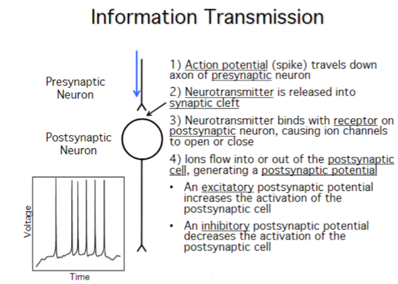
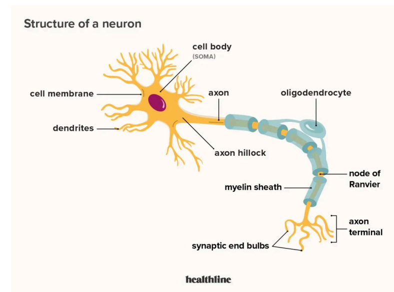
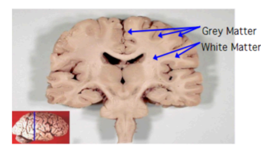
## Underlying Biology:

### *Neurons:*

One of the base information transmitters in the brain. Dendrites receive input from other neurons through a synapse, then send signals to cell body. Cell body integrates signal, and if threshold is reached, sends an action potential / fires / spikes. This signal travels through the axon and all its axon terminals, and fires neurotransmitters into the synaptic clefts, sending a signal to the next neuron.
Dendrites -> Cell body -> Axon -> Axon terminal -> Synaptic cleft
Pre-synaptic neuron: Neuron that fires signal. The AXON side.
Post-synaptic neuron: Neuron that receives signal. The DENDRITE side.
[Link to video]



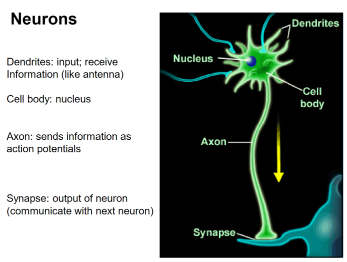




- The cell bodies and dendrites of the neurons are in the gray matter, and long-range axons between neurons travel through the underlying white matter.
- Short-range axons are often unmyelinated and travel through the gray matter.
- Information is sent between hemispheres via the corpus callosum.

### *Dendrites:*

Receive input from other neurons. They will register an input when neurotransmitter is fired into their post-synaptic terminal.




### *Axons:*

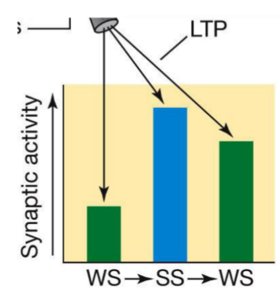
One axon to a neuron (usually). This axon can branch off, but can all be traced back to one root. VERY useful for identifying visually.
These axons can be thought of as the output of the neuron. Send signals to the next neuron.

### *Myelin:*

Fatty sheaths that cover the axon to improve the conductance of the axon. This is partly why the inside of the brain (the white matter) is white, its fattier and more well myelinated because the neurons have to travel farther and faster.

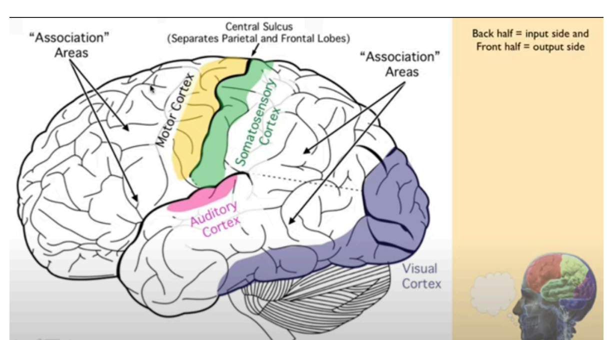
### *Glial Cells:*

Cells that maintain neurons.
“The four main functions of glial cells are: to surround neurons and hold them in place, to supply nutrients and oxygen to neurons, to insulate one neuron from another, and to destroy and remove the carcasses of dead neurons (clean up)”




### *Hebbian Learning:*

A synaptic property that “cells that fire together wire together”.

