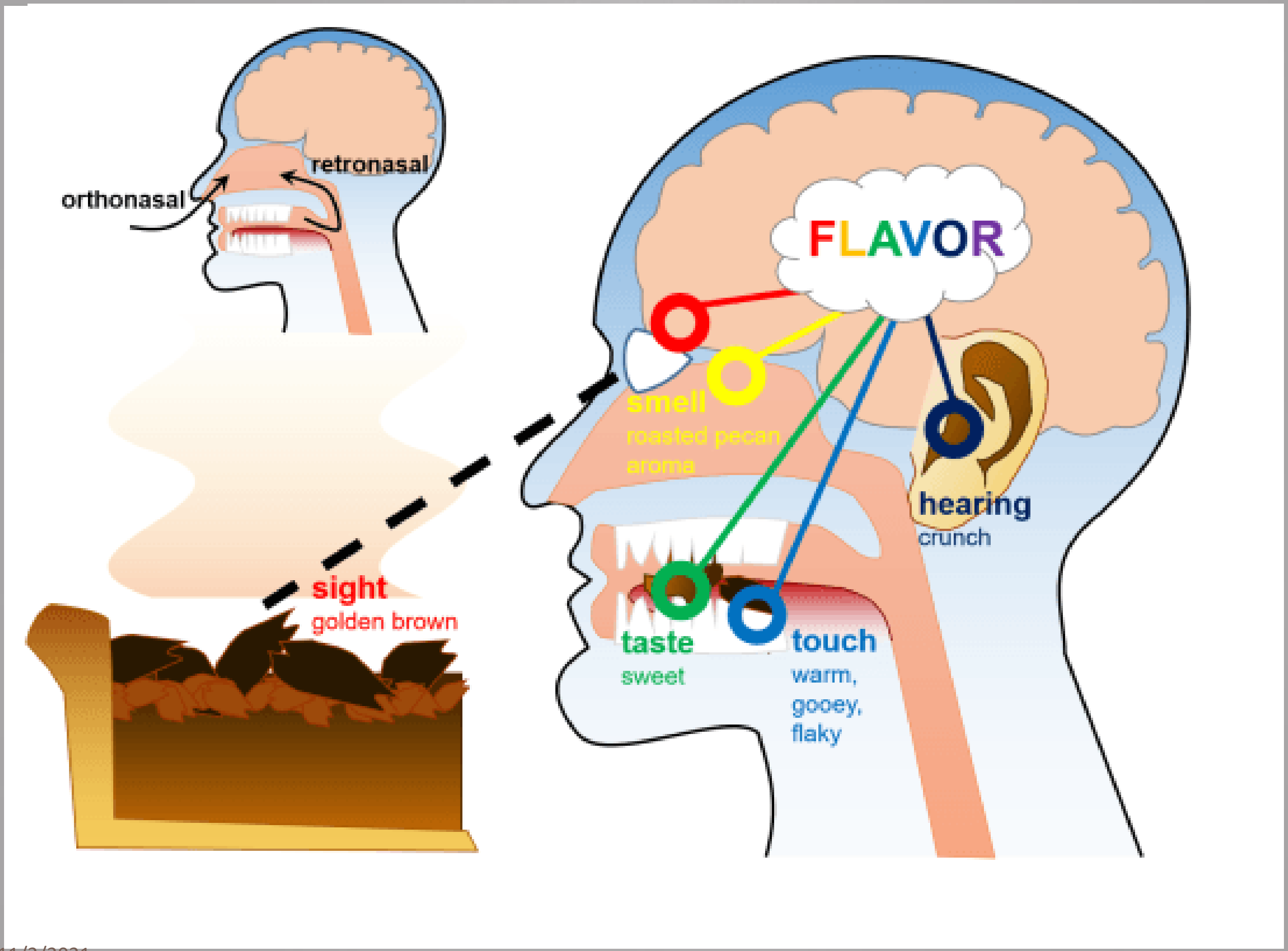
Selected Topics from Food Chemistry

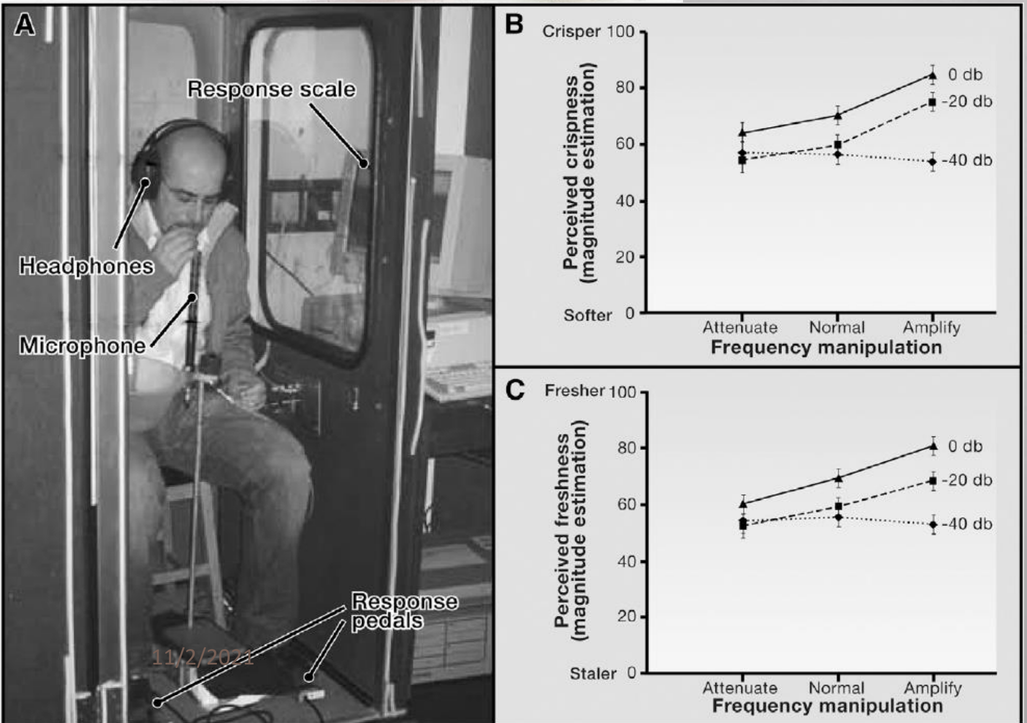
Food Flavor

Flavor =Texture + Smell + Taste + ?



Auditory Contributions

- Responsible for the following food attributes; crunchy, crispy, crackly, carbonated and creamy
- Perception of ripeness in apples
- Generates expectations about the food
    - Disconfirmations about expectations generates negative perceptions



- Researches found a 15% increase in the perceived crispness and freshness of potato chips when playing crisp biting sounds

Visual Contributions

Figure 2 Meret Oppenheim's [26] *Fur Covered Cup* (1936). Most people find the idea of putting their lips to such a textured cup rather off-putting. Just one extreme example, then, of how the texture of the plateware may affect us. (Picture downloaded from http://www.moma.org/collection/browse_results.php?object_id=80997 on 27 September 2012).

Experience in Food through Our Senses

<u>Familiar senses:</u>

Touch (pressure) and temperature (somatoreceptros are responsible to identify outside and inside our body and to formulate body action)

