Introduction to Brain & Behavior
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Lecture 14 - Neuroscience of Sensation and Perception

Hello! And welcome to the course, Introduction to Brain and Behavior. I am Ark Verma from IIT, Kanpur. As you know, I work at the Department of Humanities and Social Sciences, and also in the interdisciplinary program for cognitive sciences at the institute.

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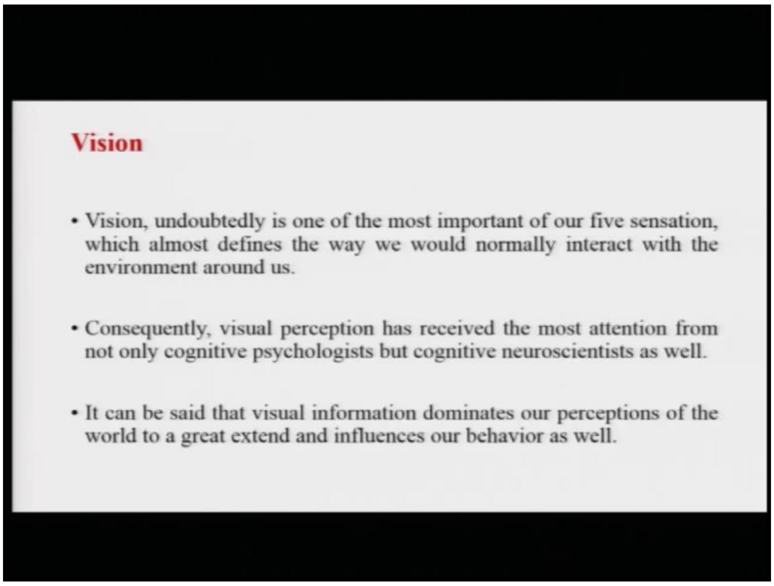

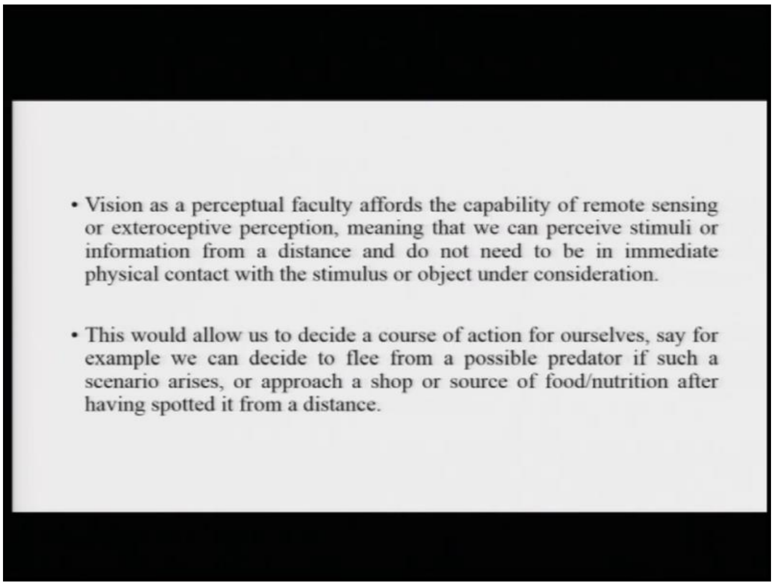

This is week third of the course. And we are talking about the neuroscience of sensation and perception. Today, we will talk about vision. Now, vision is undoubtedly one of the most important or probably the most important of our five senses. Vision defines almost the way we would normally interact with the environment around us. Most of our interactions with the environment are basically modulated first by vision and then it is followed by many other senses. Say for example, if you have given some fruit to eat, you will first look at it and then you probably pick it up, touch it, taste it, smell it and whatever.

Now, consequently, visual perception has therefore received the most attention from not only cognitive psychologists, but also our cognitive neuroscientists. It can be said that visual information dominates our perceptions of the world to great extent. And also in that sense influences our behavior predominantly as well, affords the capability of remote sensing or extra-receptive perception. Meaning basically, that we can perceive stimuli or information from a distance and we do not need to be in immediate physical contact with the stimulus or the object in question.

It sort of allows us a lot of advantages. Things like say, for example, we can decide a course of action for ourselves with respect to that object, even before that object has reached us, or is it or is in close proximity with us. I am sure this is something which had been, which would have been very, very useful, say for example, in cases when you wanted to flee from a predator, or say for example, you want to look for a source of food and reach towards it.

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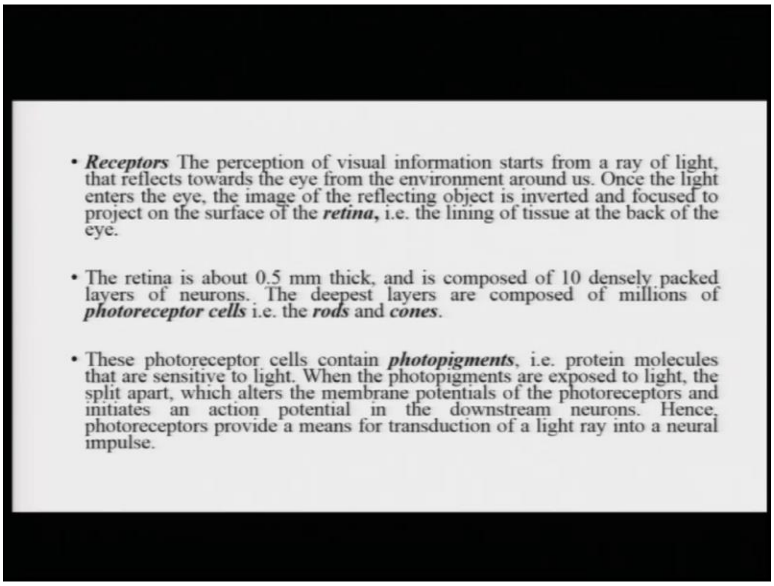

Now, what are the receptors that are responsible for perception? The perception of visual information starts basically from a ray of light. This ray of light is reflected towards the eye from the objects around you or the objects in the environment. Once this ray of light has entered the eye, the image of the reflecting object is inverted and is focused to project on the surface of the retina, which is the back portion of the eye.

