Introduction to Brain & Behavior
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Lecture 12 - Sensation and Perception

Hello! And welcome to the course, Introduction to Brain and Behavior. I am Ark Verma from IIT, Kanpur. This is the third week of the course and we are talking about the neuroscience of sensation and perception.

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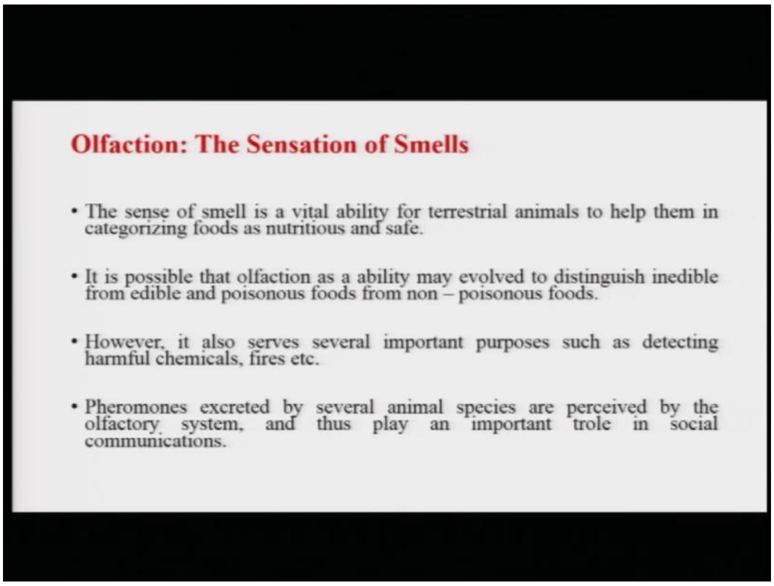

Olfaction: The Sensation of Smells

- The sense of smell is a vital ability for terrestrial animals to help them in categorizing foods as nutritious and safe.
- It is possible that olfaction as a ability may evolved to distinguish inedible from edible and poisonous foods from non – poisonous foods.
- However, it also serves several important purposes such as detecting harmful chemicals, fires etc.
- Pheromones excreted by several animal species are perceived by the olfactory system, and thus play an important trole in social communications.

We talked about the sense of audition in the last lecture. And today we are going to start talking about olfaction, or the sensation of smells. Now, the sensation of smell is a vital ability for terrestrial animals to help them in categorizing foods as nutritious and safe.

Typically, if something is smelling foul, or if something is smelling too bad, it is highly likely that the food is A inedible, and B it might even be poisonous. So, it is the sense of olfaction or the sensory sense of smell that provides us with the ability to distinguish between edible from inedible food and non-poisonous from poisonous food.

However, the sense of olfaction also serves other important purposes, such as detecting the presence of harmful chemicals, avoiding fires, etcetera. Pheromones excreted by several animal species are also perceived by the olfactory system and therefore can play a very important role in social communications.

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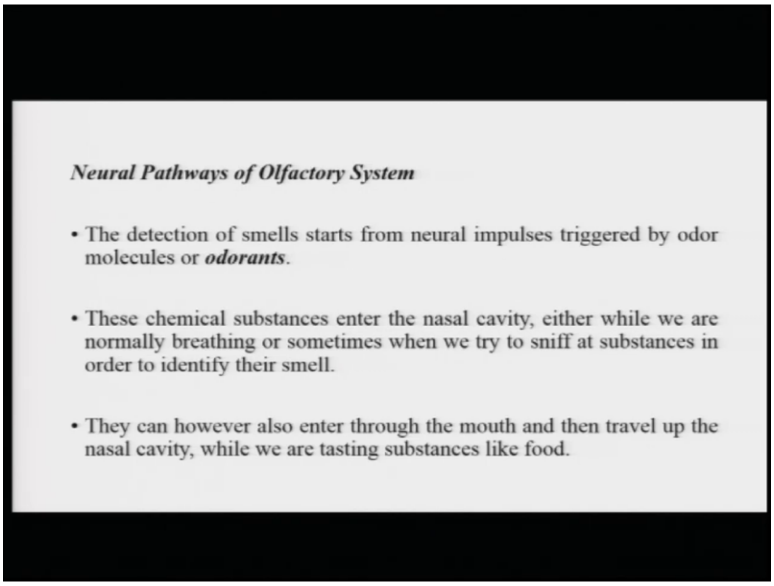

Neural Pathways of Olfactory System

- The detection of smells starts from neural impulses triggered by odor molecules or ***odorants***.
- These chemical substances enter the nasal cavity, either while we are normally breathing or sometimes when we try to sniff at substances in order to identify their smell.
- They can however also enter through the mouth and then travel up the nasal cavity, while we are tasting substances like food.

Now, let us talk a little bit about the neural pathways that are recruited in the olfactory system. The detection of smells starts from the neural impulses that are triggered by odor molecules or as the are called odorants. These are chemical substances that would enter the nasal cavity either while we are normally breathing or sometimes when we are trying to sniff at substances to identify their smell. They can also enter through the mouth while we are eating something and then travel back upwards the nasal cavity, so that the odor molecules are received in this olfactory tract.

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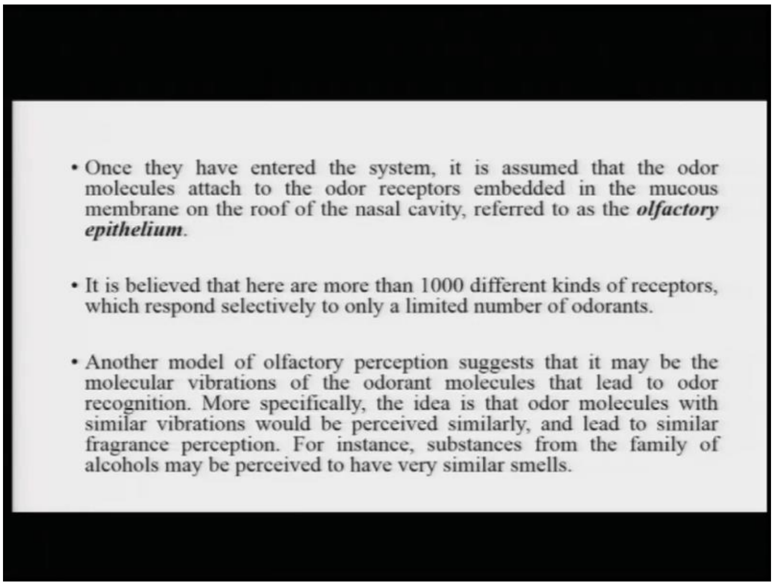