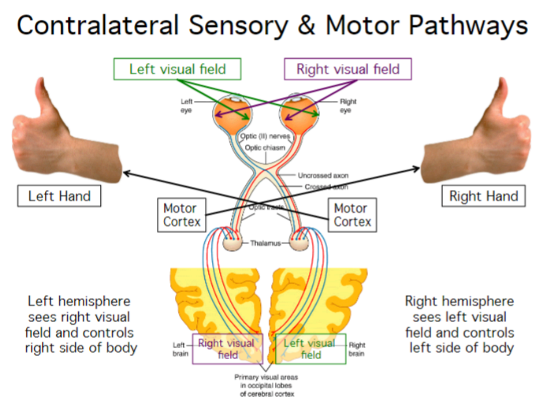


You can induce increased responsiveness by first doing a weak stimulus (WS), followed by strong stimulus (SS), then WS again. You will notice stronger responsiveness.
It is postulated that proteins are needed to modify the synapse.

## Lobes:

***Frontal Lobe:***
Higher-order thought. A lot of decision-making, regulation of thought and emotions. Also includes the motor cortex.

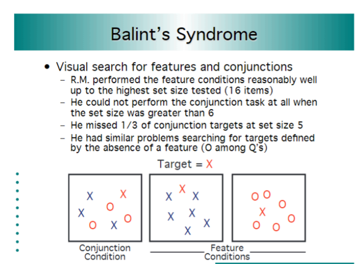
***Temporal Lobe:***
Processing auditory information and the encoding of memory.
Declarative memory.
"It subdivides further into the superior temporal lobe, the middle temporal lobe, and the inferior temporal lobe. It houses several critical brain structures including the hippocampus and the amygdala"
"hypothalamus, as well as other organs that form part of the limbic system such as the hippocampus, amygdala, thalamus, and mammillary body"



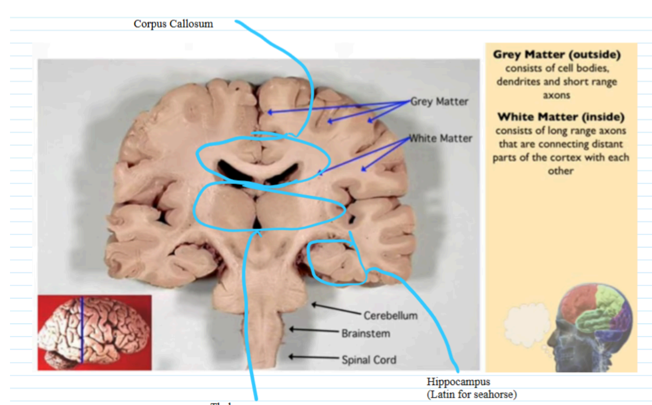

***Parietal Lobe:***
Receive and process sensory information. Includes the somatosensory cortex. Involved in attention.

Damage to the right parietal lobe (usually from a stroke) leads to "unilateral neglect"
- Patients do not pay attention to the contralateral side of space (usually the left side following a right hemisphere lesion, but sometimes vice versa)
- Patients can recover from neglect, but can be left with extinctions, where they will favor one side of space over the other
- These are not sensory deficits, as imagined things (such as the Piazza del Duomo [courtyard]) will also show this pattern of neglect

Damage to both causes Balint's Syndrome. Unable to give attention (at some level).




