**(Slide 1) Lecture 12**

**Physiology of sensory systems**

**(Slide 2)** Lecture plan:

1. Physiology of Sensory Receptors.
2. Structural Receptor Types.
3. Functional Receptor Types.
4. Sensory Modalities.
5. Physiology of taste.
6. Threshold for taste.
7. Taste buds and their function.
8. Location of the Taste Buds.
9. Mechanism of Stimulation of Taste Buds Receptor Potential.
10. Generation of Nerve Impulses by the Taste Bud.
11. Transmission of taste signals into the central nervous system.
12. Olfactory membrane.
13. Stimulation of the olfactory cells.
14. Rapid Adaptation of Olfactory Sensations.
15. Threshold for Smell.
16. Transmission of smell signals into the central nervous system.
17. Primitive and Newer Olfactory Pathways Into the Central Nervous System.

**(Slide 3)** A major role of sensory receptors is to help us learn about the environment around us, or about the state of our internal environment. Different types of stimuli from varying sources are received and changed into the electrochemical signals of the nervous system. This process is called sensory transduction. This occurs when a stimulus is detected by a receptor which generates a graded potential in a sensory neuron.

**(Slide 4)** If strong enough, the graded potential causes the sensory neuron to produce an action potential that is relayed into the central nervous system (CNS), where it is integrated with other sensory information − and sometimes higher cognitive functions − to become a conscious perception of that stimulus. The central integration may then lead to a motor response.

**(Slide 5)** Describing sensory function with the term sensation or perception is a deliberate distinction. Sensation is the activation of sensory receptors at the level of the stimulus. Perception is the central processing of sensory stimuli into a meaningful pattern involving awareness. Perception is dependent on sensation, but not all sensations are perceived. Receptors are the structures (and sometimes whole cells) that detect sensations. A receptor or receptor cell is changed directly by a stimulus. A transmembrane protein receptor is a protein in the cell membrane that mediates a physiological change in a neuron, most often through the opening of ion channels or changes in the cell signaling processes. Some transmembrane receptors are activated by chemicals called ligands. For example, a molecule in food can serve as a ligand for taste receptors. Other transmembrane proteins, which are not accurately called receptors, are sensitive to mechanical or thermal changes. Physical changes in these proteins increase ion flow across the membrane, and can generate a graded potential in the sensory neurons.

**(Slide 6)** Stimuli in the environment activate specialized receptors or receptor cells in the peripheral nervous system. Different types of stimuli are sensed by different types of receptors. Receptor cells can be classified into types on the basis of three different criteria: cell type, position, and function. Receptors can be classified structurally on the basis of cell type and their position in relation to stimuli they sense. They can also be classified functionally on the basis of the transduction of stimuli, or how the mechanical stimulus, light, or chemical changed the cell membrane potential.

**(Slide 7)** The cells that interpret information about the environment can be either (1) a neuron that has a free nerve ending (dendrites) embedded in tissue that would receive a sensation; (2) a neuron that has an encapsulated ending in which the dendrites are encapsulated in connective tissue that enhances their sensitivity; or (3) a specialized receptor cell, which has distinct structural components that interpret a specific type of stimulus. The pain and temperature receptors in the dermis of the skin are examples of neurons that have free nerve endings. Also located in the dermis of the skin are lamellated and tactile corpuscles, neurons with encapsulated nerve endings that respond to pressure and touch. The cells in the retina that respond to light stimuli are an example of a specialized receptor cell, a photoreceptor.

**(Slide 8)** Graded potentials in free and encapsulated nerve endings are called generator potentials. When strong enough to reach threshold they can directly trigger an action potential along the axon of the sensory neuron. Action potentials triggered by receptor cells, however, are indirect. Graded potentials in receptor cells are called receptor potentials. These graded potentials cause neurotransmitter to be released onto a sensory neuron causing a graded post-synaptic potential. If this graded post-synaptic potential is strong enough to reach threshold it will trigger an action potential along the axon of the sensory neuron.