- Once they have entered the system, it is assumed that the odor molecules attach to the odor receptors embedded in the mucous membrane on the roof of the nasal cavity, referred to as the ***olfactory epithelium***.
- It is believed that here are more than 1000 different kinds of receptors, which respond selectively to only a limited number of odorants.
- Another model of olfactory perception suggests that it may be the molecular vibrations of the odorant molecules that lead to odor recognition. More specifically, the idea is that odor molecules with similar vibrations would be perceived similarly, and lead to similar fragrance perception. For instance, substances from the family of alcohols may be perceived to have very similar smells.

Once these molecules have entered the system, it is assumed that the odor molecules attached to the odor receptors embedded in the mucous membrane on the roof of the nasal cavity, which is referred to as the olfactory epithelium.

It is believed that there are more than 1,000 different kinds of receptors, which respond selectively to odors of different kinds. Another model of olfactory perception actually suggests that it may be the molecular vibrations of the odor molecules or odorant molecules that lead to odor recognition.

More specifically, the idea is that odor molecules with similar vibrations would be perceived in a similar manner leading to similar fragrance perception. For instance, substances from the family of alcohols may be, may vibrate at a very similar rate and hence can be perceived to have very similar smells.

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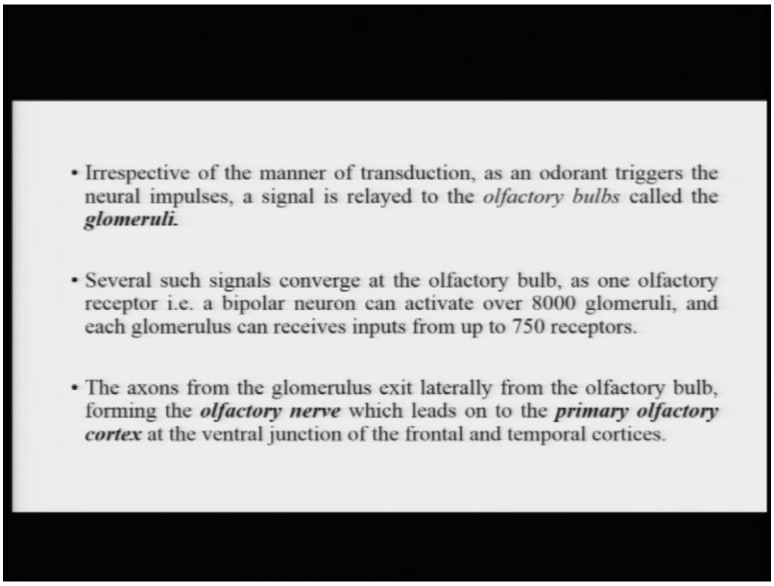

- Irrespective of the manner of transduction, as an odorant triggers the neural impulses, a signal is relayed to the *olfactory bulbs* called the ***glomeruli.***
- Several such signals converge at the olfactory bulb, as one olfactory receptor i.e. a bipolar neuron can activate over 8000 glomeruli, and each glomerulus can receives inputs from up to 750 receptors.
- The axons from the glomerulus exit laterally from the olfactory bulb, forming the ***olfactory nerve*** which leads on to the ***primary olfactory cortex*** at the ventral junction of the frontal and temporal cortices.

Now, irrespective of the manner of transduction, as an odorant triggers the neural impulses, a signal is relayed to the olfactory bulbs, which are also referred to as the glomeruli. Several such signals converge at the olfactory bulb as one olfactory receptor, which is a bipolar neuron can activate over 8,000 glomeruli. And each glomerulus can receive inputs from up to 750 receptor. So, there is a high degree of convergence of signals actually that is going on at these odor receptors.

Now, the axons from the glomerulus which is these, you know olfactory bulbs basically form what is called the olfactory nerve, which leads onto the primary olfactory cortex, which lies at the ventral junction, the bottom junction of the frontal and temporal cortices.

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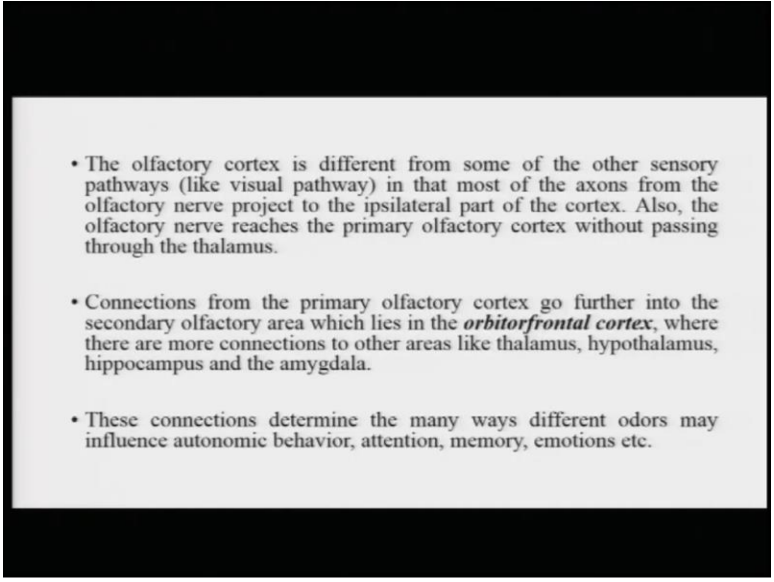

- The olfactory cortex is different from some of the other sensory pathways (like visual pathway) in that most of the axons from the olfactory nerve project to the ipsilateral part of the cortex. Also, the olfactory nerve reaches the primary olfactory cortex without passing through the thalamus.
- Connections from the primary olfactory cortex go further into the secondary olfactory area which lies in the ***orbitorfrontal cortex***, where there are more connections to other areas like thalamus, hypothalamus, hippocampus and the amygdala.
- These connections determine the many ways different odors may influence autonomic behavior, attention, memory, emotions etc.

