Brain and higher cortical functions

-Cortex composed of **gyri** and **sulci**

-Consist of 5 lobes **>> frontal, parietal, temporal, occipital and insula**.

Layers of the cortex :

- *Histological aspect :*

➢ Two types of cortex : neocortex and paleocortex

-**Neocortex** >>6 layers which has the ability to do processing.

-Paleocortex/ Allocortex/ Archicortex >> 3 or 5 layers, most of them 3 layers. (Allocortex includes 2 types; Paleocortex and Archicortex but the Dr. used the three terms interchangeably.)

➢ The brain is divided into 7 lobes :

-Two of them paleocortex

-The five remaining >> neocortex (frontal, parietal, temporal, occipital and insula)

***Insula found between frontal and parietal lobe.

➢ **The six layers**: each layer has different cells with different structures which suit their function.

✓ **Layer 4:**
The 'input' of the cortex, so any ascending sensation will synapse in layer 4, therefore the somatosensory area, primary

visual area and primary auditory area have a bigger layer 4 than other areas.

>>Based on that, Brodmann classified the cortex according to layer 4 where some areas have a large layer 4 and others have a small layer 4, so he concluded that these areas have different functions and he gave them different numbers.

- ✓ **Layers 2 ,3**:

  They are for processing, so the areas which do further processing of information like secondary cortical areas have largest layers 2, 3.

  >>Each cortical area processes some information then sends this information to the neighboring area; it means layers 2, 3 have connections with neighboring layers 2, 3 and are even connected with layers 2, 3 in the other the half of the brain through corpus callosum fibers. **Most of the fibers in the corpus callosum are formed by the connection fibers between layers 2, 3 in each half.**

- ✓ **Layer 5:**

  Main exit or "output" of the cortex, so any order getting out of the cortex to the spinal cord or the subcortical area is sent through layer 5. It means layer five is the cortical area that controls spinal cord or subcortical area.

- ✓ **Layer 6:** resembles layer 5 but it mainly controls subcortical or allocortical regions.

- ✓ **Layer 1:** it’s not important; contains few cells and short connections.

- *physiological aspect :*

➢ 3 types of the cortices :

1- **Primary type**: connects with areas outside of the cortex, receives sensation or sends output.

>>>Primary somatosensory area, primary visual area, primary motor area, primary auditory area...

Primary somatosensory area receives sensory information then sends it to other areas for further processing and memory, these areas called 2- **secondary cortical area.**

Each primary cortical area has secondary cortical area, but we need to combine all the sensations (vision, hearing ...) to take a complete picture of what surrounds us and this done by the 3- **association cortical area**; so the association areas are (primary motor + secondary motor) , (primary visual + secondary visual) , (primary olfactory + secondary olfactory) and (primary sensory + secondary sensory).

Almost two thirds of the brain areas are association areas and are distributed in 3 main regions: anterior temporal, superior frontal (rostral part of the frontal, also called the prefrontal cortex) and superior posterior part of parietal

- Loss of primary somatosensory cortex area 3,1,2 >>> loss of sensation (and everything carried by the PCML).
- Loss of primary visual area 17 >>> blindness.

- Loss of primary olfactory area >>> inability to smell .

BUT .. loss of secondary or association area of the previous areas will lead to **inability to recognize** what we see or smell or touch ..

***As we said previously, taste and olfactory sensations go to association areas which combine the two of them and analyze these sensations in the orbitofrontal cortex, mainly on the right side... If this area gets damaged we can still smell and taste but we cannot recognize what we smell or what we taste.

Agnosia:

Inability to identify; damage in secondary or association area.

1- **Olfactory agnosia**: damage in secondary or association olfactory area, I can smell but I cannot identify what I smell.
2- **Astereognosis :** damage in PCML; I still feeling a little bit but I cannot identify what I feel.
3- **Visual agnosia**: damage in secondary or association visual area; I see but I cannot recognize what I see.

In the sensory cortex **we receive sensations which are then processed**, but in the motor cortex **processing occurs before sending the order,** so we call the motor area that processes, the secondary or **premotor** area, and the area that sends the order is called the primary motor area.

So damage in primary motor area >>> **paralysis**

But damage in premotor area >>> **apraxia**

Apraxia :

Inability to do complex movements in a sequence like playing the guitar.

