Lecture 4: Mapping Function to Structure

November 8, 2016

Functional Organization of the Brain

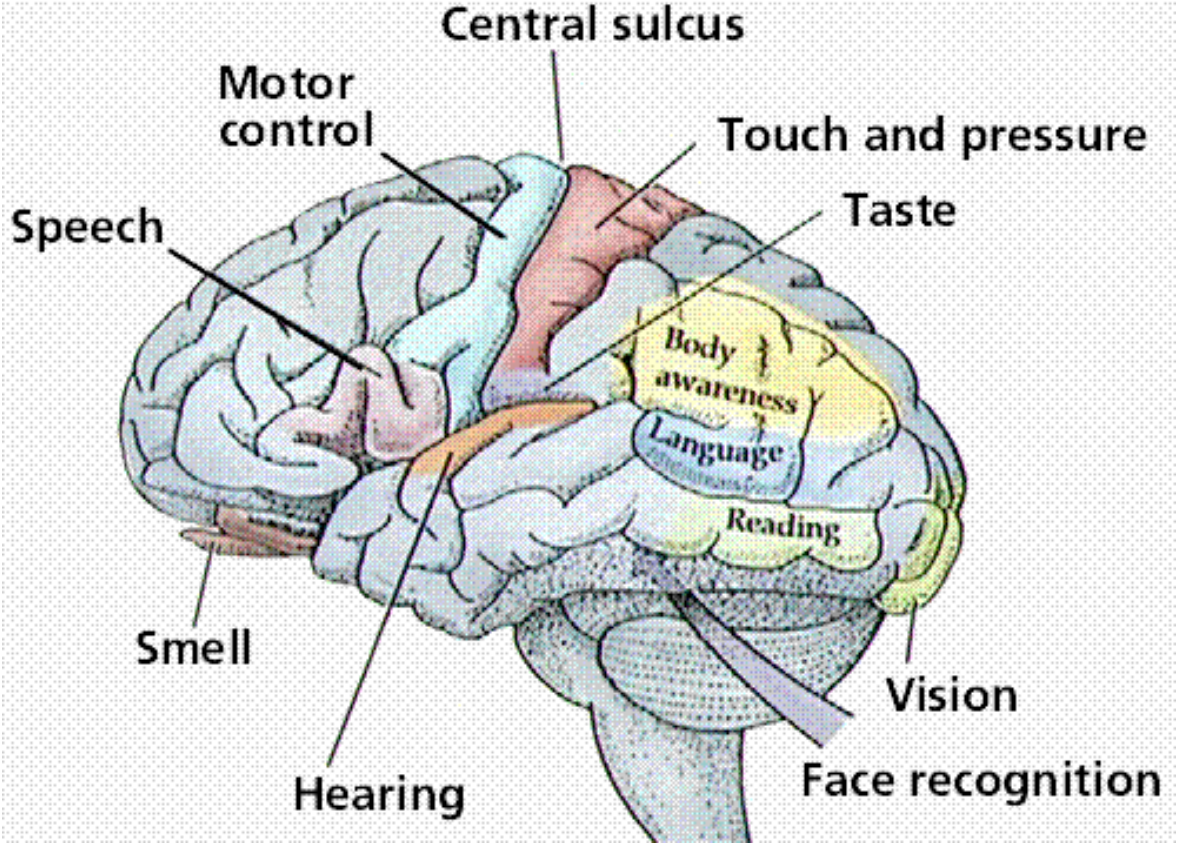
- Anatomical regions of the brain that work together for functioning and behavior
- Often linked together through bundles of nerve fibers or white matter tracts
  - Sensory systems
    - Vision (optical)
    - Hearing (auditory)
    - Touch (sensory)
    - Motor
    - Taste (gustation)
    - Smell (olfaction)

Functional Organization of the Brain

- Speech and language system
- Reward system
- Executive cognitive functioning
  - Attention
  - Inhibitory Control
  - Emotions & Emotion Regulation
  - Fear network
- Memory networks
- Resting state networks

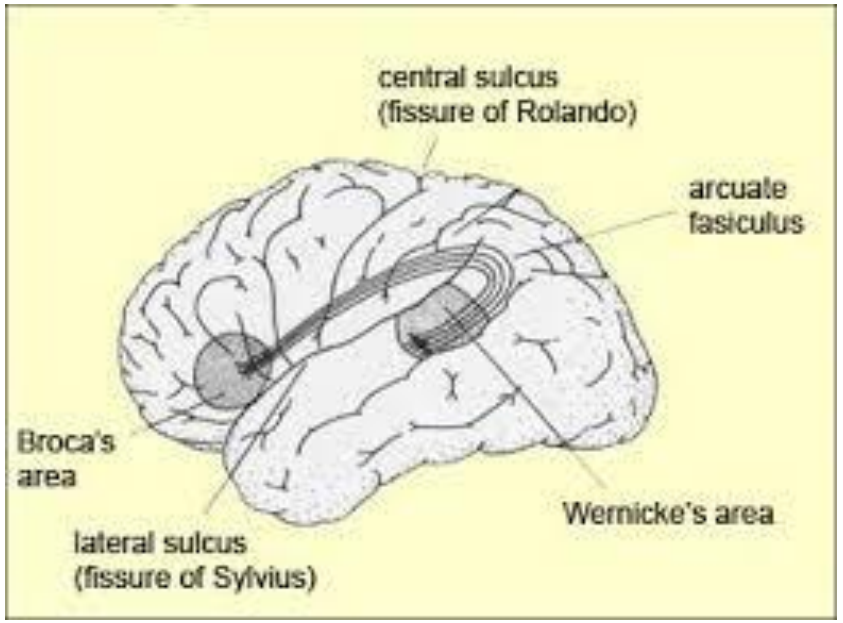
Functional Systems

- None of these systems exists exclusively or independently
- Integration of information