The olfactory cortex as I was saying in the last lecture, is different from other sensory pathways in the respect that axons from the olfactory nerve directly project to the ipsilateral part, mostly project to the ipsilateral part of the cortex, and also that they do not pass through the thalamus, but directly converge in the olfactory cortices.

Now connections from these primary olfactory cortex basically go further into the secondary olfactory cortex in an area which lies, which lies in the area called orbitofrontal cortex, the bottom part of the frontal cortices, which we have seen in the last lectures.

Now there at around the orbitofrontal cortex area, there are more connections of this olfactory nerve to areas like the thalamus, the hypothalamus, the hippocampus, which is responsible for memory, the amygdala, which is responsible for emotional processing.

These connections, therefore, they determine the many ways different odors might influence our autonomic behavior, might interact with our attentional resources, our memory, our emotions, etc. So, this is how basically the odor molecules starting from impinging in the nasal cavity kind of are received and then finally processed.

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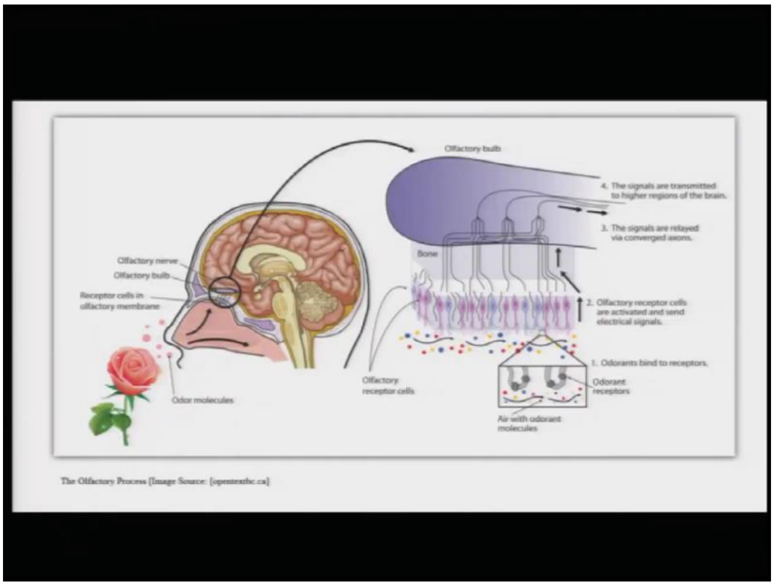

The Olfactory Process [Image Source: [opentextbc.ca]

This is where you can sort of see that. You can see the olfactory bulb here. Now, this is where the olfactory cortex lies, which is the ventral portion of the orbitofrontal cortex. This region was the orbitofrontal cortex. Here you can see how the olfactory bulb is actually constructed.

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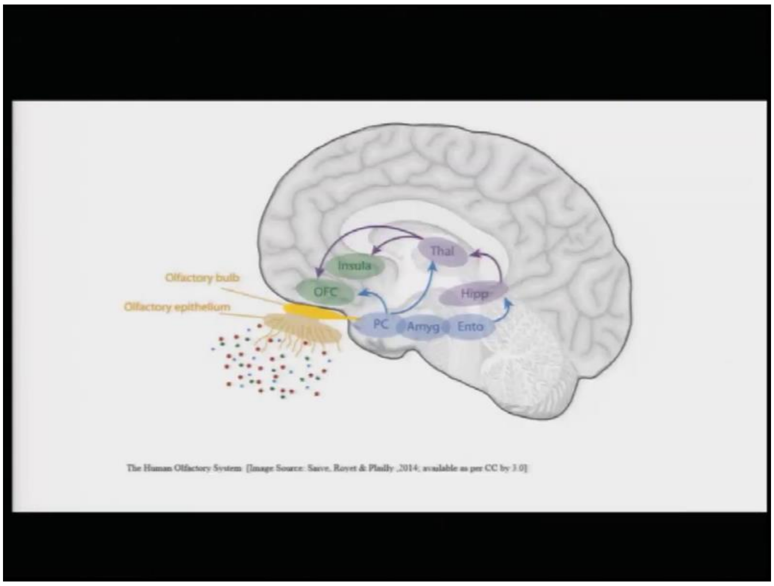

The Human Olfactory System [Image Source: Saive, Royet & Plailly ,2014; available as per CC by 3.0]

Here you can see a bit of a schematic diagram of how the connections or how the network is. So the olfactory epithelium receives the odor molecules. It kind of converges into the olfactory bulb, which basically converges through, say, for example, different regions, which is the primary olfactory cortex, orbitofrontal cortex, insula, thalamus, hippocampus, entorhinal cortex, and the amygdala. So, this is where this flow of information is going to take place.

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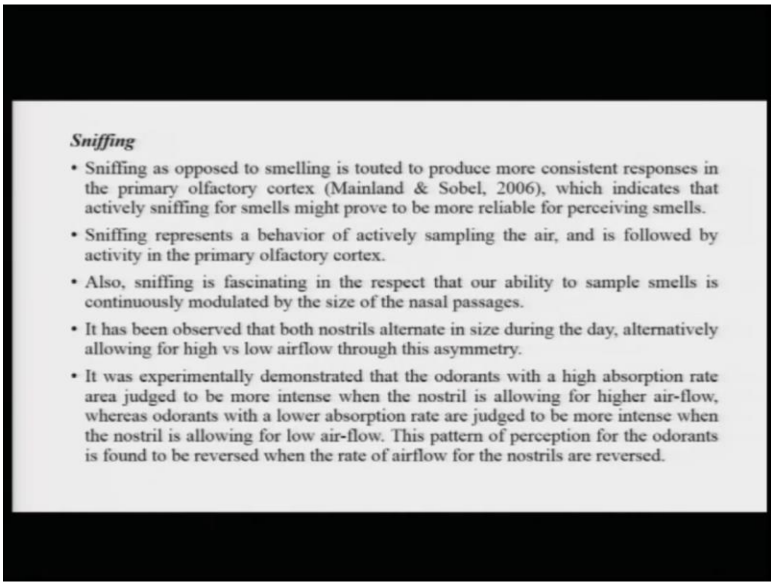