***Occipital Lobe:***
Visual processing.
"It contains the primary and association visual cortex"




***Cerebral Cortex:***
All the brain but the brain stem

- All the brain not involved in automated functions that keep us alive (breathing, heartbeat)
- Literally our thinking cap

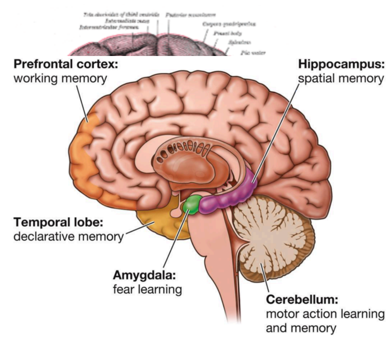
## Brain Areas

***ACPC:***

"In clinical brain MR imaging, the anterior/posterior commissure (ACPC) line has been widely used as the standard imaging reference line since 1988"
AC: Anterior Commissure / PC: Posterior Commissure

***Brain Stem:***

Most primitive, breathing, controlling the heartbeat, your overall state of arousal, sleeping and waking



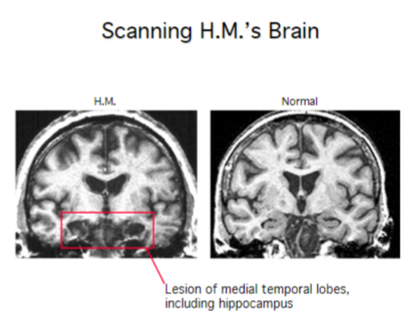

***Cerebellum***

Responsible for motor control and balance. Motor actiona learning and memory.
"The cerebellum ("little brain")is best known for its role in movement and some forms of conditioning, but we're increasingly seeing that it plays a role in higher cognitive functions as well"
Grape ball in bottom behind brain

***Corpus Collosum:***

Band of axons that connects left and right hemispheres of the brain. Severing causes split-brain behavior. This is done for a rare subset of epilepsy patients whose seizures bounce back and forth between the hemispheres, reinforcing each other.
While split, the two hemispheres can still communicate at a very base level through the brain stem, for things like coordinating movement, walking normally, holding things with two hands, etc. No transfer of detailed information.

People born without corpus callosum (congenital agenesis of the corpus callosum) will develop overgrown anterior and posterior commissures, so their hemispheres can communicate fairly well.

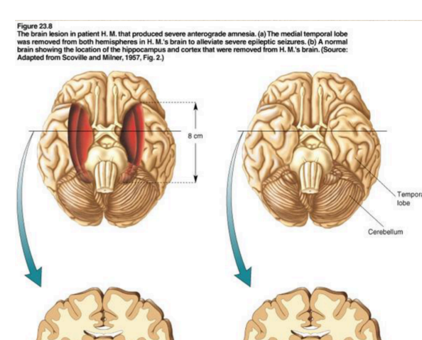



***VTA:***

"The ventral tegmental area (VTA) is well known for regulating reward consumption, learning, memory, and addiction behaviors through mediating dopamine (DA) release in downstream regions"[1]

***Substantia Nigra:***

Known for creating dopamine as well. Dopamine important for Reward Learning (RL)




[1] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9164627/

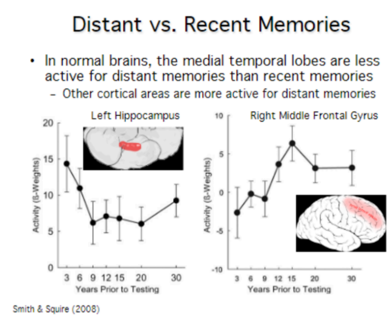
| Neurotransmitter | Origin (cell bodies) |
|---|---|
| Dopamine | Substantia Nigra and VTA |
| Norepinephrine | Locus ceoruleus |
| Epinephrine (adrenaline) | Medulla |
| Histamine | Hypothalamus |
| Serotonin | Raphe Nuclei |
| Acetylcholine | Basal forebrain |

***Thalamus:***
Called the sensory relay of the brain (smell does not pass through).

***Medial Temporal Lobes:***
THE CENTER OF LONG TERM MEMORY (LTM) RESEARCH

H.M. famously had a bilateral medial temporal lobectomy, removing this part of the brain.
Bilateral MTL damage can cause amnesia. Monkey lesion experiments have been performed that recreate the effects seen in H.M.