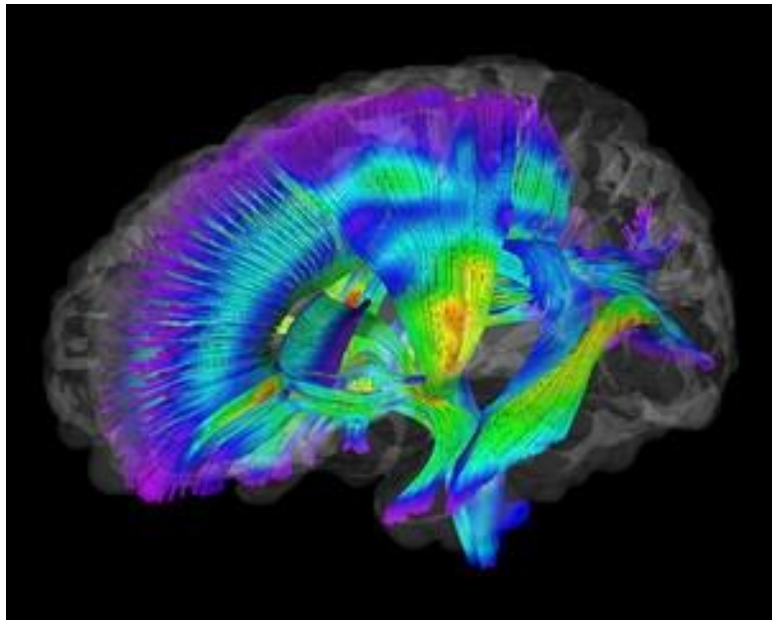
Functional Connections

- Broca's area and Wernicke's area are connected by a large bundle of nerve fibers called the arcuate fasciculus.



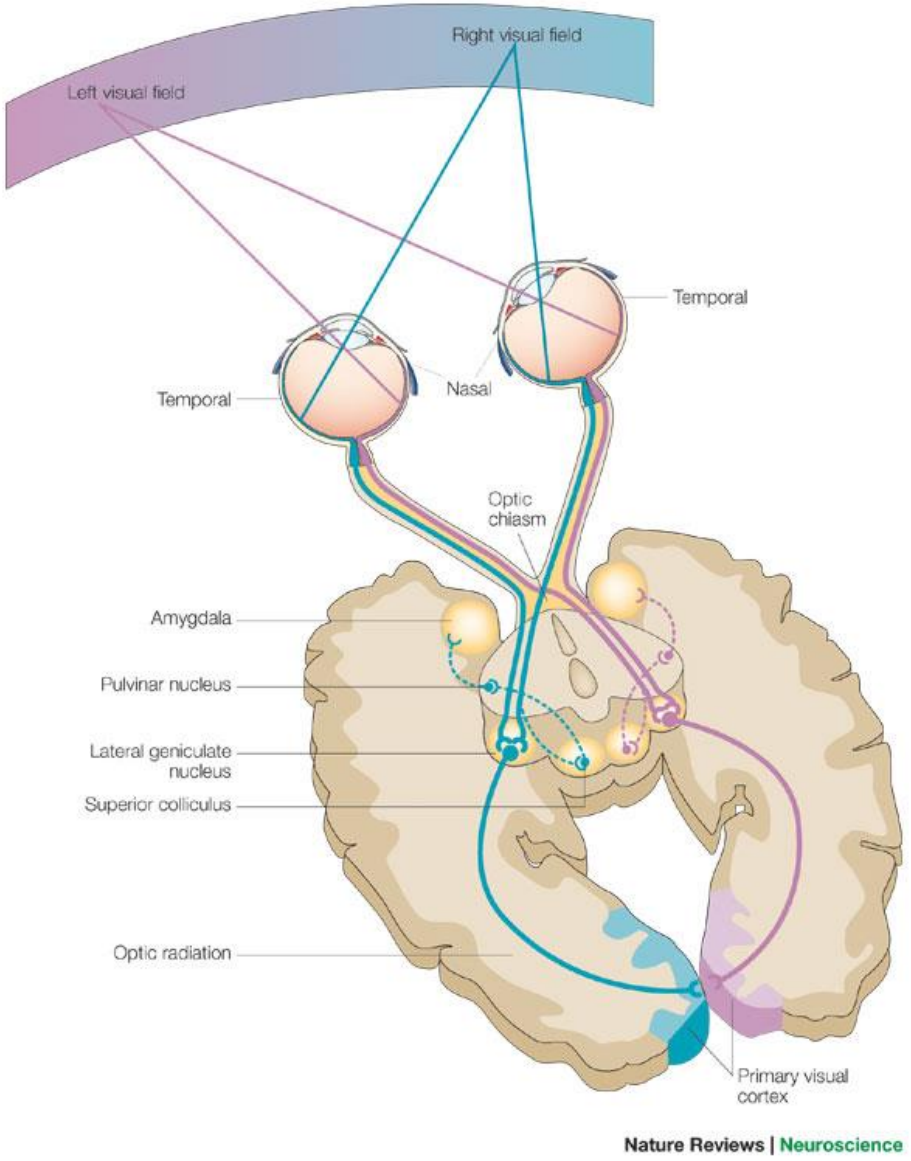
thebrain.mcgill.ca

- White matter tracts allow for dense networks of connections between regions of the cerebral cortex.



