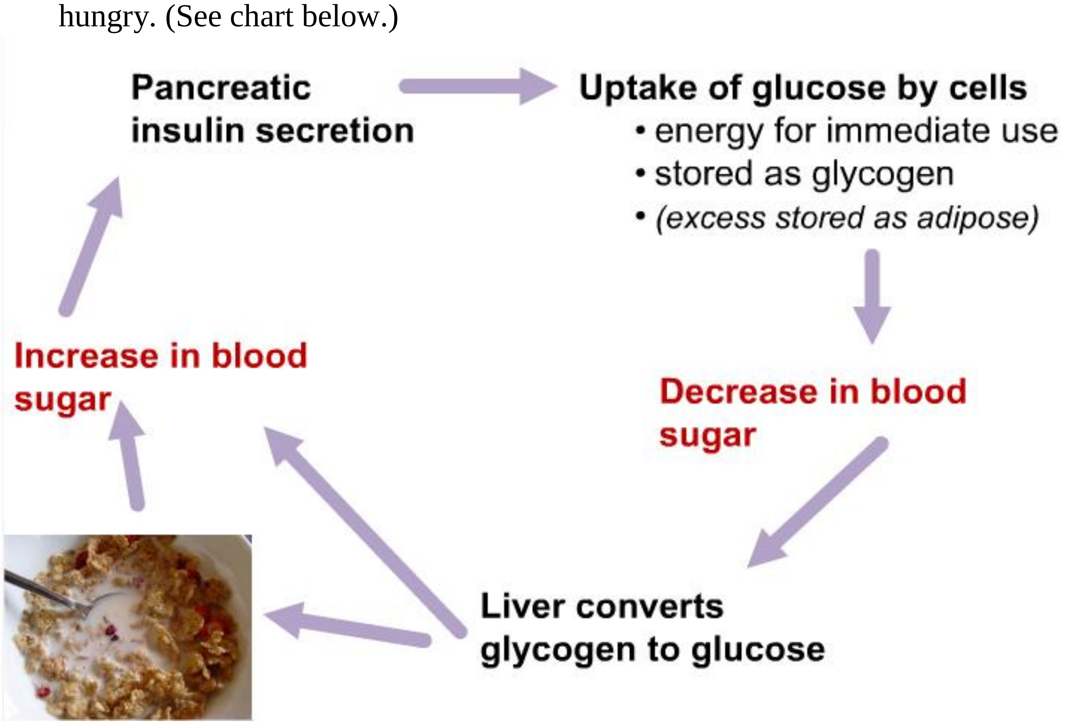
Psych 1XX3 – Hunger and Chemical Senses Notes – Mar 26, 2010

Introduction:

- Human evolutionary past: food sources were scarce and behaviours were motivated by the constant need to obtain energy and nutrients essential to survival
- Feeding behaviours may be motivated by hunger and satiety signals, but are guided by the interaction of the senses of taste and smell

Hunger and Satiety:
Glucose and Glycogen Balance:

- One of the main reasons that you feel hungry is low blood glucose levels.
- Glucose is important for keeping your body's functions operating and is the preferred source of energy for the brain; unlike other organs and tissues, the brain cannot use fat energy stores for fuel which makes regulating glucose availability a top priority.
- You are very sensitive to the level of glucose in your blood, and this directly relates to your feelings of hunger.
- To keep your brain constantly supplied with energy, your body can store glucose in the form of glycogen which can be released in between meals.
- Some glycogen is stored in the muscles, but the main supply is in your liver where it can be readily converted back into glucose.
- This glucose-glycogen balance is mediated to a large degree by the liver and a pancreatic hormone called insulin
- The pancreas secretes insulin to promote the uptake of glucose by cells in your body for immediate use, but also to stimulate storage of excess glucose as glycogen.
- When these levels get low enough, the liver begins to break down 'its stored glycogen into glucose, releasing it back into circulation.
- In this way, the liver and pancreas help to buffer extreme swings in blood glucose levels. As this cycle continues and the time since your feast increases, your glycogen reserves in the liver will decrease and a status signal is sent to the brain.
- At some point, the glucose and glycogen levels get too low and you will feel hungry. (See chart below.)



Neuropeptide Y:

- Another hunger cue comes from Neuropeptide Y or NPY.
- High levels of NPY activity in the hypothalamus are associated with increased appetite and food seeking behaviours - such as heading to the kitchen.
- NPV affects feeding behaviour similarly in fish, reptiles, birds, and other non-human mammals.