sight, hearing, taste, and smell

<u>Less familiar:</u>

Chemesthesis

Experience in Food through Our Senses

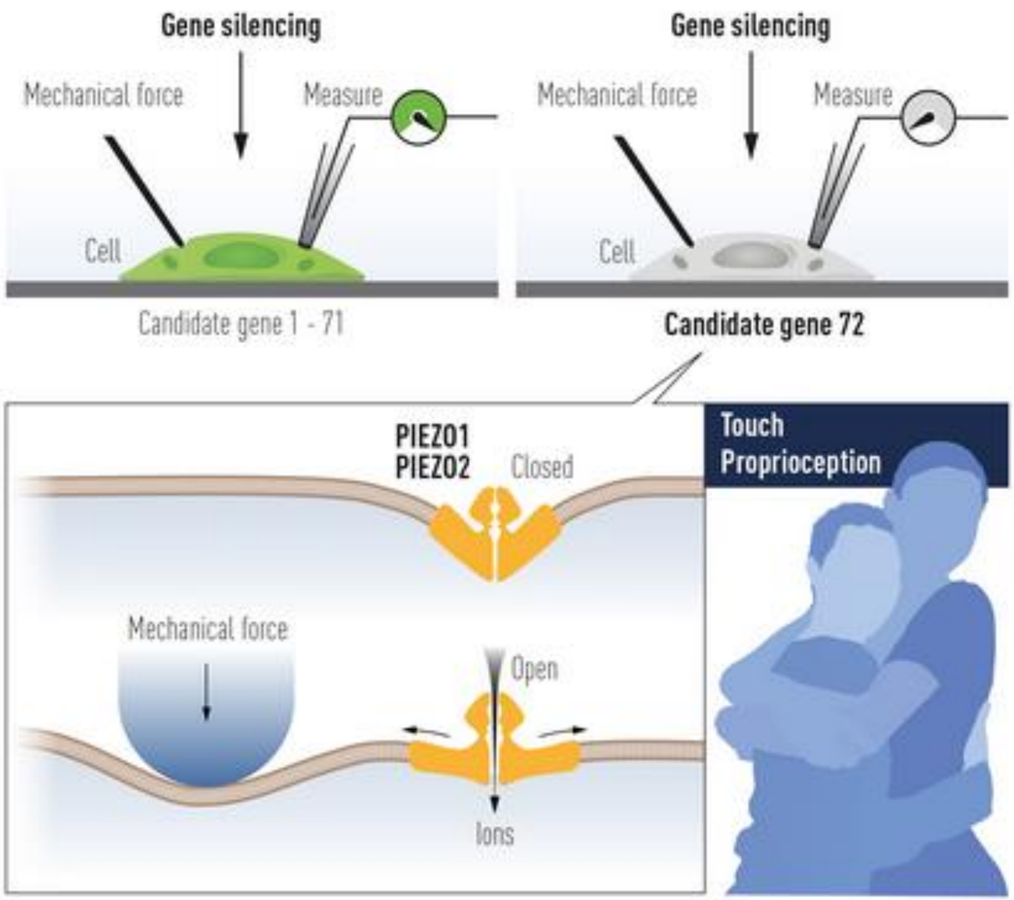


Figure 3 Patapoutian used cultured mechanosensitive cells to identify an ion channel activated by mechanical force. After painstaking work, Piezo1 was identified. Based on its similarity to Piezo1, a second ion channel was found (Piezo2).

The very same mechanosesitive receptors are involved in our food perception.

Chemesthesis

Defined as the chemical sensibility of the skin and mucous membranes.

Chemesthetic sensations arise when chemical compounds activate receptors associated with other senses that mediate touch, and thermal perception. Chemical compounds activate somatoreceptors.

Temperature sensitive receptors are the ones that response also to capsaicin or to menthol creating sensation of hotness or coldness.

Experience in Food through Our Senses

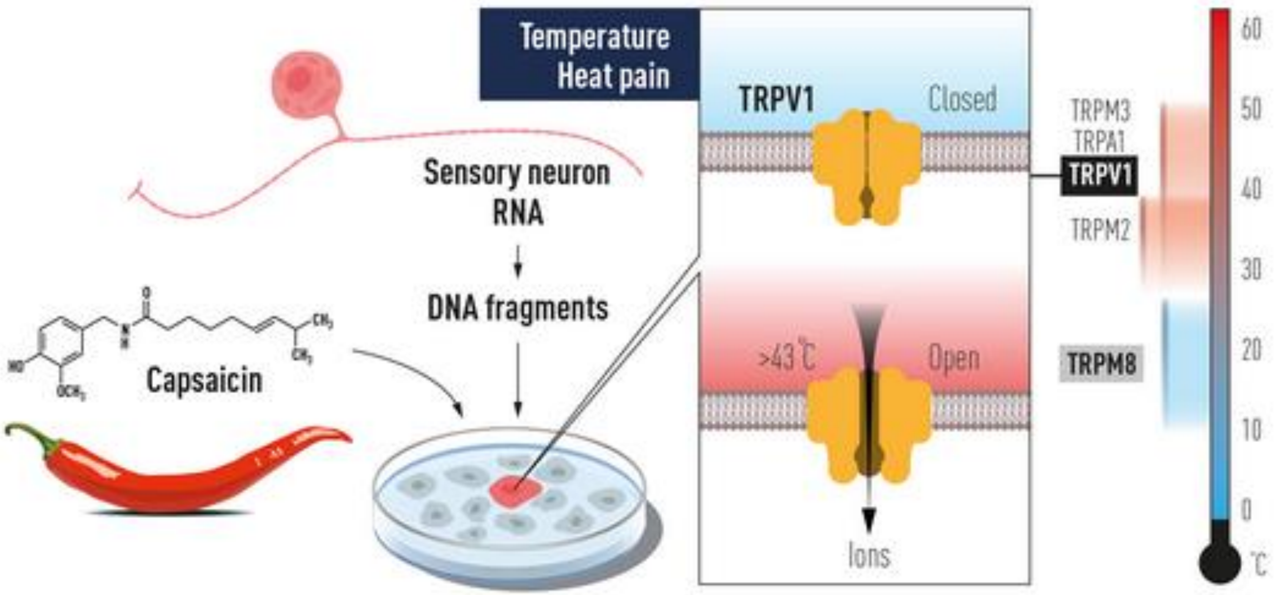


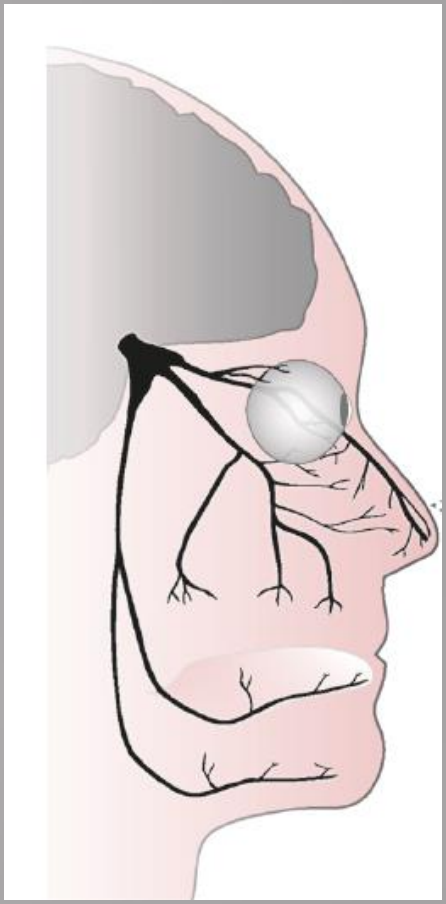
Figure 2 David Julius used capsaicin from chili peppers to identify TRPV1, an ion channel activated by painful heat. Additional related ion channels were identified and we now understand how different temperatures can induce electrical signals in the nervous system.

Hot or Spicy, Pungency Sense

Pungency is the condition of having a strong, sharp smell or flavor that is often so strong that it is unpleasant. Pungency is the technical term used by scientists to refer to the characteristic of food commonly referred to as spiciness or hotness and sometimes heat, which is found in foods such as chili peppers.

Hot or Spicy, Pungency Sense

- Sensory endings covering the face, the mucous membranes of the nasal and oral cavities, and the lining of the eye.
- These endings can be activated by physical stimuli (mechanical forces and temperature) and by a huge array of chemical agents.
- These stimuli evoke sensations of touch, temperature, and pain.



Type of Receptors Involved in Food Perception

- Mechanoreceptors are responsive to any kind of mechanical skin deformation;
- Thermoreceptors are responsive to changes in skin temperature;
- Nociceptors are detecting painful stimuli;
- Photoreceptors.

- Chemoreceptors are sensing chemical environment.

Chemoreceptors are sensing chemical environment.

