

# Human Physiology/Senses

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## What are Senses?

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We experience reality through our senses. Senses are the physiological methods of perception, so a sense is a faculty by which outside stimuli are perceived. The senses and their operation, classification, and theory are overlapping topics studied by a variety of fields. Many neurologists disagree about how many senses there actually are due to a broad interpretation of the definition of a sense. Our senses are split into two different groups. Our **exteroceptors** detect stimulation from the outsides of our body. For example smell, taste, and equilibrium. The **interoceptors** receive stimulation from the inside of our bodies. For instance, blood pressure dropping, changes in the glucose and pH levels. Children are generally taught that there are five senses (sight, hearing, touch, smell, taste). However, it is generally agreed that there are at least seven different senses in humans, and a minimum of two more observed in other organisms. Sense can also differ from one person to the next. Take taste for an example: what may taste great to one person will taste awful to someone else. This has to do with how the brain interprets the stimuli that are received.

## Chemoreception

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The senses of **gustation** (taste) and **olfaction** (smell) fall under the category of **chemoreception**. Specialized cells act as receptors for certain chemical compounds. As these compounds react with the receptors, an impulse is sent to the brain and is registered as a certain taste or smell. Gustation and olfaction are chemical senses because the receptors they contain are sensitive to the molecules in the food we eat, along with the air we breathe.

## Gustatory System

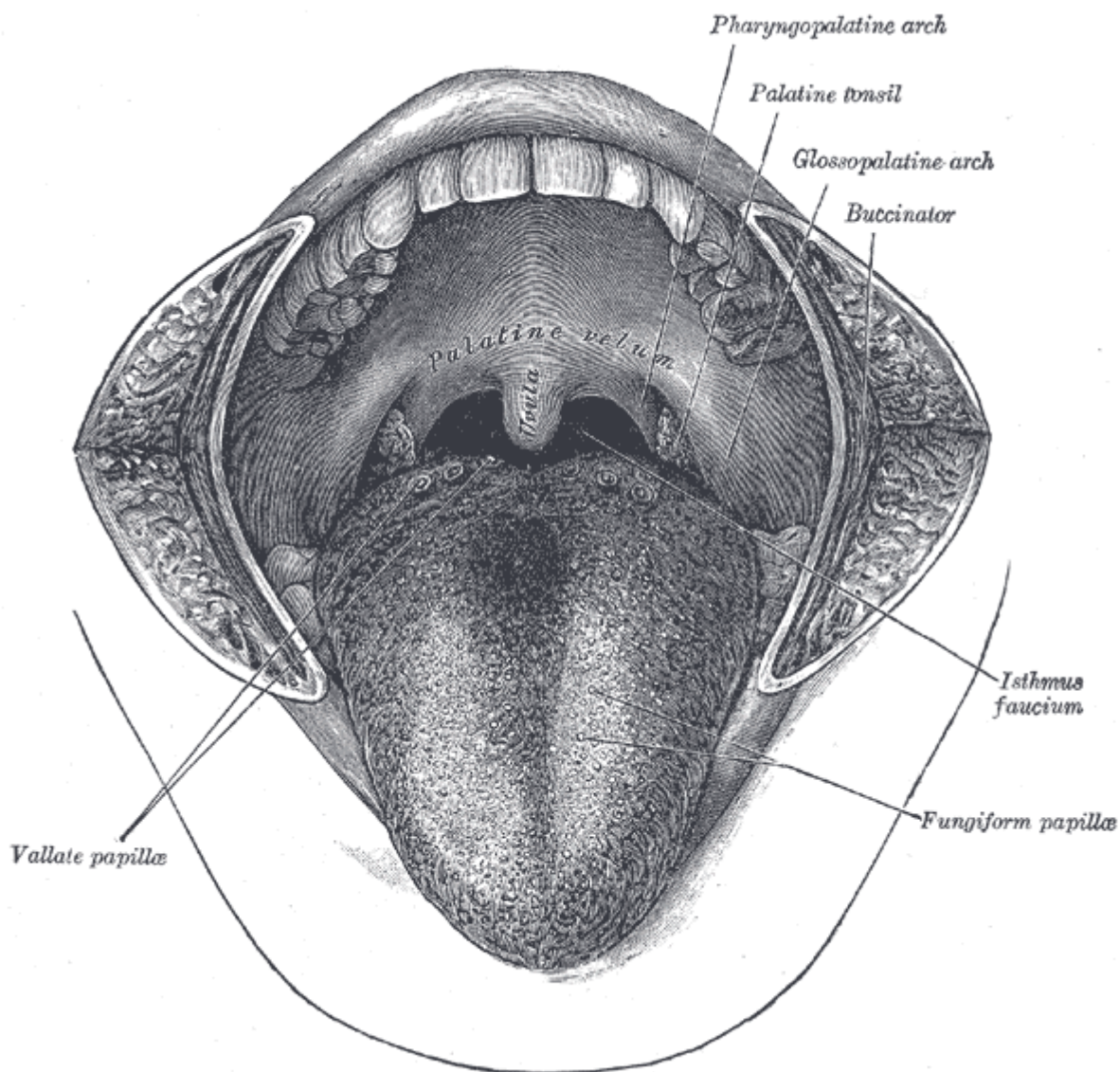
In humans, the sense of **taste** is transduced by **taste buds** and is conveyed via three of the twelve cranial nerves. Cranial nerve VII, the facial nerve, carries taste sensations from the anterior two thirds of the tongue (excluding the circumvallate papillae, see lingual papilla) and soft palate. Cranial nerve IX the glossopharyngeal nerve carries taste sensations from the posterior one third of the tongue (including the circumvallate papillae). Also a branch of the vagus nerve carries some taste sensations from the back of the oral cavity (i.e. pharynx and epiglottis). Information from these cranial nerves is processed by the gustatory system. Though there are small differences in sensation, which can be measured with highly specific instruments, all taste buds can respond to all types of taste. Sensitivity to all tastes is distributed across the whole tongue and indeed to other regions of the mouth where there are taste buds (epiglottis, soft palate).

### Papilla

**Papilla** are specialized epithelial cells. There are four types of papillae: **filiform** (thread-shape), **fungiform** (mushroom-shape), **foliate** (leaf-shape), and **circumvallate** (ringed-circle). All papillae except the filiform have taste buds on their surface. Some act directly by ion channels, others act indirectly.

- **Fungiform papillae** - as the name suggests, are slightly mushroom shaped if looked at in section. These are present mostly at the apex (tip) of the tongue.
- **Filiform papillae** - these are thin, longer papillae that don't contain taste buds but are the most numerous. These papillae are mechanical and not involved in gustation.
- **Foliate papillae** - these are ridges and grooves towards the posterior part of the tongue.
- **Circumvallate papillae** - there are only about 3-14 of these papillae on most people and they are present at the back of the oral part of the tongue. They are arranged in a circular-shaped row just in front of the sulcus terminalis of the tongue.

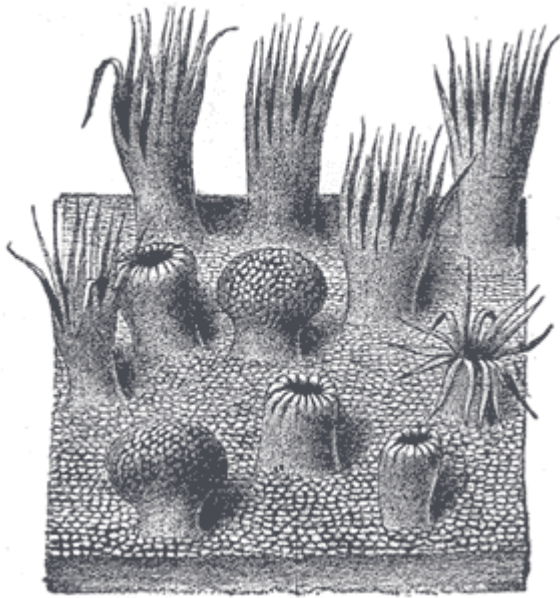
## Structure of Taste Buds



The mouth cavity. The cheeks have been slit transversely and the tongue pulled forward.

Each taste bud is flask-like in shape, its broad base resting on the corium, and its neck opening by an orifice, the gustatory pore, between the cells of the epithelium.

The bud is formed by two kinds of cells: supporting cells and gustatory cells.



Semidiagrammatic view of a portion of the mucous membrane of the tongue. Two fungiform papillae are shown. On some of the filiform papillae the epithelial prolongations stand erect, in one they are spread out, and in three they are folded in.