Sniffing

- Sniffing as opposed to smelling is touted to produce more consistent responses in the primary olfactory cortex (Mainland & Sobel, 2006), which indicates that actively sniffing for smells might prove to be more reliable for perceiving smells.
- Sniffing represents a behavior of actively sampling the air, and is followed by activity in the primary olfactory cortex.
- Also, sniffing is fascinating in the respect that our ability to sample smells is continuously modulated by the size of the nasal passages.
- It has been observed that both nostrils alternate in size during the day, alternatively allowing for high vs low airflow through this asymmetry.
- It was experimentally demonstrated that the odorants with a high absorption rate area judged to be more intense when the nostril is allowing for higher air-flow, whereas odorants with a lower absorption rate are judged to be more intense when the nostril is allowing for low air-flow. This pattern of perception for the odorants is found to be reversed when the rate of airflow for the nostrils are reversed.

Now one of the behaviors that sort of allows us to actively sample or actively engage in smells or in smelling is basically referred to as sniffing. Sniffing is actually when you are actually taking up a substance and you are trying to sniff it, trying to take in the olfactory molecules and basically, engage or identify the smell of a particular substance.

Now sniffing as opposed to smelling, you know, in a general manner is touted to produce more consistent responses in the primary olfactory cortex. So basically, if you are sniffing at a substance, you are more likely to process the smell in its entirety in its more detail, because the primary olfactory cortex is going to be more activated while sniffing as opposed to generally just smelling through the substance.

Mainland and Sobel in their experiment actually demonstrated that actively sniffing for smells might to be more reliable for perceiving smells as opposed to just smelling from a distance in a less active manner.

Sniffing basically also refers to, represents a behavior of actively sampling the air and it is followed by more activity in the primary olfactory cortex. Similarly, sniffing is interesting behavior. It is fascinating in the sense that it represents our ability to sample smells continuously, and this whole behavior can be modulated by the changing size of the nasal passages.

It has been observed that both nostrils alternate in size during the day, alternatively, allowing for high versus low airflow and through this asymmetry. So basically, at one point of time, the left nostril might be allowing high airflow because it is increased a little bit in size. On at other time of the day, the right nostril might be allowing for higher airflow because it has increased in size and now the left nostril has sort of, has sort of shrunk in size a little bit.

Now, this is very unique property of the nasal passage. And it seems to interact with how the odors are sort of received or perceived at the olfactory cortices. Now, it was experimentally demonstrated that odorants that have a high absorption rate are judged to be more intense, if they are being perceived through the nostril allowing for higher airflow.

Similarly, in the same manner, odorants which have a low absorption rate are judged to be more intense, when they are perceived through nostrils that are allowing for low airflow. So, and this thing actually keeps alternating, as I say, for example, the passage of air through the nostrils is reversed.

Say, for example, once this pattern of, which nostril is allowing high airflow versus which nostril is allowing low airflow is changed, the perception of these two kinds of odorants in the two nostrils also reverses itself. So this is something which is fairly interesting to sort of note.

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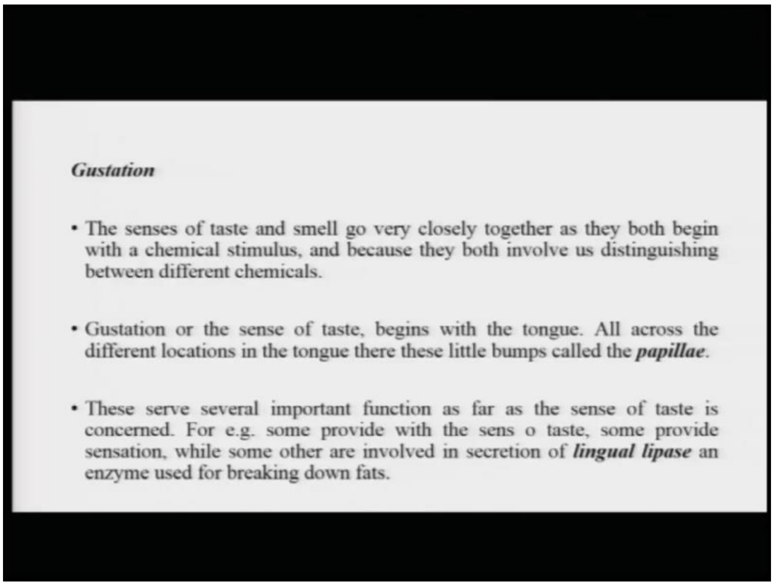

Gustation

- The senses of taste and smell go very closely together as they both begin with a chemical stimulus, and because they both involve us distinguishing between different chemicals.
- Gustation or the sense of taste, begins with the tongue. All across the different locations in the tongue there these little bumps called the ***papillae***.
- These serve several important function as far as the sense of taste is concerned. For e.g. some provide with the sens o taste, some provide sensation, while some other are involved in secretion of ***lingual lipase*** an enzyme used for breaking down fats.

Now, we have talked a little bit about the olfactory system or the sensation of smell. We can now talk about gustation or the sense of taste. Now, as we know, the sense of taste and the sense of smell go very closely together, as they both begin with the chemical stimulus and depend upon our analysis of the chemical stimulus and depend upon our capability of distinguishing between different chemicals.

In gustation or the sense of taste begins with the tongue. All across the tongue the different locations, there are these little bumps called the papillae. And these papillae basically contain what are called taste buds, I will come to that in a bit.

But these papillae serve several important functions, as far as the sense of taste is concerned. Say, for example, some of them are dedicated to providing with a sense of taste, while some provide different kinds of sensation. While others are engaged in secretion of substance called the lingual lipase, which is basically an enzyme that is used to break down the fat molecules when you are eating the food.