Smell and taste

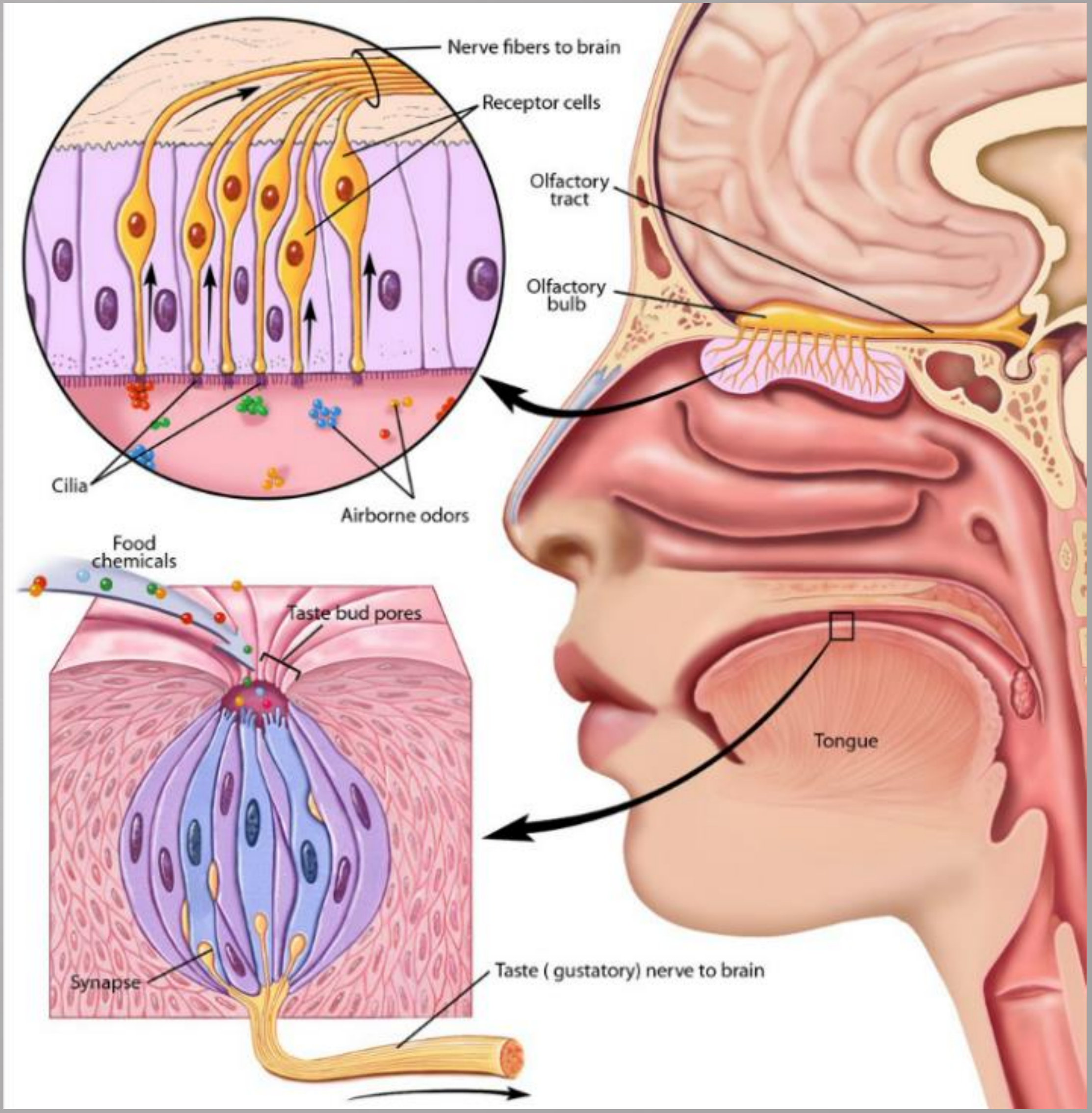
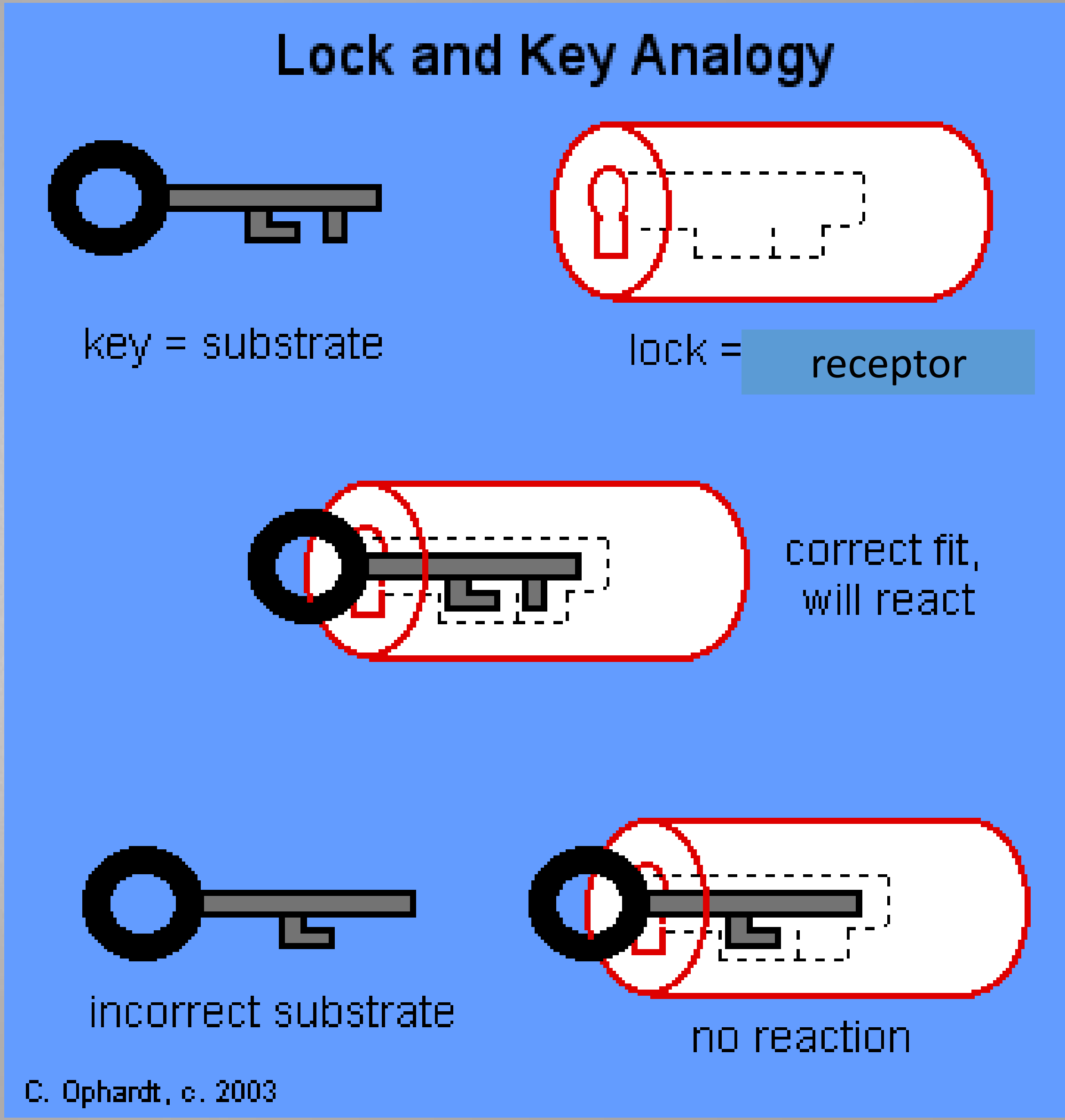


Illustration by Lydia V. Kibiuk, Baltimore, MD; Devon Stuart, Harrisburg, PA

Smell and Taste Receptors: What is in Common?

- Signaling molecules are binding to the specific chemoreceptors- STEREOSPECIFICITY
- Chemoreceptors recognize molecules at extremely low concentrations – SENSITIVE
- Chemoreceptors "inform" the brain about the events through transduction mechanism. (Stimuli recognition event is translated to graded receptor potential = nerve impulse).

How Chemoreceptors Recognize Chemicals, Key-Lock Concept, Specific Fit.



Smell

Olfactory System

- Smell of food is very important for overall perception of this food,
- Particular odors associate with memories, emotions, and mood (We remember odors very well),
- Although olfactory system is less important than hearing or vision for the human adults.