The retina is around 0.5 millimeters thick, and is composed of 10 densely packed layers of neurons. The deepest layers of the retina are composed of millions of photoreceptor cells called the rods and the cones. These photoreceptor cells contain substances called photopigments, which are actually protein molecules that are sensitive to light.

Meaning that when the photopigments are exposed to light, they would just split apart and alter the membrane potential of these photoreceptors and eventually cause an action potential to be generated.

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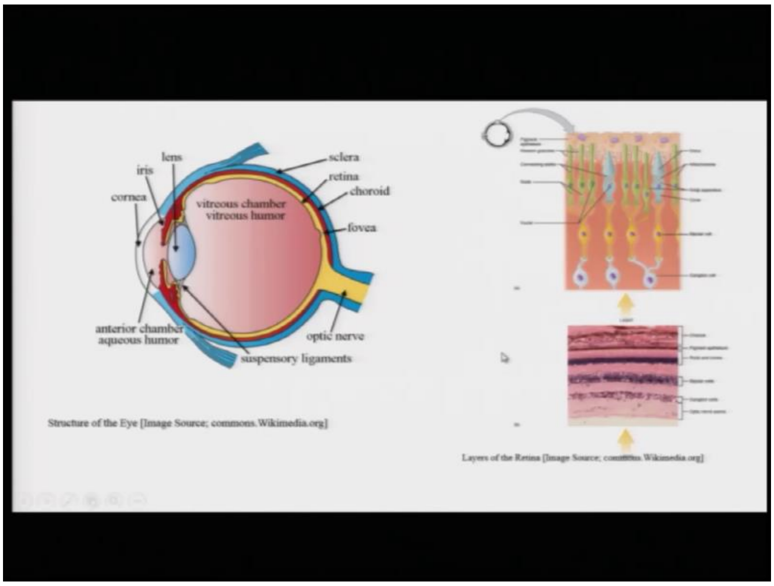

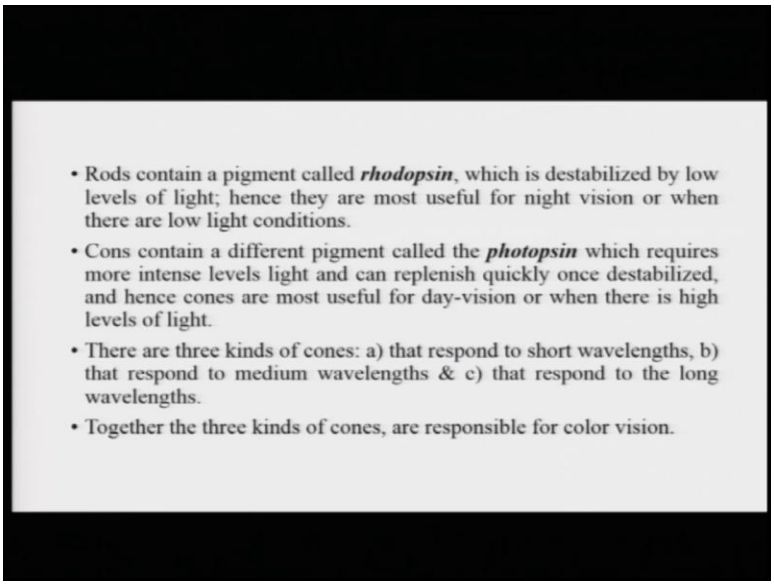

Here you can see the figure of the eye. And here you can see the back lining of the eye, which is called the retina. This is a region which has a small protrusion at the back of the retina, which is called the fovea. We will talk about that in some detail moving further.

Here you can see a cross-section of the retina, wherein you can see different cells like the rods and these blue ones are the cones. You can see the photopigment and some of the other things. These photoreceptors called rods contain a pigment called rhodopsin, which is destabilized only by low levels of light. Hence, they are most useful for night vision or where there are low light conditions. So rods are the pigments that actually help us navigate when the laser light or say for example even in the dark. Rhodopsin basically also destabilizes when there is a lot of light, but then it sort of gets, it gets used up very quickly.

Cones on the other hand contain a different pigment called photopsin, which requires more intense levels of light and can replenish rather quickly once it is destabilized. Hence cones are the most useful for day vision or when there is high levels of light. So, typically, when you want to say for example, have look around in, when the light is adequate, when there is enough light and you want to sort of look at everything in high resolution, cones are the photoreceptors that are going to make it possible.

Now, there are three kinds of cones. One that respond to short wavelengths, the other that respond to medium wavelengths and the third kind that respond to longer wavelengths. In combination of these or combination of action from these different kinds of cones, we kind of, we get color vision. So color vision is basically the responsibility of cones, different kinds of them, which are sensitive to different bands of wavelength.