Satiety and the Liver:

- What makes you stop after eating?
- Just as your liver can send signals to your brain to trigger hunger it also sends signals to the brain that trigger satiety.
- If you take a dog that is eating and you inject glucose into a vein that connects directly to the liver, the dog will stop eating.
- However, when the same glucose dose is injected into a different vein, say one that does not directly connect to the liver; the dog will continue eating.

CCK and Meal Duration:

- The small intestine also has a role to play in feelings of satiety.
- food moves from your stomach to your gut, the small intestine produces Cholecystokinin, or CCK, a hormone that is responsible for feelings of satiety or fullness after a meal.
- Receptors in the brain detect CCK, which serve as a signal to stop eating.
- How do we know this? Well, scientists have found that if you inject individuals with CCK, they report feeling satiated sooner.
- In another study researchers administered CCK to rats leading to shorter than average meal durations, compared to controls.
- Interestingly, these rats who received CCK ate more total meals per day than the controls, and the total daily intake was the same for both groups.
- This shows that CCK is a short-term satiety signal.

Long-Term Weight Regulation:

- Whenever possible, long-term energy storage takes place in the form of fat (i.e. adipose tissue).
- Both short-term and long-term mechanisms interact to regulate overall energy balance and body-weight.
- Why do animals store most of their excess energy in the form of fat? Why not store it all as glycogen, which is a quickly transferable source of energy?
    - Fat has more than twice the energy that carbohydrates, like glycogen, have. For every 1 gram of fat, there are 9 units of kilocalories. Compare that with carbohydrates which contain only 4 kilocalories per gram.
    - And unlike glycogen, fat is found in virtually all parts of the body. If you took a 70 kg man, he has about 1200 kcal of energy stored in the form of glycogen. This would be enough to fuel his activities for 12-18 hours.
    - However, that same man has approximately 120 000 kcal stored in fat - that‘s enough energy to live off of for a couple of months!
    - So for the long-term, fat is the better choice for storing more energy. But the fat or adipose tissue is so much more than just a passive energy storehouse. It is an active component of your regulatory physiology and was fairly recently classified as an endocrine organ as well.

Leptin:

- Adipose tissue secretes a hormone called leptin, which is involved in long-term energy balance and correlated with fat mass.
- When leptin levels rise, they act on receptors in the hypothalamus to reduce appetite → food consumption decreases.
- Leptin production is controlled by the OB Gene → in genetically altered knock-out mice lacking an OB Gene, leptin production stops; in this state, mice are missing a key hormonal signal to regulate appetite and become extremely obese.
- This condition can be reversed if the mice are given regular injections of leptin, causing their eating behaviour and weight to return to normal.

OB Gene Revisited:

- These studies suggest that a contributing factor for obesity in humans 'may involve defective OB genes or receptors.
- However, this inference is not supported in clinical findings; very few obese people have known defects in the leptin signalling system.
- What happens if you give leptin to an obese animal who happens to have normal leptin levels? In this case, giving additional leptin actually does not reliably result in weight loss to return to normal levels.
- It appears that humans and other animals are capable of becoming leptin resistant: that is, at beyond a certain point, leptin's ability to inhibit appetite is reduced.
- Consider that access to calories was a limited resource for most of human evolutionary history;' taking in too many calories must have been a rare luxury.
- It is more likely that the primary adaptive function of leptin was to serve as indicator of low energy stores, rather than as a signal to directly reduce food intake.
- Low leptin levels would signal to increase foraging effort or minimize activity in order to conserve energy.
- Rarely would an individual have had very high levels of leptin or suffered from the negative effects associated with excess adipose tissue.

NPY:

- What is the mechanism of leptin action? If you think of NPV activity in the hypothalamus as the ON switch for appetite, leptin acts to inhibit the actions of NPY.
- And so, the NPV mediated increase is appetite is prevented by leptin, leading to decreased appetite and energy consumption.
- Together leptin and NPV interact to regulate your weight to optimal levels.

Maladaptive Feeding and NPY:

- Evidence in rats suggests that NPYergic neurons can specifically affect reward-driven feeding for high calorie foods such as sucrose.
  - In one series of experiments, NPY was injected directly into the brain of rats who were satiated by previous food consumption. This revealed some interesting results: first, there is an increase in the intake of sucrose.
  - Second, rats will begin to work harder for a cue associated with sucrose
  - Third, rats also increased the consumption of saccharin (similar taste to sucrose but without calories)
  - Finally, these rats will also preferentially choose a diet of carbohydrates over protein, or fat.