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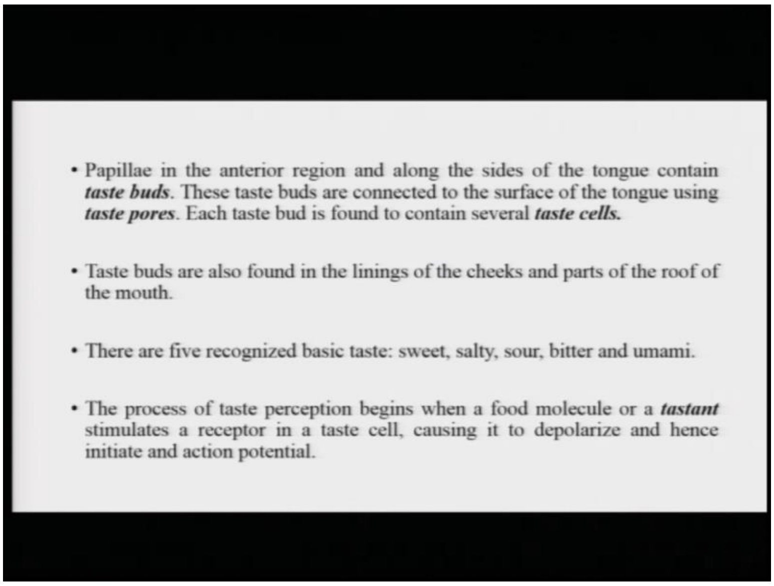

- Papillae in the anterior region and along the sides of the tongue contain ***taste buds***. These taste buds are connected to the surface of the tongue using ***taste pores***. Each taste bud is found to contain several ***taste cells***.
- Taste buds are also found in the linings of the cheeks and parts of the roof of the mouth.
- There are five recognized basic taste: sweet, salty, sour, bitter and umami.
- The process of taste perception begins when a food molecule or a ***tastant*** stimulates a receptor in a taste cell, causing it to depolarize and hence initiate and action potential.

Now the papillae in the anterior region along the sides of the tongue mainly contain the taste buds. So for example, in the front region of the tongue, and along the side of the tongue, these papillae contain what are called taste buds.

These taste buds are basically connected to the surface of the tongue through what are called taste ports, which basically allow to ingest the chemical substances in food and allow for further processing of the taste, taste molecules through what are called these taste cells. Now these taste buds are also found along the lining of the cheeks and the roof of the mouth. There are basically five recognized basic tastes. Say for example, the sweet taste, salty taste, sour taste, bitter taste and umami taste.

The umami taste is typically when you eat protein rich substances like meat. Now, this process of perception of taste actually begins when a food molecule or as it is called a tastant stimulates the receptor in a taste cell. So, for example, when you are eating food, as soon as you start chewing the food or the food interacts with the saliva, and it starts to get broken down, and it stimulates a receptor in one of the taste cells, which are as I said, located in the taste buds. These receptors or these tastants, basically, are then depolarized and initiate what is an action potential.

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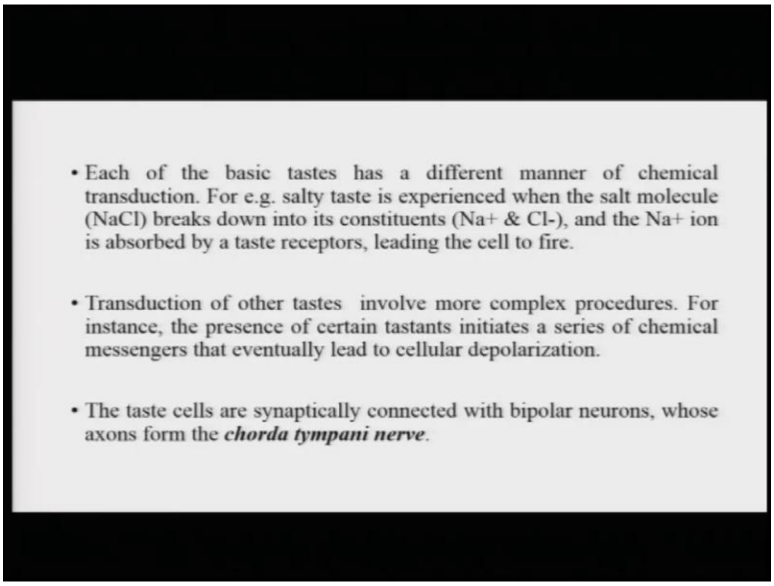

- Each of the basic tastes has a different manner of chemical transduction. For e.g. salty taste is experienced when the salt molecule (NaCl) breaks down into its constituents (Na+ & Cl-), and the Na+ ion is absorbed by a taste receptors, leading the cell to fire.
- Transduction of other tastes involve more complex procedures. For instance, the presence of certain tastants initiates a series of chemical messengers that eventually lead to cellular depolarization.
- The taste cells are synaptically connected with bipolar neurons, whose axons form the ***chorda tympani nerve***.

Each of these basic tastes have a different manner of chemical transduction. Say, for example, the process of tasting salty taste or a sweet taste or umami taste might actually be very different when it comes to how the tastes would be transduced into neural impulses. Let us take an example. Salty taste is experienced when the salt molecule of NaCl breaks down into its constituents of sodium and chloride. And when the sodium chloride, when the sodium ion is absorbed by a taste receptor, leading the cell to depolarize and fire an action potential.

Transduction of other tastes may involve slightly more complex procedures. For instance, presence of certain tasted molecules could initiate a series of chemical messages that eventually lead to cellular depolarization.