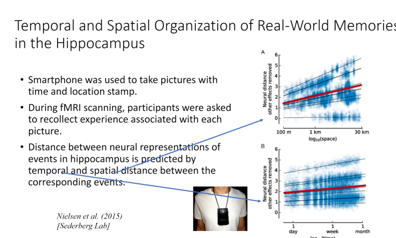
"At the broadest level, the MTL can be subdivided into the perirhinal cortex, the parahippocampal cortex, and entorhinal cortex (collectively referred to as the parahippocampal region), and the hippocampus (including the dentate gyrus, Ammon's horn, and subiculum)."
"The medial temporal lobe (MTL) includes the hippocampus, amygdala and parahippocampal regions, and is crucial for episodic and spatial memory. MTL memory function consists of distinct processes such as encoding, consolidation and retrieval."




***Medial diencephalic areas (midline thalamic areas):***
Damage to the medial diencephalic areas (midline thalamic areas) also causes profound anterograde Amnesia

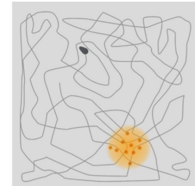
- Example: Korsakoff's Syndrome:
    - Typically a result of alcoholism and other forms of malnutrition!
- Patient N.A. also had anterograde amnesia caused by damage to the medial diencephalic areas (midline thalamic areas)

***Hippocampus (HPC):***
Learning and memory. Associated with contextual memory, key in assigning and retrieving context for memories. Encoding and decoding. Spatial memory. Assigns context to memories. When damaged, have difficulty with memories after amnesia and shortly before. No loss of memories for events long before.MTL less active for distant memories than recent memories (left hippocampus?). Instead right middle frontal gyrus more active.
von Restorff Effect - Distinct items (say red word in grey list) are remembered better. The unexpected isolate item has more hippocampal activity.
Contains "place cells", cells dedicating to representing the current position in space relative to its environent. Remaps when entering new environment/location




- John O'Keefe discovered, in 1971, that certain nerve cells in the brain were activated when a rat assumed a particular place in the environment. Other nerve cells were activated at other places.

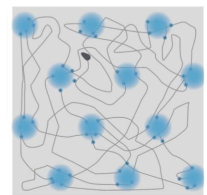
He proposed that these “place cells” build up an inner map of the environment. Place cells are located in a part of the brain called the hippocampus(PSC 130, L06_SpaceTimeEpisodicMemory)



- When spatial context changes sufficiently, hippocampal place cells “remap” (i.e., change their place fields). Back in the familiar environment, old place fields re-appear, revealing spatial memory.
- Place specific and omni-directional

Has temporal and spatial encoding, and objects with similar temporal and/or spatial locations are correlated with similar signatures.
The HPC associates items with representations of the context in which they were encountered
Hippocampal activity should be sensitive to recollection (recalling event with context)

***Entorhinal Complex:***
With the perirhinal cortex, the parahippocampal cortex, and entorhinal cortex, collectively referred to as the parahippocampal region.
Contains grid cells

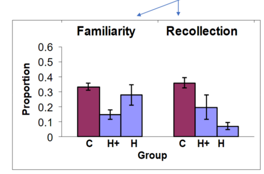


- May-Britt och Edvard I. Moser discovered in 2005 that other nerve cells in a nearby part of the brain, the entorhinal cortex, were activated when the rat passed certain locations. Together, these locations formed a hexagonal grid, each “grid cell” reacting in a unique spatial pattern. Collectively, these grid cells form a coordinate system that allows for spatial navigation.
- Grid cells do not remap, and are not 1 to 1, forming a collective hexagonal grid.

***Perirhinal cortex (PRC):***
PRC represents information about Items (people, things, words, etc.)
PRC activity should be sensitive to familiarity (the subjective sense that you recognize something, is familiar)
Familiarity is dependent on the PRC

***Parahypocampal Gyrus:***
Created deficits of familiarity when damaged alongside the hippocampus.
“The parahippocampal gyrus (or hippocampal gyrus) is a grey matter cortical region of the brain that surrounds the hippocampus and is part of the limbic system. The region plays an important role in memory encoding and retrieval. It has been involved in some cases of hippocampal sclerosis.”

