Chapter 15

**OLFACTION AND TASTE**

The chemical senses, olfaction and gustation, allow us to detect molecules either in the air or in our mouths, respectively. Odors are the perceptual experiences of odorants, which are airborne chemical molecules that enter our nose through the nostrils. Turbinates then ensure that some air is passed to through the olfactory cleft to the olfactory epithelium. Olfactory receptor neurons are located inside the olfactory epithelium and serve as the olfactory transducers. Humans have about 350 different types of olfactory receptor neurons, each of which responds to a relatively small class of odorants. As a particular odorant contacts the tip of the cilia of the olfactory receptor neurons, it triggers a neural signal. The axons of the olfactory receptor neurons converge to form the olfactory nerve, which exits through tiny holes in the cribiform plate, a bone in the skull separating the nose and brain. The olfactory nerve projects to the olfactory bulb and then synapse with dendrites in spherical structures called glomeruli. Cells in the glomeruli form an odorant map. From the glomeruli, the olfactory tract is formed, which projects olfactory information to the amygdala, entorhinal cortex, and the piriform cortex. The piriform cortex is often considered the primary olfactory cortex. The anterior piriform cortex is associated with representing the chemical structures of odorants, whereas the posterior piriform cortex is associated with an odor’s quality, regardless of its chemical composition. The orbitofrontal cortex receives projections from the piriform cortex and the limbic system and is likely critical in establishing the emotional nature of odors. Detection thresholds vary across odorants, but it generally does not take many odorants to elicit an odor. The tip-of-the-nose phenomenon occurs when one is familiar with an odor but cannot recall its name, despite feeling as if he or she can. Most people report being unable to experience olfactory images, though a minority of people report being able to. Several olfactory illusions arise from context effects. Anosmia is the inability to smell, which results from causes such as damage to the cribiform plate or olfactory nerve. It may also be congenital. Phantosmia is a neurological condition in which people smell odors that are not physically present.

Like the sense of smell, the sense of taste probably evolved to help us differentiate edible food from toxins. Tastants are molecules that induce responses in taste receptors on the tongue. Tastes are the perception of the transduction of tastants along the surface of the tongue. Tastes can be categorized into five basic tastes: sweet, salt, sour, bitter, and umami (savory). Taste buds, found within papillae, are the small structures in the mouth that contain between approximately 40 and 100 taste receptor cells. There are two types of taste receptor cells. Receptor cells transduce tastes that are sweet, umami, or bitter, whereas presynaptic cells transduce tastes that are salty or sour. Information leaves the taste buds through the 7th, 9th, and 10th cranial nerves, which synapse in the nucleus of the solitary tract in the medulla. Then, axons project to the ventral posterior medial nucleus of the thalamus before projecting to the anterior insular cortex in the frontal lobe. The insular cortex is sometimes called the gustatory cortex. The insular cortex projects to the orbitofrontal cortex where taste and olfaction mix, along with the somatosenses, vision, and even audition, to produce the total perceptual experience of flavor. Individual differences in taste perception may be learned but others have a genetic basis. Ageusia is a condition in which people lose the ability to taste.

Introduction

* **Olfaction** is the sense of smell, the ability to detect odors.
* **Gustation** is the sense of taste.
* Together, they are considered chemical senses because their role is to detect chemicals in the environment.
* In an evolutionary context, the chemical senses may be the oldest senses.

Olfaction

* **Odors** are the perceptual experiences that derive from the detection of **odorants**, which are airborne chemical molecules.
* The olfactory system does not respond to all airborne chemicals, such as carbon monoxide and natural gas.

The Anatomy and Physiology of the Olfactory System

The Nose

* The nostrils are separated by a wall of cartilage called the **nasal septum**.
* Inside the nasal cavity, bony knots of tissue called **turbinates** ensure that some air is passed upward through the **olfactory cleft** and land on the **olfactory epithelium.**
* **Olfactory receptor neurons** are located inside the olfactory epithelium and serve as the olfactory transducers
  + Cilia from the olfactory receptor neurons extend into the mucus covering of the olfactory epithelium.
  + As a particular odorant comes into contact with the tip of the cilia, triggering a neural signal to be sent to the olfactory bulb.
* The olfactory epithelium also contains supporting cells and basal cells.
  + **Supporting cells** provide metabolic supplies to the olfactory receptor neurons.
  + **Basal cells** create olfactory receptor neurons, which die after about one month.
* Approximately 20 million olfactory receptor neurons are found in the human nose.
  + This is much fewer than the number seen in many other species, such as pigs, bears, and dogs.
  + Species that depend heavily on smell are called **macrosmatic.**
  + Humans and other species that depend more on vision and audition are called **microsmatic.**
* Humans have about 350 different types of olfactory receptor neurons.
  + Each kind responds to a relatively small class of odorants.
  + Macrosmatic species may have as many as 1,000 different types of olfactory receptor neurons.