The supporting cells are mostly arranged like the staves of a cask, and form an outer envelope for the bud. Some, however, are found in the interior of the bud between the gustatory cells. The gustatory cells occupy the central portion of the bud; they are spindle-shaped, and each possesses a large spherical nucleus near the middle of the cell. The peripheral end of the cell terminates at the gustatory pore in a fine hair-like filament, the gustatory hair.

The central process passes toward the deep extremity of the bud, and there ends in single or bifurcated varicosities.

The nerve fibrils after losing their medullary sheaths enter the taste bud, and end in fine extremities between the gustatory cells; other nerve fibrils ramify between the supporting cells and terminate in fine extremities; these, however, are believed to be nerves of ordinary sensation and not gustatory.

## Types of Taste

### Salt

Arguably the simplest receptor found in the mouth is the salt (NaCl) receptor. An ion channel in the taste cell wall allows  $\text{Na}^+$  ions to enter the cell. This on its own depolarises the cell, and opens voltage-regulated  $\text{Ca}^{2+}$  gates, flooding the cell with ions and leading to neurotransmitter release. This sodium channel is known as *enac* and is composed of three sub-units. *Enac* can be blocked by the drug amiloride in many mammals, especially rats. The sensitivity of the salt taste to amiloride in humans, however, is much less pronounced, leading to conjecture that there may be additional receptor proteins besides *ENAC* that may not have been discovered yet.

### Sour

Sour taste signals the presence of acidic compounds ( $\text{H}^+$  ions in solution). There are three different receptor proteins at work in sour taste. The first is a simple ion channel which allows hydrogen ions to flow directly into the cell. The protein for this is *ENAC*, the same protein involved in the distinction of salt taste (this implies a relationship between salt and sour receptors and could explain why salty taste is reduced when a sour taste is present). There are also  $\text{H}^+$  gated channels present. The first is a  $\text{K}^+$  channel, which ordinarily allows  $\text{K}^+$  ions to escape from the cell.  $\text{H}^+$  ions block these, trapping the potassium ions inside the cell (this receptor is classified as *MDEG1* of the *ENAC/Deg* Family). A third protein opens to  $\text{Na}^+$  ions when a hydrogen ion attaches to it, allowing the sodium ions to flow down the concentration gradient into the cell. The influx of ions leads to the opening of a voltage regulated  $\text{Ca}^{2+}$  gate. These receptors work together and lead to depolarization of the cell and neurotransmitter release.

### Bitter

There are many classes of bitter compounds which can be chemically very different. It is interesting that the human body has evolved a very sophisticated sense for bitter

substances: we can distinguish between the many radically different compounds which produce a generally “bitter” response. This may be because the sense of bitter taste is so important to survival, as ingesting a bitter compound may lead to injury or death. Bitter compounds act through structures in the taste cell walls called G-protein coupled receptors (GPCR's). Recently, a new group of GPCR's was discovered, known as the T2R's, which is thought to only respond to bitter stimuli. When the bitter compound activates the GPCR, it in turn releases gustducin, the G-protein it was coupled to. Gustducin is made of three subunits. When it is activated by the GPCR, its subunits break apart and activate phosphodiesterase, a nearby enzyme. It then converts a precursor within the cell into a secondary messenger, which closes potassium ion channels. This secondary messenger can stimulate the endoplasmic reticulum to release  $\text{Ca}^{2+}$ , which contributes to depolarization. This leads to a build-up of potassium ions in the cell, depolarization, and neurotransmitter release. It is also possible for some bitter tastants to interact directly with the G-protein, because of a structural similarity to the relevant GPCR.

## Sweet

Like bitter tastes, sweet taste transduction involves GPCR's. The specific mechanism depends on the specific molecule. “Natural” sweeteners such as saccharides activate the GPCR, which releases gustducin. The gustducin then activates the molecule adenylate cyclase, which is already inside the cell. This molecule increases concentration of the molecule cAMP, or adenosine 3', 5'-cyclic monophosphate. This protein will either directly or indirectly close potassium ion channels, leading to depolarization and neurotransmitter release. Synthetic sweeteners such as saccharin activate different GPCR's, initiating a similar process of protein transitions, starting with the protein phospholipase A, which ultimately leads to the blocking of potassium ion channels.

## Umami

Umami is a Japanese word meaning "savory" or "meaty". It is thought that umami receptors act much the same way as bitter and sweet receptors (they involve GPCR's), but not much is known about their specific function. We do know that umami detects glutamates that are common in meats, cheese and other protein-heavy foods. Umami receptors react to foods treated with monosodium glutamate (MSG). This explains why eating foods that have MSG in them often give a sense of fullness. It is thought that the amino acid L-glutamate bonds to a type of GPCR known as a metabotropic glutamate receptor (mGluR4). This causes the G-protein complex to activate a secondary receptor, which ultimately leads to neurotransmitter release. The intermediate steps are not known.

## Disorders of the Tongue

### Loss of taste

You may lose your sense of taste if the facial nerve is damaged. Then there is also Sjogren's Syndrome where the saliva production is reduced. In most cases the loss of taste is typically a symptom of **anosmia** - a loss of the sense of smell.

### Sore tongue

It is usually caused by some form of trauma, such as biting your tongue, or eating piping-hot or highly acidic food or drink.

If your top and bottom teeth don't fit neatly together, tongue trauma is more likely.

Some people may experience a sore tongue from grinding their teeth (**bruxism**).

Disorders such as diabetes, anemia, some types of vitamin deficiency and certain skin diseases can include a sore tongue among the range of symptoms.

### Glossodynia

A condition characterized by a burning sensation on the tongue.

### **Benign migratory glossitis**

This condition is characterized by irregular and inflamed patches on the tongue surface that often have white borders. The tongue may be generally swollen, red and sore. Another name for this condition is geographic tongue. The cause of benign migratory glossitis is unknown.

**Risk factors are thought to include:**

- Mineral or vitamin deficiencies
- Local irritants, such as strong mouthwashes, cigarettes or alcohol
- Certain forms of anemia
- Infection
- Certain medications
- Stress

## **Olfactory System**

**Olfaction** is the sense of smell. In humans the sense of **Smell** is received in **nasopharynx**. Airborne molecules go into solution on moist epithelial surface of nasal passage. An olfactory receptors neuron sends an impulse via Cranial nerve I the olfactory nerve. Although 80-90% of what we think is "taste" actually is due to smell. This is why when we have a head cold or stuffed up nose we have a harder time tasting our foods.

### **Receptors**

Humans have 347 functional odor receptor genes; the other genes have nonsense mutations. This number was determined by analyzing the genome in the Human Genome Project; the number may vary among ethnic groups, and does vary among individuals. For example, not all people can smell androstenone, a component of male sweat.

Each olfactory receptor neuron in the nose expresses only one functional odor receptor. Odor receptor nerve cells may function like a key-lock system: if the odor molecules can fit into the lock the nerve cell will respond. According to shape theory, each receptor detects a feature of the odor molecule. Weak-shape theory, known as odotope theory, suggests that different receptors detect only small pieces of molecules, and these minimal inputs are combined to create a larger olfactory perception (similar to the way visual perception is built up of smaller, information-poor sensations, combined and refined to create a detailed overall perception). An alternative theory, the vibration theory proposed by Luca Turin (1996, 2002), posits that odor receptors detect the frequencies of vibrations of odor molecules in the infrared range by electron tunneling. However, the behavioral predictions of this theory have been found lacking (Keller and Vosshall, 2004).

An olfactory receptor neuron, also called an olfactory sensory neuron, is the primary transduction cell in the olfactory system. Humans have about 40 million olfactory receptor neurons. In vertebrates, olfactory receptor neurons reside on the olfactory epithelium in the nasal cavity. These cells are bipolar neurons with a dendrite facing the interior space of the nasal cavity and an axon that travels along the olfactory nerve to the olfactory bulb.



Many tiny hair-like cilia protrude from the olfactory receptor cell's dendrite and into the mucus covering the surface of the olfactory epithelium. These cilia contain olfactory receptors, a type of G protein-coupled receptor. Each olfactory receptor cell contains only one type of olfactory receptor, but many separate olfactory receptor cells contain the same type of olfactory receptor. The axons of olfactory receptor cells of the same type converge to form glomeruli in the olfactory bulb.

