The Chemical Senses

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Lesson Objectives:

By the end of this workshop, teachers should be able to:

- Define the chemical senses and demonstrate an understanding of why smell and taste are evolutionarily important
- Demonstrate basic knowledge of olfactory and gustatory transduction pathways
- Discuss individual differences in smell and taste perception, and how perception can change based on expectations and experience
- Implement several interactive activities demonstrating these concepts

Activities: Materials Needed

- 1lb bag of tropical fruit flavored jellybellys ($12 on Amazon)
- Pine oil (NOW Foods Pine Oil is $7 on Amazon, but essential oils can also be purchased at Whole Foods), note that other odorants can also be used for the odor perception activity
- Glass or plastic bottles to hold odorants
- 1 tube of PTC supertaster paper ($8 on Amazon)
- Miracle berries ($15 for pack of 10 on Amazon)
- Lemons or limes

Introduction to the Chemical Senses

The sense of smell (or **olfaction**) and the sense of taste (or **gustation**) are also called the **chemical senses**, because both senses involve the detection of chemicals. The chemical senses are very important, because they allow us to react appropriately when we encounter chemicals in our environment. For instance, we seek out foods that taste good and are necessary for survival, and we avoid foods that are poisonous or spoiled. The chemical senses evolved very early, and we know this because even bacteria can utilize the chemical senses. Though bacteria cannot smell or taste in the same way that humans can, they are able to seek out rewarding chemicals and avoid harmful ones. When bacteria move in response to chemicals in their environment, it is called **chemotaxis**.

Introduction to Olfaction

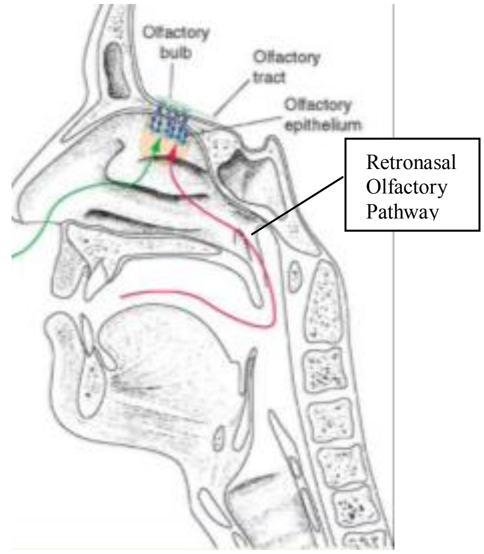
Olfaction is a very complicated system to study in neuroscience for many reasons. For instance, there are thousands and thousands of odorous chemicals, and it not usually possible to predict what an odorous chemical will smell like by simply knowing its chemical structure. Some odorous chemicals have almost identical chemical structures, yet smell completely different. For example, there are two forms, or **enantiomers**, of the chemical carvone: R-(-)-carvone smells like spearmint, while its mirror image S-(+)-carvone smells like caraway seeds. Also, odor objects found in nature often contain lots and lots of odorous compounds. Chemists have been analyzing the aroma of coffee for over 100 years, and have found that it contains over 800 different aromatic compounds!

Olfactory Transduction

The process through which odor molecules are detected in your environment, and converted into electrical signals in your brain where they are ultimately perceived as smells is called **olfactory transduction**. Olfactory transduction is a complicated process, but it can be broken down into 3 steps: (1) odor molecules bind to **olfactory receptors** on **olfactory sensory neurons** located on the roof of the nasal cavity, or **nasal epithelium**, (2) olfactory sensory neurons send electrical signals, or **action potentials** to neurons in the **olfactory bulb**, and (3) these signals are then sent to higher order brain regions, such as the **primary olfactory cortex** and **limbic system**. The limbic system supports emotion and memory function, which could explain in part why many people associate certain odors with vivid memories. For instance, the aroma of baking gingerbread may summon the memory of a particular

Christmas holiday, or a whiff of insect repellant might be evocative of a favorite childhood camping trip. Can you think of an odor that triggers a strong memory for you?

Retronasal Olfaction



Though we typically encounter odors in our environment through our noses (**orthonasal olfaction**), odorous chemicals are also released from our food when we chew it. These odorous chemicals travel through the **nasopharynx** to interact with olfactory sensory neurons in the nasal epithelium. The detection of odorous compounds released from foods is called **retronasal olfaction**, and this sensation constitutes a large part of what we experience as **flavor**. See for yourself with the jellybean activity! The jellybean activity demonstrates how important retronasal olfaction is when experiencing flavor.