**(Slide 9) Video. Generator potentials vs Action potentials in sensory receptor and Node of ranvier**

**(Slide 10)** Another way that receptors can be classified is based on their location relative to the stimuli. An **exteroceptor** is a receptor that is located near a stimulus in the external environment, such as the somatosensory receptors that are located in the skin. An **interoceptor** is one that interprets stimuli from internal organs and tissues, such as the receptors that sense the increase in blood pressure in the aorta or carotid sinus. Finally, a proprioceptor is a receptor located near a moving part of the body, such as a muscle or joint capsule, that interprets the positions of the tissues as they move.

**(Slide 11)** A third classification of receptors is by how the receptor transduces stimuli into membrane potential changes. Stimuli are of three general types. Some stimuli are ions and macromolecules that affect transmembrane receptor proteins by binding or by directly diffusing across the cell membrane. Some stimuli are physical variations in the environment that affect receptor cell membrane potentials. Other stimuli include the electromagnetic radiation from visible light. For humans, the only electromagnetic energy that is perceived by our eyes is visible light. Some other organisms have receptors that humans lack, such as the heat sensors of snakes, the ultraviolet light sensors of bees, or magnetic receptors in migratory birds.

**(Slide 12)** Receptor cells can be further categorized on the basis of the type of stimuli they transduce. Chemical stimuli can be detected by a **chemoreceptors** that detect chemical stimuli, such as a chemicals that lead to the sense of smell. **Osmoreceptors** respond to solute concentrations of body fluids. **Pain** is primarily a chemical and sometimes mechanical sense that interprets the presence of chemicals from tissue damage, or intense mechanical stimuli, through a nociceptor. Physical stimuli, such as pressure and vibration, as well as the sensation of sound and body position (balance), are interpreted through a **mechanoreceptor**. Another physical stimulus that has its own type of receptor is temperature, which is sensed through a **thermoreceptor** that is either sensitive to temperatures above (heat) or below (cold) normal body temperature.

**(Slide 13)** Ask anyone what the senses are, and they are likely to list the five major senses − taste, smell, touch, hearing, and sight. However, these are not all of the senses. The most obvious omission from this list is balance. Also, what is referred to simply as touch can be further subdivided into pressure, vibration, stretch, and hair-follicle position, on the basis of the type of mechanoreceptors that perceive these touch sensations. Other overlooked senses include temperature perception by thermoreceptors and pain perception by nociceptors.

**(Slide 14)** Within the realm of physiology, senses can be classified as either general or special. A general sense is one that is distributed throughout the body and has receptor cells within the structures of other organs. Mechanoreceptors in the skin, muscles, or the walls of blood vessels are examples of this type. General senses often contribute to the sense of touch, as described above, or to proprioception (body position) and kinesthesia (body movement), or to a visceral sense, which is most important to autonomic functions. A special sense is one that has a specific organ devoted to it, namely the eye, inner ear, tongue, or nose.

**(Slide 15)** Each of the senses is referred to as a sensory modality. Modality refers to the way that information is encoded into a perception. The main sensory modalities can be described on the basis of how each stimulus is transduced and perceived. The chemical senses include taste and smell. The general sense that is usually referred to as touch includes chemical sensation in the form of nociception, or pain. Pressure, vibration, muscle stretch, and the movement of hair by an external stimulus, are all sensed by mechanoreceptors and perceived as touch or proprioception. Hearing and balance are also sensed by mechanoreceptors. Finally, vision involves the activation of photoreceptors.

**(Slide 16)** Listing all the different sensory modalities, which can number as many as 17, involves separating the five major senses into more specific categories, or submodalities, of the larger sense. An individual sensory modality represents the sensation of a specific type of stimulus. For example, the general sense of touch, which is known as somatosensation, can be separated into light pressure, deep pressure, vibration, itch, pain, temperature, or hair movement.

**(Slide 17)** The senses of taste and smell allow us to separate undesirable or even lethal foods from those that are pleasant to eat and nutritious. They also elicit physiological responses involved in the digestion and utilization of foods. The sense of smell allows animals to recognize the proximity of other animals or even individual animals. Finally, both senses are strongly tied to primitive emotional and behavioral functions of our nervous systems. In this chapter, we discuss how taste and smell stimuli are detected and how they are encoded in neural signals transmitted to the brain.

