Outline of Sense of Taste
November 6, 2014

Contents

1. Physical properties

Tastable molecules include hydrogen ions, hydroxide ions, salt ions, and sugars, which are water-soluble and have molecular weights less than 200. Water-soluble molecules vary in size, shape, chemical sites, acidity, and ionicity. Water-soluble chemicals vary in concentration. Tastable molecules attach to tongue chemical receptors.

2. Anatomy

Taste anatomy includes tongue, taste buds, chemical receptors, and neurons. Tongue chemical receptors send to thalamus, which sends to cortical regions.

2.1. Tongue

Tongue has bumps {papillae} of four types.

Circumvallate papilla are largest, are large circular mounds with depressed circumference, have three to five taste buds, and are before tonsils on tongue rear sides.

Filiform papilla are smallest, are most, have no taste buds, and are down tongue top middle.

Foliate papilla are medium-size, have taste buds, and are tissue folds at tongue rear and outsides.

Fungiform papilla are next smallest, are one-millimeter-size mushroom shapes, have six taste buds each, and are at tongue tip, edges, and broad part.

2.2. Taste buds

Tongue and soft-palate have hemispherical cell clusters {taste bud}. Adult tongue has 10,000 taste buds (babies have more). Taste buds last one week, and then fade as new ones grow.

Taste buds hold taste receptor cells that have tips with projections {microvilli} that extend into taste pore.

All taste buds have salt, sweet, and sour receptor types (so tongue has no special salt, sweet, or sour regions).

2.3. Receptors

Tongue receptors chemically bind to water-soluble molecules with molecular weights less than 200: hydrogen ions, hydroxide ions, salt ions, sugars, or amino acids. Receptor cells have 50 chemoreceptors, all of the same receptor type.

T1R proteins make cell-membrane taste chemoreceptors. Sweet receptor has one T1R2 and one T1R3 protein. Umami savory receptor has one T1R1 and one T1R3 protein. Bitter receptor has 25 possible proteins.

Tongue chemical receptors are mainly for sweet, sour, salty, bitter, and L-glutamate. Each has variations, making dozens of combinations.

Salt receptors detect positively charged salt ions, including sodium and potassium ions. Positive ions enter ion channels and directly cause depolarization.

Sour receptors detect acids. Hydrogen ions enter ion channels, block potassium channels, or bind to and open other positive-ion channels.

Sweet receptors detect non-ionic organic compounds, mostly sugars. Sweet receptors couple to G-proteins, and second messengers close potassium channels.

Thirty different bitter receptors detect non-ionic organic compounds, such as alkaloids, including quinine and unripe-potato alkaloid {solanine}. Bitter receptors couple to G-proteins. Second messengers release calcium ions from endoplasmic reticulum.

L-glutamate receptors {umami receptor} are metabotropic receptors similar to brain glutamate receptors and underlie savory taste [Ikeda, 1909]. Glutamate receptors couple to G-proteins, which have unknown second messengers.

Other amino-acid receptors are altered sweet receptors that bind amino acids. Other amino-acid receptors couple to G-proteins, which have unknown second messengers.

2.4. Neurons

Taste neurons typically receive from more than one taste-receptor type, but detect one main taste category: salt-best, sugar-best, acid-best, and bitter-best.

All bitter-receptor types synapse on same taste-neuron type (so people cannot discriminate among bitters).

Medulla solitary tract nucleus receives from tongue cranial nerves 7, 9, and 10, and sends to thalamus and to parabrachial nucleus (which also receives from GI tract).

Taste cortex is in insula, which sends to orbitofrontal cortex.

3. Physiology

Taste detects and measures relative concentrations of acid, base, salt, sugar, L-glutamate, and other amino acids. For example, salt taste receptors measure salt concentration as salt-to-receptor binding per second. People can distinguish hundreds of flavors.

Because signals from similar receptors go to same-type taste neuron, similar taste sensations vary only in intensity, not in quality.

Taste habituates quickly.

Tongue taste-receptor pattern affects taste.

If a new flavor associates with gastrointestinal illness, people are averse to the flavor {learned taste aversion}.

3.1. Taste zero

Taste stimulus of salt, acid, base, or sugar at same concentration as saliva concentration is tasteless {taste zero}. To have taste, salt, acid, base, or sugar must have higher concentration than saliva concentration.

Saliva substance concentrations vary during the day. For example, saliva salt concentration is highest in morning, drops until afternoon, and then rises again to high morning value, so salt amount needed for salt taste varies over the day. Concentrations can be up to ten times lowest concentration.

3.2. Neurons

Taste neurons inhibit and excite each other to compare sugar, acid, base, salt, and L-glutamate receptor inputs to find differences and indicate taste types [Kadohisa et al., 2005] [Pritchard and Norgren, 2004] [Rolls and Scott, 2003].

Tastes are relative. For example, salt only tastes salty relative to other tastes [Brillat-Savarin, 1825].

3.3. Salty

Salty chemicals are small and ionic and have neutral acidity. Sodium-chloride sodium ions make pure salt taste. Potassium-chloride potassium ions make salt and bitter taste.