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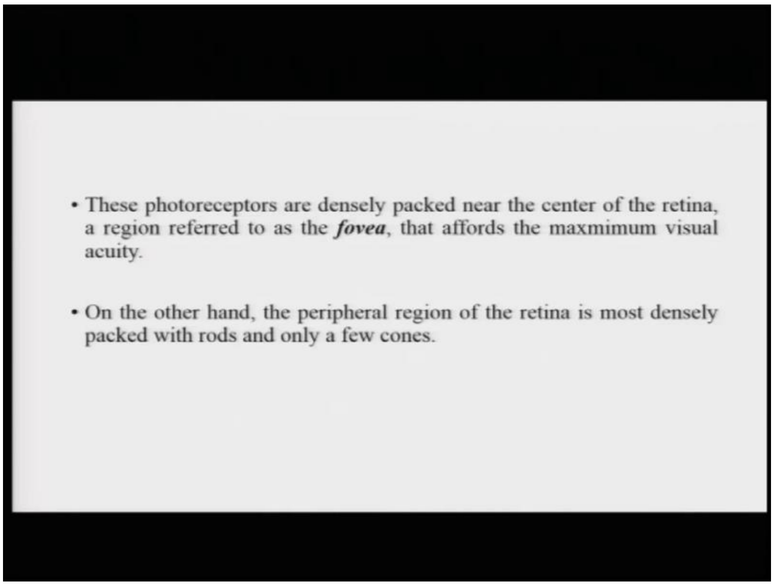

Now, these photoreceptors, the rods and cones are densely the cones densely packed near the center of the retina, a region referred to as the fovea, as we just showed. This region affords us the maximum visual equity. On the other hand, the peripheral region of the retina is most densely packed with rods and only a few cones. This is the region that helps you get peripheral vision. And also say for example, other than the high resolution color images, it helps you navigate in times of less light or when things are not very clearly visible.

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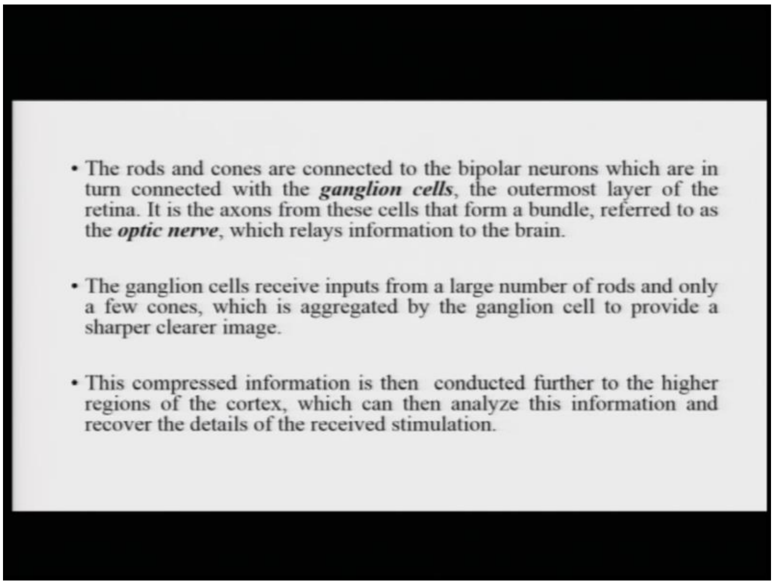

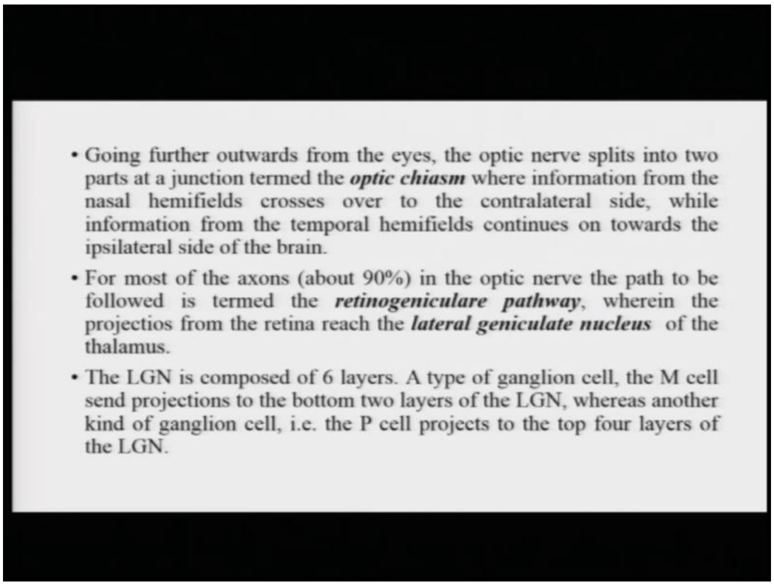

And the rods and cones are actually connected to a kind of neurons called the bipolar neurons, which are in turn connected to the ganglion cells. The ganglion cells from the outermost layer of the retina. It is the axons from these ganglion cells form a bundle, which is referred to as an optic nerve.

This optic nerve is a nerve that released information for socket of the eye towards the brain. The ganglion cells receive inputs from a large number of cones and only a few from a large number of rods and only a few cones, which is then aggregated by the ganglion cell to provide a sharper and a clearer image. This compressed information that is gained by the ganglion cells is then further connected to the higher regions of the cortex, which would later analyze this information and recover the details of the received stimulation.