Visual System

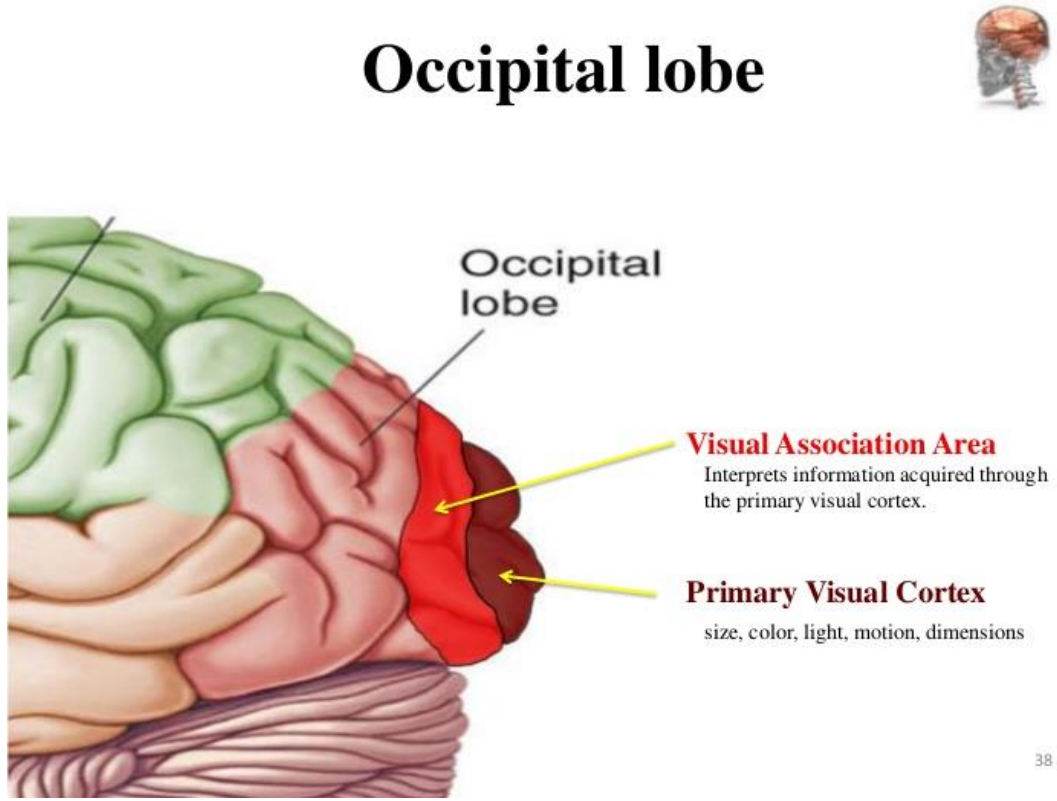
- Pathway from retina to the cortex ends in the primary visual cortex
- Rods and cone in the retina convert light signal to neural signal
- Signal passes through the thalamus
- Travels to occipital cortex



Primary Visual Cortex

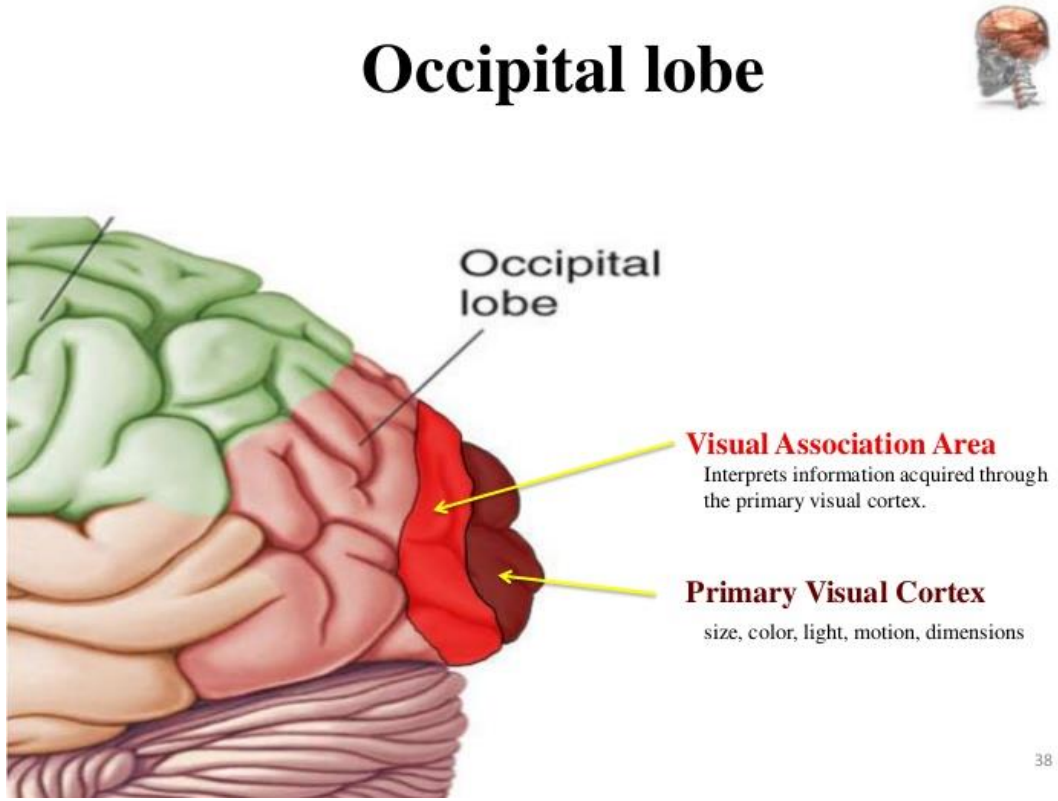
- Highly specialized for processing information about static and moving objects and is excellent in pattern recognition

- Contains a number of specialized regions that process such things as color, spatial information, depth, texture, and motion