So any damage in this area does not lead to weakness or paralysis in your muscle, but you can not do a complex movement like playing the guitar even if you're a professional guitarist and this is called apraxia.

Right and left brain:

The two hemispheres look like each other and they are almost identical, but they have some differences in their anatomy and physiology.

Remember that each hemisphere controls the contralateral side of the body

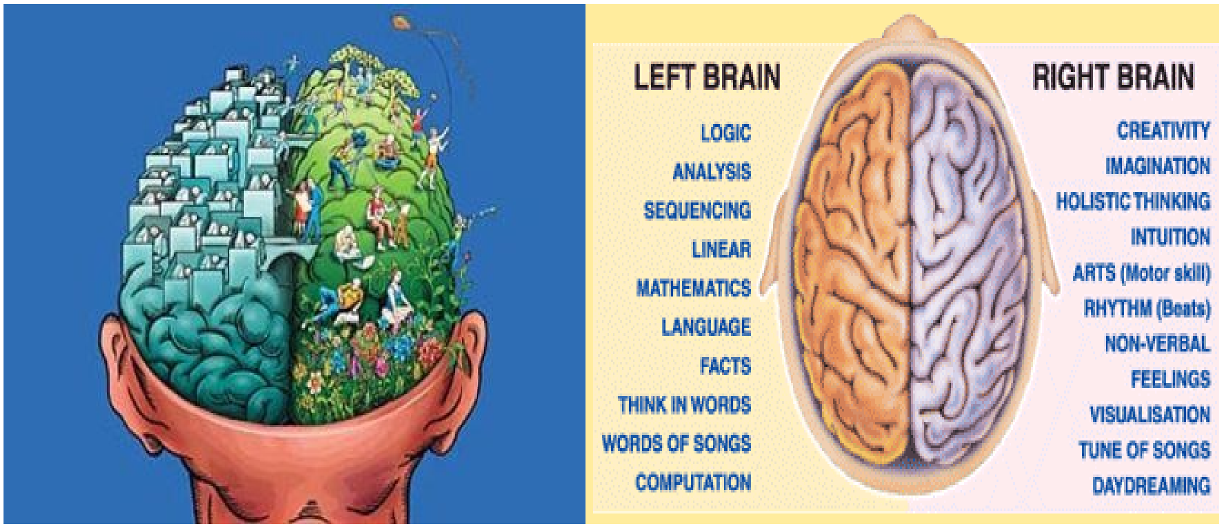
For example:

We have primary and secondary auditory areas at both sides and both of them receives impulses from both ears, but each side functions more than the other in certain conditions.

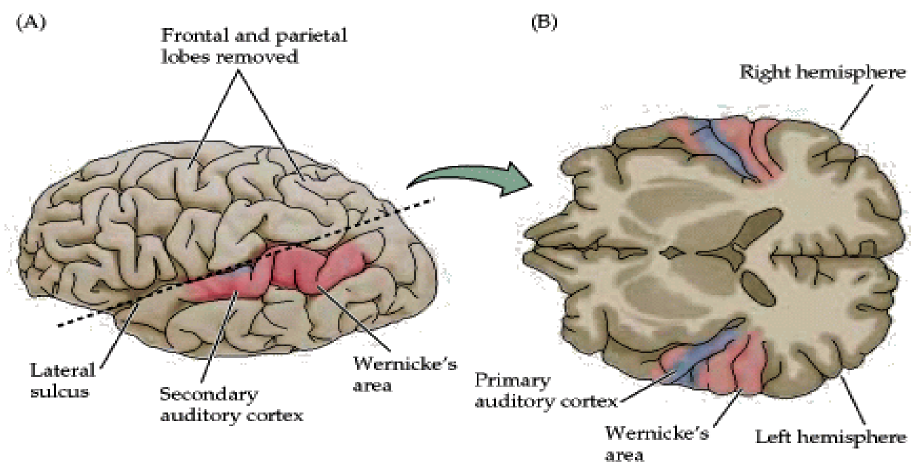
We hear in both ears, but :

-The **Right brain** (left ear): functions more and is responsible for hearing **music**, taste art, etc….

-**The Left brain** (right ear): functions more and is responsible for hearing things that need **anal**ysis, language, when someone talks to you.