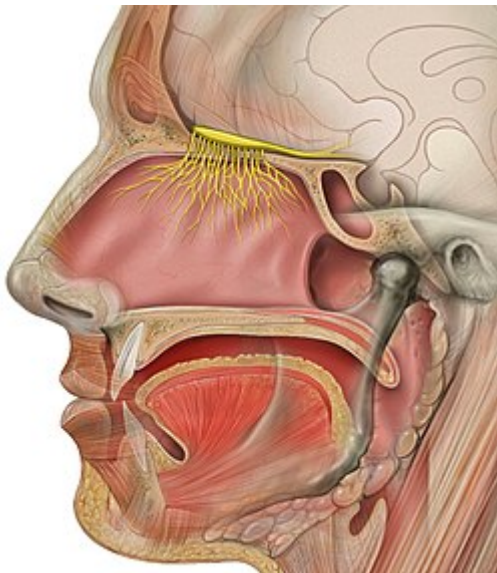
Olfactory receptors can bind to a variety of odor molecules. The activated olfactory receptor in turn activates the intracellular G-protein GOLF, and adenylate cyclase and production of Cyclic AMP opens ion channels in the cell membrane, resulting in an influx of sodium and calcium ions into the cell. This influx of positive ions causes the neuron to depolarize, generating an action potential.

Individual olfactory receptor neurons are replaced approximately every 40 days by neural stem cells residing in the olfactory epithelium. The regeneration of olfactory receptor cells, as one of the only few instances of adult neurogenesis in the central nervous system, has raised considerable interest in dissecting the pathways for neural development and differentiation in adult organisms.

### **In the brain**

The axons from all the thousands of cells expressing the same odor receptor converge in the olfactory bulb. Mitral cells in the olfactory bulb send the information about the individual features to other parts of the olfactory system in the brain, which puts together the features into a representation of the odor. Since most odor molecules have many individual features, the combination of features gives the olfactory system a broad range of odors that it can detect.

Odor information is easily stored in long term memory and has strong connections to emotional memory. This is possibly due to the olfactory system's close anatomical ties to the limbic system and hippocampus, areas of the brain that have long been known to be involved in emotion and place memory, respectively.



The Olfactory Nerve leading to the brain.

### **Pheromonal olfaction**

Some pheromones are detected by the olfactory system, although in many vertebrates pheromones are also detected by the vomeronasal organ, located in the vomer, between the nose and the mouth. Snakes use it to smell prey, sticking their tongue out and touching it to the organ. Some mammals make a face called flehmen to direct air to this organ. In humans, it is unknown whether or not pheromones exist.

## Olfaction and Gustation

Olfaction, taste and trigeminal receptors together contribute to flavor. It should be emphasized that there are no more than 5 distinctive tastes: salty, sour, sweet, bitter, and umami. The 10,000 different scents which humans usually recognize as 'tastes' are often lost or severely diminished with the loss of olfaction. This is the reason why food has little flavor when your nose is blocked, as from a cold.

The key nutrition players in our taste is the olfactory function, 80-90% of what we consider taste is dependent on our senses of smell. With aging our olfactory function declines. In the elderly careful monitoring of appetite is necessary due to the alterations in the olfactory function. Nutritionist suggest giving a dual approach of supplementation of the trace minerals zinc and iron to enhance the smell and taste senses.

## Disorders of Olfaction

### Anosmia

Anosmia is the lack of olfaction, or a loss of the sense of smell. It can be either temporary or permanent. A related term, hyposmia refers to a decrease in the ability to smell. Some people may be anosmic for one particular odor. This is called "specific anosmia" and may be genetically based. Anosmia can have a number of detrimental effects. Patients with anosmia may find food less appetizing. Loss of smell can also be dangerous because it hinders the detection of gas leaks, fire, body odor, and spoiled food. The common view of anosmia as trivial can make it more difficult for a patient to receive the same types of medical aid as someone who has lost other senses, such as hearing or sight. A temporary loss of smell can be caused by a stuffy nose or infection. In contrast, a permanent loss of smell may be caused by death of olfactory receptor neurons in the nose, or by brain injury in which there is damage to the olfactory nerve or damage to brain areas that process smell. The lack of the sense of smell at birth, usually due to genetic factors, is referred as congenital anosmia. Anosmia may be an early sign of degenerative brain diseases such as Parkinson's disease and Alzheimer's disease. Another specific cause of permanent loss could be from damage to olfactory receptor neurons due to use of nasal sprays. To avoid loss of smell from nasal sprays, use them for only a short amount of time. Nasal sprays that are used to treat allergy related congestion are the only nasal sprays that are safe to use for extended periods of time.

### Phantosmia

Phantosmia is the phenomenon of smelling odors that aren't really present. (AKA Phantom odors) The most common odors are unpleasant smells such as rotting flesh, vomit, feces, smoke etc. Phantosmia often results from damage to the nervous tissue in the olfactory system. The damage can be caused by viral infection, trauma, surgery, and possibly exposure to toxins or drugs. It can also be induced by epilepsy affecting the olfactory cortex. It is also thought the condition can have psychiatric origins.

### Dysosmia

When things smell differently than they should.

## The Sense of Vision

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**Vision** needs to have the work of both the eyes and the brain to process any information. The majority of the stimuli is done in the eyes and then the information is sent to the brain by the way of nerve impulses. At least one-third of the information of what the eye sees is processed in the cerebral cortex of the brain.

# Anatomy of the Eye

The human eye is a elongated ball about 1-inch (2.5 cm) in diameter and is protected by a bony socket in the skull. The eye has three layers or coats that make up the exterior wall of the eyeball, which are the sclera, choroid, and retina.

## Sclera

The outer layer of the eye is the sclera, which is a tough white fibrous layer that maintains, protects and supports the shape of the eye. The front of the sclera is transparent and is called the cornea. The cornea refracts light rays and acts like the outer window of the eye.

## Choroid

The middle thin layer of the eye is the choroid, also known as the choroidea or choroid coat, it is the vascular layer of the eye lying between the retina and the sclera. The choroid provides oxygen and nourishment to the outer layers of the retina. It also contains a nonreflective pigment that acts as a light shield and prevents light from scattering. Light enters the front of the eye through a hole in the choroid coat called the pupil. The iris contracts and dilates to compensate for the changes in light intensity. If the light is bright the iris then contracts making the pupil smaller, and if the light is dim, the iris dilates making the pupil bigger. Just posterior to the iris is the lens, which is composed mainly of proteins called crystallins. The lens is attached by the zonules to the ciliary body that contains the ciliary muscles that control the shape of the lens for accommodation. Along with the ciliary body and iris, the choroid forms the uveal tract. The uvea is the middle of the three concentric layers that make up an eye. The name is possibly a reference to its almost black color, wrinkled appearance and grape-like size and shape when stripped intact from a cadaveric eye.

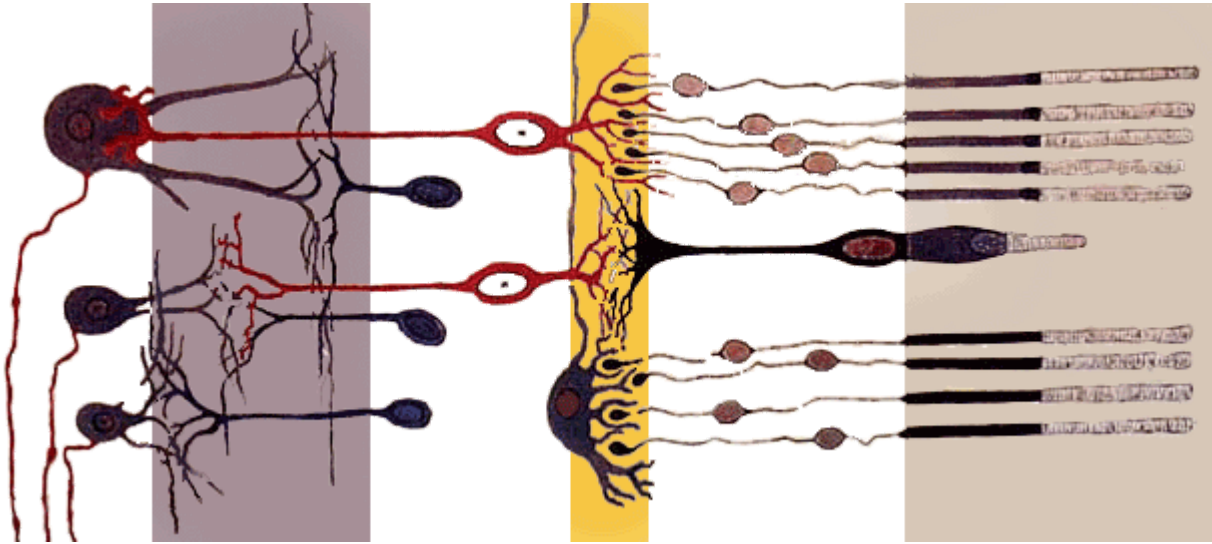
## Retina

The third or the innermost layer of the eye is call the retina. In adult humans the entire retina is 72% of a sphere about 22 mm in diameter. The retina lays over the back two thirds of the choroid coat, which is located in the posterior compartment. The compartment is filled with vitreous humor which is a clear, gelatinous material. Within the retina there are cells called rod cells and cone cells also known as photoreceptors. The rod cells are very sensitive to light and do not see color, that is why when we are in a darkened room we see only shades of gray. The cone cells are sensitive to different wavelengths of light, and that is how we are able to tell different colors. It is a lack of cones sensitive to red, blue, or green light that causes individuals to have deficiencies in color vision or various kinds of color blindness. At the center of the retina is the optic disc, sometimes known as "the blind spot" because it lacks photoreceptors. It is where the optic nerve leaves the eye and takes the nerve impulses to the brain. The cornea and the lens of the eye focuses the light onto a small area of the retina called the **fovea centralis** where the cone cells are densely packed. The fovea is a pit that has the highest visual acuity and is responsible for our sharp central vision - there are no rods in the fovea.