**Remember/Know test**
Study: word1, word2,…
Test: word2, word7…”R / K / No”




(*C for Control)

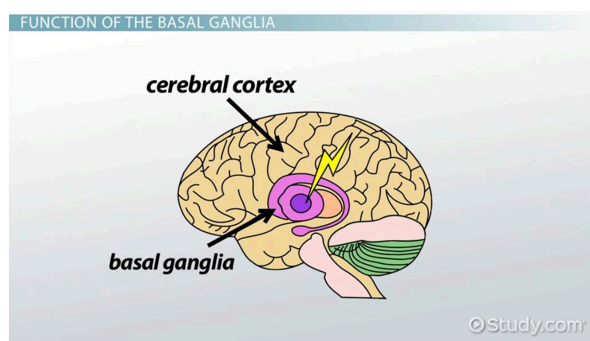
*•Patients with focal hippocampal damage (H) show specific recollection deficits (poor “Remember”)*

*•Patients with hippocampal + parahippocampal damage (H+) show deficits in familiarity and recollection (poor “Remember” and “Know”)*

"The parahippocampal cortex (PHC) has been associated with many cognitive processes, including visuospatial processing and episodic memory."[2]

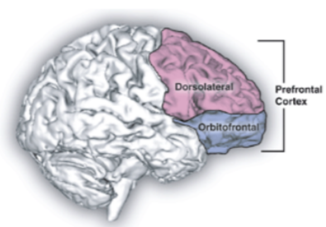
***Amygdala:***
Ties to fear learning.
"Contemporary theories of emotion converge around the key role of the amygdala as the central subcortical emotional brain structure that constantly evaluates and integrates a variety of sensory information from the surroundings and assigns them appropriate values of emotional dimensions, such as valence, intensity, and approachability. The amygdala participates in the regulation of autonomic and endocrine functions, decision-making and adaptations of instinctive and motivational behaviors to changes in the environment through implicit associative learning, changes in short- and long-term synaptic plasticity, and activation of the fight-or-flight response via efferent projections from its central nucleus to cortical and subcortical structures."[3]
"Your amygdala is a small, almond-shaped structure inside of your brain. It's part of a larger network in your brain called the limbic system. When it comes to your survival, your amygdala and limbic system are extremely important. These are parts of your brain that automatically detect danger. They also play a role in behavior, emotional control and learning."

***Basal Ganglia:***
"The "basal ganglia" refers to a group of subcortical nuclei responsible primarily for motor control, as well as other roles such as motor learning, executive functions and behaviors, and emotions… The basal ganglia are responsible for motor control, and their proper functioning requires dopamine to be released at the input nuclei. Dopamine dysfunction is associated with several movement disorders (e.g., Parkinson's)."[4]
Implicit learning is impaired in Parkinson's patients with basal ganglia damage.




***Hypothalamus***

***PFC:***
Prefrontal Cortex, associated with higher order thought. Decisionmaking, regulation of thoughts and emotion. Critical for executive functions of the brain (incl. attention & WM). Big ties to <u>WM</u>




Dorsolateral PFC plays an important role in relational encoding (associated with successful remembering of relationships between items)

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[2] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3786097/
[3] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8228195/
[4] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3543080/

Damage Study for patients with PFC damage: No impairment in simple item memory (item on list). Impairment in linking different pieces of information together (order memory) Memory enhance when people engage in elaborative encoding, which often involves finding relationships

***OFC:***

Orbito Frontal Cortex. One of the key players in decision-making. "decoding and representing some primary reinforcers such as taste and touch; in learning and reversing associations of visual and other stimuli to these primary reinforcers; and in controlling and correcting reward-related and punishment-related behavior, and thus in emotion"[5]