Now, going further outwards from the eyes through the optic nerve, the optic nerve, you will find that it splits into two parts at a junction called the optic chiasm. The optic chiasm is the junction where information from the two nasal hemifields crosses over to the other side. So information from the left nasal hemifield crosses over to the right hemisphere. While information from the right nasal hemifield crosses over to the left hemisphere.

The information from the temporal hemifields continues on to go to the same hemisphere, which is the ipsilateral hemisphere, or the ipsilateral side of the brain. For most of the axons, the optic nerve, for most of the axons from the optic nerve, about 90 percent of them, the path that they follow is called the retinogeniculare pathway, wherein the projections from the retina reach the lateral geniculate nucleus of the thalamus.

This geniculate nucleus of the thalamus is composed of six layers. M-cells, which are a type of ganglion cells, send projections to the bottom two layers of the LGN, whereas as the P cells, which are another type of ganglion cells, send projection to the top four layers of the LGN.

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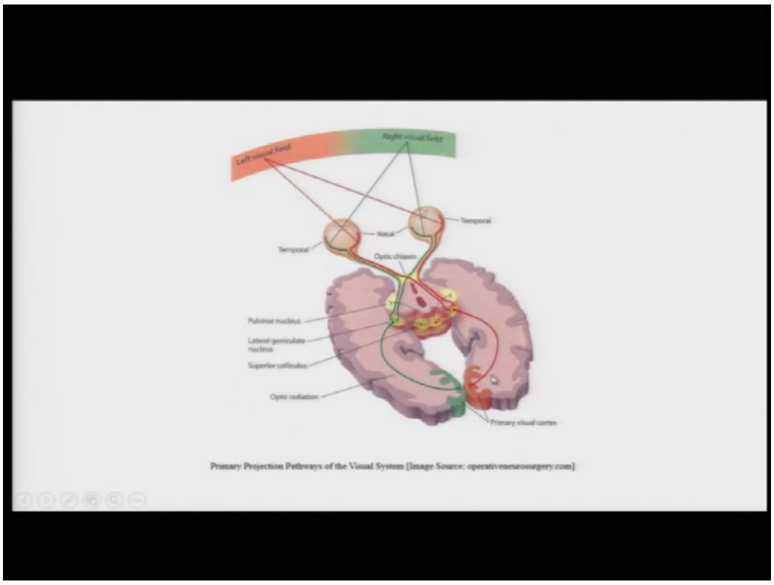

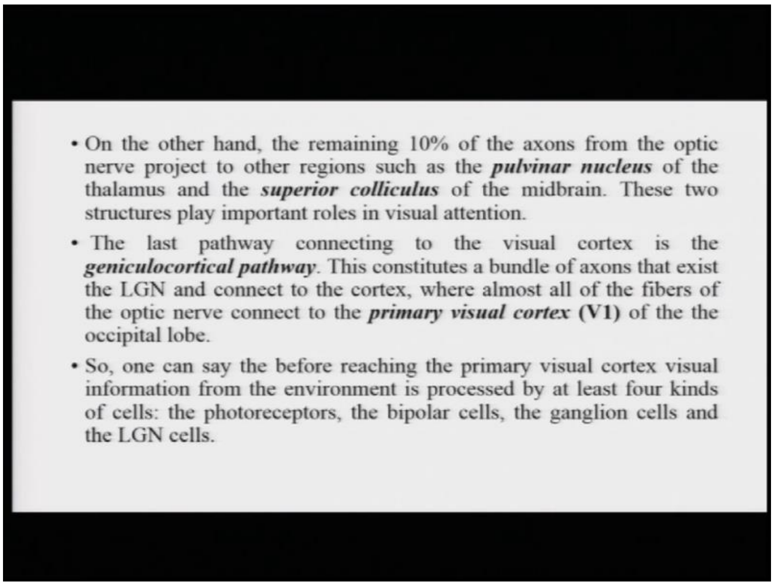

Let us have a quick look at how this connection is happening. So, you can see that the optic nerve coming out of the eye sockets is crossing over at the optic chiasm to the left and the right side of the brain. You can see that projections are to the pulvinar nuclei, the lateral geniculate nuclei and also to the superior colliculus. And finally, the information from this region is led to the primary visual cortices, which are at the back of the brain.

The remaining 10 percent of the axons from the optic nerve project to other regions as we just saw, such as the pulvinar nucleus of the thalamus, and the superior colliculus of the midbrain. These two regions are very important structures, and they play important roles in different aspects of visual attention, such as orienting our attention to orienting our vision to objects, which say for example, flash in the periphery and so on, which grab your attention.

Now, the last pathway connecting to the visual cortex is called the geniculocortical pathway. And the geniculocortical pathway is basically composed of a bundle of axons that exists around LGN and connect to the cortex. Almost all fibers of the optic nerve, finally project to the primary visual cortex or V1 of the occipital lobe.

So one can see that before reaching the primary visual cortex, the visual information from the environment is processed at several layers or at least four layers; the photoreceptor cells, the bipolar cells, the ganglion cells, and the cells at the LGN.