***Language** function is mostly achieved in **the left** side of the cortex, (this explains the anatomy of the left cortex and why it is larger, has more gyri and it's more complex in comparison to the right side of the cortex).



Question:

You are hearing music, and you remember that you heard this tone before, you start focusing to remember where you heard this before, or to what song it belongs, in this case in which ear you are hearing?

A: Right ear B: Left ear C: Both ears the same

The answer is**: B**

Fact:

-In 99.99% of RIGHT handed people, the language area is found in the left cortex.

-In 97% of left handed people (they are 12% of all people) the language area is found also in the left cortex.

-In 3% of the left handed people the language area found on the right cortex, and part of them have it in both sides.

In conclusion, the Language area is found in the Left side in most people.

Cortical processing:

Signals will enter the cortex and will be analyzed by the brain to be processed in order to come up with information from that signal.

It occurs in two ways:

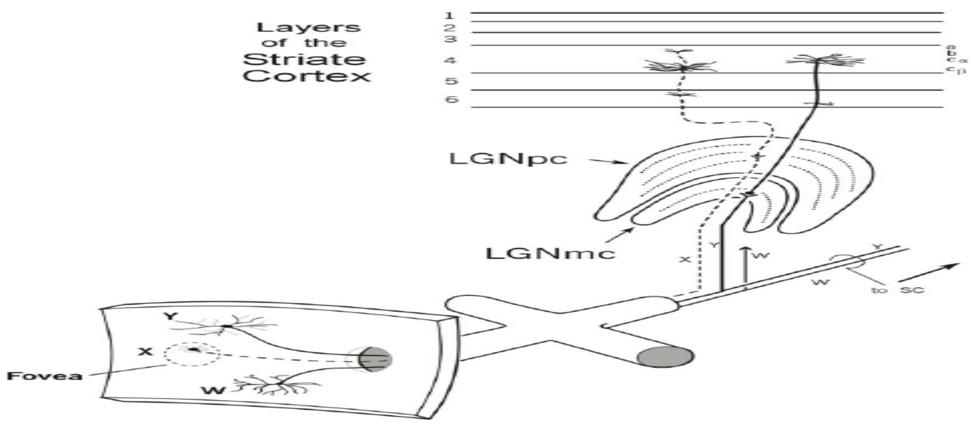
1-**Continous**: The same signal is analyzed gradually until we reach useful information. For e.g.: information enters area 1 then goes to area 2 for further processing then goes to area 3 then area 4 then area 5.

2-**Parallel**: Each signal here is analyzed separately and has its own pathway, and there might be gathering of information in the end. For e.g.: information enters area1 then it will separate into 2 parts; one goes to area 2,3 and 4 and the other part will go to area 21,22,23 then these 2 information will be gathered again to one point, so we have very connected areas in the cortex.

Most processing pathways occur together (Continuous and parallel), an example on this is seen in vision; we have **what** pathways and **where** pathways separated from each other but in the same pathway there is continuous processing. The best example on cortical processing is visual processing because vision takes a big part of the cortex, and because it is highly studied and understood.

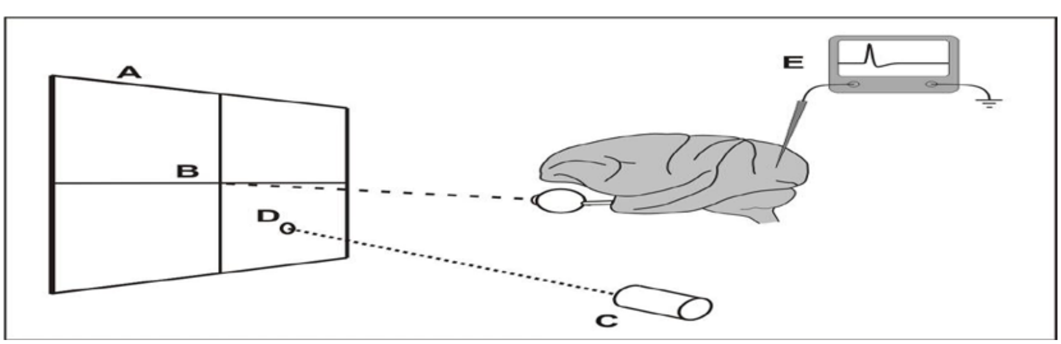
- **<u>Visual processing as an example:</u>**

First, the receptors in the retina receive light then the ganglionic cells (X and Y cells) will be activated and send action potential through their axons reaching finally to the **primary visual cortex V1, Area 17; Layer 4 mainly which activates cells in this layer**. From here the processing starts more and more to end up with a picture.