***dlPFC:***

Dorsolateral PFC, Dorsolateral Prefrontal Cortex

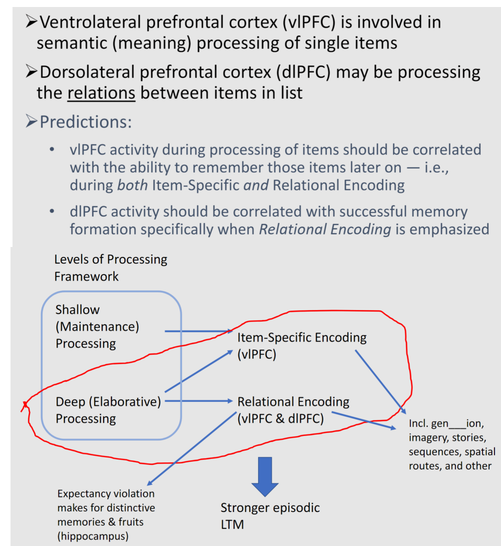
Plays an important role in relational encoding, dlPFC activity is associated with successful remembering of relationships between items

Research suggests that the dorsolateral prefrontal cortex (dlPFC) is critical for the functions that are associated with the "central executive" [the distribution of attention and selection in working memory in the Baddeley and Hitch model of memory]

Monkeys with dorsolateral prefrontal (dlPFC) lesions are impaired in a WM task

Far more dLFC activation during a WM manipulation task (say alphabetizing) then a maintenance task (simple remembering)

Dorsolateral prefrontal cortex (dlPFC) may be processing the relations between items in list




***vlFPC:***

Ventrolateral prefrontal cortex, the *left* vLFPC is more active during deep processing than during shallow processing (Levels of Processsing Framework) and activity in these same regions during deep encoding (e.g., "is this a living or non-living thing?") predicts whether an item will be subsequently remembered or forgotten

Ventrolateral prefrontal cortex (vlPFC) is involved in semantic (meaning) processing of single items

***Fusiform Gyrus:***

Known for its involvement in face perception. Contains the Fusiform Face Area (FFA).

"The fusiform gyrus (FG) is commonly included in anatomical atlases and is considered a key structure for functionally-specialized computations of high-level vision such as face perception, object recognition, and reading"[6]

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[5] https://pubmed.ncbi.nlm.nih.gov/15134840/

[6] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4714959/

***Fronto-Parietal Control Network:***

Neuroimaging studies examine control by cuing a location and then examining sustained activity between cue and target:

- Stimulation of these areas (Frontal Eye Fields and Posterior Parietal Cortex?) in monkeys leads to enhanced single-unit sensory responses in occipital cortex (makes a monkey more receptive to one cue over another).

**Medulla**

Bottom part of the brain that controls survival functions such as breathing

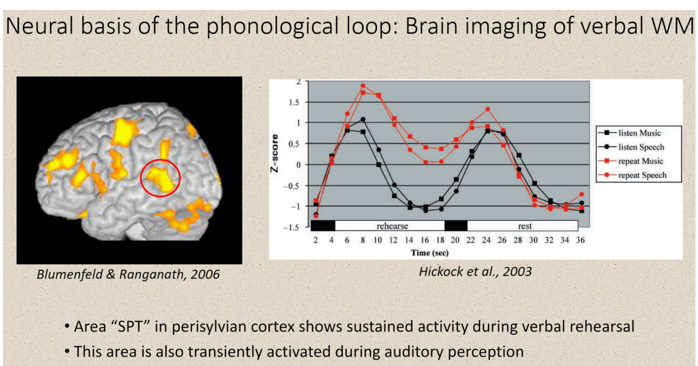
***Meninges***

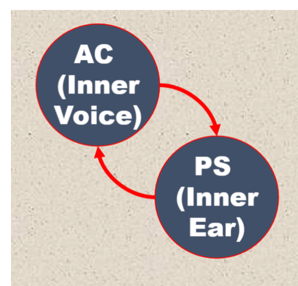
Protective cover on the outside of the brain

***Ventricles***

Open structures in the center of the brain filled with cerebrospinal fluid protects from injury and circulates nutrients.