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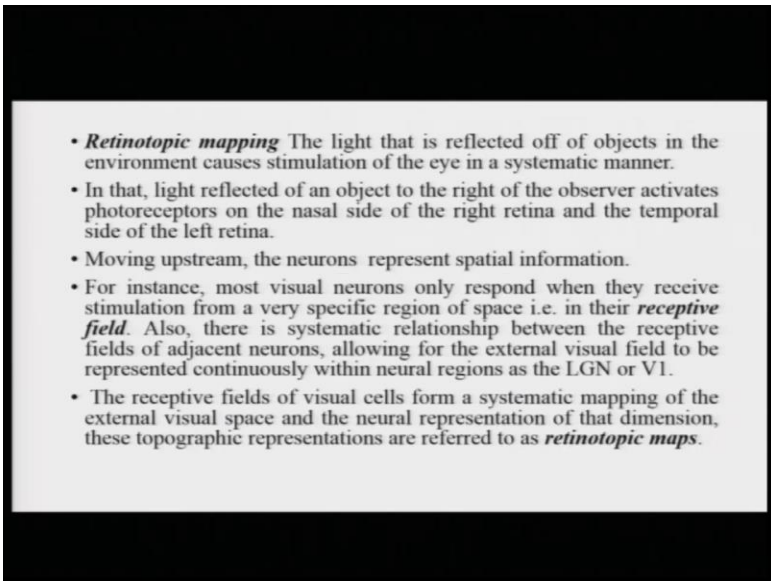

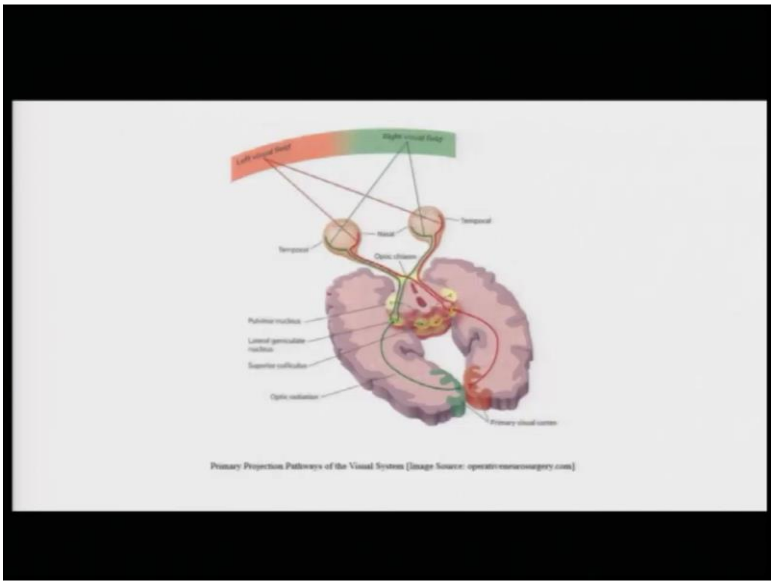

Let us talk about retinotopic mapping or organization of information in the visual cortex. Now, the light that is reflected off of objects in the environment causes stimulation of the eye in a very systematic manner. In that the light that is reflected off an object to the right of the observer activates photoreceptor on the nasal side of the right retina and the temporal side of the left retina. Again, you can see this thing here, nasal side of the right retina and the temporal side of the left retina.

Moving upstream, neurons represent spatial information. They represent information about the area of the space, where the visual stimulation is actually coming from. For instance, most visual neurons only respond when they receive stimulation in their specified regions, which are called the receptive fields.

Also, there is a systematic relationship between the receptive fields of adjacent neurons. Entire visual field, the entire space outside can be represented as a continuum by the help of these neurons. Now, the receptive fields of visual cells they form a systematic mapping of the external visual space. And the neural representation of that dimension. These topographic representations are referred to as retinotopic maps. Basically saying that the information in the space is represented as a continuum on the neural surface.

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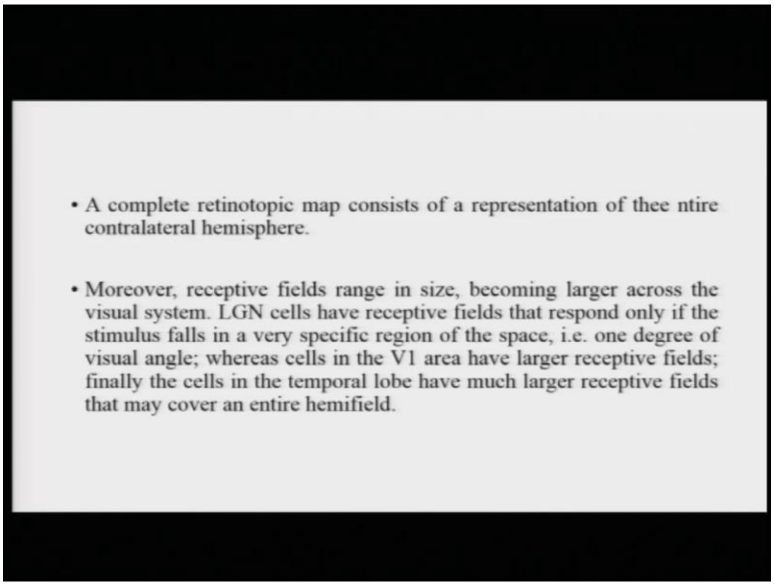

A complete retinotopic map consists of a representation of the entire contralateral hemisphere. Moreover, receptive fields vary in size. They become larger across the visual system. Say for example, at the start, the LGN cells have receptive, have very small receptive fields that respond only if the stimulus falls in a very, very specific region of the space.

That is generally about 1 degree of visual angle. Whereas cells in the area V1, which lies in the cortex, have much larger receptive fields. Finally, the cells in the temporal lobe have even larger receptive fields that could cover an entire hemifield, the half of the visual space.