Illustration of the "blind spot." Situate your head about one foot from the monitor. Close your right eye and look at the dot on the right with your left eye. Move your head slowly closer. When you get to the correct spot, the dot on the left will disappear.





*Retina's simplified axial organization. The retina is a stack of several neuronal layers. Light is concentrated from the eye and passes across these layers (from left to right) to hit the photoreceptors (right layer). This elicits chemical transformation mediating a propagation of signal to the bipolar and horizontal cells (middle yellow layer). The signal is then propagated to the amacrine and ganglion cells. These neurons ultimately may produce action potentials on their axons. This spatiotemporal pattern of spikes determines the raw input from the eyes to the brain.*

### Photoreceptors

A photoreceptor, or photoreceptor cell, is a specialized type of neuron found in the eye's retina that is capable of phototransduction. More specifically, the photoreceptor sends signals to other neurons by a change in its membrane potential when it absorbs photons. Eventually, this information will be used by the visual system to form a complete representation of the visual world. There are 2 types of photoreceptors: **rods** are responsible for scotopic, or night vision, whereas **cones** are responsible for photopic, or daytime vision as well as color perception.

### Extraocular muscles

Each eye has six muscles that control its movements: the lateral rectus, the medial rectus, the inferior rectus, the superior rectus, the inferior oblique, and the superior oblique. When the muscles exert different tensions, a torque is exerted on the globe that causes it to turn. This is an almost pure rotation, with only about one millimeter of translation, thus, the eye can be considered as undergoing rotations about a single point in the center of the eye. Five of the extraocular muscles have their origin in the back of the orbit in a fibrous ring called the **annulus of Zinn**. Four of these then course forward through the orbit and insert onto the globe on its anterior half (i.e., in front of the eye's equator). These muscles are named after their straight paths, and are called the four rectus muscles, or four recti. They insert on the globe at 12, 3, 6, and 9 o'clock, and are called the superior, lateral, inferior and medial rectus muscles. (Note that lateral and medial are relative to the subject, with lateral toward the side and medial toward the midline, thus the medial rectus is the muscle closest to the nose).

### Eye Movement

The visual system in the brain is too slow to process that information if the images are slipping across the retina at more than a few degrees per second, thus, for humans to be able to see while moving, the brain must compensate for the motion of the head by turning the eyes. To get a clear view of the world, the brain must turn the eyes so that the image of the object of regard falls on the fovea. Eye movements are thus very important for visual perception, and any failure to make them correctly can lead to serious visual disabilities.

Having two eyes is an added complication, because the brain must point both of them accurately enough that the object of regard falls on corresponding points of the two retinas; otherwise, double vision would occur. The movements of different body parts are controlled by striated muscles acting around joints. The movements of the eye are no exception, but they have special advantages not shared by skeletal muscles and joints, and so are considerably different.

### **Try This Experiment**

Hold your hand up, about one foot (30 cm) in front of your nose. Keep your head still, and shake your hand from side to side, slowly at first, and then faster and faster. At first you will be able to see your fingers quite clearly. But as the frequency of shaking passes about one hertz, the fingers will become a blur. Now, keep your hand still, and shake your head (up and down or left and right). No matter how fast you shake your head, the image of your fingers remains clear. This demonstrates that the brain can move the eyes opposite to head motion much better than it can follow, or pursue, a hand movement. When your pursuit system fails to keep up with the moving hand, images slip on the retina and you see a blurred hand.

### **How we see an object**

- The light rays enter the eye through the cornea (transparent front portion of eye to focus the light rays).
- Then, light rays move through the pupil, which is surrounded by Iris to keep out extra light
- Then, light rays move through the crystalline lens (Clear lens to further focus the light rays )
- Then, light rays move through the vitreous humor (clear jelly like substance)
- Then, light rays fall on the retina, which processes and converts incident light to neuron signals using special pigments in rod and cone cells.
- These neuron signals are transmitted through the optic nerve,
- Then, the neuron signals move through the visual pathway - Optic nerve > Optic Chiasm > Optic Tract > Optic Radiations > Cortex
- Then, the neuron signals reach the occipital (visual) cortex and its radiations for the brain's processing.
- The visual cortex interprets the signals as images and along with other parts of the brain, interpret the images to extract form, meaning, memory and context of the images.

### **Depth Perception**

Depth perception is the visual ability to perceive the world in three dimensions. It is a trait common to many higher animals. Depth perception allows the beholder to accurately gauge the distance to an object.

Depth perception is often confused with binocular vision, also known as Stereopsis. Depth perception does rely on binocular vision, but it also uses many other monocular cues.

### **Diseases, disorders, and age-related changes**

There are many diseases, disorders, and age-related changes that may affect the eyes and surrounding structures. As the eye ages certain changes occur that can be attributed solely to the aging process. Most of these anatomic and physiologic processes follow a gradual decline. With aging, the quality of vision worsens due to reasons independent of aging eye diseases. While there are many changes of significance in the non-diseased eye, the most functionally important changes seem to be a reduction in pupil size and the loss of accommodation or focusing capability (presbyopia). The area of the pupil governs the amount of light that can reach the retina. The extent to which the pupil dilates also decreases with age. Because of the

smaller pupil size, older eyes receive much less light at the retina. In comparison to younger people, it is as though older persons wear medium-density sunglasses in bright light and extremely dark glasses in dim light. Therefore, for any detailed visually guided tasks on which performance varies with illumination, older persons require extra lighting.

### Color Blindness

Color Blindness or color vision deficiency, in humans is the inability to perceive differences between some or all colors that other people can distinguish. It is most often of genetic nature, but may also occur because of eye, nerve, or brain damage, or due to exposure to certain chemicals. There are many types of color blindness. The most common variety are hereditary (genetic) photoreceptor disorders, but it is also possible to acquire color blindness through damage to the retina, optic nerve, or higher brain areas. There is generally no treatment to cure color deficiencies, however, certain types of tinted filters and contact lenses may help an individual to distinguish different colors better.

File:Colorblind3.png

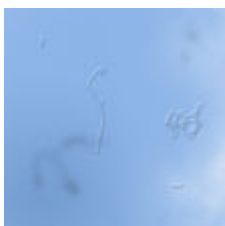
This image contains a two digit number similar to the sample above. Someone who is protanopic might not see this number.

### Night Blindness

Also known as Nyctalopia, is a condition making it difficult or impossible to see in the dark. It is a symptom of several eye diseases. Night blindness may exist from birth, or be caused by injury or malnutrition (for example, a lack of vitamin A). The most common cause of nyctalopia is retinitis pigmentosa, a disorder in which the rod cells in the retina gradually lose their ability to respond to the light. Patients suffering from this genetic condition have progressive nyctalopia and eventually their day-time vision may also be affected. In congenital stationary night blindness the rods do not work from birth, but as the name implies, sufferers do not get worse. Another cause of night blindness is a deficiency of retinol, or vitamin A, found in fish oils, liver and dairy products.

### Day Blindness

Also known as Hemeralopia is the inability to see clearly in bright light. The daytime vision gets worse and worse. Nighttime vision remains unchanged due to the use of rods as opposed to cones (during the day), which get affected by hemeralopia and in turn degrade the daytime optical response.



Impression of floaters, as seen against a blue sky.

### Floater

Also known as "Muscae Volitantes" are deposits of various size, shape, consistency, refractive index, and motility within the eye's normally transparent vitreous humour. Floaters are suspended in the vitreous humour, the thick fluid or gel that fills the eye. Thus, they generally follow the rapid motions of the eye, while drifting slowly within the fluid. Floaters are visible only because they do not remain perfectly fixed within the eye. The shapes are shadows projected onto the retina by tiny structures of protein or other cell debris discarded over the years and trapped in the vitreous humour. They are also common after cataract operations or after trauma. In some cases, floaters are congenital.