Genes and Olfaction

* A collection of genes regulates the expression of different olfactory receptor neurons.
* In humans, the number of active genes is a predictor of individual differences in olfaction. The presence or absence of a specific gene means you may be more or less sensitive, respectively, to a specific odor.

The Trigeminal Nerve

* Some odorants also cause reactions in the somatosensory system.
* This aspect of olfaction is mediated by the **trigeminal nerve**, which transmits information about the feel of an odorant, such as the cooling sensation of menthol.

The Pathway to the Brain

* The axons of the olfactory receptor neurons converge to form the **olfactory nerve**, which exits through tiny holes in the **cribiform plate**, a bone in the skull separating the nose and brain.
  + Damage to the cribiform plate may sever the axons, causing impairment in smell.
    - **Anosmia** (or **smell blindness)** is the inability to smell.
    - Despite the regeneration of olfactory receptor neurons, a fractured cribiform plate may scar over, preventing new neurons from reaching the brain.
* The olfactory nerve projects to the **olfactory bulb**, a part of the brain just behind the nose.
* Then, the olfactory receptor neurons enter and synapse with dendrites in spherical structures called **glomeruli.**
  + Cells in the glomeruli form an odorant map, organizing similarly structured odorants together.
  + This map is analogous to frequency coding in the auditory cortex or spatial mapping in the visual brain.
* From the glomeruli, the **olfactory tract** is formed, which projects olfactory information from the olfactory bulb to other regions of the brain, including the **amygdala** (a central emotion area), the **entorhinal cortex** of the temporal lobe (a memory area), and the **piriform cortex** of the temporal lobe.
* The piriform cortex is often considered the primary olfactory cortex, because it is devoted exclusively to olfaction.
  + The piriform cortex has two main subdivisions.
    - The **anterior piriform cortex** is associated with representing the chemical structures of odorants. It creates a map of odorants organized by their chemical structure.
    - The **posterior piriform cortex** is associated with an odor’s quality, regardless of its chemical composition. Neurons are grouped by subjective similarities between odors.
* The **orbitofrontal cortex**, particularly the right orbitofrontal cortex, receives projections from the piriform cortex and the limbic system.
  + This area is likely critical in establishing the emotional nature of odors.

Olfactory Perception

Detection

* The amount of odorant in the environment is typically measured in parts per million (ppm).
* Some odors can be detected in much smaller quantities than others. For example, vanilla requires only 0.000035 ppm to detect it, but acetone (nail polish remover) requires 15 ppm to detect it.

Identifying Odors

* The **tip-of-the-nose phenomenon** occurs when one is familiar with an odor but cannot recall its name, despite feeling as if he or she can.
* There seems to be a disconnect between olfaction and language, making it difficult to identify the names of certain odors.
* Though identification is difficult, discrimination is not. The average person can distinguish over 1000 different odors and professionals (e.g., wine tasters and perfumists) can discriminate as many as 100,000 odors.

Odor Imagery

* Most people report being unable to experience olfactory images, though a minority of people report being able to.

Olfactory Illusions

* Several olfactory illusions arise from context effects.
* Surrounding odors can affect the perception of a target odor.
* Verbal labeling can cause olfactory illusions. The same odor with different labels can affect the perceived pleasantness (e.g., “Christmas tree” vs. “toilet bowl cleaner” for a pine scent).
* Visual perception of colors can affect whether an odor is present regardless of whether it is or not.
* In olfactory rivalry, one odorant is presented to one nostril and a different one is presented to the other nostril. The odorant that people report smelling seems to be random.

Taste Perception

* Like the sense of smell, the sense of taste probably evolved to help us differentiate edible food from toxins.
* **Tastants** are molecules that induce responses in taste receptors on the tongue.
* **Tastes** are the perception of the transduction of tastants along the surface of the tongue.
* **Flavor** refers to the combined sensory experience of a food, which combines its taste, its odor, and its effect on the trigeminal nerve.
* Tastes can be categorized into five basic tastes, which correspond to specific receptors along the surface of the tongue. These are sweet, salt, sour, bitter, and umami (savory).
  + Sweet, salty, and umami tastes alert us to foods with needed nutrients.
  + Sour and bitter tastes likely evolved as warnings about foods to avoid. Pleasure from sour and bitter is usually acquired.