Sense of Smell

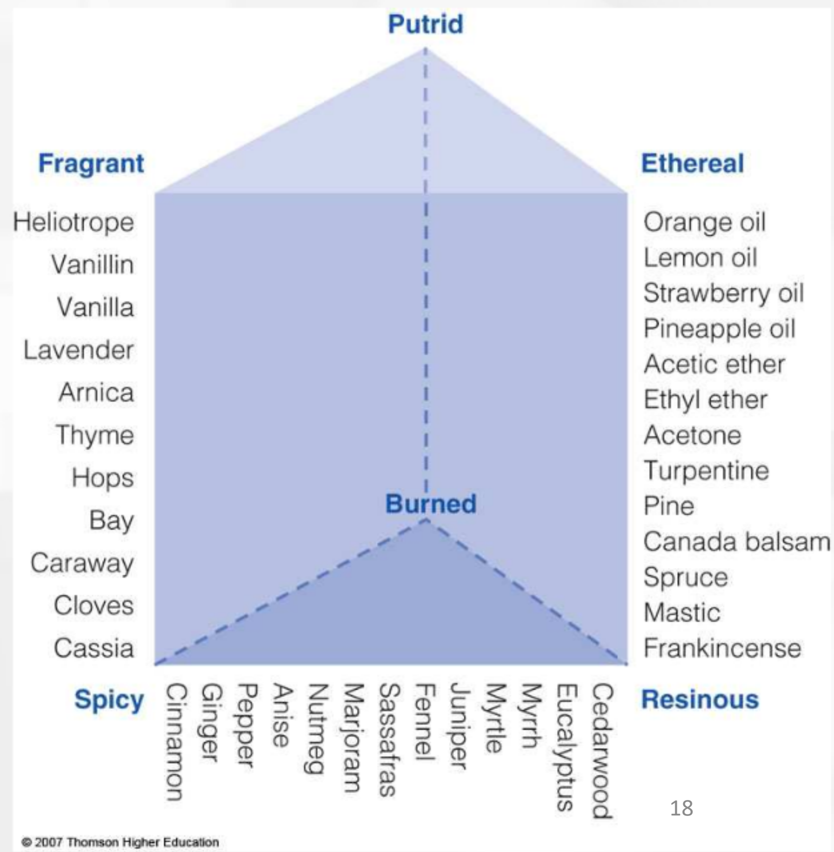
- The receptors of the olfactory system detect molecules in the air.
- The range of receptors provides a wide sensitivity to volatile molecules.
- Some of the most potent thiols can be detected in concentrations as low as 6×10^7 molecules/ml air (2-propene-1-thiol)
- Ethanol requires around 2×10^{15} molecules/ml air.
- The sensitivity of the sense of smell varies quite significantly between individuals.
- People can be trained to become sensitive to some odorants.
- The sense of smell develops during the human lifetime;
- We tend to lose sensitivity at an older age, especially after the seventh decade.

Smell

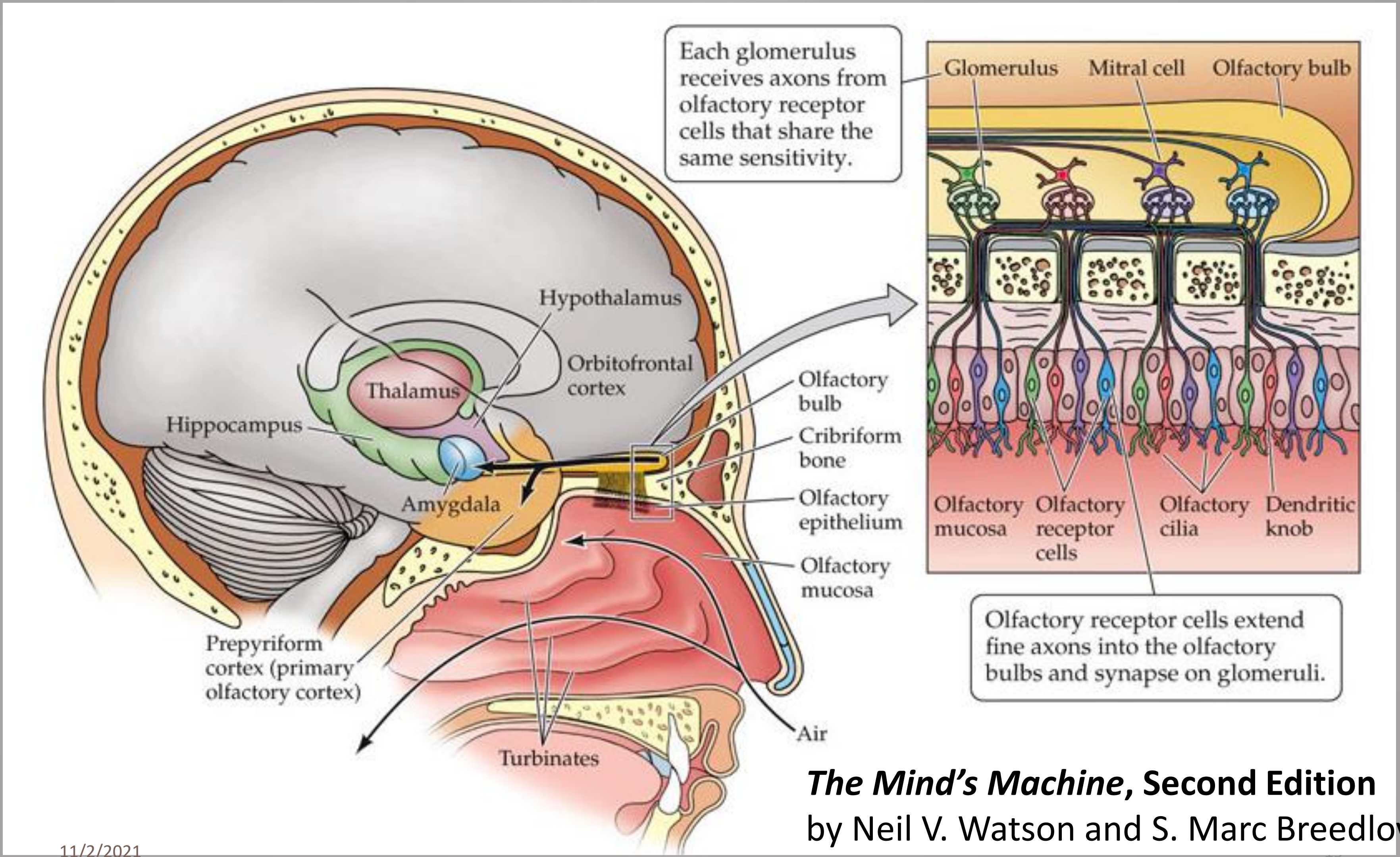
“Did you ever try to measure a smell? Can you tell whether one smell is just twice as strong as another. Can you measure the difference between one kind of smell and another. It is very obvious that we have very many different kinds of smells, all the way from the odor of violets and roses up to asafetida. But until you can measure their likenesses and differences you can have no science of odor. If you are ambitious to found a new science, measure a smell.” Alexander Graham Bell, 1914

Henning’s odor prism (1916)

- 6 corners with the qualities putrid, ethereal, resinous, spicy, fragrant, and burned
- Other odors located in reference to their perceptual relation to the corner qualities
- Unfortunately, Henning’s prism has proven of little use in olfactory research



