

Lecture 17: Taste and Smell

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Transcribed by Chris Kellner

Note: There was no tape for this lecture and Dr. Firestein has not posted his slides online so I'm not sure exactly what slides he used, but I noted as many as possible.

We sense chemicals in the environment through the combination of 4 different systems:

Smell – olfaction

Taste – gustation

Trigeminal – sensitivity to heat

Vomer nasal – vestigial, disappears by birth,
pseudogenes - receptors not functional in primates and humans

Slide 1: Netter tongue (plate 54)

The **4 principles of chemical sense** that will be covered in this lecture:

1. **specialized primary neurons**

polarized and relies on specialized end receptor: photo receptors in vision

2. **labeled lines vs. across fiber patterns**

3. **convergence and divergence**

4. **topography** – representation of stimulus in a spatial manner

we maintain xyz coordinates throughout the nervous system

this is less clear in the chemical senses and applies more to taste

Taste

Taste vs Flavor

There are 4 primary tastes (salty, sour, sweet, bitter) + umami (sodium glutamate)

Flavor - the perception of taste resulting from many sensations, including the temperature and texture of foods – this is also called 'mouth feel'

dysgusia – dysfunction of taste

example: in not choosing types of metal fillings carefully, dentists could set up an electric current in the mouth and stimulate certain taste receptors, leading the false perception of taste

Location and threshold of taste

Particular tastes are not specific to regions of the tongue, but there are threshold and sensitivity differences: Anterior – sweet, posterior – bitter, lateral – salt and sour

Thresholds are generally high

It takes 20mM of sucrose

2mM of Na – giving us a desire for high salt foods

Bitter, however, has a low threshold (<1 micromolar) to avoid even small amounts of plant alkaloids, poisons – things that aren't good for you

Anatomy of Taste

Taste receptors are found in **taste buds**, which are found in **papillae**

Taste Receptors

Taste receptors are found on the tongue, palate, pharynx, epiglottis, and upper esophagus

Taste cell receptors are modified **epithelial cells**, not neurons

They come in 4 varieties: light, intermediate, dark, and basal (stem cell)

The 3 nonbasal taste receptors may be different stages of development of

the same type of receptor

Slide of taste bud, Figure 32.13 in Principles

Taste Bud

Polarized microvilli on the apical surface of taste cell receptors extend into the taste pore

It is not clear if nerves are specific for modalities

Individual receptor cells may sense more than one taste

The Tongue

The majority of it has nothing to do with taste

It has 4000 **taste buds** with 30-100 **taste receptors** in each

Taste buds are located in **papillae**

Also found on palate, pharynx, epiglottis, esophagus

There are three types of papillae:

Fungiform

Anterior 2/3rds of tongue

Several hundred

Contain 1-5 taste buds each

Circumvallate

9 on posterior 1/3

like a trench, with 250 taste buds along the walls

Foliate

2 on each postero-lateral region of the tongue

600 taste buds in each

Innervation

CN slide, Figure 32-17 in Principles

Nerves

Somas of bipolar taste nerves are located in the associated ganglion while the proximal axon synapses in the medulla

Anterior 2/3rds is innervated by the chorda tympani nerve of CNVII

Through the geniculate ganglion

Taste receptors are located in **fungiform** papillae

Posterior 1/3rd is innervated by the lingual branch of CNIX

Through the petrose ganglion

Taste receptors are located in **circumvallate** and **foliate** papillae

Medulla

Nerves project to the rostral and lateral part of the **solitary nucleus**

Remember that spatial organization in the mouth is retained throughout the nervous system

There is a rostral to caudal organization in the solitary nucleus

Thalamus – Ventral posterior nucleus via the **central tegmental tract**

Cortex – **gustatory cortex**, which is in the anterior insula-frontal operculum region

Taste Transduction

Ion channel mediated: salt and sour

G-protein mediated: sweet and bitter

Salt

Direct depolarization happens by Na entering the cell through Na channels

The threshold is 2mM, which is high

Amiloride can block this channel

Sour

pH mediated – evidence from amphibians shows that protons block K channels, leading to depolarization