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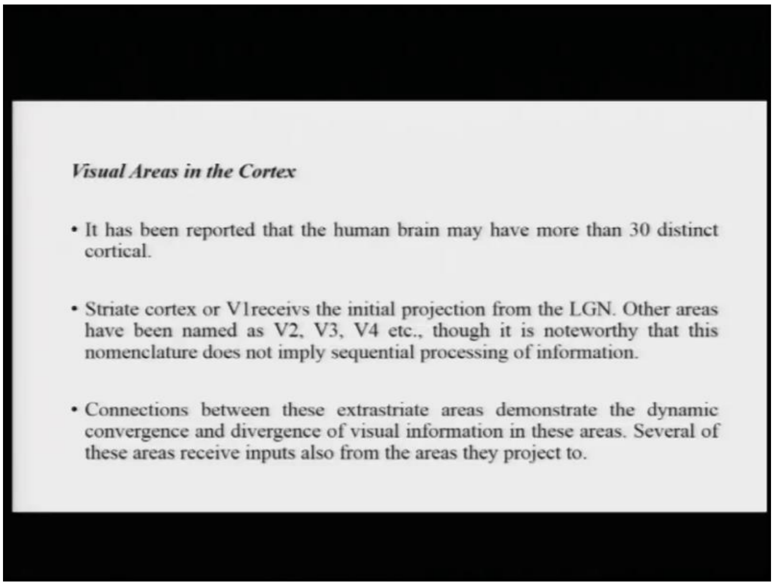

Let us talk about a specific visual areas in the cortex. Now, it has been reported that the human brain may have more than 30 distinct cortical areas. Striate cortex or V1 receives the initial projection from LGN. Other joining areas we named as V2, V3, V4 and so on.

Although you should note that V2, V3, V4 or V1, V2, V3 before does not really mean that information is being processed sequentially from one region to the other. Information processing might as well be parallel. The connections between these extrastriate areas actually demonstrate the dynamic convergence and divergence of visual information in this area. So, basically, information is coming from various sources, various aspects of information are coming in, they are probably being processed in parallel, and then they need to be integrated to help you form a holistic percept.

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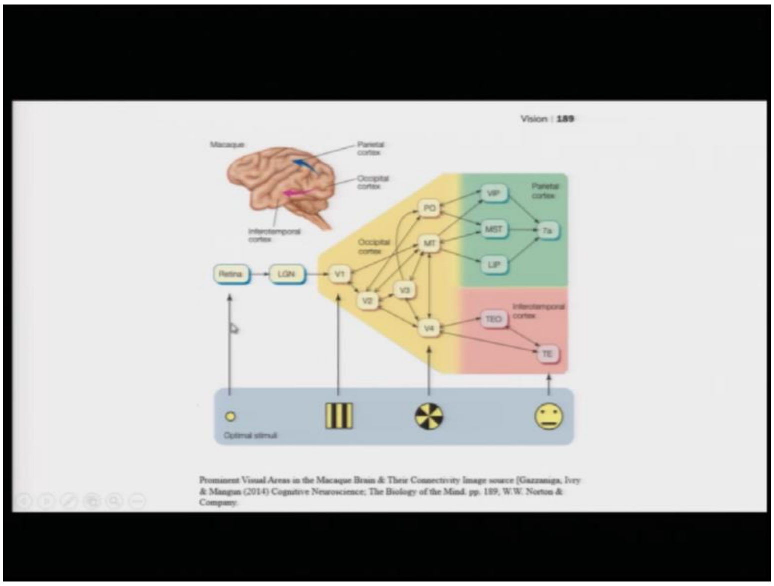

Let us look at the network here. So information is basically from a macaque visual cortex. Macaque is a kind of a monkey. So information from the retina goes to the LGN. It goes to the V1. And then there are so many connections to the field to the areas like V2, V3, V4, parietal, occipital cortex, parietal cortex, medial temporal cortex, inferior temporal cortex and so on.

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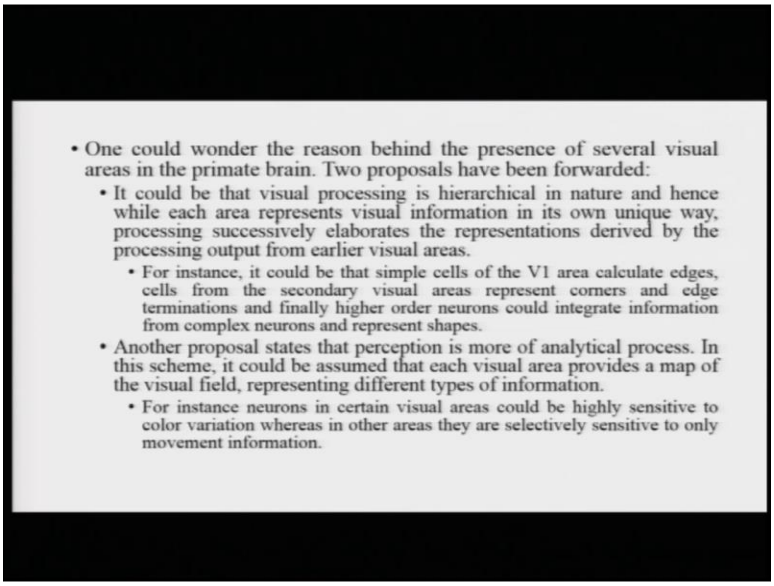

Now, one would wonder, what could be the reason behind the presence of these several visual areas in the primary brain? Two proposals have been offered to sort of try and explain this. It could be that visual processing is hierarchical in nature. And hence what happens is that each area represents visual information in its own unique way and then processing successively, it elaborates the representations derived by each preceding area.