Olfactory System



***The Mind's Machine*, Second Edition**
by Neil V. Watson and S. Marc Breedlove

Olfactory Cells

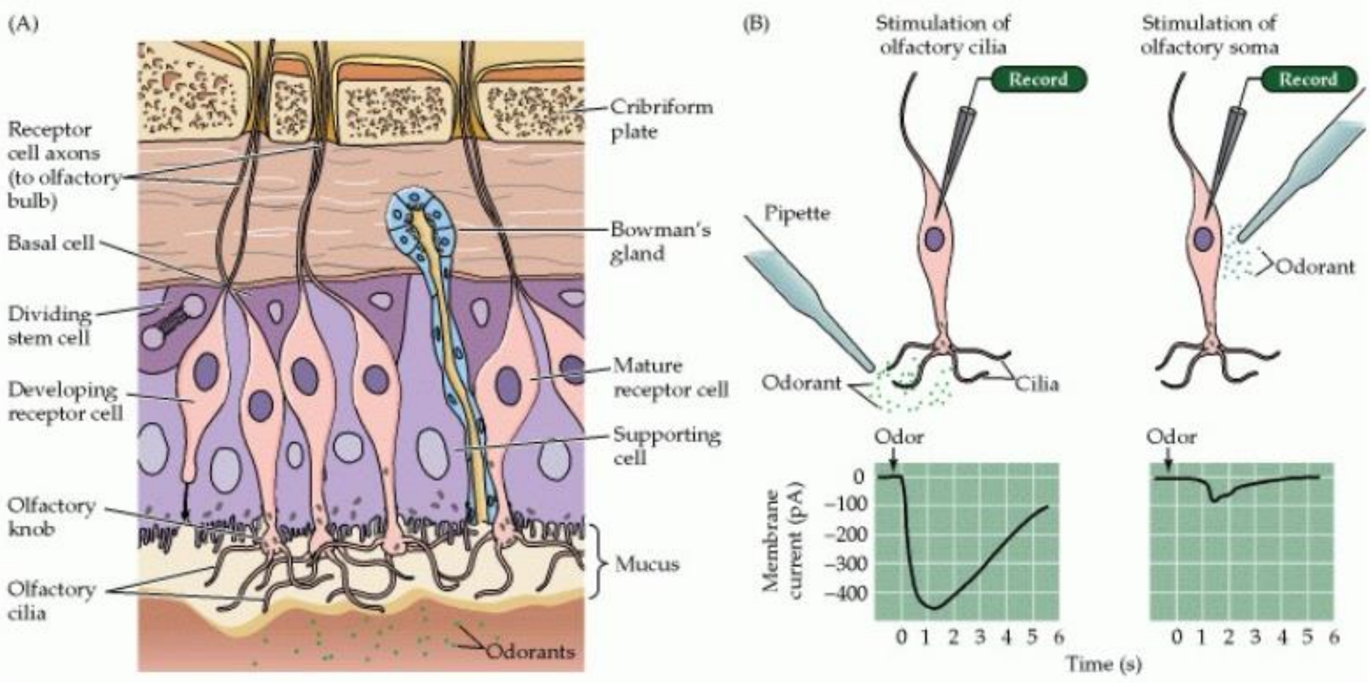


Figure 15.5

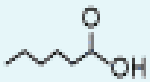
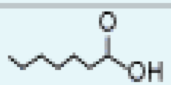
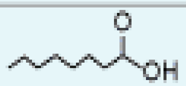
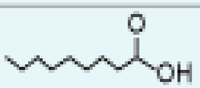
Structure and function of the olfactory epithelium. (A) Diagram of the olfactory epithelium showing the major cell types: olfactory receptor neurons and their cilia, sustentacular cells (that detoxify potentially dangerous chemicals), and basal cells. Bowman's glands produce mucus. Nerve bundles of unmyelinated neurons and blood vessels run in the basal part of the mucosa (called the lamina propria). Olfactory receptor neurons are generated continuously from basal cells. (B) Generation of receptor potentials in response to odors takes place in the cilia of receptor neurons. Thus, odorants evoke a large inward (depolarizing) current when applied to the cilia (left), but only a small current when applied to the cell body (right). (A after Anholt, 1987; B after Firestein et al., 1991.)

Nature's Chemical Signatures in Human Olfaction: A Foodborne Perspective for Future Biotechnology

Andreas Dunkel, Dr. Martin Steinhaus, Matthias Kotthoff, Bettina Nowak, Priv.-Doz. Dr. Dietmar Krautwurst, Prof. Dr. Peter Schieberle and Prof. Dr. Thomas Hofmann
Angewandte Chemie, Volume 53, Issue 28, p. 7124

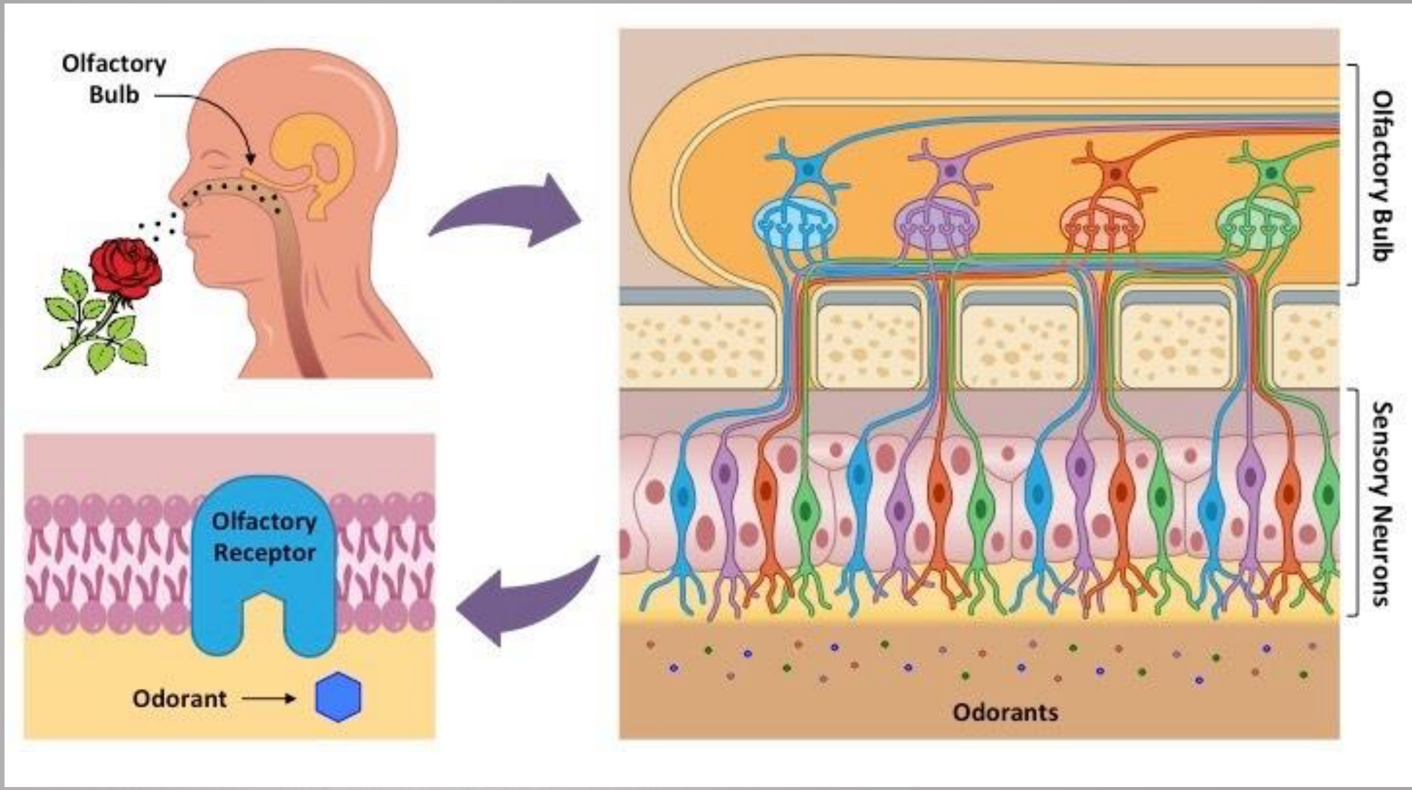
- Humans are unable to identify individual odorants in a mixture.
- Humans can easily discriminate mixtures from each other.
- Evidence was found that the identification and discrimination of complex olfactory stimuli rely on the formation and modulation of such "odor objects" in the piriform cortex (region of the brain).
- Artificial re-engineering of such complex olfactory objects by using synthetic blends of 3, 12, 27, and 28 odor-active key molecules was convincingly demonstrated to reconstruct the authentic chemosensory percept of, for example, sour-cream butter, fresh strawberry, Arabica coffee, and red wine, respectively.
- On the other hand, compound mixtures showed an increasingly similar smell with increasing the number of their components.
- Odorant mixtures comprising more than 30 volatiles were reported to reach a generic quality coined "olfactory white" under two conditions; first, when the mixture components span olfactory space and, second, when the individual odorants are of equal intensity.

Combinatorial Receptor Codes

Odorant receptors	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Odorants															**Description**
A 					●										rancid, sour, goat-like
B 		●				●									sweet, herbal, woody
C 	●			●	●		●			●	●				rancid, sour, sweaty
D 		●			●	●									violet, sweet, woody
E 	●			●	●		●	●		●	●	●			rancid, sour, repulsive
F 				●	●		●			●					sweet, orange, rose
G 	●			●	●		●	●		●		●		●	waxy, cheese, nut-like
H 				●	●		●			●		●			fresh, rose, oily floral

MODIFIED AFTER LINDA BUCK AND COLLEAGUES IN CELL VOL 96, MARCH 5, 1999

One Type of Odorant Receptor in Each Olfactory Receptor Cell



- Every single olfactory receptor cell expresses one and only one of the odorant receptor genes.
- There are as many types of olfactory receptor cells as there are odorant receptors.
- Each cell reacts to several related odorant molecules – although with varying intensity.

Olfactory System is Different from All Other Sensory System

- Olfaction is the only modality that directly connected to the brain. Olfactory cells are neurons.
- Total number of receptors (number of olfactory cells in nasal cavity) is about 10 millions.
- Olfactory neurons have a shot life 30-60 days and are constantly replaced by mitotic division.

Taste

Flavor =Taste + Smell + Texture ?