- This line of research suggests that NPV action promotes unconditional and conditional behaviours that specifically lead to increased carbohydrate consumption.
- A rat's preexisting preferences, plays an important role in this NPV-induced increase in carbohydrate preference; rats that showed a higher baseline preference for carbohydrates showed the greatest preference for carbohydrates following the NPY injection.
- These studies suggest an interesting implication for genetic predisposition toward carbohydrate consumption.

Endogenous Opioids:

- Another interesting hypothesis on overeating is related to **endogenous opioids**.
- Endogenous opioids have morphine-like actions within the body and also contribute to palatability and reward driven feeding.
- Interestingly, blocking the opioid receptors with a drug called naloxone reduces intake of rewarding foods such as saccharin and sucrose.
- Consistent with this hypothesis, knock-in mice which have been genetically modified to lack the opioid receptor show lower preference for saccharin than do control mice.
- Some researchers have speculated that overeating in some people may be reflective of a maladaptive opioid-mediated reward-driven feeding.

Conclusion:

- Energy balance and body weight regulation by hormones and mechanisms are asymmetric. → That is, the body defends itself against weight loss more strongly than it does against weight gain.
- This asymmetry can be understood from an evolutionary perspective, where calories and nutrition were less certain. However, this asymmetry may have an unintentional maladaptive expression in a modern, fast-food nation where calories are cheap and physical exertion is minimal.
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Molecule/ Hormone	Source	Function
Glucose	Food, glycogen	Primary fuel for the brain
Glycogen	Liver, muscles	Stored form of glucose
Insulin	Pancreas	Stimulates glucose metabolism and glycogen synthesis
CCK	Small intestine	Responsible for short-term satiation, terminating meals
NPY	Hypothalamus	Stimulates appetite, food consumption
Leptin	Adipose	- High levels inhibit NPY, appetite - Low levels promote feeding, energy conservation

Taste Preferences and Food Selection:

- Through the course of evolution, foods that are bitter or sour are associated with flavours not commonly enjoyed, because they are often indicative of toxins or noxious foods.
- Special acquired tastes for bitter and sour must be learned through experience.
- In contrast, foods that are sweet, salty or savory are associated with flavours that are craved, because they are more often indicative of foods that are safe, nutritious and rich in energy, such as fruits and protein.
- Individuals who could detect these taste differences effectively had a survival advantage, as they were better able to avoid dangerous foods while accessing reliable sources of energy for good health.

Choosy Tasters:

- Two lines of evidence suggest that certain taste responses are universal, and basic to human behaviour, Particular tastes will elicit the same reactions in infants from all over the world.
- Fully healthy infants as well as those with extensive brain damage, exhibit the same characteristic responses to tastes. (See image below.)
- In panel A, infant subjects are given a neutral solution to taste. When given a sweet or salty solution to sample in panel 8 and C, infants show characteristic acceptance responses and smile.
- When given a bitter or sour solution in panel D and E, infants show a characteristic rejection response and are altogether unhappy.