**(Slide 18)** Taste is mainly a function of the taste buds in the mouth, but it is common experience that one’s sense of smell also contributes strongly to taste perception. In addition, the texture of food, as detected by tactual senses of the mouth, and the presence of substances in the food that stimulate pain endings, such as pepper, greatly alter the taste experience. The importance of taste lies in the fact that it allows a person to select food in accord with desires and often in accord with the body tissues’ metabolic need for specific substances.

**(Slide 19)** The identities of the many specific chemicals that excite different taste receptors are not all known. For practical analysis, the primary sensations of taste have been grouped into five general categories − sour, salty, sweet, bitter, and “umami.” A person can perceive hundreds of different tastes. They are all thought to be combinations of the elementary taste sensations, just as all the colors we can see are combinations of the three primary colors.

**(Slide 20) Sour Taste.** The sour taste is caused by acids − that is, by the hydrogen ion concentration − and the intensity of this taste sensation is approximately proportional to the logarithm of the hydrogen ion concentration (i.e., the more acidic the food, the stronger the sour sensation becomes).

**(Slide 21) Salty Taste.** The salty taste is elicited by ionized salts, mainly by the sodium ion concentration. The quality of the taste varies somewhat from one salt to another because some salts elicit other taste sensations in addition to saltiness. The cations of the salts, especially sodium cations, are mainly responsible for the salty taste, but the anions also contribute to a lesser extent.

**(Slide 22) Sweet Taste.** The sweet taste is not caused by any single class of chemicals. Some of the types of chemicals that cause this taste include sugars, glycols, alcohols, aldehydes, ketones, amides, esters, some amino acids, some small proteins, sulfonic acids, halogenated acids, and inorganic salts of lead and beryllium. Note specifically that most of the substances that cause a sweet taste are organic chemicals. It is especially interesting that slight changes in the chemical structure, such as the addition of a simple radical, can often change the substance from sweet to bitter.

**(Slide 23) Bitter Taste.** The bitter taste, like the sweet taste, is not caused by any single type of chemical agent. Here again, the substances that give the bitter taste are almost entirely organic substances. Two particular classes of substances are especially likely to cause bitter taste sensations: (1) long-chain organic substances that contain nitrogen; and (2) alkaloids. The alkaloids include many of the drugs used in medicines, such as quinine, caffeine, strychnine, and nicotine. Some substances that initially taste sweet have a bitter aftertaste. This characteristic is true of saccharin, which makes this substance objectionable to some people. High concentrations of salts may also result in a bitter taste. The bitter taste, when it occurs in high intensity, usually causes the person or animal to reject the food. This reaction is undoubtedly an important function of the bitter taste sensation because many deadly toxins found in poisonous plants are alkaloids, and virtually all these alkaloids cause an intensely bitter taste, usually followed by rejection of the food.

**(Slide 24) Umami Taste**. Umami, a Japanese word meaning “delicious,” designates a pleasant taste sensation that is qualitatively different from sour, salty, sweet, or bitter. Umami is the dominant taste of food containing l-glutamate, such as meat extracts and aging cheese. The pleasurable sensation of umami taste is thought to be important for nutrition by promoting ingestion of proteins.

**(Slide 25)** The molar threshold for stimulation of the sour taste by hydrochloric acid averages 0.0009 M, for stimulation of the salty taste by sodium chloride, 0.01 M, for the sweet taste by sucrose, 0.01 M, and for the bitter taste by quinine, 0.000008 M. Note especially that the bitter taste sense is much more sensitive than all the others, which provides an important protective function against many dangerous toxins in food.

**Slide 26 lists** the relative taste indices (the reciprocals of the taste thresholds) of different substances. In this table, the intensities of four of the primary sensations of taste are referred, respectively, to the intensities of the taste of hydrochloric acid, quinine, sucrose, and sodium chloride, each of which is arbitrarily chosen to have a taste index of 1. Taste Blindness. Some people are taste blind for certain substances, especially for different types of thiourea compounds. A substance used frequently by psychologists for demonstrating taste blindness is phenylthiocarbamide, for which about 15% to 30% of all people exhibit taste blindness; the exact percentage depends on the method of testing and the concentration of the substance.