Newborns do not taste salt, but babies soon can taste it, and they like it.

Perhaps, salt receptors evolved because animals need sodium and need associated chloride.

(Glasorisic acid increases sodium-ion retention.)

3.4. Sour

Sour receptors detect acids. Hydrogen ions enter ion channels, block potassium channels, or bind to and open other positive-ion channels.

Sour chemicals are small, ionic, and acidic. Hydrogen chloride makes pure sour taste.

Newborns can taste sour. Children like sour taste.

Perhaps, sour receptors evolved to detect food or dangerous acidic conditions.

3.5. Sweet

Sweet receptors detect non-ionic organic compounds, mostly sugars. Sweet receptors couple to G-proteins, and second messengers close potassium channels.

Sweet chemicals are large and polar and have neutral acidity. Glucose makes pure sweet taste. Fructose and galactose are sweet.

Temperature affects taste, so sweets taste less sweet when warm than when cold.

Newborns can taste sweet and think it pleasant.

Perhaps, sweet receptors evolved to detect sugar nutrients.

Asclepiad, similar to milkweed, inhibits tasting sweet. African miraculous berry makes everything taste sweet. Artificial sweeteners mimic sugar molecules.

3.6. Bitter

Thirty different bitter receptors detect non-ionic organic compounds, such as alkaloids, including quinine and unripe-potato alkaloid {solanine}. Bitter receptors couple to G-proteins. Second messengers release calcium ions from endoplasmic reticulum.

Bitter chemicals are small or large, ionic, and basic. Hydroxide ions make pure bitter taste.

Babies can taste bitter and think it aversive.

Perhaps, bitter receptors evolved to detect poisons.

For one-half to two-thirds of people, with dominant allele, urea compounds {phenylthiourea} (PTU) can taste bitter. PTU has no taste to other one-half to one-third of people, who cannot recognize NC=S chemical functional group [Kalmus and Hubbard, 1960].

6-n-propylthiouracil (PROP) tastes bitter. Supertasters have its chemoreceptors {6-n-propylthiouracil taste receptor}, have many fungiform papillae, and have high-intensity tastes. One-third of people cannot taste PROP, lack those receptors, have fewer fungiform papillae, and have low-intensity tastes.

Phenylthiocarbamide tastes bitter and is similar to propylthiouracil. One-third of people cannot taste it.

3.7. Umami

L-glutamate receptors {umami receptor} are metabotropic receptors similar to brain glutamate receptors and underlie savory taste [Ikeda, 1909]. Glutamate receptors couple to G-proteins, which have unknown second messengers. People with L-glutamate chemoreceptors can detect monosodium glutamate (MSG) and can distinguish umami savory taste from salt taste.

Savory chemicals are large, ionic-polar, and slightly acidic. L-glutamic acid sodium salt {monosodium glutamate} tastes distinctively salty and sweet.

Other amino-acid receptors are altered sweet receptors that bind amino acids. Other amino-acid receptors couple to G-proteins, which have unknown second messengers.

3.8. Acidity

Molecule atoms, bonds, and electric charge determine acidity, which can be acidic, neutral, or basic.

Sour is acidic. Salty is neutral acidity. Savory is neutral. Sweet is neutral. Bitter is basic.

Salty, savory, and sweet have similar neutrality.

Sour and bitter have opposite acidity.

3.9. Ionicity

Molecule atoms and bonds and molecule-electron properties determine ionicity, which can be ionic or polar.

Sweet and some bitters are polar. Salty, savory, sour, and some bitters are ionic.

Sour and sweet, salty and sweet, and savory and sweet have opposite ionicity.

3.10. Size

Sour and some bitters have similar small size.

Salts have medium size.

Sweet, savory, and some bitters have similar large size.

3.11. Polarity or Ionicity; Acidity, Neutrality, or Basicity; and Size

Taste molecules have a combination of polarity or ionicity; acidity, neutrality, or basicity; and size.

Taste molecules can be:

- acidic: hydrogen ion (sour)
- neutral: monosodium glutamate (savory)
- neutral: sodium chloride and potassium chloride (salt)
- neutral: glucose and fructose (sweet)
- slightly basic: phenylthiourea, phenylthiocarbamide, and 6-n-propylthiouracil (bitter)
- basic: hydroxide ion (bitter)

Taste molecules can be:

- polar: glucose and fructose (sweet)
- polar: phenylthiourea, phenylthiocarbamide, and 6-n-propylthiouracil (bitter)
- ionic: hydroxide ion (bitter)
- ionic: hydrogen ion (sour)
- ionic: sodium chloride and potassium chloride (salt)
- ionic: monosodium glutamate (savory)

(They cannot be non-polar, because non-polar does not dissolve in water.)