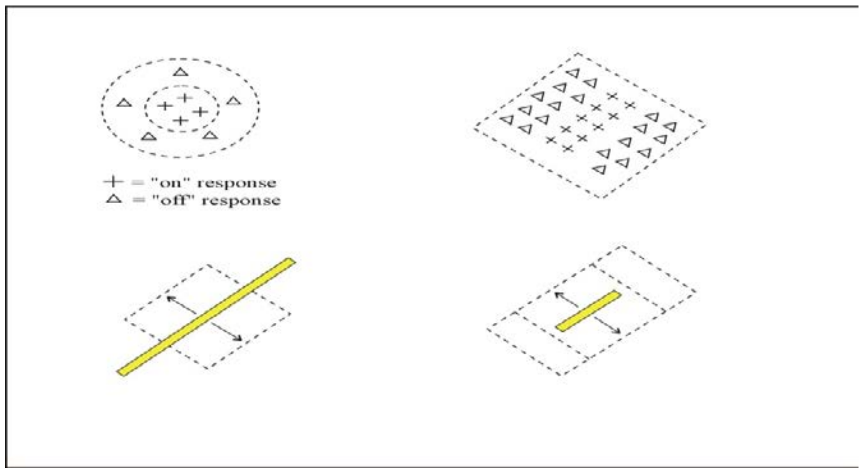


**Remember that: in the retina we have ON and OFF ganglionic cells.

Before talking about the visual processing we should understand the concept of the receptive field here. The following figure shows a study on the receptive field:



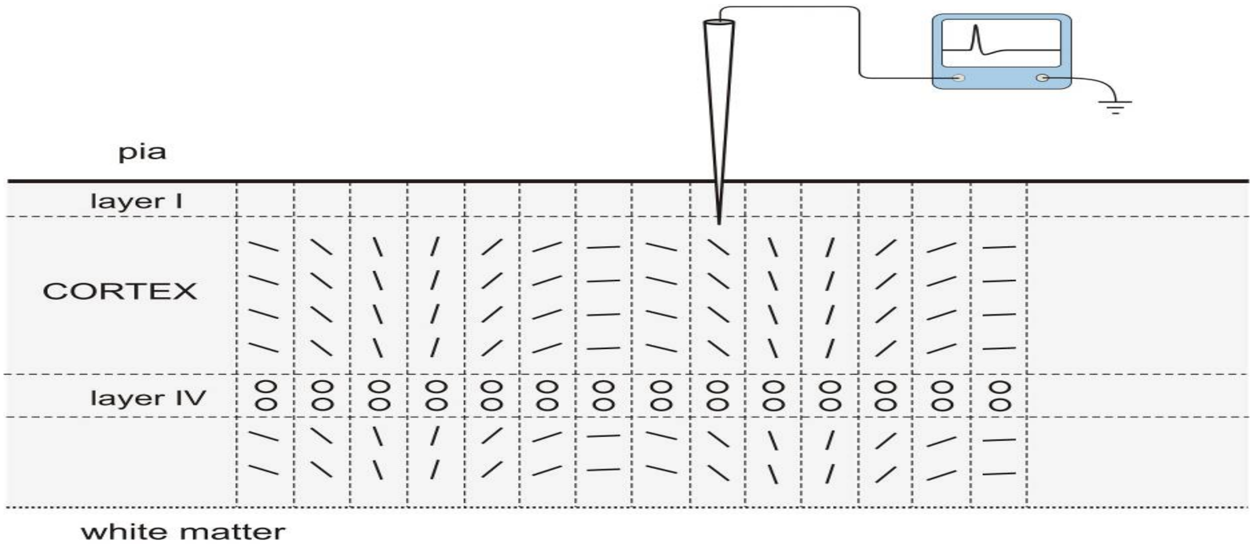
If we try to make a recording for a neuron in layer 4 in V1 (which is the primary visual cortex), and we put spots of light toward a screen in front of the eye and see whether the studied neuron will respond or not, we will notice that **on one** spot there is **a response** on the recorder(there is action potential), but if the spot of light is in the surrounding areas it will produce no sound from the recorder so there is no electrical signal i.e. there is no response to the stimulus (spot of light) from the studied neuron (no action potential). This is called **concentric or centric or dot-like** receptive field neuron which means that the neuron responds to light in a specific or center spot (where the pluses are in the figure) and doesn't respond to light when it's in the surrounding area (where the triangles are in the figure).