So, what happens is, what would be happening is that information arrives in different degrees of elaboration at these different areas, and it kind of gets sort of completely or fully recovered or fully elaborated at the higher visual areas.

For instance, it could be that simple areas, simple cells of the area V1 only calculate edges. Cells from the secondary visual areas calculate or say for example, come up with corners and edge admonitions. And finally, even higher order neurons in the association areas could integrate this information about edges and corners from complex neurons, and then be able to represent shape information.

That is one of the proposals. Another proposal states that perception is more of an analytical process. It is a process that sort of requires us to analyze different aspects of the visual stimulus and later recombine it to form a whole percept.

Under this scheme, it could be assumed at each visual area that we have just seen provides a map of the visual field, representing different kinds of information. Say for example, there could be specialized regions focusing on just color, motion, or say for example shape information, and other different aspects.

So, for example, it could be possible that neurons in certain visual areas would just be highly sensitive to color variation, whereas in other areas different neurons are just highly sensitive to only movement information. All of this information will eventually need to come together to give you a percept of a moving object such as a car.

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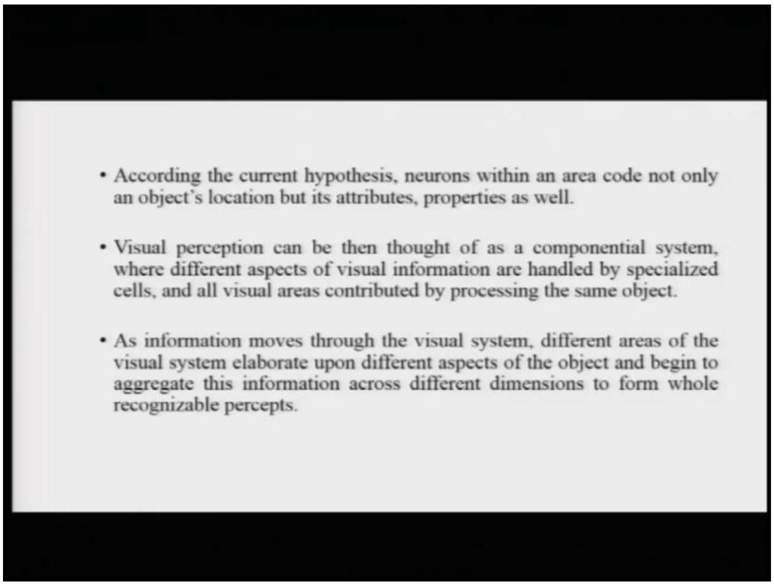

According to this current hypothesis, the one that I just talked about, the neurons within an area will code not only an object's location, but its other attributes and properties as well. Visual perception can then be thought of as a combinational system, the one that I was saying, where different aspects of visual information are handled by specialized cells.

And all visual areas contribute by processing the same different aspects of the same object. As information moves through the visual system, different areas of the visual system would elaborate upon different aspects of the object, and then begin to aggregate this information across different dimensions to form, hold recognizable percepts. So that is one of the views behind why there are so many dedicated areas to the visual cortex.

Now, let us talk, I mean, because we have this idea, let us focus on, or let us talk about the possible presence of such specialized processing visual areas.

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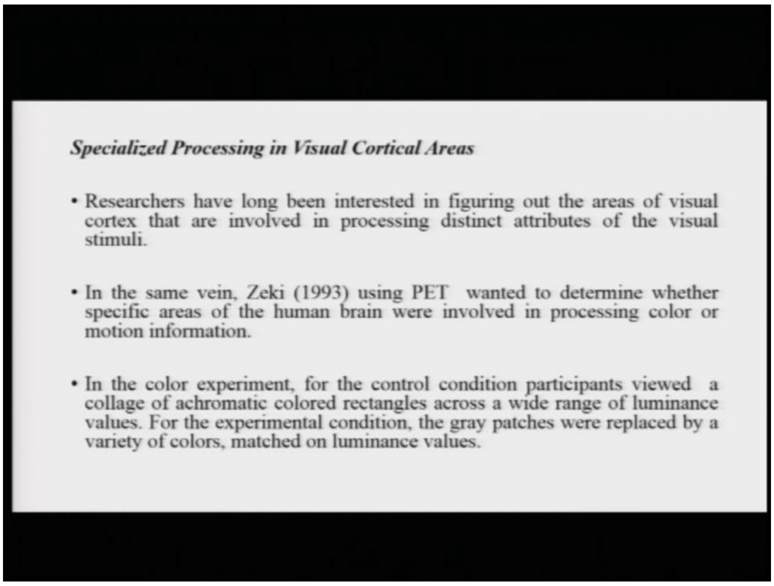

Researchers have actually been interested in figuring out the areas of the visual cortex that are involved in processing distinct specialized attributes of visual stimuli. In the same vein, Zeki in 1993, using the Positron Emission Tomography method, wanted to determine whether some specific areas of the brain are involved in processing, either color or motion information.

In the color experiment for the control condition, the participants were shown a collage of achromatic uncolored rectangles across a wide range of luminance values. For the gray patches were replaced by a variety of colors matched on luminance values. There is a bit of a typo here. In the control condition participants were shown a collage of achromatic rectangles which are non-colored, but varying luminance. For the experimental condition, the gray patches were replaced by a variety of colors but matched on luminance values.