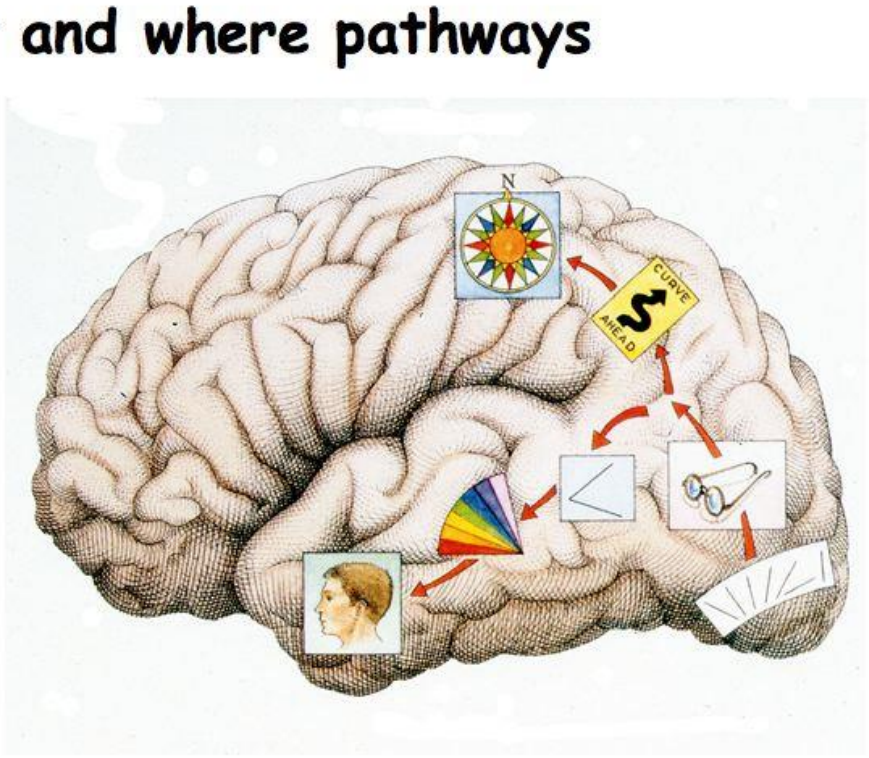
Secondary Visual Cortex

- Information travels to visual association area
- Then moves along to the parietal lobe or the temporal lobe



Secondary Visual System

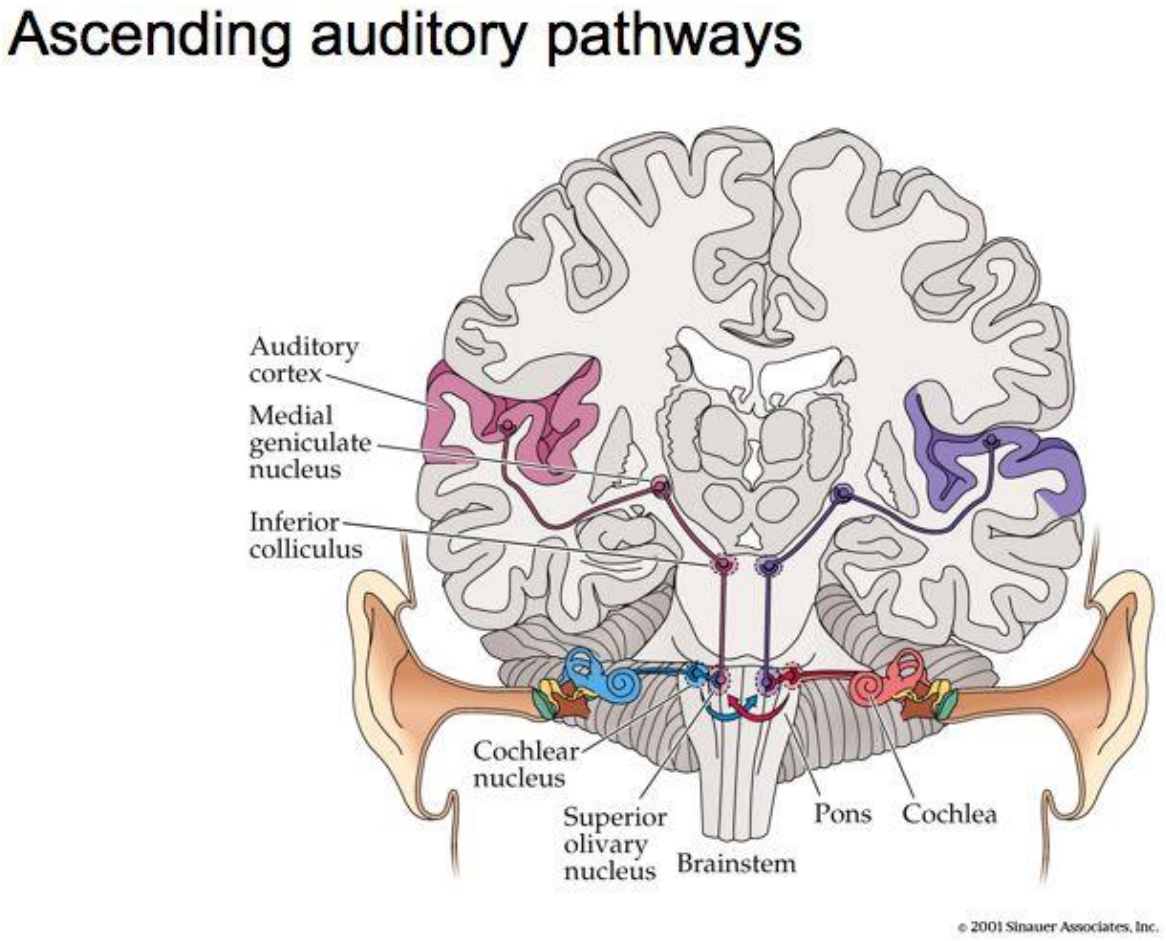
- Parietal lesions lead to deficits in spatial orientation, attention (this is the "where" pathway).
- Temporal lobe lesions lead to deficits in object recognition (this is the "what" pathway).
- Patients with temporal lobe lesions are aware that there's a problem and they develop strategies to compensate for it. Parietal patients are often unaware of their deficits.



http://www.cns.nyu.edu/~david/courses/perception/lecturenotes/what-where/what-where.html