**Slide 27 shows** a taste bud, which has a diameter of about 1⁄30 of a millimeter and a length of about 1⁄16 of a millimeter. The taste bud is composed of epithelial cells; some are supporting cells called sustentacular cells and others are called taste cells. There are about 100 taste cells in each taste bud. The taste cells are continually being replaced by mitotic division of surrounding epithelial cells, so some taste cells are young cells. Others are mature cells that lie toward the center of the bud; these cells soon break up and dissolve. The average life span of each taste cell is estimated to be about 10 days, although there is considerable variation, with some taste cells being eliminated in only 2 days while others may survive for over 3 weeks. The outer tips of the taste cells are arranged around a minute taste pore. From the tip of each taste cell, several microvilli, or taste hairs, protrude outward into the taste pore to approach the cavity of the mouth. These microvilli provide the receptor surface for taste. Interwoven around the bodies of the taste cells is a branching terminal network of taste nerve fibers that are stimulated by the taste receptor cells. Some of these fibers invaginate into folds of the taste cell membranes. Many vesicles form beneath the cell membrane near the fibers. These vesicles are believed to contain a neurotransmitter substance that is released through the cell membrane to excite the nerve fiber endings in response to taste stimulation.

**(Slide 28)** The taste buds are found on three types of papillae of the tongue, as follows: (1) a large number of taste buds are on the walls of the troughs that surround the circumvallate papillae, which form a V line on the surface of the posterior tongue; (2) moderate numbers are on the foliate papillae located in the folds along the lateral surfaces of the tongue; and (3) moderate numbers of taste buds are on the fungiform papillae over the flat anterior surface of the tongue. Additional taste buds are located on the palate, and a few are found on the tonsillar pillars, on the epiglottis, and even in the proximal esophagus. Adults have 3000 to 10,000 taste buds, and children have a few more. Beyond the age of 45 years, many taste buds degenerate, causing taste sensitivity to decrease in old age.

Specificity of Taste Buds for a Primary Taste Stimulus. Microelectrode studies from single taste buds show that each taste bud usually responds mostly to one of the five primary taste stimuli when the taste substance is in low concentration. However, at high concentration, most buds can be excited by two or more of the primary taste stimuli, as well as by a few other taste stimuli that do not fit into the “primary” categories.

**(Slide 29)** The membrane of the taste cell, like that of most other sensory receptor cells, is negatively charged on the inside with respect to the outside. Application of a taste substance to the taste hairs causes partial loss of this negative potential—that is, the taste cell becomes depolarized. In most cases, the decrease in potential, within a wide range, is approximately proportional to the logarithm of concentration of the stimulating substance. This change in electrical potential in the taste cell is called the receptor potential for taste.

**(Slide 30)** The mechanism whereby most stimulating substances react with the taste villi to initiate the receptor potential is by binding of the taste chemical to a protein receptor molecule that lies on the outer surface of the taste receptor cell, near to or protruding through a villus membrane. This action, in turn, opens ion channels, which allows positively charged sodium ions or hydrogen ions to enter and depolarize the normal negativity of the cell. Then, the taste chemical is gradually washed away from the taste villus by the saliva, which removes the stimulus. The type of receptor protein in each taste villus determines the type of taste that will be perceived. For sodium ions and hydrogen ions, which elicit salty and sour taste sensations, respectively, the receptor proteins open specific ion channels, likely the epithelial sodium channel (ENaC), in the apical membranes of the taste cells, thereby activating the receptors. However, for the sweet and bitter taste sensations, the portions of the G-protein coupled receptors that protrude through the apical membranes activate second-messenger transmitter substances inside the taste cells; these second messengers cause intracellular chemical changes that elicit the taste signals. Sweet-tasting compounds are detected by a combination of two closely related G-protein-coupled taste receptors, T1R2 and T1R3. The receptors responsible for umami taste is believed to be a complex of T1R1 and T1R3 proteins. Thus, T1R3 appears to function as a co-receptor for sweet and umami tastes. Bitter taste is sensed by another family (T2R) of approximately 30 different G-protein coupled receptors. Individual bitter-sensing taste receptor cells express multiple T2Rs, each of which recognizes a unique set of bitter compounds. This pattern of receptor expression permits detection of a variety of bitter compounds through a single type of taste receptor cell. Sour taste, associated with acidic food or drink, is believed to be sensed by ion channels that are opened by hydrogen ions although the precise mechanisms are not fully understood. Recent studies suggest that an acid-sensitive potassium channel (KIR2.1) and a hydrogen ion–selective ion channel (otopetrin 1) may mediate acid responses in taste receptor cells.