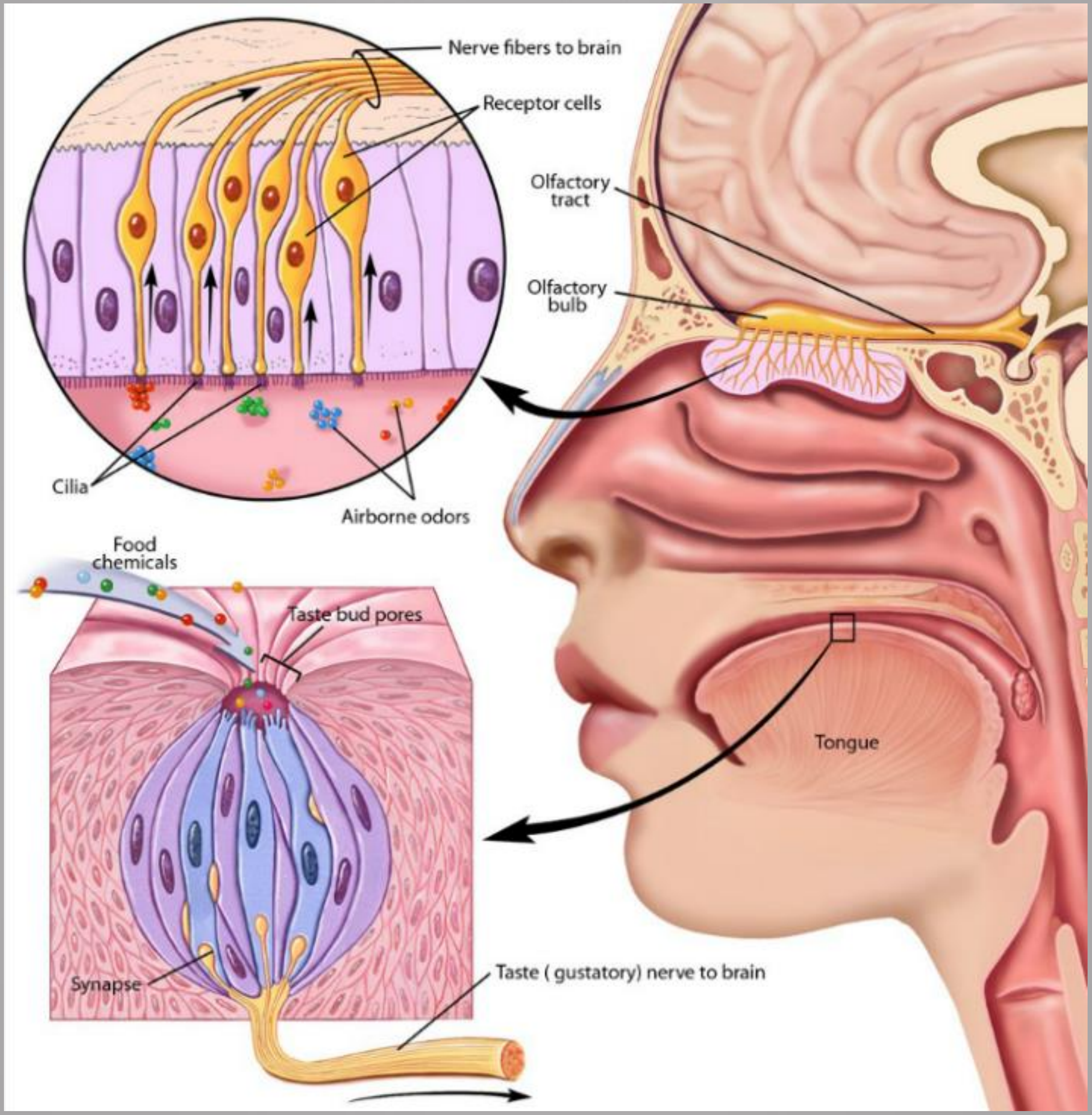
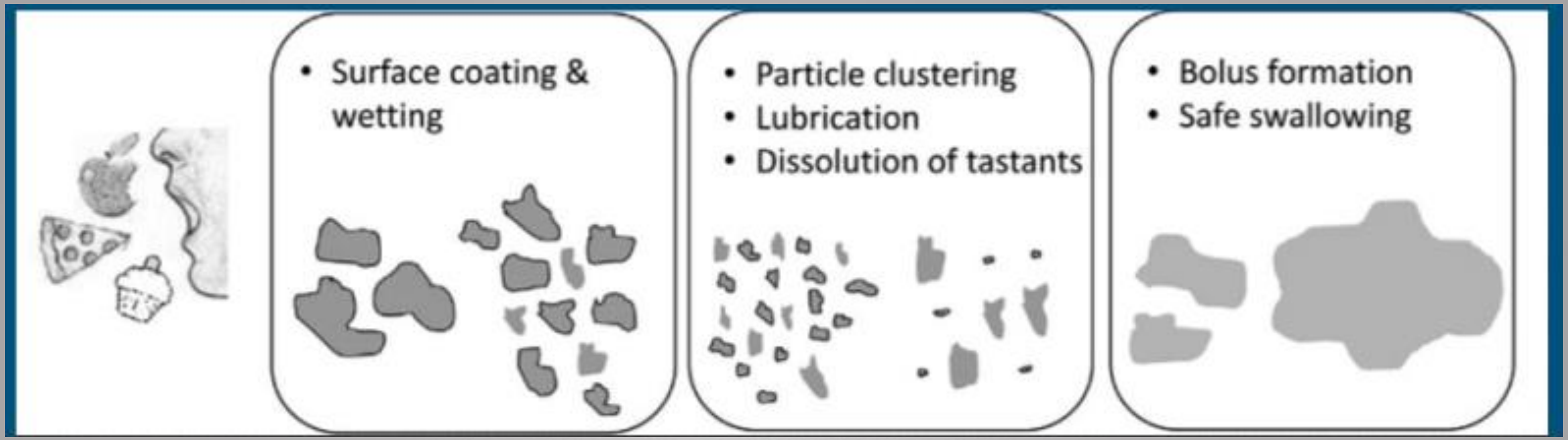


Illustration by Lydia V. Kibiuk, Baltimore, MD; Devon Stuart, Harrisburg, PA

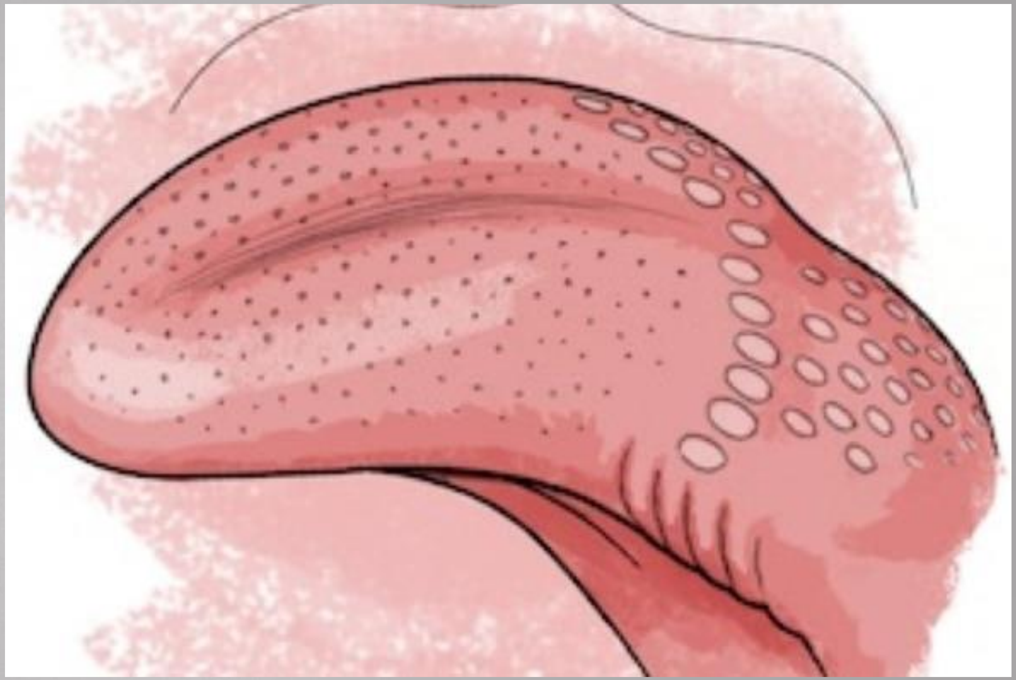
Oral Processing, Texture and Mouthfeel



- Fragmenting solid food to small particle sizes,
- Mixing with saliva,
- Forming a bolus that is then swallowed and transferred to the stomach,
- The organoleptic properties of food, including texture perception, should depend on the constantly changing status of the food during oral processing, and the changing status of the salivary film coating oral surfaces and saliva itself.