***Area SPT:***



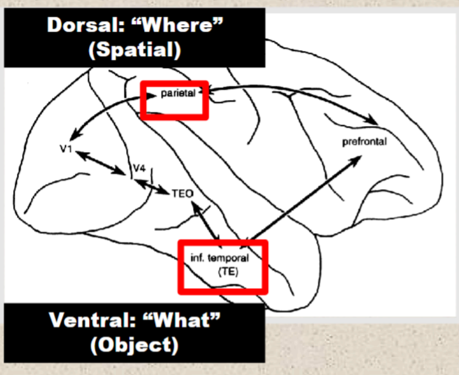




Verbal rehearsal involved two componenets: Articulatory Control Process and Phonological Store. Can be thought of as bouncing back and forth between subvocally saying and remembering something. "Subvocal rehearsal"

Damage to Area "SPT" (superior planum temporale) is seen in patients with deficits in maintenance of phonological information (conduction aphasia patients), and same area is activated in fMRI studies

Suggests relationship between speech perception and phonological (verbal) working memory

# Dorsal/Ventral Split in Vision



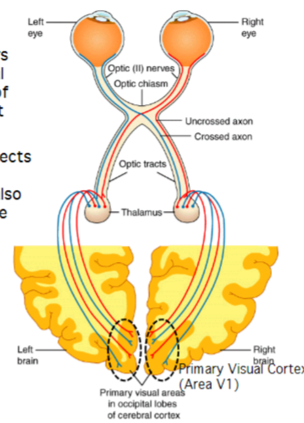

- Ungerleider & Mishkin (1982) proposed differences between a spatial- and an object-processing pathway in visual perception.
- Also supported by imaging studies examining brain activation during tasks that emphasized spatial or object processing (e.g., Haxby et al., 1994)

***Vision Slides:***

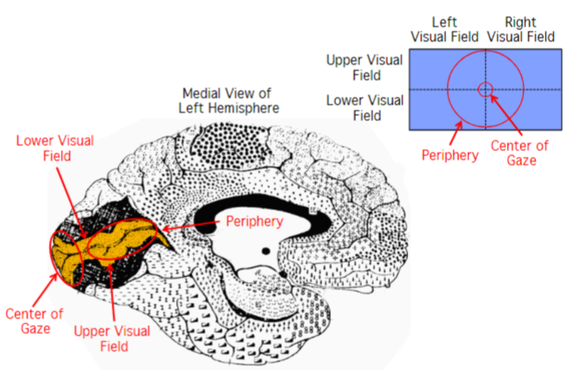
## Receptive Field

A neuron's receptive field is the area of space in which the presentation of an appropriate stimulus will cause the neuron to fire

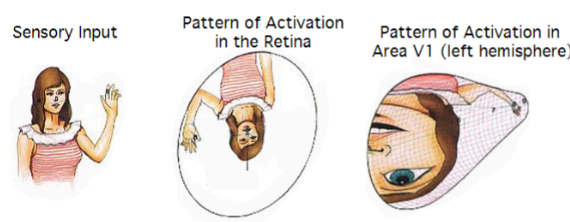
- Each photoreceptor in the retina has a tiny receptive field, and the photoreceptors on a given side of the retinal form a precise spatial map of the contralateral visual input
- Each spot on the retina projects to a distinct region of the thalamus, so the thalamus also contains a spatial map of the contralateral visual input
- Each region of the thalamus projects to a distinct region of primary visual cortex (area V1), so V1 also contains a spatial map of the contralateral visual input




## Topographic Map in Area V1




## Topographic Map in Area V1




- Here we can see what the representation would be like in area V1 in the left hemisphere.
- The left hemisphere represents the right half of the woman, because the left hemisphere codes the right side of the sensory input.

Notice the overrepresentation of the middle of the sensory input (what the fovea registers). This allows us to get higher detail for things we directly look at, compared to things in our periphery.