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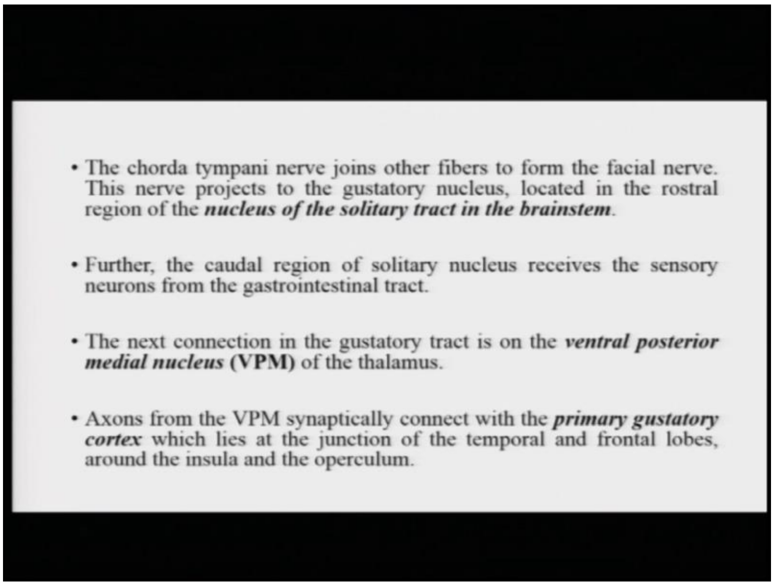

- The chorda tympani nerve joins other fibers to form the facial nerve. This nerve projects to the gustatory nucleus, located in the rostral region of the ***nucleus of the solitary tract in the brainstem***.
- Further, the caudal region of solitary nucleus receives the sensory neurons from the gastrointestinal tract.
- The next connection in the gustatory tract is on the ***ventral posterior medial nucleus*** **(VPM)** of the thalamus.
- Axons from the VPM synaptically connect with the ***primary gustatory cortex*** which lies at the junction of the temporal and frontal lobes, around the insula and the operculum.

Now the taste cells are synaptically connected with what are called bipolar neurons. And the axons from these bipolar neurons form the chorda tympani nerve, which is basically supposed to be the gustatory nerve.

Now, this chorda tympani nerve joins other fibers to form the facial nerve. And from thereon, this projects to the gustatory nucleus located at the roastral, or the bottom region of the nucleus of the solitary tract, which is found in the brainstem. So, I am just talking about these different tracts that you sort of have to remember.

Now the chorda region of the solitary nucleus receives the sensory neurons also from the gastrointestinal tract. It sort of kind of and you know, sort of, can affect some of the other behavior related to consumption of food such as the gag reflex, and so on. Now, the next connection in the gustatory tract is on the ventral posterior medial nucleus of the thalamus which is the VPM nucleus of the thalamus. Axons on the VBM syntactically connect with the primary gustatory cortex, which lies at the junction of the temporal and frontal lobes around the insula and the operculum.

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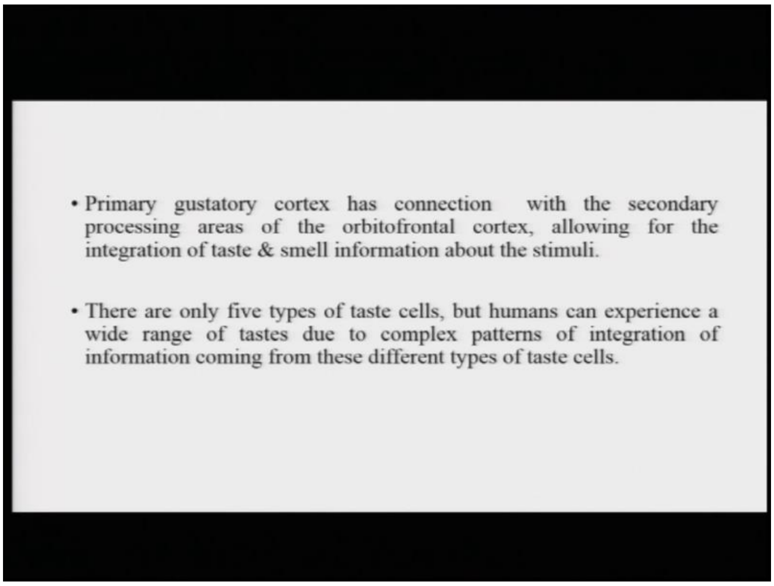

- Primary gustatory cortex has connection with the secondary processing areas of the orbitofrontal cortex, allowing for the integration of taste & smell information about the stimuli.
- There are only five types of taste cells, but humans can experience a wide range of tastes due to complex patterns of integration of information coming from these different types of taste cells.

Now, this primary gustatory cortex has a connection with the secondary processing areas of the orbitofrontal cortex, lying for integration of the taste and smell information from same kind of stimuli.

There are only five types of taste cells, but humans can experience a wide range of tastes, due to the complex patterns of integration of information, which is coming from these different taste cells.

So, in the sense, you can see that the system already allows for the integration of information about the taste and the smell of food at the same time. This definitely must have evolutionary consequences, or say, for example, is something that is arising out of the evolutionary process because we typically look at food or we typically great food that tastes well, that smells well as tastier as opposed to food that does not smell too well as less tasty so on. So we have a sense of a combined processing of taste and smell of the same food item.

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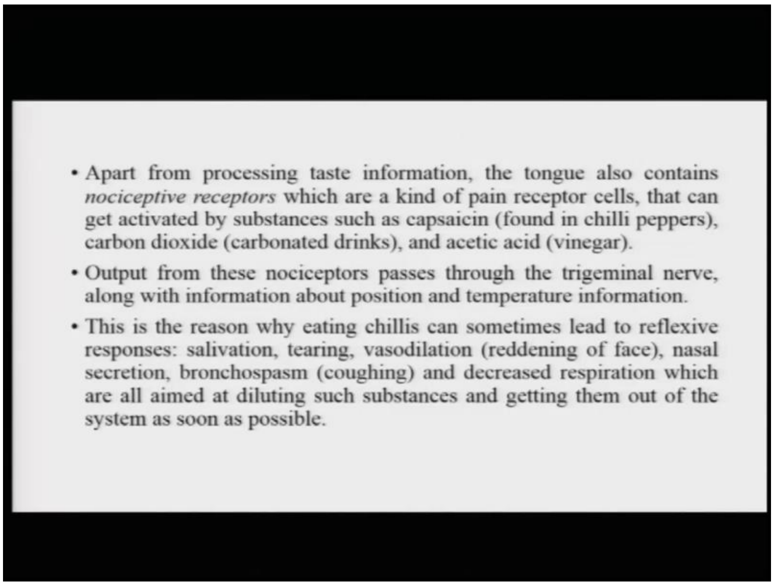

- Apart from processing taste information, the tongue also contains *nociceptive receptors* which are a kind of pain receptor cells, that can get activated by substances such as capsaicin (found in chilli peppers), carbon dioxide (carbonated drinks), and acetic acid (vinegar).
- Output from these nociceptors passes through the trigeminal nerve, along with information about position and temperature information.
- This is the reason why eating chillis can sometimes lead to reflexive responses: salivation, tearing, vasodilation (reddening of face), nasal secretion, bronchospasm (coughing) and decreased respiration which are all aimed at diluting such substances and getting them out of the system as soon as possible.