Anatomy of the Tongue and Taste Coding

* **Taste buds** are the small structures in the mouth that contain receptor cells. Most of the approximately 10,000 taste buds are on the tongue, but about a third can be found on the epiglottis, the soft palate, and the upper esophagus.
* Taste buds are found within **papillae**, which line the surface of the tongue and mouth. There are four different kind of papillae.
  + The **fungiform papillae** are located mostly along the edges and top of the tongue.
  + The **foliate papillae** are located along the side of the tongue.
  + The **circumvallate papillae** are located along the very back of the tongue.
  + The **filiform papillae** are found all over the tongue. They contain somatosensory receptors instead of taste buds.
* Each taste bud contains from 40 to about 100 **taste receptor cells**, the cells within the taste buds that transduce tastants into a neural signal.
  + Like olfactory receptor cells, taste receptors cells die after a week and are replaced.
  + There are two types of taste receptor cells.
    - **Receptor cells** transduce tastes that are sweet, umami, or bitter.
    - **Presynaptic cells** transduce tastes that are salty or sour.
* Information leaves the taste buds through the 7th, 9th, and 10th cranial nerves, which synapse in the nucleus of the solitary tract in the medulla.
* Then, axons project to the ventral posterior medial nucleus of the thalamus before going to the **anterior insular cortex** in the frontal lobe.
  + The insular cortex is sometimes called the gustatory cortex.
  + The insular cortex projects to the orbitofrontal cortex, where taste and olfaction mix to produce flavor perception.
  + It is thought that the orbitofrontal cortex is largely responsible for the pleasure involved in eating food.

Taste and Flavor

* **Flavor** is defined as the total perceptual experience that occurs during eating, which combines taste, olfaction, the somatosenses, vision, and even audition.
* Most of this integration occurs in the orbitofrontal cortex.

Individual Differences in Taste Perception

* Some individual differences in taste perception are learned.
* Some individual differences in taste perception have a genetic basis.
  + The most widespread of these genetic differences is our ability to taste bitter foods.
  + **Tasters** are people who can detect bitter compounds.
  + **Nontasters** cannot detect bitter compounds, except at very high concentrations.
  + **Supertasters** are extremely sensitive to bitter tastes and usually do not like foods with bitter compounds.
    - Asians are more likely to be supertasters than Europeans.
    - Women are more likely to be supertasters than men.
    - Supertasters have a high concentration of fungiform papillae.

The Wonderful World of Chili Peppers

* The painful or burning sensation caused by capsaicin in chili peppers is caused by its activation of the trigeminal nerve, which codes for heat in the mouth.
* Capsaicin also stimulates taste receptors in the fungiform papillae, which contribute to the sensation of heat on the tongue.
* Exposure to capsaicin causes the receptors to desensitize to it, meaning that the more of it you eat, the more you can eat.

Development of Taste Perception

* Infants are seemingly born with an attraction to foods that are sugary or salty.
* However, many taste preferences are conditioned responses that develop as a function of experience and reinforcement.
* A person’s early environment can shape taste perception. For example, an early salt deficiency can cause later cravings for and a higher intake of salts.

# In Depth: Anosmia

* Anosmia may be temporary or permanent, depending on the damage to the cribiform plate and olfactory nerve.
* In addition to head trauma, anosmia may be caused by inflammation in the nasal cavities, blockage to the nasal cavities, damage to the areas of the brain responsible for olfactory perception, or as a symptom of neurological disorders such as Parkinson’s disease and Alzheimer’s disease.
* Anosmia may also occur in depressed patients.
* Anosmia may occur in the normal process of aging. If the sense of smell is compromised, food may not be as appealing, leading to declines in caloric intake or to adding too much salt to compensate.
* Some individuals are born with congenital anosmia.
* With regard to brain injury, the orbitofrontal cortex may often be damaged in accidents, because of its location near the front of the skull.
  + Damage to the orbitofrontal cortex may be more similar to a form of olfactory agnosia than anosmia. That is, damage to the nose or olfactory bulb produces deficits in odor detection, whereas damage to the orbitofrontal cortex produces deficits in odor recognition and discrimination.
* There also exists **phantosmia**, a neurological condition in which people smell odors that are not physically present. It is like an olfactory hallucination.
* **Ageusia** is a condition in which people lose the ability to taste.