Jellybean activity:
1. Mix jellybeans of different flavors in a bowl
2. Instructs student to pinch their noses shut, close their eyes, and choose a jellybean
3. Instruct students to chew the jelly bean and attempt to guess the flavor
4. After the guess is made, student can un-pinch their noses, and guess again

Key concept: *It is much more difficult to guess the flavor of the jellybean while pinching the nose, since retronasal olfaction has been blocked. This activity also demonstrates why you can't experience flavors as fully when you're congested!*

Odor Perception is Modulated by Expectation

The sense of olfaction is very suggestible, meaning that it can be easily altered by experience, context, or expectation. Researchers have found that by simply changing the label associated with an odor, it is possible to alter the perception of that odor. In one experiment, researchers labeled various chemical compounds with either positive labels (Christmas tree, parmesan cheese, incense) or negative labels (e.g., spray disinfectant, vomit, musty basement). People that smelled the odors with positive labels rated them as more pleasant than those that smelled the odors with negative labels, even though they were the exact same odors. Try this activity in your own classroom!

Odor perception activity:
1. Place ~1ml of pine oil odorant in two separate containers (glass bottles work well).
2. Label one bottle "Christmas tree", and label the other bottle "spray disinfectant"
3. Split the students into two groups, and give one of the bottles to each group
4. Ask students to pass around the odorant and rate on a scale of 1-5 in terms of pleasantness (1 = extremely unpleasant, 5 = extremely pleasant)
5. Compare ratings across groups

Key concept: *Odor perception is easily influenced by expectations.*

Note: *This activity can be repeated with various odors using various labels. See Herz & von Cleft, 2001 for more examples). You can purchase essential oils to use as odorants from Amazons, or from Whole Foods.*

For another example of expectation altering odor perception, read the article "The Color of Odors" by Morrot and Dubourdieu. The article details an experiment where wine-tasting students described the odor of red and white wines. Unbeknownst to the students, one of the "red" wines was actually a white wine dyed red!

Introduction to Gustation

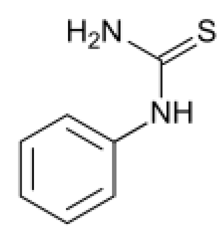
Like olfaction, gustation also helps us to consume tasty nutrients and avoid dangerous toxins. There are 5 basic taste qualities: sour, sweet, salty, bitter, and umami. Each of these taste qualities seem to serve a different evolutionary purpose. Through **sour** taste, we can detect acidity in our food, which is important for maintaining acid balance and avoiding spoiled foods. A **sweet** taste indicates the presence of sugars, which the body needs as a source of energy. Through **salty** taste, organisms can detect salts (of course!), which is essential for maintaining the body's water balance. We tend to avoid **bitter** tastes, because they can contain toxins or other harmful substances. Though **umami** taste is the least well-known, it is just as important as the other 4 taste qualities. Umami taste is also called savory taste, and it indicates the presence of amino acids in foods, which reflects protein content.

Gustatory Transduction

We can detect the different taste qualities by using different types of **taste receptors** located in the **taste buds**. Taste buds are organized in the fleshy **papillae** found on the tongue. Each taste bud contains many taste cells, and each taste cell can sense a particular taste quality. We know that salty taste is detected by taste cells containing **sodium ion channels**, and that sour taste is detected by taste cells containing **proton-sensitive** channels. Unfortunately, the taste receptors necessary to detect the other taste qualities are not as well-understood yet. A common misconception about taste is that different parts of the tongue are sensitive to different taste qualities. This is a myth! Actually, each taste bud contains a variety of taste cell types, and the different types of taste cells seem to be distributed evenly across the tongue.

Taste information is transmitted from the taste cells in the tongue to the brain via 3 different **cranial nerves**: the facial nerve (CN VII), the glossopharyngeal nerve (CN IX), and the hypoglossal nerve (CN XII). Taste information is initially sent to the **primary gustatory cortex**. By using **function Magnetic Resonance Imaging** (fMRI) to measure brain activity, researchers have found that the primary gustatory cortex is activated when different parts of the tongue detect taste.