Taste molecules can have molecular weight 1 to 200:

- 1: hydrogen ion (sour)
- 17: hydroxide ion (bitter)
- 58: sodium chloride (salt)
- 75: potassium chloride (salt)
- 152: phenylthiourea and phenylthiocarbamide (bitter)
- 169: monosodium glutamate (savory)
- 170: 6-n-propylthiouracil (bitter)
- 180: glucose and fructose (sweet)

Taste molecules are:

- Sour: acidic, ionic, and small.
- Salt: neutral, ionic, and medium.
- Savory: neutral, ionic, and large.
- Sweet: neutral, polar, and large.
- Bitter: slightly basic, polar, and large.
- Bitter: basic, ionic, and small.

Acidic and polar do not exist, because acids are ionic. Basic and polar do not exist, because bases are ionic.

Small and polar do not exist, because small molecules are ionic. Medium and polar do not exist, because medium molecules are ionic.

Small and neutral do not exist, because small molecules have hydrogen ions or hydroxide ions. Large and acidic do not exist, because acidic molecules have small hydrogen ions. Large and basic do not exist, because basic molecules have small hydroxide ions.

Taste molecules fall into six categories:

- Large polar: neutral (sweet) or slightly basic (bitter)
- Large ionic: neutral (savory)
- Medium ionic: neutral (salt)
- Small ionic: acidic (sour) or basic (bitter)

3.12. Timing

Taste has limited temporal properties.

3.13. Adaptation

After tasting, taste is less sensitive to later flavors.

3.14. Taste processes use egocentric space

Taste uses tactile three-dimensional space to locate tastes on tongue.

3.15. Evolution

Perhaps, salt receptors evolved because animals need sodium and need associated chloride.

Perhaps, sour receptors evolved to detect food or dangerous acidic conditions.

Perhaps, sweet receptors evolved to detect sugar nutrients.

Perhaps, bitter receptors evolved to detect poisons.

3.16. Development

Newborns do not taste salt, but babies soon can taste it, and they like it.

Newborns can taste sour. Children like sour taste.

Newborns can taste sweet and think it pleasant.

Babies can taste bitter and think it aversive.

4. Perceptual properties

Henning [Henning, 1916] said tastes are salty, sweet, sour, and bitter {primary taste} {basic taste}. Tastes can also be meaty/savory.

People can distinguish five or more tastes and hundreds of flavors.

4.1. Intensity

Concentration determines taste intensity. People can distinguish 10 intensity levels.

4.2. Temporal order

Taste has early, middle, and late sensations.

4.3. Similarities

Sour acid and salt are similar. Bitter and salt are similar. Sweet and salt are similar.

4.4. Opposites

Sour (acid) and bitter (base) are opposites. Sweet (neutral) and sour (acid) are opposites. Salt and sweet are opposites.

4.5. Mixing

Bitter, sweet, salt, sour, and savory can mix. Taste is a synthetic sense, with some analysis.

4.6. Source location

Taste can detect source location. Taste can detect several sources from one location.

Taste has few spatial affects. However, taste can have interference from more than one source.

4.7. Effects

Sour makes people's lips pucker, sometimes downward.

Bitter makes people's eyes and nose change.

Salt is alerting.

Savory is less alerting.

Sweet is calming.

5. Relations to other senses

Taste and retronasal-area smell can combine to make flavor. Odors affect taste receptors. Taste has higher concentration than smell.

Taste is at tongue surface and so has touch. Texture affects taste. Touch can feel solutions on tongue and react to noxious tastes. Touch locates tongue taste receptors.

Taste is painful at high concentrations.

Taste seems unrelated to hearing and vision.

6. Sensations

Tastes are salty, sweet, sour, bitter, and meaty/savory.

References

Brillat-Savarin, Jean Anthelme (1825/2000) *Physiologie du Gout or The Physiology of Taste*. Translated by M. F. K. Fisher. Paris/New York: Counterpoint Press.

Henning, Hans (1916) Die Qualitätenreihe des Geschmacks or Qualities of Tastes. *Zeitschrift für Psychologie und Physiologie der Sinnesorgane*, 74, 203-219.

Ikeda, Kikunae (1909) New seasonings. *Journal of the Tokyo Chemical Society*, 30, 820-836.

Kadohisa, Mikiko; Rolls, Edmund T.; and Verhagen, Justus V. (2005) Neuronal representations of stimuli in the mouth: The primate insular taste cortex, orbitofrontal cortex, and amygdala. *Chemical Senses*, 30, 401-419.

Kalmus, Hans; and Hubbard, Sydney J. (1960) *The Chemical Senses in Health and Disease*. Springfield, IL: Thomas.

Pritchard, Thomas C.; and Norgren, Ralph (2004) Gustatory system. In: George Paxinos and Jurgen K. Mai (ed.), *The Human Nervous System*, 2nd edn., 1171-1196. Amsterdam: Elsevier.

Rolls, Edmund T.; and Scott, Thomas R. (2003) Central taste anatomy and neurophysiology. In: Richard L. Doty (ed.), *Handbook of Olfaction and Gustation*, 2nd edn., 679-705. New York: Dekker.

Note: The Bibliography of Taste, Flavor, and Gustation and the Consciousness Bibliography of 10,000 books and articles, with full journal and author names, is available in text and PDF file formats at http://www.outline-of-knowledge.info/Consciousness_Bibliography/index.html.

Date: November 6, 2014