Now, apart from processing the taste information, the tongue also contains these special nociceptive receptors which are a kind of pain receptor cells, that can actually get activated by substances such as capsaicin, which is contained in chili peppers, carbon dioxide and acetic acid like vinegar.

Now, basically output from these nociceptors when say for example, you eat something which has a lot of chilli in it, passes through the trigeminal nerve along with the information about the position and temperature of the substances.

Now, this is one of the reasons why say for example, when you are eating chillies, it could sometimes lead to reflexive responses of salivation, tearing, and vasodilation, which is the reddening of the face, nasal secretion and bronchospasm which is basically you know, when you start coughing if you have eaten something very, very hot and very spicy.

It also leads to a decreased respiration rate, all of which are basically reflexive responses, which are aimed at diluting such substances and getting them out of the system as soon as possible. So this is basically a little bit about the initial processing of taste sense in the mouth.

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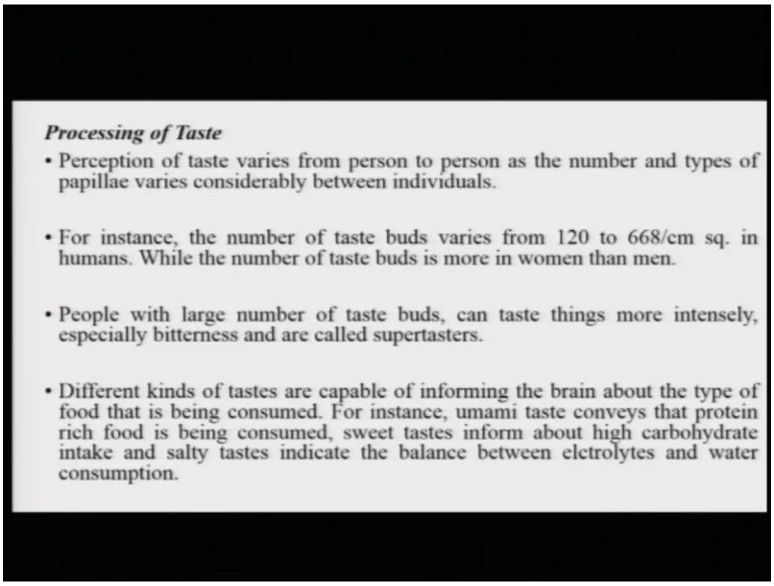

Processing of Taste

- Perception of taste varies from person to person as the number and types of papillae varies considerably between individuals.
- For instance, the number of taste buds varies from 120 to 668/cm sq. in humans. While the number of taste buds is more in women than men.
- People with large number of taste buds, can taste things more intensely, especially bitterness and are called supertasters.
- Different kinds of tastes are capable of informing the brain about the type of food that is being consumed. For instance, umami taste conveys that protein rich food is being consumed, sweet tastes inform about high carbohydrate intake and salty tastes indicate the balance between elctrolytes and water consumption.

Now processing of taste basically also varies from person to person. Say, for example, as the number and types of papillae vary considerably between individuals. Say, for example, typically the number of taste buds that a human being has is anywhere between 120 to 668 papillae per centimeter square on the tongue, while the number of taste buds it is an interesting trivia, that the number of taste buds that is present in women exceeds the number that is present in men.

People with the large number of taste buds can be referred to as Supertasters, because they taste everything much more intensely than the average individual. So these are the kind of people who will say for example, find something extremely tasty, or say for example, if they are tasting something very bitter, they will actually find something extremely bitter. And the reactions as I said in the past slide, say for example, things like vasodilation or tearing up or coughing and et cetera, they are much more extreme in these cases when these people would eat something which is highly bitter.

Now one of the other things that is important is different types of taste are capable of also, are also capable of informing the brain of what kind of food is being consumed at the instance. Say, for example, if you are experiencing umami taste in your mouth, it basically conveys that protein rich food is basically being consumed.

Similarly, say for example, if you are tasting a sweet taste in the mouth, then it will inform the brain that carbohydrate rich food is being taken. Similarly, if you are sort of tasting a lot of salt or say for example, something like a salty drink, then sort of conveys information about the balance between the amount of electrolytes versus water consumption in the body.

So apart from just doing the initial processing of the food, or say for example, the initial processing that will tell us about the taste of the food, there are other allied processes also that are basically being performed or that are basically being served by the tongue.