Remember that these neurons are present in all V1 (primary visual cortex) and exactly in layer 4 of V1 because there we receive action potential from ganglionic cells.

After this information reaches area 17 and is processed in this area, it will be divided into 2 parts: dorsal ''where'' pathway and ventral ''what'' pathway, then it will gather again; this is parallel processing. Although visual processing is mainly parallel processing, it also has continuous processing.

In more details, the visual pathway goes like this:



1- Retina will send **dots** (from X and Y ganglionic cell) to the **primary visual cortex** and as **layer 4** gets the input, processing is started, layer 4 just responds to dots (because we see in both eyes each dot will be send to both hemispheres, so each dot has 2 columns in layer 4; one from the ipsilateral and one from the contralateral eye).

2- From layer 4 processing will continue to layers 2 and 3 (still we are in V1, in these layers simple vision occur; dots start gathering to form lines in different directions) and if we start recording from layer 2 and 3 of V1 we will notice that neurons respond to a line in a specific direction and specific location. What really happens is that a group of neurons in layer 4 will go to stimulate or converge on specific neurons in layer 2 and 3 (each 4 -5 neurons from layer 4 stimulate one neuron in area 2 and 3 which respond to a certain line and in a certain direction). That's why V1 is divided into columns; each column is related to a specific orientation. Don't forget that each column contains ipsilateral and contralateral visual inputs. Each column is called: the orientation column of the visual cortex. So all the layers of one column in the V1 will identify only one **line in one direction in the space**.

3- Now we will move to complex vision (not only one line). When we move to **V2** area 18 and 19, we will notice that it will respond to multilines (3-4 lines) in that area.

4- Then we will move to a more complex one as these multilines (3-4 lines) will stimulate and converge on one neuron that is involved in processing of hypercomplexed type which responds to direction and space but is related also to volume and length of lines. Each shape whether circular or triangular has its own hypercomplex neuron.

5- Then we continue more and more processing through association and decomposition of the picture; as different lines will make for example a square with certain volume, or a triangle.

After the information comes out from area 18 and 19 V2, the information divides into two parts:

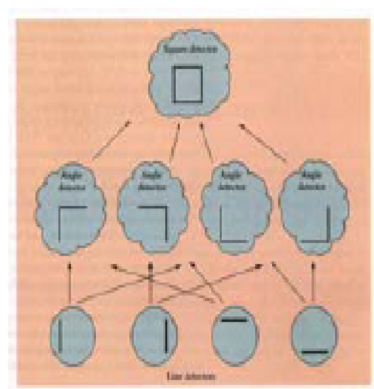
-If the information is related to movement, depth, location it will go to the 'Where pathway".

-If the information is related to shape, colour it will go to the "what pathway".

- We have 37 cortical areas related to vision and memory of vision.

Visual Image Decomposition

Simple, complex and hypercomplex cells can work together to decompose the outlines of a visual image into short segments, the basis of simple and complex object recognition.



- **Damage to V1: area 17, primary visual cortex:**

BLINDNESS will occur, also two phenomena will be found in those patients:

1-**Blindsight**: the patient can see different movements in front of him although he is blind, he can also tell you that he walked next to a table or something long.

2-**Visual hallucination**: area18 and area 19 are still intact and active, and they can become sensitized and activate different areas, for example if they activate an area responsible for seeing flying faces, the patient will tell you that he saw a flying face, or a bird in the tree, although he is blind, he will see things that are not present.