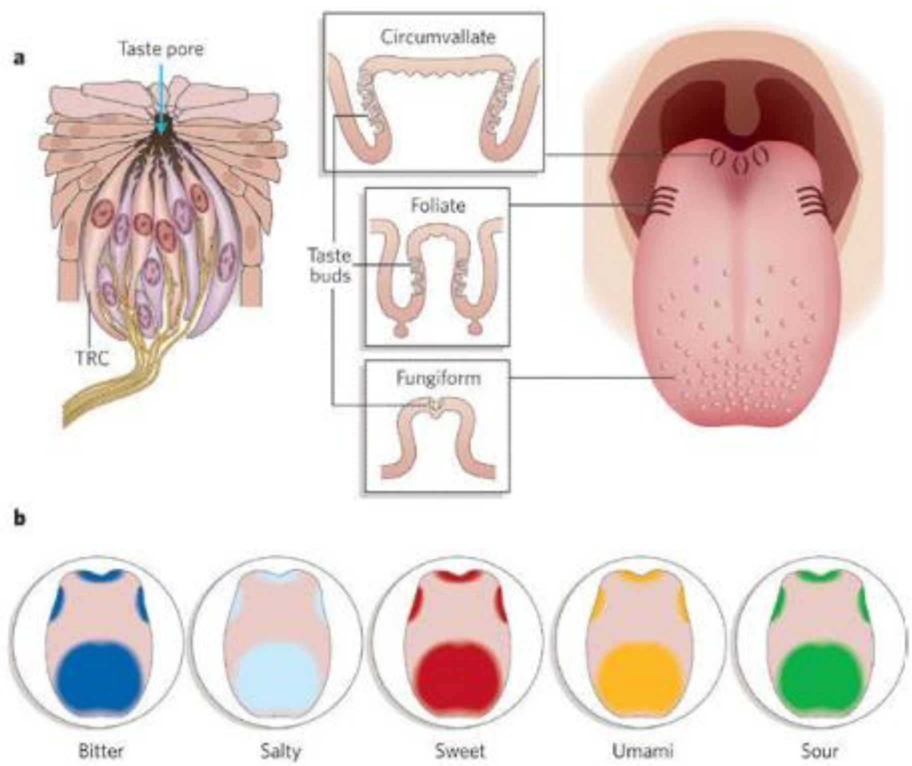
- Interestingly, these same responses are mirrored by the infant without a cortex in the centre, and by the infant with hydrocephalus in the right-most column, suggesting that these responses are governed by lower regions of the brain.
- The perception and response to particular tastes are adaptive mechanisms, controlled by older regions of the brain and they enable you to discriminate foods that are safe and nutritious from foods that are potentially spoiled or toxic.

Cultural Influences:

- Although these universal taste responses guide your consumption of food, taste preference is also shaped by cultural influences which presumably were shaped by local food availability.
- In addition to the universal taste preferences that infants display, the foods that you enjoy are learned by experience.
- But just like any other trait, there are individual differences in taste sensitivity.

Taste Sensitivity:

- Perhaps within your own family, you can spot differences in taste sensitivity. Why is that?
- One reason for this individual difference may have to do with the number of taste buds on your tongue. (See image below)
- Highly sensitive tasters have many more taste buds than the average person.



- Generally, women tend to be more sensitive to some sweet and bitter tastes than men. This increases even more so during the first trimester of pregnancy corresponding to the period during which the fetus is most sensitive to toxins and harmful substances.
- It's easy to speculate how superior tasting abilities would have evolved: enhanced taste sensitivity would have allowed for better nutrition and toxin avoidance during pregnancy and beyond.

Taste Preferences:

- Taste preferences and sensitivity guide your feeding behaviour because for much of evolutionary history, humans have lived in an environment where calories and essential nutrients were difficult to come by.
- The sense of taste provided critical information about the safety and nutritional quality of a wide range of potential foods.

Introduction to the Chemical Senses:

- While visual, auditory and tactile sensory systems deal with physical stimuli like light, sound waves and touch, your sense of taste and smell are unique in their ability to detect chemical stimuli.
- The “chemical senses" of taste and smell depend on receptors that can interact with molecules of food particles to provide you with the pleasurable experience of eating.
- Together; taste and smell influence your perception of flavour I’m sure you can recall the experience of food tasting bland when you were sick; it's your clogged sinuses and impaired sense of smell that are to blame.

How Taste is Processed in the Brain:

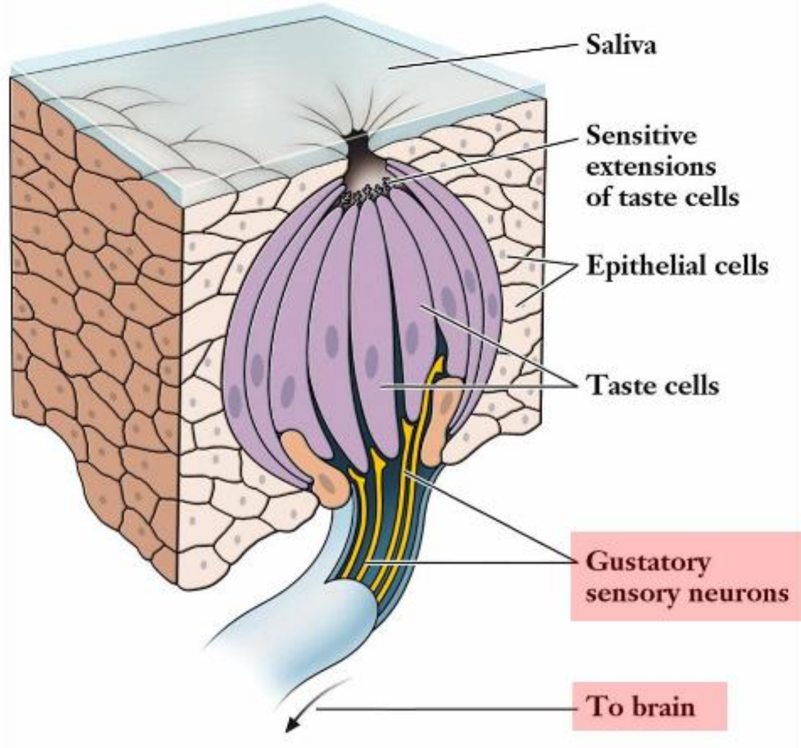
- Chewing on a juicy apple grinds the whole fruit pieces into a pulp of saliva and molecules of water, sugar and carbohydrates.
- Taste buds containing taste receptor cells detect and respond to the dissolved apple molecules.
- Each taste bud has anywhere from 50 to 150 taste receptor cells. About two-thirds of your taste buds are located on your tongue, with the remaining on the soft palate and the opening of the throat.