### Glaucoma

A group of diseases of the optic nerve involving loss of retinal ganglion cells in a characteristic pattern of optic neuropathy. Although raised intraocular pressure is a significant risk factor for developing glaucoma, there is no set threshold for intraocular pressure that causes glaucoma. One person may develop nerve damage at a relatively low pressure, while another person may have high eye pressures for years and yet never develop damage. Untreated glaucoma leads to permanent damage of the optic nerve and resultant visual field loss, which can progress to blindness.

## Visual Agnosia

Visual agnosia is the inability of the brain to make sense of or make use of some part of otherwise normal visual stimulus, and is typified by the inability to recognize familiar objects or faces. This is distinct from blindness, which is a lack of sensory input to the brain due to damage to the eye or optic nerve. Visual agnosia is often due to damage, such as stroke, in posterior parietal lobe in the right hemisphere of the brain. Careful analysis of the nature of visual agnosia has led to improved understanding of the brain's role in normal vision.



Picture of children holding a ball as seen by someone with glaucoma.

## Deadly Nightshade

Deadly Nightshade is a plant oil that can potentially kill you. Atrophine taken from this plant causes your eyes to dilate. This was used in the middle ages by women who wanted to look more attractive for men. To this day, it is still used by ophthalmologists. How this works is that the atrophine is a competitor with acetylcholine. The Nightshadow goes into your receptors on the postsynaptic membrane of an action potential. This makes it so that the acetylcholine doesn't have any receptor site so the Na ion is not able to be released.

## Critical Thinking

The answers for these critical thinking questions is right here ([https://en.wikibooks.org/wiki/Human\\_Physiology/Appendix\\_1:\\_answers\\_to\\_review\\_questions#Critical\\_Thinking:\\_Vision](https://en.wikibooks.org/wiki/Human_Physiology/Appendix_1:_answers_to_review_questions#Critical_Thinking:_Vision))

1. Explain why you are normally unaware of your blind spot.
2. Stare at a bright light for 10 seconds and then stare at a white sheet of paper. What do you observe and why?
3. What is it that makes things "disappear" when you are staring at them at night, and how do you make them reappear?
4. Name what rods are sensitive to and also what cones are sensitive to.
5. Explain how Deadly Nightshade works.

## The Senses Of Hearing

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The ear is the sense organ that collects and detects sound waves and plays a major role in the sense of balance and body position. The sensory receptors for both hearing and equilibrium are mechanoreceptors found in the inner ear; these receptors are hair cells that have stereocilia (long microvilli) that are extremely sensitive to mechanical stimulations.

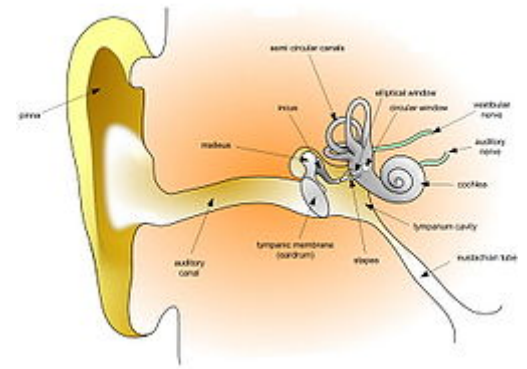
## Anatomy of the Ear

The ear has three divisions: the outer ear, the middle ear, and the inner ear.

### Outer Ear (Auricle, Ear Canal, Surface of Ear Drum)

The outer ear is the most external portion of the ear. The outer ear includes the pinna (also called auricle), the ear canal, and the very most superficial layer of the ear drum (also called the tympanic membrane). Although the word "ear" may properly refer to the pinna (the flesh covered cartilage appendage on either side of the head), this portion of the ear is not vital for hearing. The complicated design of the human outer ear does help capture sound, but the

most important functional aspect of the human outer ear is the ear canal itself. This outer ear canal skin is applied to cartilage; the thinner skin of the deep canal lies on the bone of the skull. If the ear canal is not open, hearing will be dampened. Ear wax (medical name - cerumen) is produced by glands in the skin of the outer portion of the ear canal. Only the thicker cerumen-producing ear canal skin has hairs. The outer ear ends at the most superficial layer of the tympanic membrane. The tympanic membrane is commonly called the ear drum.



Anatomy of the human ear.

### **Middle Ear (Air Filled Cavity behind the Ear Drum, includes most of the Ear Drum, and Ear Bones)**

The middle ear includes most of the ear drum (tympanic membrane) and the 3 ear bones ossicles: malleus (or hammer), incus (or anvil), and stapes (or stirrup). The opening of the Eustachian tube is also within the middle ear. The malleus has a long process (the handle) that is attached to the mobile portion of the ear drum. The incus is the bridge between the malleus and stapes. The stapes is the smallest named bone in the human body. The stapes transfers the vibrations of the incus to the **oval window**, a portion of the inner ear to which it is connected. It is the final bone in the chain to transfer vibrations from the eardrum to the inner ear. The arrangement of these 3 bones is a sort of Rube Goldberg device: movement of the tympanic membrane causes movement of the first bone, which causes movement of the second, which causes movement of the third. When this third bone pushes down, it causes movement of fluid within the cochlea (a portion of the inner ear). This particular fluid only moves when the stapes footplate is depressed into the inner ear. Unlike the open ear canal, however, the air of the middle ear is not in direct contact with the atmosphere outside the body. The Eustachian tube connects from the chamber of the middle ear to the back of the pharynx. The middle ear in humans is very much like a specialized paranasal sinus, called the tympanic cavity, it, like the paranasal sinuses, is a hollow mucosa lined cavity in the skull that is ventilated through the nose. The mastoid portion of the temporal bone, which can be felt as a bump in the skull behind the pinna, also contains air, which ventilates through the middle ear.

### **Inner Ear (Cochlea, Vestibule, and Semi-Circular Canals)**

The inner ear includes both the organ of hearing (the cochlea) and a sense organ (the labyrinth or vestibular apparatus) that is attuned to the effects of both gravity and motion. The balance portion of the inner ear consists of three semi-circular canals and the vestibule. The inner ear is encased in the hardest bone of the body. Within this ivory hard bone, there are fluid-filled hollows. Within the cochlea are three fluid filled spaces: the tympanic canal, the vestibular canal, and the middle canal. The eighth cranial nerve comes from the brain stem to enter the inner ear. When sound strikes the ear drum, the movement is transferred to the footplate of the stapes, which attaches to the oval window and presses into one of the fluid-filled ducts of the cochlea. The hair cells in the organ of Corti are stimulated by particular frequencies of sound, based on their location within the cochlea. High pitch sounds are at a higher frequency and, due to the shorter wavelength they "hit" the membrane "faster" (ie. close to the oval window). In contrast, low frequency sounds have large wavelengths, and will travel further through the scala vestibuli before "hitting" the tectorial membrane near the apex of the cochlea. The fluid inside the cochlea is moved, flowing against the receptor (hair) cells of the organ of Corti, which fire in a graded response based on the volume of the sound. The hair cells then stimulate the nerve cells in the Spiral Ganglion, which sends information through the auditory portion of the eighth cranial nerve to the brain. Humans are able to hear sounds between about 20 Hz and 20,000 Hz. Mammals that can hear lower frequency sounds, such as whales and elephants, have a longer cochlea. Humans tend to lose high-frequency hearing first, which has led some teenagers to

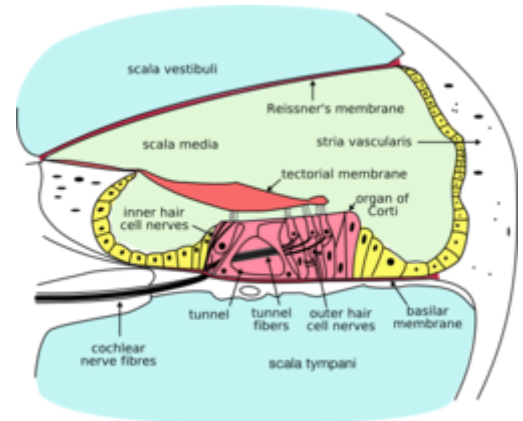


using high-frequency ring tones (above 17,000 Hz) that may go undetected by their middle-aged teachers.