On first application of the taste stimulus, the rate of discharge of the nerve fibers from taste buds rises to a peak in a small fraction of a second but then adapts within the next few seconds back to a lower steady level as long as the taste stimulus remains. Thus, a strong immediate signal is transmitted by the taste nerve, and a weaker continuous signal is transmitted as long as the taste bud is exposed to the taste stimulus.

**Slide 31 show** the neuronal pathways for transmission of taste signals from the tongue and pharyngeal region into the central nervous system. Taste impulses from the anterior two-thirds of the tongue pass first into the lingual nerve, then through the chorda tympani into the facial nerve, and finally into the tractus solitarius in the brain stem. Taste sensations from the circumvallate papillae on the back of the tongue and from other posterior regions of the mouth and throat are transmitted through the glossopharyngeal nerve also into the tractus solitarius, but at a slightly more posterior level. Finally, a few taste signals are transmitted into the tractus solitarius from the base of the tongue and other parts of the pharyngeal region by way of the vagus nerve. All taste fibers synapse in the posterior brain stem in the nuclei of the tractus solitarius. These nuclei send second-order neurons to a small area of the ventral posterior medial nucleus of the thalamus, located slightly medial to the thalamic terminations of the facial regions of the dorsal column–medial lemniscal system. From the thalamus, third-order neurons are transmitted to the lower tip of the postcentral gyrus in the parietal cerebral cortex, where it curls deep into the sylvian fissure, and into the adjacent opercular insular area. This area lies slightly lateral, ventral, and rostral to the area for tongue tactile signals in cerebral somatic area I. From this description of the taste pathways, it is evident that they closely parallel the somatosensory pathways from the tongue.

**(Slide 32)** Taste Reflexes Are Integrated in the Brain Stem. From the tractus solitarius, many taste signals are transmitted within the brain stem itself directly into the superior and inferior salivatory nuclei. These areas transmit signals to the submandibular, sublingual, and parotid glands to help control the secretion of saliva during the ingestion and digestion of food.

**(Slide 33) Video. 2-Minute Neuroscience\_Taste**

**(Slide 34)** Everyone is familiar with the fact that taste sensations adapt rapidly, often almost completely, within a minute or so of continuous stimulation. Yet, from electrophysiological studies of taste nerve fibers, it is clear that adaptation of the taste buds usually accounts for no more than about half of this rapid taste adaptation. Therefore, the final extreme degree of adaptation that occurs in the sensation of taste almost certainly occurs in the central nervous system, although the mechanisms are not known. This mechanism of adaptation is different from that of many other sensory systems, which adapt mainly at the receptors.

**(Slide 35)** Smell is the least understood of our senses, partly because the sense of smell is a subjective phenomenon that cannot be studied with ease in lower animals. Another complicating problem is that the sense of smell is poorly developed in human beings compared with the sense of smell in many other mammals.

**(Slide 36)** The olfactory membrane lies in the superior part of the nasal cavity. Medially, the olfactory membrane folds downward along the surface of the superior septum; laterally, it folds over the superior turbinate and even over a small portion of the upper surface of the middle turbinate. The olfactory membrane has a total surface area of about 5 square centimeters in humans.

**(Slide 37)** Olfactory Cells Are the Receptor Cells for Smell Sensation. The olfactory cells are actually bipolar nerve cells derived originally from the central nervous system. There are about 100 million of these cells in the olfactory epithelium interspersed among sustentacular cells. The mucosal end of the olfactory cell forms a knob from which 4 to 25 olfactory hairs (also called olfactory cilia), measuring 0.3 micrometer in diameter and up to 200 micrometers in length, project into the mucus that coats the inner surface of the nasal cavity. These projecting olfactory cilia form a dense mat in the mucus, and it is these cilia that react to odors in the air and stimulate the olfactory cells, as discussed later. Spaced among the olfactory cells in the olfactory membrane are many small Bowman glands that secrete mucus onto the surface of the olfactory membrane.