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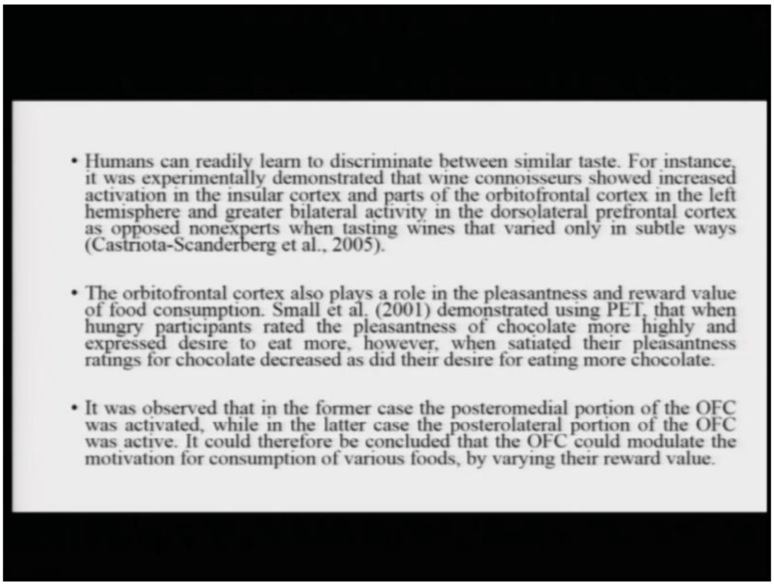

- Humans can readily learn to discriminate between similar taste. For instance, it was experimentally demonstrated that wine connoisseurs showed increased activation in the insular cortex and parts of the orbitofrontal cortex in the left hemisphere and greater bilateral activity in the dorsolateral prefrontal cortex as opposed nonexperts when tasting wines that varied only in subtle ways (Castriota-Scanderberg et al., 2005).
- The orbitofrontal cortex also plays a role in the pleasantness and reward value of food consumption. Small et al. (2001) demonstrated using PET, that when hungry participants rated the pleasantness of chocolate more highly and expressed desire to eat more, however, when satiated their pleasantness ratings for chocolate decreased as did their desire for eating more chocolate.
- It was observed that in the former case the posteromedial portion of the OFC was activated, while in the latter case the posterolateral portion of the OFC was active. It could therefore be concluded that the OFC could modulate the motivation for consumption of various foods, by varying their reward value.

Now, going a little further. Humans can also learn to discriminate between similar tastes. Say, for example, apart from the fact that tasting is something that is innate in nature, and we have almost an innate appreciation of let us say, at least some of the basic taste, tasting is also something that can be learned over time.

And we can sort of develop a sort of a taste to discriminate between different kind of tastes. This point was very interestingly demonstrated in an experiment by Castriota and Scanderberg and colleagues, where they actually compared the activations in the insular cortex between people who were called wine connoisseurs or (())(17:48) and the non-experts. So, these wine connoisseurs were basically asked to taste different kinds of wines. And the idea was to measure the degree of activation that will be observed in their insular cortex.

It was found that wine connoisseurs actually showed increased activation in the insular cortex into parts of the orbitofrontal cortex in the left hemisphere and greater bilateral activity in the dorsolateral prefrontal cortex which probably is involved in making decisions about what I mean they like this taste or not as opposed to non-experts, while they were tasting wines, which were very, very similar in taste, but differed only in very, very subtle aspects.

So, for example, because these wine connoisseurs had developed through practice through a lot of interest, they developed this taste, therefore, their brain was responding differently as opposed to the non-experts while tasting these wines.

Apart from this, the orbitofrontal cortex also plays a very, very important role in our experience of pleasantness and the reward value associated with food consumption. Small and colleagues did this experiment, where they demonstrated using the Positron Emission Tomography technique that when hungry participants, they asked these hungry participants to rate the pleasantness of chocolates. And say for example, when they were asked to rate this pleasantness of chocolate, they were basically found to rate the chocolate as highly pleasant, and they expressed more desire to eat the chocolate.

However, as and when they were saturated when their hunger was sort of subsiding. Then they actually, their ratings for the pleasantness of chocolate actually decreased, and also their desire for eating more chocolate actually was decreased. It was therefore, and with respect to the brain, it was observed that in the former case, when the chocolate was supposed to be more rewarding and more pleasant, the posterior medial portion of the orbitofrontal cortex was activated. Whereas in the latter case, when the hunger was subsiding, and they were not finding chocolate as pleasant or as rewarding, the posterolateral portion of the orbitofrontal cortex was activated.

So in some sense, you could say that these regions of the orbitofrontal cortex are actually can, actually modulate your motivation to consume certain kinds of food by playing with or by modulating the reward value associated with these foods.

So, this is something fairly interesting that sort of might be used to explain why when you are quite hungry or say for example, when you develop a liking for certain kinds of food, why do you want to eat those foods more often and in large quantities versus say, for example, when you are more, your hunger is more on the saturated side, when it is subsidizing, you will sort of not find the same foods as rewarding and you will express less desire to consume more and more of these foods.

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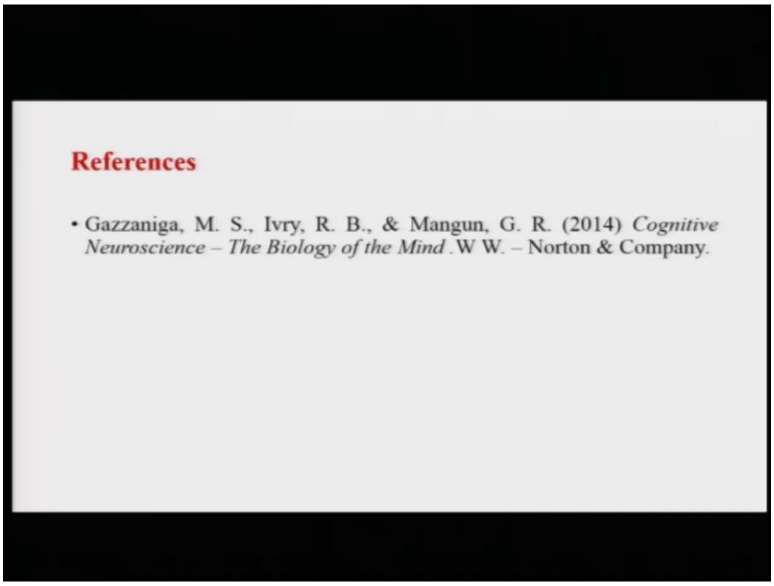

References

- Gazzaniga, M. S., Ivry, R. B., & Mangun, G. R. (2014) *Cognitive Neuroscience – The Biology of the Mind* . W W. – Norton & Company.

So, I think this is all we talked about the sense of smell that is olfaction and the sense of taste that is gustation in this lecture. I will continue to talk about different kinds of sensory perception in the coming lectures. Thank you.