## Hair Cell

Hair cells are columnar cells, each with a bundle of 100-200 specialized cilia at the top, for which they are named. These cilia are the mechanosensors for hearing. Lightly resting atop the longest cilia is the tectorial membrane, which moves back and forth with each cycle of sound, tilting the cilia and allowing electric current into the hair cell. Hair cells, like the photoreceptors of the eye, show a graded response, instead of the spikes typical of other neurons. Immediately over the hair cells of the organ of Corti is an overhanging “tectorial membrane.” When the Bones of the Middle Ear vibrate the oval window, these vibrations are transmitted to the fluid within the cochlea and eventually cause the round window on the cochlea

to bulge outward. These vibrations deflect the membrane on which the Organ of Corti is located, causing the three rows of outer hair cells to “rub” against the overhanging tectorial membrane. By their muscle-like activity they amplify the weakest vibrations for the inner hair cells. The louder sounds are not amplified. The disturbed inner hair cells will then activate the cochlear nerve fibers. The current model is that cilia are attached to one another by “tip links”, structures which link the tips of one cilium to another. Stretching and compressing the tip links may open an ion channel and produce the receptor potential in the hair cell. These graded potentials are not bound by the “all or none” properties of an action potential. There are far fewer hair cells than afferent (leading to the brain) nerve fibers in the cochlea. The nerve that innervates the cochlea is the cochlear nerve, and forms cranial nerve number VIII with the vestibular nerve from the balance organ. Neuronal dendrites innervate cochlear hair cells. The neurotransmitter itself is thought to be **glutamate**. At the presynaptic junction, there is a distinct “presynaptic dense body” or ribbon. This dense body is surrounded by synaptic vesicles and is thought to aid in the fast release of neurotransmitter. Efferent projections from the brain to the cochlea also play a role in the perception of sound. Efferent synapses occur on outer hair cells and on afferent dendrites under inner hair cells.



Cross section of the cochlea

## Process of Hearing

Detection of sound motion is associated with the right posterior superior temporal gyrus. The superior temporal gyrus contains several important structures of the brain, including: (1) marking the location of the primary auditory cortex, the cortical region responsible for the sensation of sound. Sections 41 and 42 are called the primary auditory area of the cerebrum, and processes the basic characteristics of sound such as pitch and rhythm. The auditory association area is located within the temporal lobe of the brain, in an area called the Wernicke's area, or area 22. This area, near the lateral cerebral sulcus, is an important region for the processing of acoustic energy so that it can be distinguished as speech, music, or noise. It also interprets words that are heard into an associated thought pattern of understanding. The gnostic area of the cerebrum, (areas 5, 7, 39 and 40) helps to integrate all incoming sense patterns so that a common thought can be formed (correlated) using all arriving sensory information.

## Hearing Under Water



Hearing threshold and the ability to localize sound sources are reduced underwater. In which the speed of sound is faster than in air. Underwater, hearing is by bone conduction and localization of sound appears to depend on differences in amplitude detected by bone conduction.

## Localization of Sound by Humans

Humans are normally able to hear a variety of sound frequencies, from about 20Hz to 20kHz. Our ability to estimate just where the sound is coming from, sound localization, is dependent on both hearing ability of each of the two ears, and the exact quality of the sound. Since each ear lies on an opposite side of the head, a sound will reach the closest ear first, and its amplitude will be loudest in that ear. Much of the brain's ability to localize sound depends on interaural (between ears) intensity differences and interaural temporal or phase differences.

Two mechanisms are known to be used.

Bushy neurons can resolve time differences as small as the time it takes sound to pass one ear and reach the other (10 milliseconds). For high frequencies, frequencies with a wavelength shorter than the listener's head, more sound reaches the nearer ear. Human echolocation is a technique involving echolocation used by some blind humans to navigate within their environment.

## Process of Equilibrium

Equilibrioception or sense of balance is one of the physiological senses. It allows humans and animals to walk without falling. Some animals are better in this than humans, for example allowing a cat (as a quadruped using its inner ear and tail) to walk on a thin fence. All forms of equilibrioception can be described as the detection of acceleration.

It is determined by the level of fluid properly called endolymph in the labyrinth - a complex set of tubing in the inner ear.

When the sense of balance is interrupted it causes dizziness, disorientation and nausea.

You can temporarily disturb your sense of balance by closing your eyes and turning rapidly in circles five or six times. This starts the fluid swirling in circles inside your ear canal. When you stop turning it takes a few seconds for the fluid to lose momentum, and until then the sense from your inner ear conflicts with the information coming from your vision, causing dizziness and disorientation. Most astronauts find that their sense of balance is impaired when in orbit, because there is not enough gravity to keep the ear's fluid in balance. This causes a form of motion sickness called space sickness.

## Disorders with the Ear

**Case Study** A 45-year-old woman wakes up not feeling well. She believes that she may be coming down with the flu due to nausea that she is feeling, so she continues with her day. As the day progresses so does the feeling of nausea. While watching a movie with members of her family, the sick feeling seems to intensify and so they leave the movie. In the lobby of the movie theater she becomes very unbalanced and collapses. The fear is that she is experiencing a stroke. After being taken to the hospital via ambulance, the ER doctors also feel that it may be a stroke and do CAT scans to verify. Nothing shows up on the scans but the feeling of nausea and vertigo are intense. The woman is later diagnosed with an inner ear infection. The next 6-9 months of her life are filled with antibiotics, balance therapy and continued nausea and vertigo. Nothing seems

to help so the doctors go into her inner ear surgically through her skull. They cut the vestibular nerve that is linked to the balance center on the left side. The right inner ear will eventually compensate for this loss of balance however it will take months of balance therapy. After a year from the onset on the inner ear infection, the woman has had three inner ear surgeries, loss of hearing in the left ear and problems with her balance. Doctors have told her they have done everything that they can and that she will now have to live with these conditions on a daily basis.

## Deafness

The word deaf can have at least two different meanings. The first term is used to indicate the presence of enough hearing loss such that an individual is not sensitive to sound. Someone with a partial loss of hearing is more likely to be referred to as hearing impaired or the qualified partially deaf by professionals. The second term is used to indicate someone who considers themselves 'culturally deaf', and they often use a capital D to distinguish this. Deaf people often are signers and consider that their Deafness is not something that needs to be medically fixed.

**Cochlear Implants** A cochlear implant is a device which has been used to restore hearing function to some deaf and hearing impaired people. It consists of an internal device; which extends electrodes into the cochlea and indirectly stimulates the auditory nerve, and an external device; which works much like a hearing aid, except it transmits information to the internal device rather than to the ear. The cochlear implant basically bypasses the middle ear and the cochlea hair cells, and allows some people with damage to these structures to hear 'electronically'.

## Otitis Media

An inflammation of the middle ear segment. It is usually associated with a buildup of fluid and frequently causes an earache. The fluid may or may not be infected. The typical progress of otitis media is: the tissues surrounding the Eustachian tube swell due to an infection and/or severe congestion. The Eustachian tube remains blocked most of the time. The air present in the middle ear is slowly absorbed into the surrounding tissues. A strong negative pressure creates a vacuum in the middle ear. The vacuum reaches a point where fluid from the surrounding tissues accumulates in the middle ear. *Streptococcus pneumoniae* and *Haemophilus influenzae* are the most common bacterial causes of otitis media. As well as being caused by *Streptococcus pneumoniae* and *Haemophilus influenzae* it can also be caused by the common cold.



## Vertigo (dizziness)

Vertigo, sometimes called a headrush, is a major symptom of a balance disorder. It is the sensation of spinning while the body is stationary with respect to the earth or surroundings. With the eyes shut, there will be a sensation that the body is in movement, called subjective vertigo; if the eyes are open, the surroundings will appear to move past the field of vision, called objective vertigo. The effects may be slight. It may cause nausea or, if severe, may give rise to difficulty with standing and walking. Vertigo is usually associated with a problem in the inner ear balance mechanisms (vestibular system), in the brain, or with the nerve connections between these two organs. The most common cause is benign paroxysmal positional vertigo, or BPPV. Vertigo can be a symptom of an underlying harmless cause,

such as in BPPV or it can suggest more serious problems. These include drug toxicities, strokes or tumors (though these are much less common than BPPV).

### **Motion sickness**

Motion sickness is a condition in which the endolymph (the fluid found in the semicircular canals of the inner ears) becomes 'stirred up', causing confusion between the difference between apparent perceived movement (none or very little), and actual movement. Depending on the cause, it is also referred to as seasickness, carsickness, airsickness, or spacesickness. Nausea is the most common symptom of motion sickness. If the motion causing nausea is not resolved, the sufferer will frequently vomit within twenty minutes. Unlike ordinary sickness, vomiting in motion sickness tends not to relieve the nausea. If you don't want to consult a doctor, one common form of relief is to eat mints.

### **Dysacusis**

Dysacusis is a hearing impairment characterized by difficulty in processing details of sound, but not primarily a loss of the ability to perceive sound. May also refer to pain or discomfort due to sound.