Auditory System

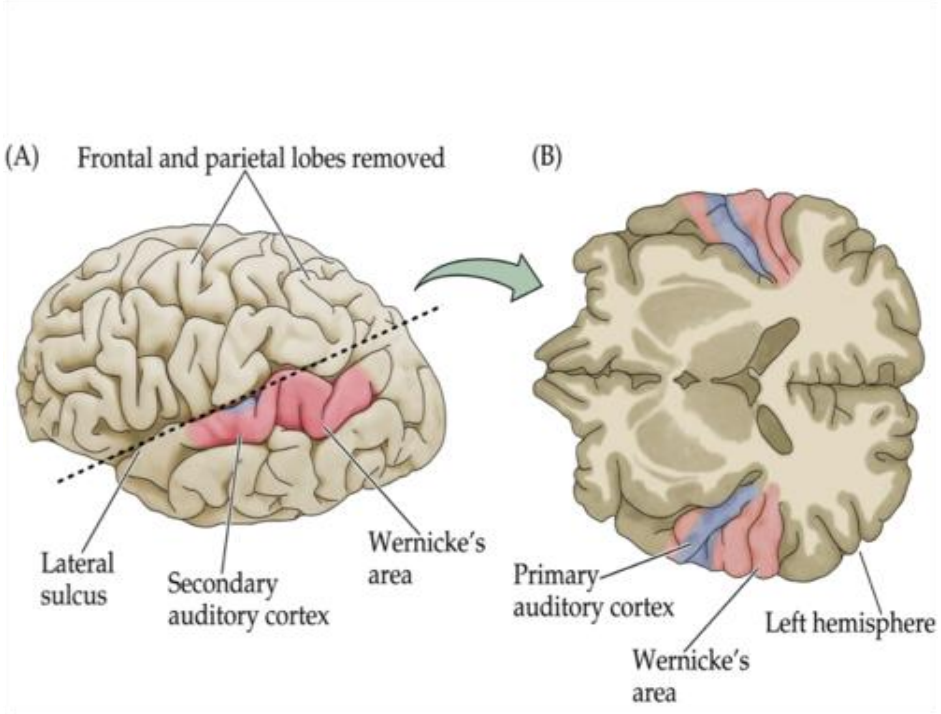
- The ear has three parts:
  - The outer ear, which collects sound waves;
  - The middle ear, which represents the sound waves as pressure
  - The inner ear, which converts those pressure signals into electrical signals that the brain perceives as sound.
- Information goes through the thalamus and to the primary auditory cortex
- The Primary Auditory Cortex performs the basics of hearing; pitch and volume



http://www.cns.nyu.edu/~david/courses/perception/lecturenotes/localization/localization.html

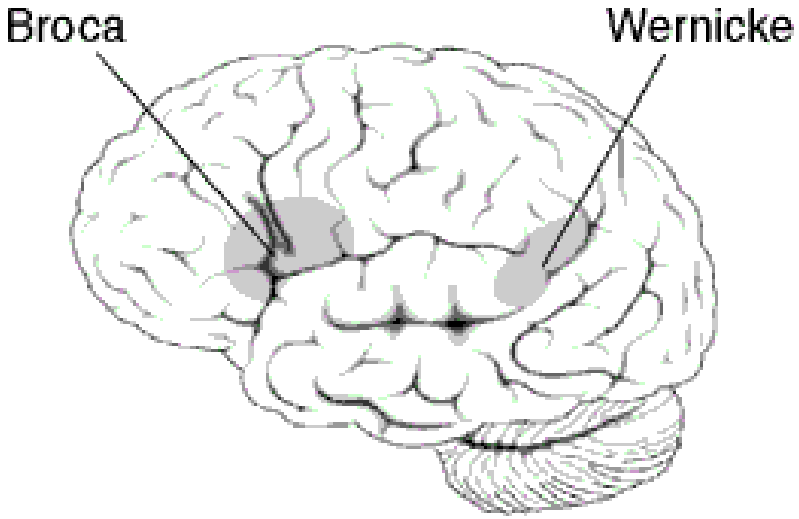
Secondary Auditory Cortex

- Perception of sound takes place in secondary areas
- Secondary Auditory Cortex – Indicated in the processing of “harmonic, melodic and rhythmic patterns
- Onto speech and language centers



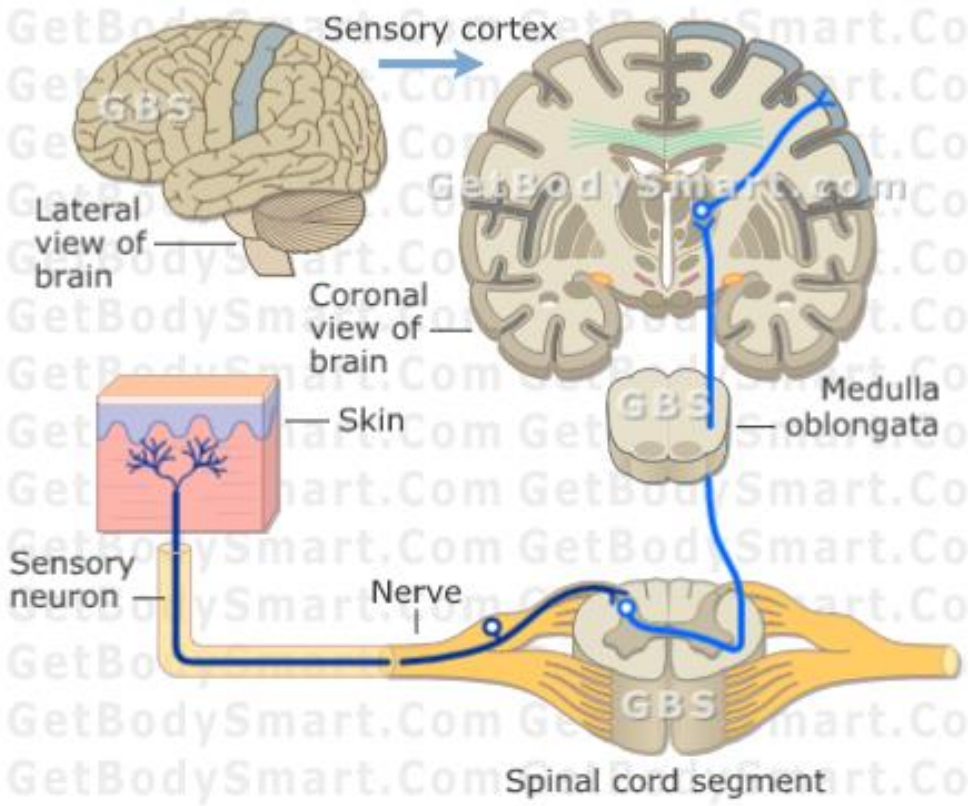
Auditory Processing

- From auditory centers, information travels to speech and language areas for further processing
- Broca’s area is necessary for the production of motor skills for speech
- Wernicke's area is involved in the comprehension or understanding of written and spoken language