- **""What pathway"":**

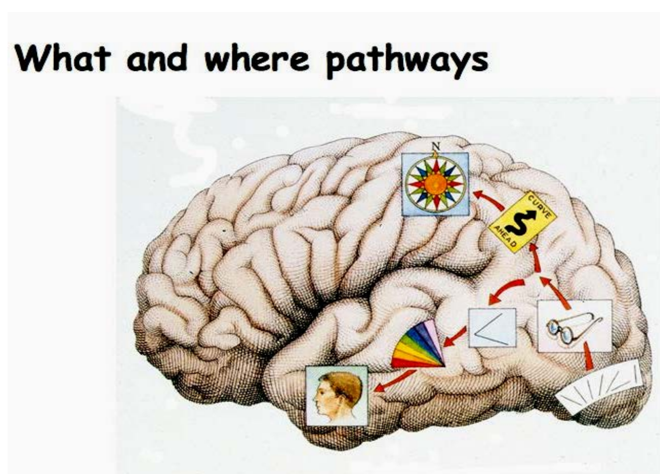
This pathway starts at the lower part of the calcarine fissure and includes:

-Lingual gyrus -Parahipocampal gyrus - Occipitotemporal gyrus

(Medial and inferior part of the brain)

In this pathway processing for color and shape occurs.

The upper part of this pathway is responsible for color processing, and the lower area is responsible for shape processing.



Damage to this pathway results in: **achromatopsia, color agnosia, color anomia.**

***Lingual gyrus**: it lies directly below area 17, and is responsible for color processing. If this area got damaged in a patient, he will see everything normally but he can't process colours, this patient will see everything in black and white. If the lesion is bilateral and complete the patient will see everything in black and white; a condition called: **achromatopsia**

But if the lesion was at one side; right for example, the patient will have **Hemiachromatopsia** (in this case he will see everything in the left visual field in black and white, and everything in the right visual field normally with colors).

<u>Colour agnosia and colour anomia:</u>

These 2 conditions are different from each other, and result from damage to 2 different cortical areas. The Dr. said that you don't need to know the difference between them you just need to know that in these 2 conditions:

The patient CAN'T differentiate between different colors! Although he sees everything normally and with colors but because he has lost the area and everything related to color memory and color knowledge, he can't remember the normal color of different things, he can't name the colors that he sees (for example he can't know that the sky is blue, the banana is yellow, and if you ask him to color a picture he can't and he will color the sky black for example etc..).

- **<u>Visual agnosia:</u>**

In the inferior part of Occipitotemporal gyri, shape processing occurs; each certain type of shapes has a specific area: animals, letters and words (superior and posterior), faces (in the middle occipitotemporal), tables and furniture).

If a lesion is introduced to this area the patient will **<u>have visual agnosia</u>**; the inability to recognize objects despite satisfactory vision.

Examples on visual agnosia:

1- **Prosopagnosia**: The most important example of visual agnosia for example a man mistaking the face of his wife with a hat; as a result of damage in the area responsible for face shape processing (in the middle of occipitotemporal gyri) the patient is unable to recognize or learn faces.

**In 95% of people we recognize faces on both sides. Because faces are more associated with emotions, the right side is more important than the left side in determining faces. If, however, the lesion was on the right side the patient still can determine faces by the left side, so most patients must have complete or bilateral lesions to have complete prosopagnosia. On the other hand, in a small percentage 3-4% of people, having a lesion on the right side only results in complete prosopagnosia and the left side can't compensate for that lesion.

Although patients with prosopagnosia have lost the area of faces shape processing they still can Identify people by other features: by gait, mannerisms or facial features- spectacles, voice, shape of body. The problem will be prominent when you show the patient a picture for a person or static non-moving faces; in this case he can't identify the person.

2- If the damage was in the area responsible for words and letters (in the fusiform and lingual gyri), processing the condition will be: **letter agnosia or specific objective agnosia** or more specifically **alexia**(the patient can't read).

3-Specific object agnosia If damage occurs in the certain object processing area; for example a damage in animal shape processing area so called: animal category agnosia; he can't recognize animal shapes.

A case for a patient, has a stroke affects the left side of the brain; part of occipitotemporal + lingual +fusiform gyri

This patient will have**: Hemiachromatopsia**, **category specific visual agnosia and pure alexia (because litters processing is prominent in the left side**).

The wind cannot defeat a tree with strong roots.

Done by:

Esraa odah and Ghaida khraisat