## **Critical Thinking**

The answers for these critical thinking questions can be found here ([https://en.wikibooks.org/wiki/Human\\_Physiology/Appendix\\_1:\\_answers\\_to\\_review\\_questions#Critical\\_Thinking:\\_Hearing](https://en.wikibooks.org/wiki/Human_Physiology/Appendix_1:_answers_to_review_questions#Critical_Thinking:_Hearing)).

1. Explain how the pitch of sound is coded. How is the loudness of sound coded?
2. What do the three semicircular canals in the inner ear enable us to do? How do they accomplish this?
3. What does the eustachian tube do? What does the eustachian tube have to do with a middle ear infection?
4. What is the advantage of having a oval window?

## **Touch**

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Touch is the first sense developed in the womb and the last sense used before death. With 50 touch receptors for every square centimeter and about 5 million sensory cells overall, the skin is very sensitive and is the largest and one of the most complex organs in our bodies. These touch receptors are grouped by type and include Mechanoreceptors (sensitive to pressure, vibration and slip), Thermoreceptors (sensitive to changes in temperature), and Nociceptors (responsible for pain).

### **Pacinian Corpuscles**

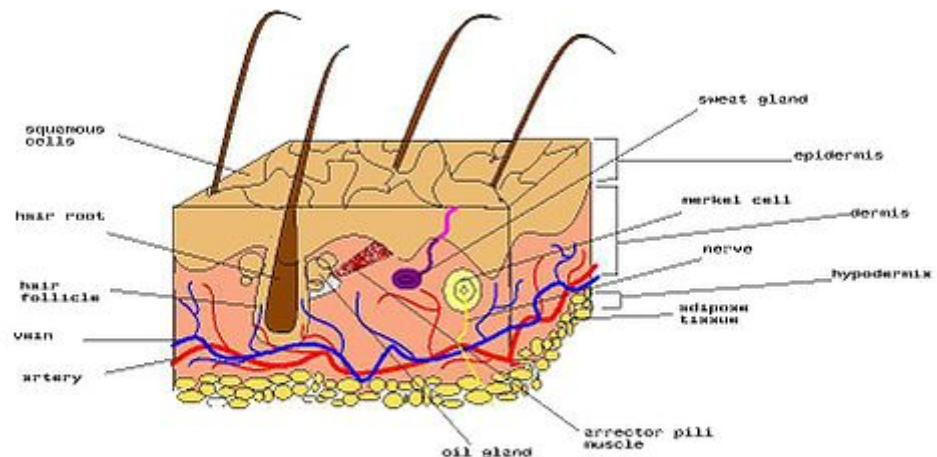
Pacinian corpuscles detect gross pressure changes and vibrations. They are the largest of the receptors. Any deformation in the corpuscle causes action potentials to be generated, by opening pressure-sensitive sodium ion channels in the axon membrane. This allows sodium ions to influx in, creating a receptor potential. Pacinian corpuscles cause action potentials when the skin is rapidly indented but not when the pressure is steady, due to the layers of connective tissue that cover the nerve ending (Kandel et al., 2000). It is thought that they respond to high velocity changes in joint position.

### **Meissner's Corpuscle**

Meissner's corpuscles are distributed throughout the skin, but concentrated in areas especially sensitive to light touch, such as the fingertips, palms, soles, lips, tongue, face, nipples and the external skin of the male and female genitals. They are primarily located just beneath the epidermis within the dermal papillae. Any physical deformation in the Meissner's corpuscle will cause an action potential in the nerve. Since they are rapidly adapting or phasic, the action potentials generated quickly decrease and eventually cease. If the stimulus is removed, the corpuscle regains its shape and while doing so (ie: while physically reforming) causes another volley of action potentials to be generated. (This is the reason one stops "feeling" one's clothes.) This process is called **sensory adaption**. Because of their superficial location in the dermis, these corpuscles are particularly sensitive to touch and vibrations, but for the same reasons, they are limited in their detection because they can only signal that something is touching the skin. Meissner's corpuscles do not detect pain; this is signaled exclusively by free nerve endings.

## Merkel's Discs

Merkel's Discs are Mechanoreceptors, making them sensitive to pressure and vibration. In humans, Merkel cells occur in the superficial skin layers, and are found clustered beneath the ridges of the fingertips that make up fingerprints. They're somewhat rigid in structure, and the fact that they are not encapsulated, causes them to have a sustained



Layers of the skin, showing the Merkel's Cell.

response (in the form of action potentials or spikes) to mechanical deflection of the tissue. Merkel nerve endings are extremely sensitive to tissue displacement, and may respond to displacements of less than 1  $\mu\text{m}$ . Several studies indicate that they mediate high-resolution tactile discrimination, and are responsible for the ability of our fingertips to feel fine detailed surface patterns (e.g. for reading Braille).

## Ruffini corpuscles

Ruffini corpuscles are Thermoreceptors, aiding in the detection of temperature changes. Named after Angelo Ruffini, the Ruffini ending is a class of slowly adapting mechanoreceptor thought to exist only in the glabrous dermis and subcutaneous tissue of humans. This spindle-shaped receptor is sensitive to skin stretch, and contributes to the kinesthetic sense of and control of finger position and movement.

## Disorders of Touch

### Sensory Processing Disorder

In most people sensory integration occurs naturally without a thought process. But in some people the sensory integration does not develop properly and becomes distorted. In these people, the brain and central nervous system misinterprets everyday sensory information such as touch, sound and movement. Research is still being done on this disorder but they

are finding direct links to SPD with other disorders like ADD/ADHD, premature birth, Autism, Down's Syndrome and Fragile X.

### **Tactile defensiveness**

Considered a category of SPD, tactile defensiveness is an overreaction to the sense of touch. Identified by Dr. Jean Ayers in the 1960's. A person with tactile defensiveness will react with a "flight or fight" reaction to touch stimuli that a normal person would interpret as harmless. Most cases are noticed in children or babies due to the fact that they do not want to be touched or cuddled as a normal child would. A child with this disorder will probably have these sign or symptoms:

- Does not like to go barefoot or have feet touched
- Does not enjoy baths, haircuts, nail clipping
- Requires tags to be removed from all clothing
- Does not want their face touched
- Hard time eating because of textures, temperatures of the food
- Does not want to touch anything that is messy or has a sticky texture

### **Congenital insensitivity to pain with anhidrosis or CIPA**

Exceedingly rare disease. There are only about 35 known cases in the United States. CIPA is a severe autosomal recessive condition in which the peripheral nerves demonstrate a loss of unmyelinated and small myelinated fibers. The actual physiopathological mechanism is still unknown and being studied- this is an extremely hard disease to study due to the rarity of cases. Most people with the disease will not live long due to injuries received that go untreated because they are unknown and severe

## **Case Study**

### **Insensitivity to pain**

Wouldn't it wonderful if you could no longer feel pain. Is that not something we all would like to have? Or do we have pain for a good reason? Although it is rare there is a disease known as congenital insensitivity to pain. This genetic abnormality cause some people to lack certain components of the sensory system to receive pain. The exact reason for the problem is unknown and varies between people. Sadly people who have the disease often die in childhood. Injuries are very common with people who have congenital insensitivity to pain. They often will lose digits, may suffer from burns and their knees often have sores from kneeling to long. Clearly pain has a purpose, it is our warning signal when things are awry.

## **The newborn's senses**

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Newborns can feel all different sensations, but respond most enthusiastically to soft stroking, cuddling and caressing. Gentle rocking back and forth will oftentimes calm a crying infant, as will massages and warm baths. Newborns may comfort themselves by sucking their thumbs, or a pacifier. The need to suckle is instinctive and allows newborns to feed.

### **Vision**

Newborn infants have unremarkable vision, being able to focus on objects only about 18 inches (45 cm) directly in front of their face. While this may not be much, it is all that is needed for the infant to look at the mother's face when breastfeeding. When a newborn is not sleeping, or feeding, or crying, he or she may spend a lot of time staring at random objects. Usually anything that is shiny, has sharp contrasting colors, or has complex patterns will catch an infant's eye. However, the newborn has a preference for looking at other human faces above all else.

## Hearing

While still inside the mother, the infant can hear many internal noises, such as the mother's heartbeat, as well as many external noises including human voices, music and most other sounds. Therefore, although a newborn's ears may have some fluid present, he or she can hear sound from birth. Newborns usually respond to a female's voice over a male's. This may explain why people will unknowingly raise the pitch of their voice when talking to newborns. The sound of other human voices, especially the mother's, can have a calming or soothing effect on the newborn. Conversely, loud or sudden noises will startle and scare a newborn.

## Taste

Newborns can respond to different tastes, including sweet, sour, bitter, and salty substances, with preference toward sweets.

## Smell

A newborn has a developed sense of smell at birth, and within the first week of life can already distinguish the differences between the mother's own breast milk and the breast milk of another female.