5 Taste Receptor Cell Types:

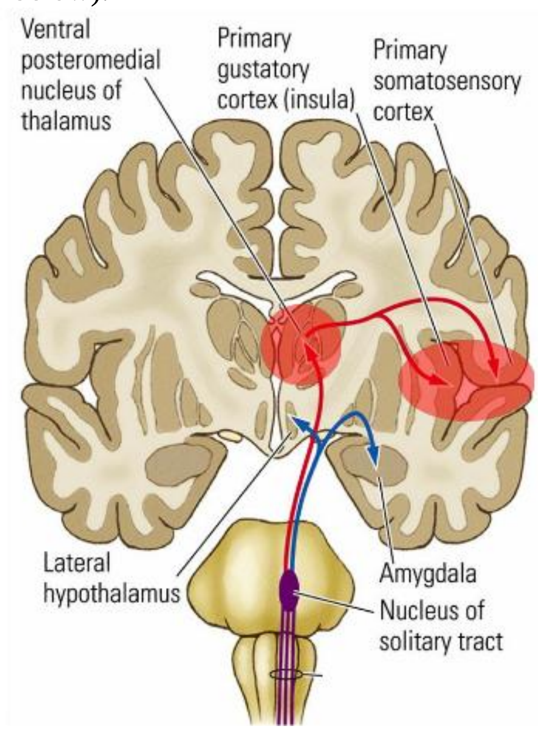
- You can discern 5 different tastes: sweet, salty, bitter, sour and umami or "savory".
- Each of these tastes gives you information about the nutritional quality and content of foods.
- Sweet signifies energy-rich foods like fruits and their sugars.
- The ability to taste salt helps you to identify and ingest essential electrolytes.
- Sour and bitter tastes warn of you of harmful, spoiled or potentially poisonous foods.
- Umami, the most recently classified taste literally means “delicious flavour" in Japanese. The umami taste detects the amino acids glutamate and aspartate.
- You may have once learned of a taste map, where different regions of the tongue respond uniquely to one particular taste. This older view has been revised in recent research. In fact, all areas of the tongue are able to detect the 5 basic tastes.
- Specifically, each taste bud contains some proportion of all 5 taste receptors.
- From each of these taste receptor cells, afferent neurons send signals to the brain for processing, to create your perception of taste.
- The mechanisms by which these signals are transduced at the levels of the taste receptor cells is still a major topic of research in neuroscience today.

Pathways to Taste:

- After a taste receptor cell fires an action potential, the information is sent from the main gustatory nerve to the brainstem, where it diverges into two main pathways.
- See image on next page.