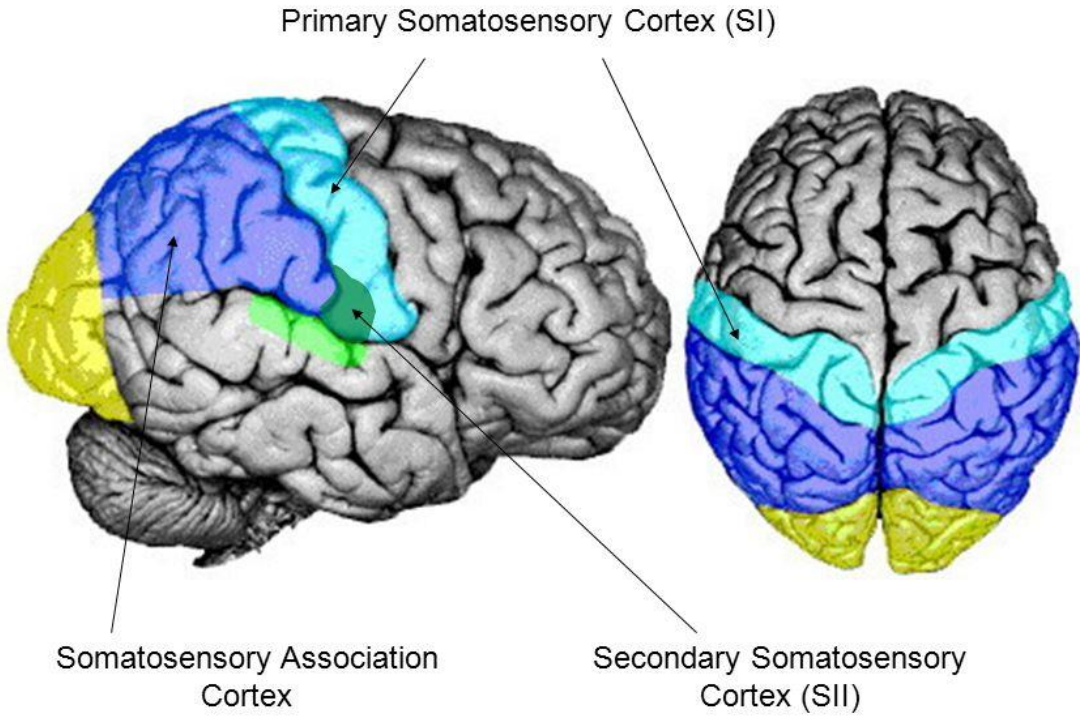
Somatosensory System (Touch)

- Neurons in the peripheral nervous system receive information from the skin, bones, joints and other locations
- Signal is sent through spinal cord, the thalamus, and into the primary sensory cortex
- Left body sensation goes to right brain, and vice versa



Somatosensory Cortex

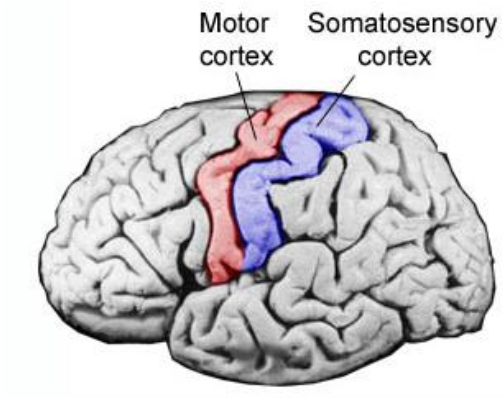
- Primary somatosensory cortex is the receptor area for sense of touch
- Secondary somatosensory cortex and association cortex believed to perform integration of information