Reflex	Stimulation	Response	Age of disappearance	Function
Eye blink	Bright light shinning in eyes or clap hands by eyes.	Closes eyelids quickly.	Permanent	This reflex protects the infant from an excessive amount of stimulation.
Withdrawal	Stick sole of foot with a stimulus like a pin.	This causes the foot to withdraw. Flexing of the knee to hip occurs.	Decreases after the 10th day of birth	This protects the infant from excessive unpleasant tactile stimulation.
Rooting	Touch cheek near the corner of the mouth.	The infant's head will turn towards the site of stimulation.	3 weeks (due to the voluntary response that is now capable for infant to do at this time)	This reflex helps baby to find the mothers' nipple.
Sucking	Place fingers in infant's mouth.	The infant will suck finger rhythmically.	4 months (voluntary sucking will come about)	This helps with feeding.
Swimming	Place the baby in pool of water face down.	The baby paddles and kicks in swimming movements.	4 to 6 month	This helps baby to survive if dropped into the water.
Moro	Hold infant in a	The baby will make a	6 months	In the



	cradling horizontal position and slightly lower the baby in a fast motion toward the ground while making a loud sound.	embracing motion and arch its back extending it's legs and throwing it's arms outward. Finally it will bring the arms in toward its body		evolutionary past this may have helped the baby cling to the mother.
Palmar grasp	Place the finger in baby's palm and press against the palm.	The baby will immediately grasp the finger.	3 to 4 months	This prepares infant for voluntary grasping.
Tonic neck	Turn the baby's head to one side while the baby is awake.	This will cause the baby to extend one arm in front of its eye or to the side to which the head has been turned.	4 months	This may prepare for voluntary reaching.
Stepping	Hold the baby under the arm and permit the bare feet of the baby to touch a flat surface.	The baby will lift one foot after the other in a stepping fashion.	2 months (this applies to a baby who has gained weight. For baby who is not as heavy, this reflex may be submissive.)	This prepares the baby for voluntary walking.
Babinski	Touch the foot in a stroking manner from the toe toward the heel.	The baby's toes will fan out and curl as the foot twists inward.	8 to 12 months	Unknown

## Review Questions

Answers for these questions can be found here ([https://en.wikibooks.org/wiki/Human\\_Physiology/Appendix\\_1:\\_answers\\_to\\_review\\_questions#Senses](https://en.wikibooks.org/wiki/Human_Physiology/Appendix_1:_answers_to_review_questions#Senses))

1. Located under the hardest bone in the body, these control not only hearing but also a sense of gravity and motion:

- A) The incus and the stapes
- B) The pinna and the ear drum
- C) the vestibular nerve and the semi circular canals
- D) The eustachian tube and the stapes

2. The retina does the following;

- A) allows vision in light and dark, using cones and rods
- B) Gives depth perception using binocular vision

C) Contains the ciliary muscles that control the shape of the lens

D) Protects and supports the shape of the eye

3. This is the reason that we stop feeling the clothes that we are wearing

A) Merkel's Discs are somewhat rigid in structure, and the fact that they are not encapsulated, causes them to have a sustained response

B) Meissner's corpuscle are rapidly adapting or phasic, the action potentials generated quickly decrease and eventually cease

C) Ruffini corpuscles is a class of slowly adapting mechanoreceptor

D) Pacinian corpuscles allow sodium ions to influx in, creating a receptor potential

4. When eating a piece of candy, I will use the following to sense that it is sweet

A) Fungiform papillae

B) Filiform papillae

C) Foliate papillae

D) Circumvallate papillae

E) All of the above

5. If I have a cold, food may not taste as good to me because

A) The nerve fibrils are not functioning properly

B) My food will taste the same; taste and smell have nothing in common

C) Papilla become blocked by mucus and are unable to function

D) Olfaction, taste and trigeminal receptors together contribute to the flavor of my food

6. Walking from a well lit room into a dark room would cause the following to occur

A) The sclera in the eye to open and eventually allow me to see in the dark

B) The extraocular muscles in the eye to open and eventually allow me to see in the dark

C) The cones in the eye to open and eventually allow me to see in the dark

D) the rods in the eye to open and eventually allow me to see in the dark

7. Hair cells in the ear

A) Are the actual sensory receptors that will fire off action potentials when they are disturbed

- B) Show a graded response, instead of the spikes typical of other neurons
- C) “Rub” against the overhanging tectorial membrane
- D) All of the above

8. Eyesight decreases with age because

- A) Older eyes receive much less light at the retina
- B) There are numerous eye diseases that can affect an older eye
- C) The extent to which the pupil dilates decreases with age
- D) all of the above

9. Teens walking off of a roller coaster in Magic Mountain seem to have vertigo because

- A) The fluid in the auricle has not stopped moving causing conflicts with the information coming from your vision
- B) the fluid in the cochlea has not stopped moving causing conflicts with the information coming from your vision
- C) The fluid in the tympanic membrane has not stopped moving causing conflicts with the information coming from your vision
- D) The fluid in the stirrup has not stopped moving causing conflicts with the information coming from your vision

10. These receptors react to foods treated with monosodium glutamate

- A) Salt
- B) Sour
- C) Bitter
- D) Sweet
- E) Umami

11. What senses fall under the category of chemoreception?

- A) Hearing and smell
- B) Touch and hearing
- C) Vision and taste
- D) Taste and smell

# Glossary

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**Anosmia:** Lack of olfaction, or a loss of the sense of smell

**Auditory Canal:** Tube from the auditory meatus or opening of the ear to the tympanic membrane

**Auditory Tube:** Either of the paired tubes connecting the middle ears to the nasopharynx; equalizes air pressure on the two sides of the eardrum

**Chemoreception:** Physiological response of a sense organ to a chemical stimulus

**Choroid:** Vascular layer of the eye lying between the retina and the sclera

**Circumvallate papillae:** Papillae that are present on the back of the oral part of the tongue

**Cochlea:** Is concerned with hearing, resembling a shell of a snail

**Dysosmia:** When things smell differently than they should

**Equilibrium:** Sense of balance

**Extraocular muscles:** Six muscles that control eye movements: lateral rectus, medial rectus, inferior rectus, superior rectus, inferior oblique and superior oblique

**Filiform papillae:** Thin, longer papillae that don't contain taste buds but are the most numerous

**Foliate papillae:** Ridges and grooves towards the posterior part of the tongue

**Fungiform papillae:** These are present mostly at the apex (tip) of the tongue- slightly mushroom shaped

**Gustation:** The sense of taste

**Hair Cell:** Mechanosensors for hearing, columnar cells each with a bundle of 100-200 specialized cilia at the top

**Haptic:** From the Greek Haphe, means pertaining to the sense of touch

**Hyposmia:** Decreased ability to smell

**Inner Ear:** Innermost part of the ear, contains the cochlea, vestibule and semi-circular canals

**Mechanoreceptor:** Sensory receptor that responds to mechanical pressure or distortion

**Meissner's Corpuscle:** Encapsulated unmyelinated nerve endings, usually found in areas sensitive to light touch

**Middle Ear:** Air Filled Cavity behind the Ear Drum, includes most of the ear Drum and ear Bones

**Nasopharynx:** Nasal part of the pharynx that lies behind the nose and above the level of the soft palate

**Nociception:** The perception of pain

**Olfaction:** The sense of smell

**Otitis Media:** An inflammation of the middle ear

**Outer Ear:** External portion of the ear, includes the auricle, ear canal and surface of the ear drum

**Oval Window:** Fenestra that has the base of the stapes attached to it

**Pacinian Corpuscles;** Detect gross pressure changes and vibrations

**Papilla:** Specialized epithelial cells that are small projections on the top of the tongue

**Perception:** The brain's interpretation of a sensation

**Phantosmia:** Phenomenon of smelling odors that aren't really present (AKA Phantom odors)

**Photoreceptors:** Specialized type of neuron found in the eye's retina that is capable of phototransduction

**Pinna:** Auricle of the ear

**Retina:** Thin layer of neural cells that lines the back of the eyeball of vertebrates and some cephalopods

**Round Window:** Fenestra leading into the cochlea

**Sclera:** White outer coating of the eye- gives the eye its shape and helps to protect the delicate inner parts

**Semicircular Canals:** Certain canals of the inner ear

**Sensation:** Occurs when nerve impulses arrive in the brain

**Sensory adaptation:** A decrease in response to stimuli

**Stapes:** One of the small bones in the tympanum of the ear; the stirrups bone

**Tactition:** The sense of pressure perception, generally in the skin

**Tympanic Membrane:** The membrane in the ear that vibrates to produce sound

**Umami:** Japanese word meaning savory or meaty- type of taste signal

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