Taste

- Sweet
- Salty
- Sour
- Bitter
- Umami
- Fatty
- ?



Counting Fungiform Papillae in one Paper hole reinforcer.

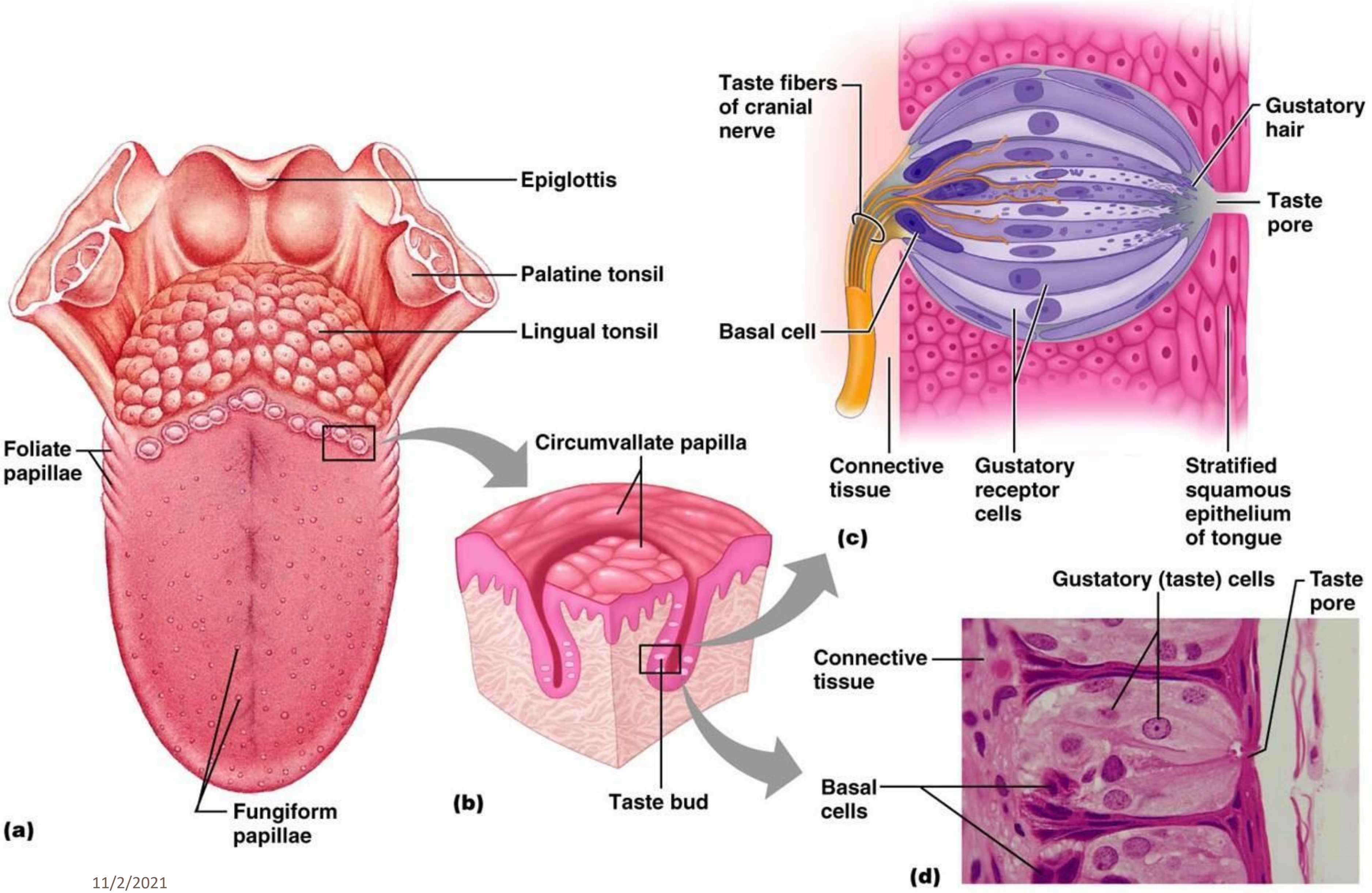
- Have more than about 30 fungiform papillae - supertaster,
- Have around 15 to 30 papillae - an average taster,
- Have fewer than 15 papillae - a non-taster.

- Around 25 to 30 percent of people are thought to be supertasters,
- 40 to 50 percent average tasters,
- And 25 to 30 percent non-tasters,
- Around 35% of women are super-tasters, compared with just 15% of men, US research has shown.

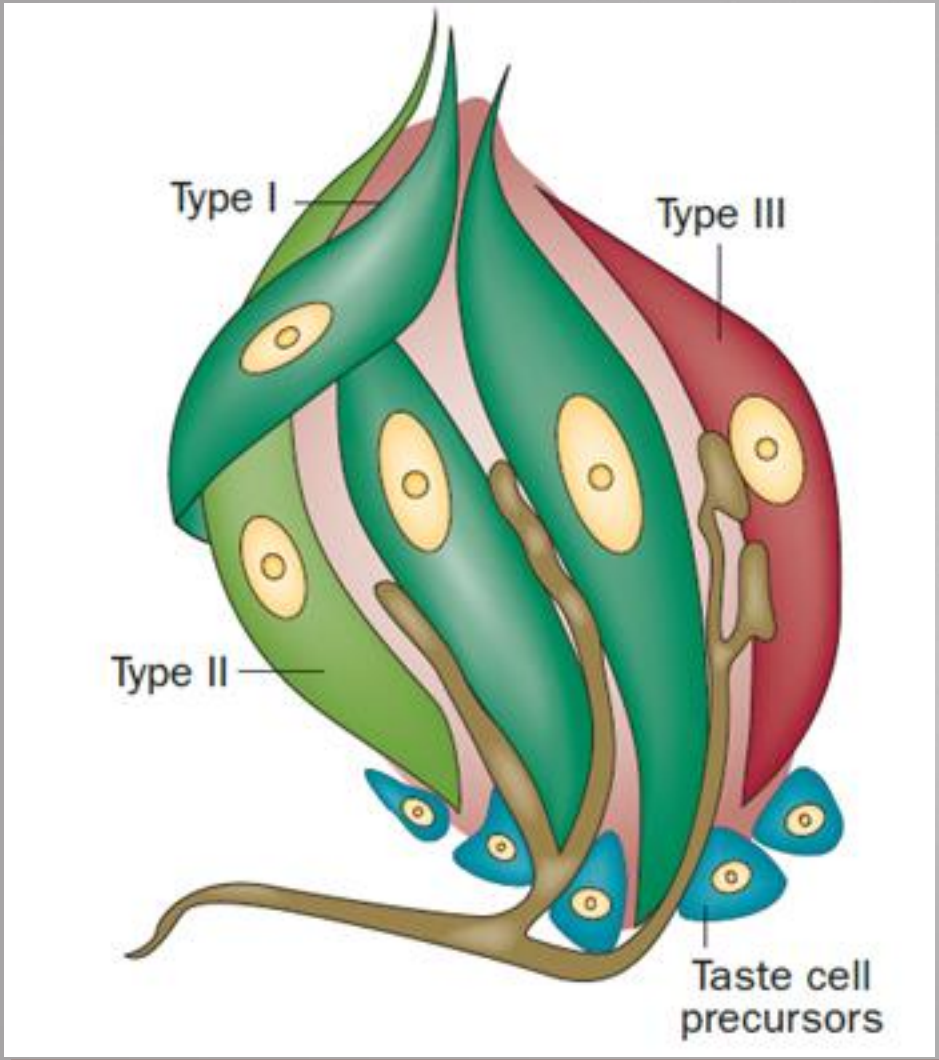
Five Basic Tastes and Human Sensation Thresholds

Taste	Substance	Threshold for tasting
Salty	NaCl	0.01 M
Sour	HCl	0.0009 M
Sweet	Sucrose	0.01 M
Bitter	Quinine	0.000008 M
Umami	Glutamate	0.0007 M

Taste Bud Cells



Taste Bud Cells



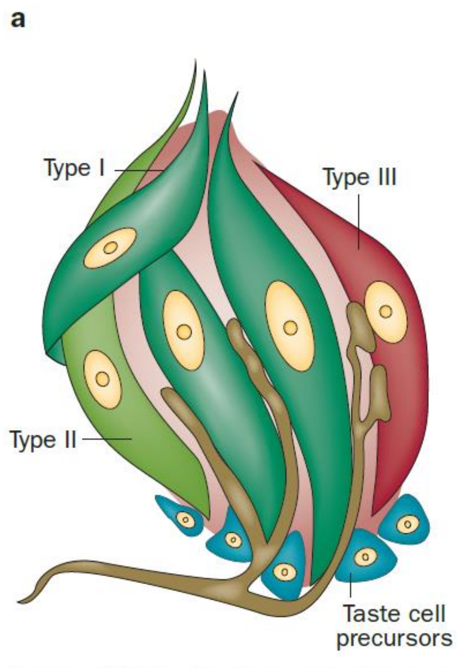
NATURE|Vol 444|16 November 2006|**doi:10.1038/nature05401**

Type I, supportive cells, hold the shape of the taste bud. Make approximately 50% of the total number of taste bud cells.