**(Slide 38)** Mechanism of Excitation of the Olfactory Cells. The portion of each olfactory cell that responds to the olfactory chemical stimuli is the olfactory cilia. The odorant substance, on coming in contact with the olfactory membrane surface, first diffuses into the mucus that covers the cilia and then it binds with receptor proteins in the membrane of each cilium.

**(Slide 39)** Each receptor protein is actually a long molecule that threads its way through the membrane about seven times, folding inward and outward. The odorant binds with the portion of the receptor protein that folds to the outside. The inside of the folding protein is coupled to a G protein, itself a combination of three subunits. On excitation of the receptor protein, an alpha subunit breaks away from the G protein and activates adenylyl cyclase, which is attached to the inside of the ciliary membrane near the receptor cell body. The activated cyclase, in turn, converts many molecules of intracellular adenosine triphosphate (ATP) into cyclic adenosine monophosphate (cAMP). Finally, this cAMP activates another nearby membrane protein, a gated sodium ion channel, that opens its “gate” and allows large numbers of sodium ions to pour through the membrane into the receptor cell cytoplasm. The sodium ions increase the electrical potential in the positive direction inside the cell membrane, thus exciting the olfactory neuron and transmitting action potentials into the central nervous system via the olfactory nerve.

**(Slide 40)** The importance of this mechanism for activating olfactory nerves is that it greatly multiplies the excitatory effect of even the weakest odorant. To summarize: (1) activation of the receptor protein by the odorant substance activates the G-protein complex, which, in turn (2) activates multiple molecules of adenylyl cyclase inside the olfactory cell membrane, which (3) causes the formation of many times more molecules of cAMP, and finally, (4) the cAMP opens still many times more sodium ion channels. Therefore, even a minute concentration of a specific odorant initiates a cascading effect that opens extremely large numbers of sodium channels. This process accounts for the exquisite sensitivity of the olfactory neurons to even the slightest amount of odorant. In addition to the basic chemical mechanism whereby the olfactory cells are stimulated, several physical factors affect the degree of stimulation. First, only volatile substances that can be sniffed into the nasal cavity can be smelled. Second, the stimulating substance must be at least slightly water-soluble so that it can pass through the mucus to reach the olfactory cilia. Third, it is helpful for the substance to be at least slightly lipid-soluble, presumably because lipid constituents of the cilium are a weak barrier to non–lipid-soluble odorants. Membrane Potentials and Action Potentials in Olfactory Cells. The membrane potential inside unstimulated olfactory cells, as measured by microelectrodes, averages about −55 millivolts. At this potential, most of the cells generate continuous action potentials at a very slow rate, varying from once every 20 seconds up to two or three per second.

**(Slide 41) Video. 2-Minute Neuroscience\_ Olfaction**

**(Slide 42)** Most odorants cause depolarization of the olfactory cell membrane, decreasing the negative potential in the cell from the normal level of −55 millivolts to −30 millivolts or less. Along with this, the number of action potentials increases to 20 to 30 per second, which is a high rate for the minute olfactory nerve fibers. Over a wide range, the rate of olfactory nerve impulses changes approximately in proportion to the logarithm of the stimulus strength, which demonstrates that the olfactory receptors obey principles of transduction similar to those of other sensory receptors.

**(Slide 43)** The olfactory receptors adapt about 50% in the first second or so after stimulation. Thereafter, they adapt very little and very slowly. Yet, we all know from our own experience that smell sensations adapt almost to extinction within a minute or so after entering a strongly odorous atmosphere. Because this psychological adaptation is far greater than the degree of adaptation of the receptors, it is almost certain that most of the additional adaptation occurs in the central nervous system, which seems to be true for the adaptation of taste sensations as well.