Taste Perception: Individual Differences and How to Alter the Sense of Taste



Phenylthiocarbamide

Just like in olfaction, there are lots of individual differences in taste perception. For instance, the number of papillae containing taste buds on the tongue can vary a lot from person to person. In fact, those that have the most papillae on the tongue are often called **supertasters**, while those that have the least are often called non-tasters. Supertasters can also be identified by their ability to taste the chemical **phenylthiocarbamide** (PTC). Try the following activities to identify supertasters, and discuss individual differences in gustatory processing!

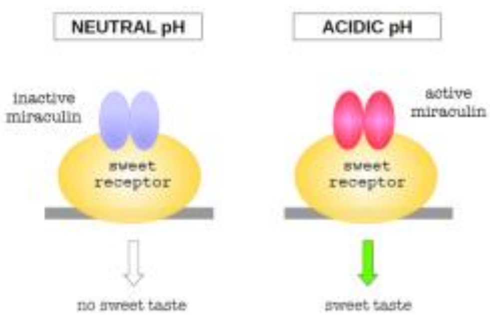
<u>PTC paper activity:</u>
1. Distribute PTC paper strips
2. Instruct student to taste the PTC paper
3. Supertasters will perceive the PTC paper as extremely bitter and aversive, while non-supertasters will merely detect a very mild bitter or papery taste

<u>Blue tongue activity:</u>
1. Apply blue food coloring to the student's tongue, and instruct them swallow to make the tongue relatively dry
2. The largest papillae (called **fungiform papillae**) will be visible as lighter blue or pink bumps
3. Pierce a hole in wax paper with a standard hole punch, and place the wax paper ring on the tongue
4. Use a magnifying glass to count the number of fungiform papillae in the hole
5. Compare the number of fungiform papillae across students (>30 papillae = supertaster)

Key concept: The sense of taste varies dramatically from person to person, and this is normal! These differences (number of papillae, ability to detect PTC) can start to explain why people experience the same foods so differently.

Interestingly, we can also develop powerful aversions to particular tastes that we associate with negative experiences. This phenomenon is called **conditioned taste aversion**. For example, in an experiment involving mice, researchers found that when they repeatedly paired a sweet taste with a medication that caused nausea, the mice developed taste aversion for sweet foods. Pairing a particular taste with nausea results in a more robust conditioned response than pairing other types of sensory cues (i.e., sound, electric shock) with nausea. This may be due to the fact that foods are more likely to cause nausea in a natural setting, and so it is easier for mice to learn that conditioned association. Can you think of a time when you experienced taste aversion?

Another way to alter the sense of taste is with **miracle berries**. Miracle berries were first discovered in the early 1700's in the forested regions of West Africa. These berries were known for one very unique property – they cause sour foods to taste sweet! Miracle berries contain the taste-modifying protein **miraculin** (MCL). MCL binds to the taste buds on the tongue. At a neutral pH, MCL is inactive, and no sweet tastes are perceived. However, when you ingest something sour, the pH in your mouth becomes acidic. In an acidic environment, MCL is activated, and sour foods taste sweet.



Miracle berry activity:
1. Distribute miracle berries
2. Have student place their miracle berry on their tongue, and let it dissolve for around 10 minutes
3. After the miracle berry is completely dissolved, allow the student to eat something sour (lemons or limes are recommend!)
4. Ask the student to describe what they taste – has anything changed? Note: this effect will wear off after around 30 minutes.

Key concept: We are used to perceiving certain foods in a particular way, but miracle berries can alter our sense of taste by interacting with gustatory transduction at the level of the taste buds.

Flavor

When we think of the word **flavor**, we often think of the sense of taste. Actually, flavor is a combination of the sense of taste, the sense of smell, and the sense of touch (or **somatosensation**). For example, when you ingest menthol from mint or capsaicin from hot chili peppers, it stimulates somatosensory receptors that evoke sensations of cooling or heating respectively. Additionally, the texture of food contributes to the sensation of flavor.

Extra Resources

- For further details of experimenters where expectation alters odor perception, read Herz & van Cleft, 2001, or Morrot, Brochet, and Dubourdieu 2001. Both articles are included in your resource folder on Google Drive.
- Check out the Daily Chicago Chocolate Smell Map (http://chicagococoasmell-blog.tumblr.com) to determine where you need to be to smell the Blommer Chocolate Factory on a daily basis!
- For some very interesting smell maps of various cities and olfactory models, visit http://sensorymaps.com.
- If you'd like to read a fiction novel where the sense of smell heavily influences the plot, we recommend Jitterbug Perfume by Tom Robbins!