Type II, receptor cells. Express receptors for sweet, umami and bitter tastants.

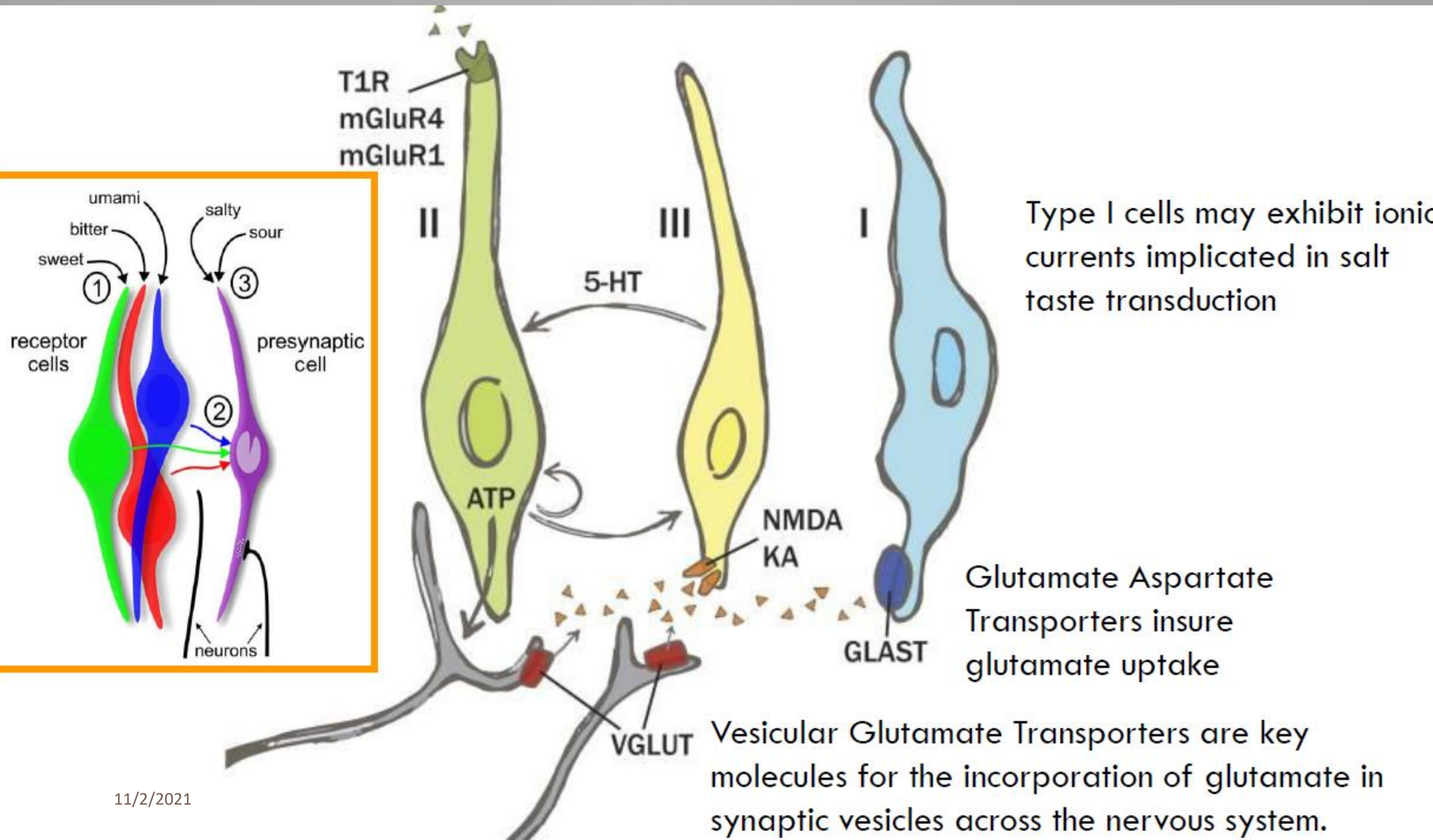
Type III, sensitive to sour taste and may be taste of fats

Type IV Taste Bud Cells or Basal Cells



- A small heterogeneous group of cells located toward the base of the taste bud structure.
- These cells were initially thought to be the exclusive progenitor cells for the differentiated taste bud cell types; however, it is no longer thought that the taste bud cell stem cells locate solely at the base of the taste bud.

Taste Bud Cells’ Communication



When the Compound Become Taste Primary

It is when it belongs to the class of affective stimuli:

- Existence of receptors specific for the class of stimuli on taste bud cells (TBC),
- TBC transmit signals to afferent nerves by way of synapses between taste cells and primary afferent sensory fibers to taste-processing regions of the brain,
- Perception independent of other taste qualities,
- Downstream physiological effects.

Bitter Taste

Bitter Taste

- Bitter taste is detected by a family of approximately three-dozen G-protein coupled receptors, the T2Rs.
- Each type II taste bud cells expresses either the T1Rs or specific members of the T2R family and, therefore, responds exclusively to either sweet and umami, or bitter tastants.

Bitter Taste Receptors and Innate Immunity

- Bitter taste receptors have been associated with sinonasal innate immunity, and with variation in upper respiratory tract pathogen susceptibility, symptoms, and outcomes.
- Bitter taste receptor phenotype appears to be associated with the clinical course and symptom duration of SARS-CoV-2 infection.

The discrimination of Bitter Taste

- Taste receptor type 2 (T2R) family members comprise a large group of taste G protein-coupled receptors (GPCRs) that detect bitter compounds;
- There are more than 40 T2R family members in rodents and 25 functional genes in humans.
- Recent studies that have systematically used numerous probe combinations on human taste buds have shown that chemosensory taste bud cells co-express overlapping subsets of 4–11 T2Rs and not the entire family.
- It is currently not known whether each T2R is expressed in a predictable combination with others or is expressed randomly.

Nature Reviews Neuroscience 18, 485–497 (2017) doi:10.1038/nrn.2017.68

Brussels Sprouts and Broccoli

- Variation in the genes that encode taste receptors probably generates different taste sensitivities among individuals.
- Individuals find PTC (phenylthiocarbamide) extremely bitter, moderately bitter or nearly tasteless.
- Genetic analyses of human populations in Africa, Asia and Europe suggest that PTC-taster and non-taster alleles of *TAS2R38* have been maintained by natural selection across more than 100,000 years of human evolution.
- The PTC-taster allele of *TAS2R38* encodes a receptor that detects a range of natural bitter compounds, some of which are toxic and others of which are beneficial.

Umami Taste

Umami Taste

- Heteromeric complex of T1R1 and T1R3 receptors mediates umami taste perception in mammals.
- It exhibits species-dependent differences in ligand specificity;
- Human T1R1/T1R3 specifically responds to monosodium glutamate,
- Mouse T1R1/T1R3 responds more strongly to other L-amino acids.

Monosodium Glutamate

In 1908, over a bowl of seaweed soup, Japanese scientist Kikunae Ikeda asked a question: what gave dashi, a ubiquitous Japanese soup base, its meaty flavor? In Japanese cuisine, dashi, a fermented base made from boiled seaweed and dried fish. It is meatless foods like vegetables and soy.

Ikeda was able to isolate the main substance. He then took the seaweed and ran it through a series of chemical experiments, using evaporation to isolate a specific compound within the seaweed. After days of evaporating and treating he saw the development of a crystalline form. When he tasted the crystals, he recognized the distinct savory taste that dashi lent to other foods.

He determined the molecular formula of the crystals: C5H9NO4, the same as glutamic acid. In the body, it is often found as glutamate. It is one of the most abundant excitatory neurotransmitters in brain, playing a crucial role in memory and learning. The FDA estimates that the average adult consumes 13 grams of it a day from the protein in food.

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