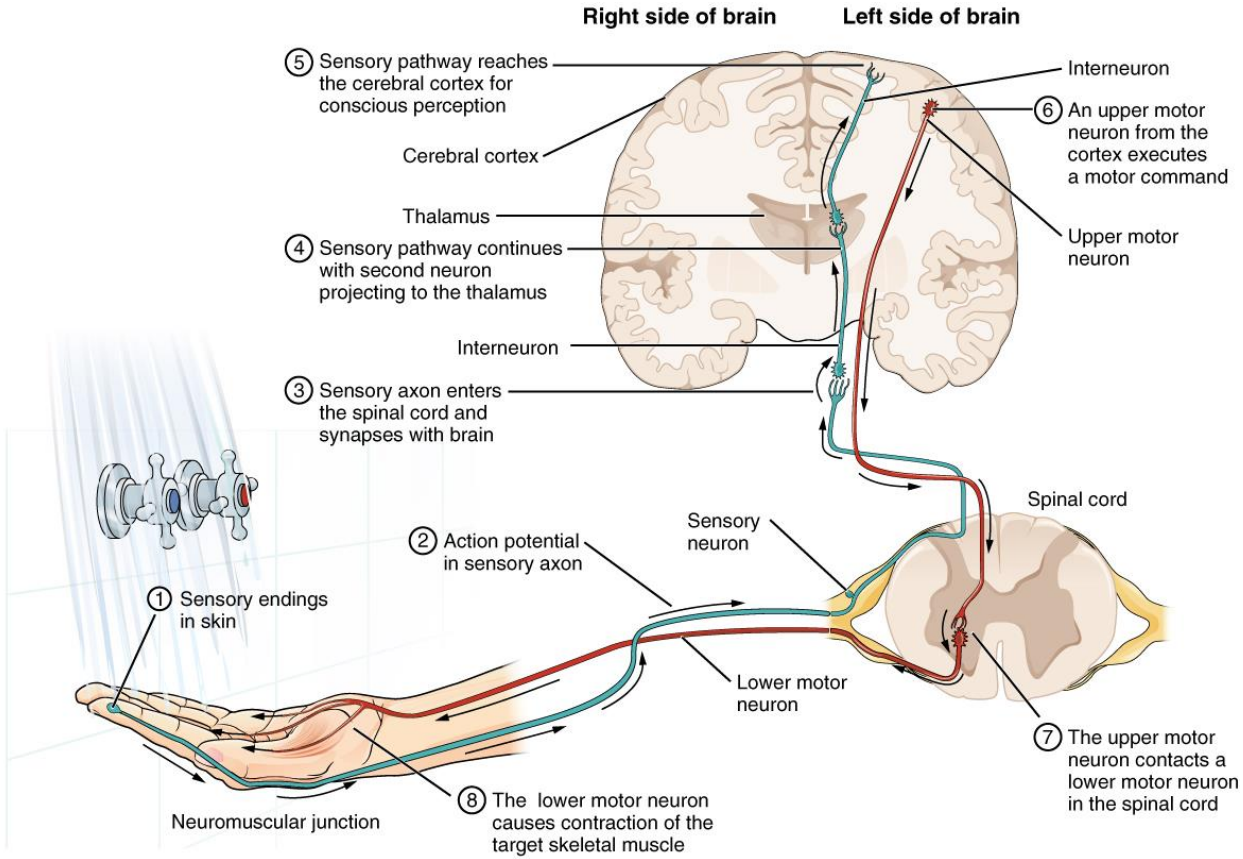


Somatosensory Areas of the Brain

Sensory motor relay

- Primary motor cortex is next to primary sensory cortex in the brain
- Allows for fast responses to pain or unpleasant stimuli

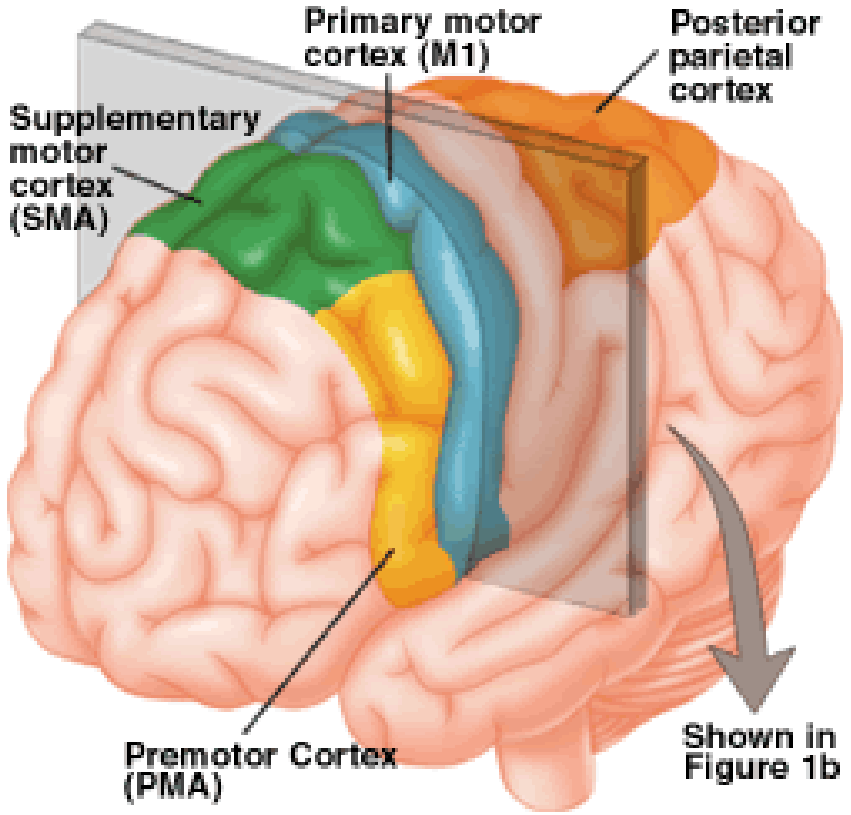




http://archive.cnx.org/contents/606c718b-c8b9-4091-b202-0a563fcc423c@5/the-function-of-nervous-tissue

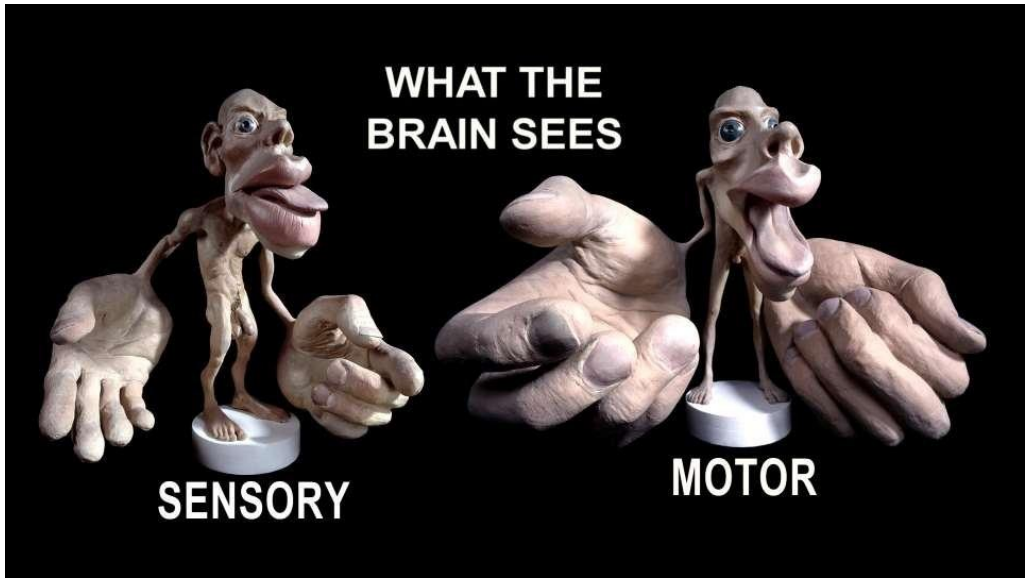
Primary Motor Cortex

- Primary motor cortex generates nerve impulses to execute movement
- Left brain controls right body, and vice versa
- Every part of the body is represented
- Representations are arranged somatotopically