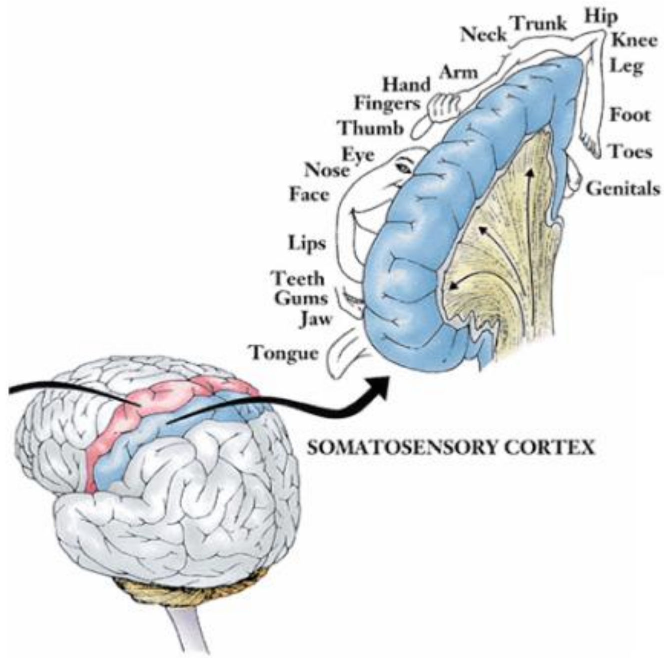


- One pathway travels through the medulla to the thalamus, from which the information is sent to both the primary somatosensory cortex and the gustatory cortex. (See image below).



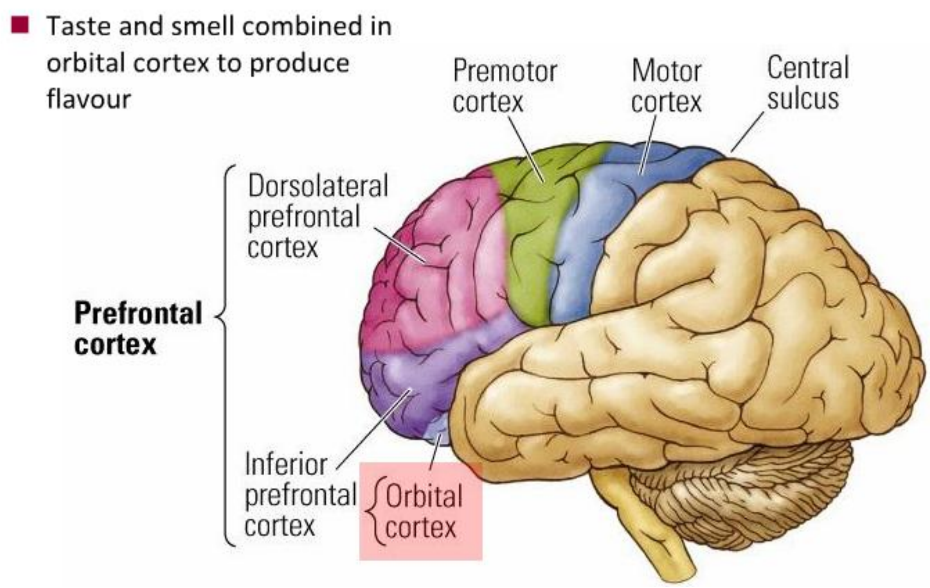
Taste and the Somatosensory Cortex:

- In the primary somatosensory cortex, the feel and texture of the food in your mouth is processed, along with where on the tongue the taste is sensed.
- See image on next page.



Taste and the Gustatory Cortex:

- The gustatory cortex is the primary taste area of the brain, with sets of neurons that respond to each of the 5 basic tastes.
- The gustatory cortex passes information to the orbital cortex, which is near the region where olfactory information enters the olfactory cortex.
- This is where smell and taste information is combined to result in flavour. (See image below.)



The Second Pathway:

- The second pathway of information traveling from the brainstem goes on to the pons, and from there, to the hypothalamus and amygdala.
- This second pathway is thought to be involved in other aspects of feeding behaviour such as satiety which complements the actions of the CCK mechanism of satiety discussed earlier.

The Nose and Taste:

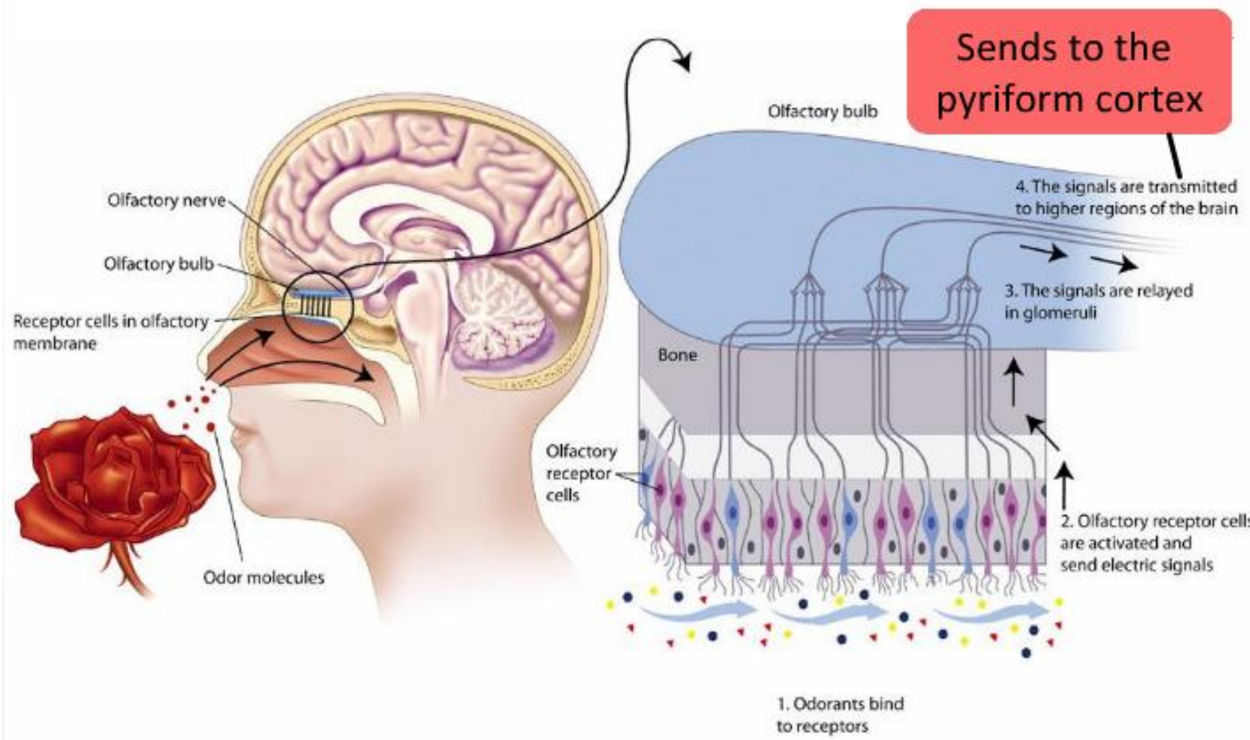
- Why can't you tell the difference between two jellybeans with your nose plugged?
- To answer this question, you must distinguish between taste and flavour Molecules from the two jellybeans would bind with receptors on taste receptor cells that detect sweetness.
- The subtle differences between the 2 jellybeans ns are not perceived by the taste buds, and instead broadly categorized as the taste of "sweet".
- Your more sophisticated ability to sense flavour comes from an interaction with taste and smell that occurs in the nasal pharynx at the back of the throat.
- It is here that the subtleness of the orange, lemon or toasted marshmallow comes out.
- When your nose is blocked, either by pinching it or by stuffed sinuses from a cold, the contribution of smell is reduced. (See image below.)
- You're left with the only the taste of food and deprived of its flavour.

How Smell is Processed in the Brain:

- Humans are certainly less adept at smell compared to some other mammals, but nevertheless, the range of the human sense of smell is still quite impressive.
- While you can distinguish up to 10,000 different smells, your deficit likely lies more with labelling these smells.
- Humans often have difficulty with naming all the different smells that can be detected.

Critical Nature of Smell:

- Of the five senses, your sense of smell is unique in that it has a direct link to the cortex, without being routed through the thalamus first.
- This may be because smell is an important system for alerting you to significant events in the environment.
- Even more so than visual stimuli or sounds, airborne molecules that you perceive by smell can communicate information over extremely long distances; this can have advantage for finding food and mates or avoiding potential predators.



Olfactory Receptor Cells:

- Like the receptors for your other senses, olfactory receptor cells respond to a range of stimuli. A specific smell does not activate a unique receptor cell, but rather activates a unique pattern of firing across receptors.
- Once an action potential is triggered in an olfactory receptor cell, it travels down the axon and synapses with cells in the olfactory bulb of the brain.
- Here, the cells form synapses with dendrites of other cells called glomeruli, each of which receives input from thousands of olfactory receptor cells.
- The output from the glomeruli is sent to different areas of the brain, most of which goes to the hypothalamus and areas of the limbic system that deal with basic drives and emotions.
- Some of the output also goes to the primary olfactory cortex in the temporal lobe, as well as the secondary olfactory cortex in the frontal lobe. (See image below.)