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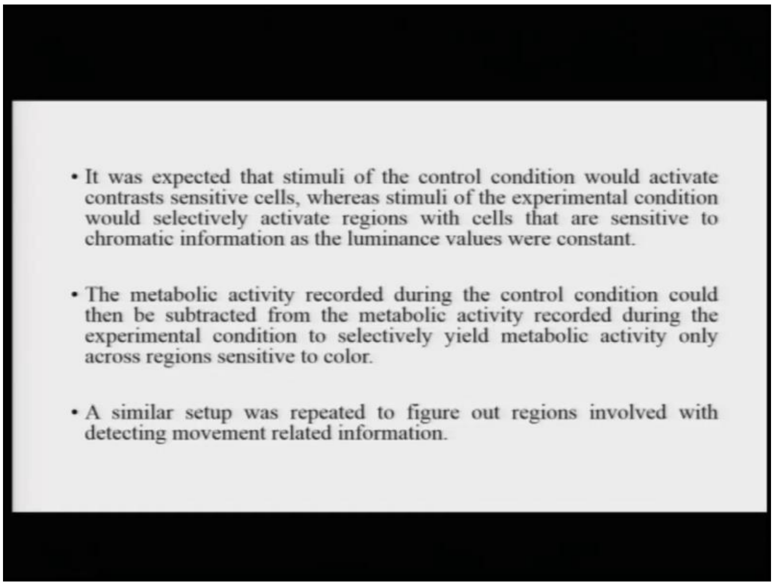

It was expected that stimuli of the control condition would activate contrast sensitive cells. Whereas stimuli of the experimental condition would activate, selectively activate regions of the cell, regions which are only sensitive to hue information or chromatic information because the luminance values are constant. The metabolic activity recorded during the control condition could then be subtracted from the metabolic activity recorded during the experimental condition, and which would yield only the metabolic activity, which is pertaining to processing color information.

A similar setup was also repeated to figure out regions involved with detecting movement related information.

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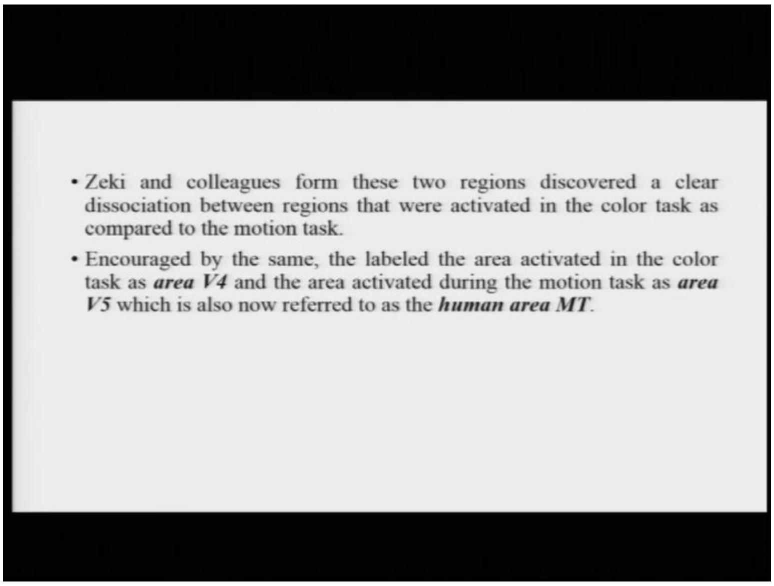

What they found was that these two regions, what they actually found was a clear dissociation between regions that were activated in the colored task as opposed to other regions that were activated selectively in the motion task. The researchers were encouraged by the same and therefore they labeled the area that was activated only in the color task as the area V4 and area that was activated during the motion task as area V5, which is now also referred as human area MT. So, this is just an example of the aspects of specialized processing in areas of the visual cortex.

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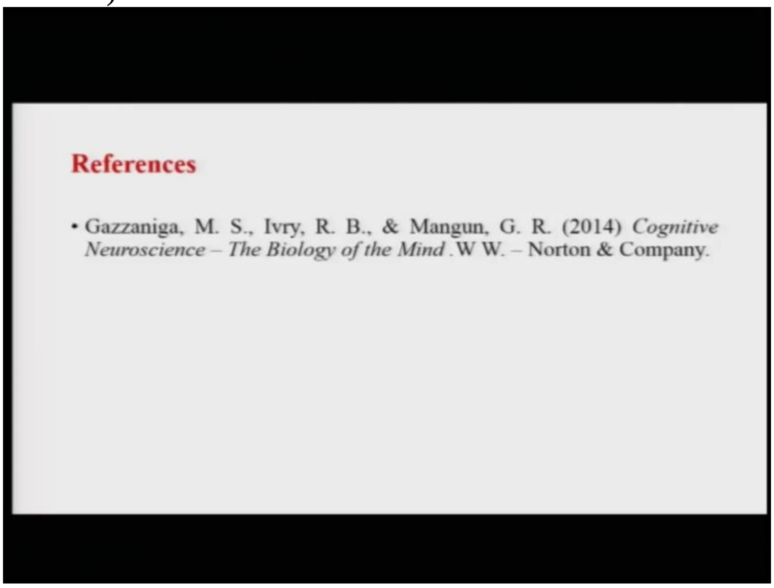

I will now wrap up the session on vision. And in the next lecture, we will talk about some other aspects of sensation and perception. Thank you.