**(Slide 44)** The following neuronal mechanism for the adaptation is postulated: large numbers of centrifugal nerve fibers pass from the olfactory regions of the brain backward along the olfactory tract and terminate on special inhibitory cells in the olfactory bulb, the granule cells. After the onset of an olfactory stimulus, the central nervous system quickly develops strong feedback inhibition to suppress relay of the smell signals through the olfactory bulb. Search for the Primary Sensations of Smell

**(Slide 45)** In the past, most physiologists were convinced that the many smell sensations are subserved by a few rather discrete primary sensations in the same way that vision and taste are subserved by a few select primary sensations. On the basis of psychological studies, one attempt to classify these sensations is the following:

1. Camphoraceous

2. Musky

3. Floral

4. Pepperminty

5. Ethereal

6. Pungent

7. Putrid

**(Slide 46)** It is certain that this list does not represent the true primary sensations of smell. Multiple clues, including specific studies of the genes that encode for the receptor proteins, suggest the existence of at least 100 primary sensations of smell—a marked contrast to only three primary sensations of color detected by the eyes and only five primary sensations of taste detected by the tongue. Some studies suggest that there may be as many as 1000 different types of odorant receptors. Further support for the many primary sensations of smell is that people have been found who have odor blindness for single substances; such discrete odor blindness has been identified for more than 50 different substances. It is presumed that odor blindness for each substance represents lack of the appropriate receptor protein in olfactory cells for that particular substance.

**(Slide 47)** One of the principal characteristics of smell is the minute quantity of stimulating agent in the air that can elicit a smell sensation. For example, the substance methylmercaptan can be smelled when only one 25 trillionth of a gram is present in each milliliter of air. Because of this very low threshold, this substance is mixed with natural gas to give the gas an odor that can be detected when even small amounts of gas leak from a pipeline.

**(Slide 48)** The olfactory nerve fibers leading backward from the bulb are called cranial nerve I, or the olfactory tract. In reality, both the tract and the bulb are an anterior outgrowth of brain tissue from the base of the brain; the bulbous enlargement at its end, the olfactory bulb, lies over the cribriform plate, separating the brain cavity from the upper reaches of the nasal cavity. The cribriform plate has multiple small perforations through which an equal number of small nerves pass upward from the olfactory membrane in the nasal cavity to enter the olfactory bulb in the cranial cavity.

**(Slide 49)** Each bulb has several thousand such glomeruli, each of which is the terminus for about 25,000 axons from olfactory cells. Each glomerulus also is the terminus for dendrites from about 25 large mitral cells and about 60 smaller tufted cells, the cell bodies of which lie in the olfactory bulb superior to the glomeruli. These dendrites receive synapses from the olfactory cell neurons; the mitral and tufted cells send axons through the olfactory tract to transmit olfactory signals to higher levels in the central nervous system. Some research has suggested that different glomeruli respond to different odors. It is possible that specific glomeruli are the real clue to the analysis of different odor signals transmitted into the central nervous system.

**(Slide 50)** The olfactory tract enters the brain at the anterior junction between the mesencephalon and cerebrum; there, the tract divides into two pathways one passing medially into the medial olfactory area of the brain stem and the other passing laterally into the lateral olfactory area. The medial olfactory area represents a very primitive olfactory system, whereas the lateral olfactory area is the input to the following: (1) a less old olfactory system; and (2) a newer system.

**(Slide 51)** The medial olfactory area consists of a group of nuclei located in the midbasal portions of the brain immediately anterior to the hypothalamus. Most conspicuous are the septal nuclei, which are midline nuclei that feed into the hypothalamus and other primitive portions of the brain’s limbic system. This is the brain area most concerned with basic behavior. The importance of this medial olfactory area is best understood by considering what happens in animals when the lateral olfactory areas on both sides of the brain are removed, and only the medial system remains. The removal of these areas hardly affects the more basic responses to olfaction, such as licking the lips, salivation, and other feeding responses caused by the smell of food or by basic emotional drives associated with smell. Conversely, removal of the lateral areas abolishes the more complicated olfactory conditioned reflexes.

**(Slide 52)** Lesson assignment:

John E. Hall and Michael E. Hall. Textbook of Medical Physiology. 14th Edition. Elsever.

Pages: 675 – 682.

Questions that we will analyze for a lesson on this topic:

1. Physiology of Sensory Receptors.
2. Structural Receptor Types.
3. Functional Receptor Types.
4. Sensory Modalities.
5. Physiology of taste.
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7. Taste buds and their function.
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17. Primitive and Newer Olfactory Pathways Into the Central Nervous System.

Finish for today

The full lecture is at the indicated website.

**Thank you for attention**