Interaction with Na – the marguerita effect

If Na conc. is low, H enters amiloride-sensitive Na channels

If Na conc. is high, H blocks Na flux through the channels and inhibits salt taste

Sweet

High sucrose threshold – 20mM

Multiple mechanisms are suspected

1. gustucin may be involved – in the same way that transducin acts in vision
2. cAMP increases in response to sucrose – and may lead to blockage of K channels on the basolateral membrane

Some molecules are sweeter than sucrose (10,000X)

Nutri-sweet a dipeptide of Asp and Phe

Thaumatococcus

Bitter

Very low threshold (<1 micromolar), helps organism to avoid harmful substances

Multiple pathways are suspected:

1. IP3 may open K channel to release intracellular Ca
2. known K channel blockers, such as **denatonium** and **quinine**, taste bitter

Umami

Means ‘delicious’ in Japanese

Activated by the amino acid, monosodium glutamate

Candidate taste receptor molecules mentioned

Sweet: T1R1/T1R2

Bitter: T2R/TRB

These clones are helping to compare different taste receptors but there is still a large amount of confusion in the field

Olfaction

Anosmia – lost sense of smell – can be general or to specific odorants

May result from nasal or sinus problems or injury

May lead to diet, sex life, or psychological problems (sleeplessness, paranoia)

Doctors usually don't understand

We have a decent sense of smell, but it's located too high

We can detect thousands of ligands, even differentiating between stereoisomers

Anatomy of Olfaction

Slide of cribriform plate and epithelium: Figure 32-1 in Principles

Structure of epithelium

basal cells: continually replace olfactory neurons

sustentacular cells: support the olfactory neurons, secrete mucus with glands

Bowman's glands: located under epithelium and extend ducts to surface

1. mucus provides molecular and ionic environment for odor detection
2. secrete odorant-binding proteins that may contribute to odorant concentration or removal

neurons: bipolar, CNS type neuron (generates APs),
has a single dendrite with a swelling as it reaches the apical epithelial surface
has cilia specialized for olfactory transduction – and increase surface area
has a short life – 30-60 days
the axon projects through the cribriform plate to a glomerulus of the olfactory bulb
there are millions in the olfactory epithelium

Neuronal organization

Epithelium

There are four expression zones on the olfactory epithelium where certain receptors are expressed only in that particular zone – *see Figure 32-6 in Principles*

Olfactory Bulb

The axons synapse in **glomeruli** in the olfactory bulb
glomeruli - specific groupings of synapses – *see Figure 32-7*
30 micrometer spherical neuropil structures
several thousand sensory neurons **converge** on 20-50 relay neurons
all axons with the same sense meet up

Mitral cells – second order neurons and the primary output neuron (Glu)

Project mostly to piriform cortex through the lateral olfactory tract
There is also direct innervation to the amygdala, hypothalamus, and hippocampus

Small amount of projection to the thalamus then to the frontal cortex

Periglomerular cells and granule cells

There are dendro-dendritic reciprocal synapses that may help to sharpen perception through inhibitory interneurons

Olfactory Transduction

G-protein coupled receptors that are homologous to members of the GPCR superfamily

Classic G-protein cascade: activation of **receptor**, to activation of **G_{olf}**, to activation of **adenylate cyclase III**, to activation of **cyclic nucleotide gated channels**, to cation influx

There is also activation of a **Ca-dependent Cl Channel** leading to depolarization

PDE hydrolyzes cAMP to end the response

Adaptation – 2 mechanisms

1. initial odorant receptor is inactivated by phosphorylation
2. sensitivity of cyclic nucleotide-gated ion channel to cAMP is adjusted

Receptor gene expression – work done by Lynda Buck in Axel's lab

There are about 1200 odor receptors - each is mono-genetic and mono-allelic
1000 olfactory receptor channels in the mouse – makes up 1-3% of the genome

Olfactory coding

Single receptor neurons respond to more than one odorant

It is theorized that one receptor gene is expressed per cell

There is zonal organization of cells that express the same receptor in the nose

The cells with the same receptor converge to a single glomerulus