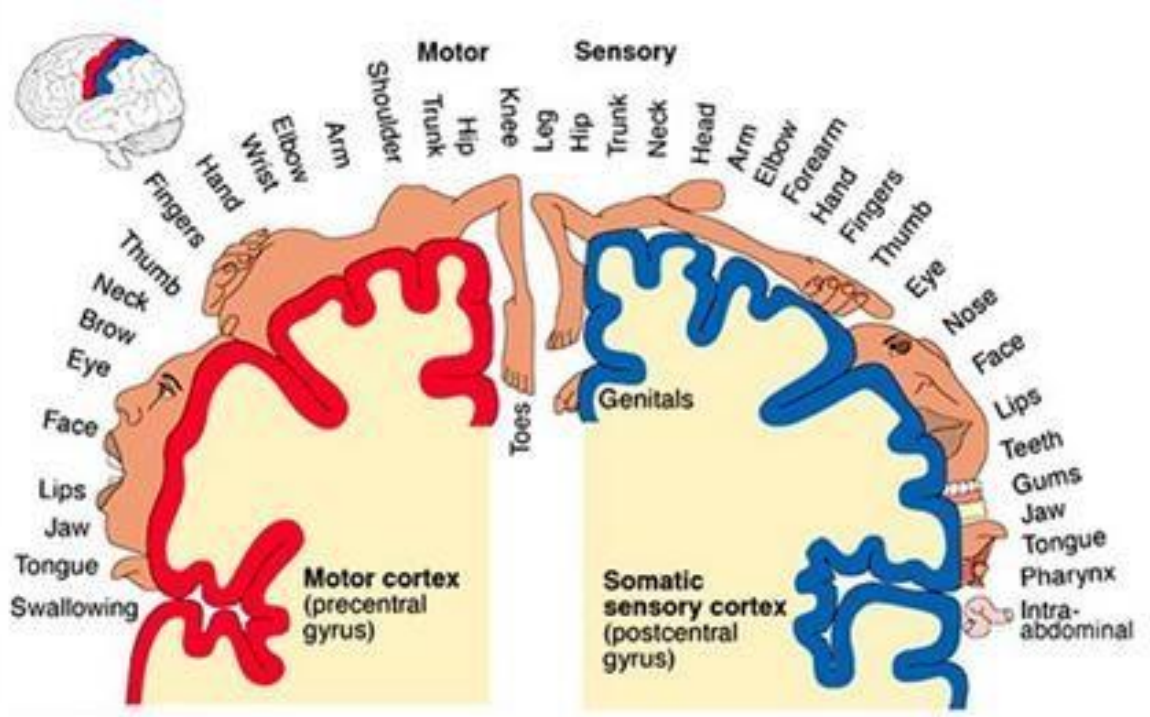


http://brainconnection.brainhq.com/2013/03/05/the-anatomy-of-movement/

Sensorimotor Representation on the Cortex (somatotopic map)

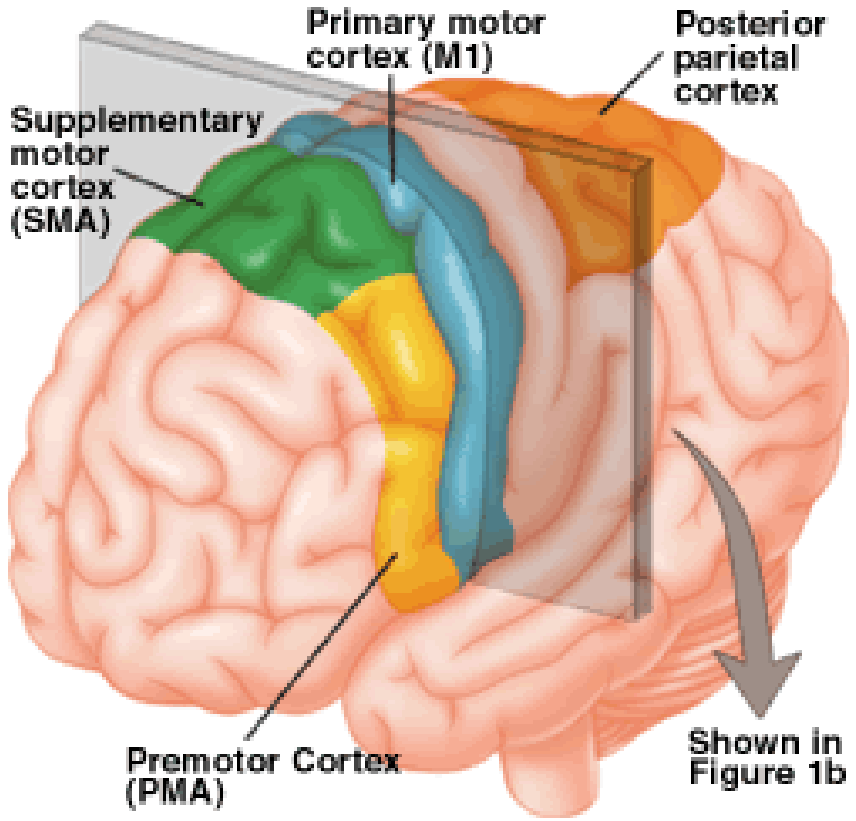


https://www.reddit.com/r/creepy/comments/32d7qu/homunculus/?st=its24trw&sh=05348c15



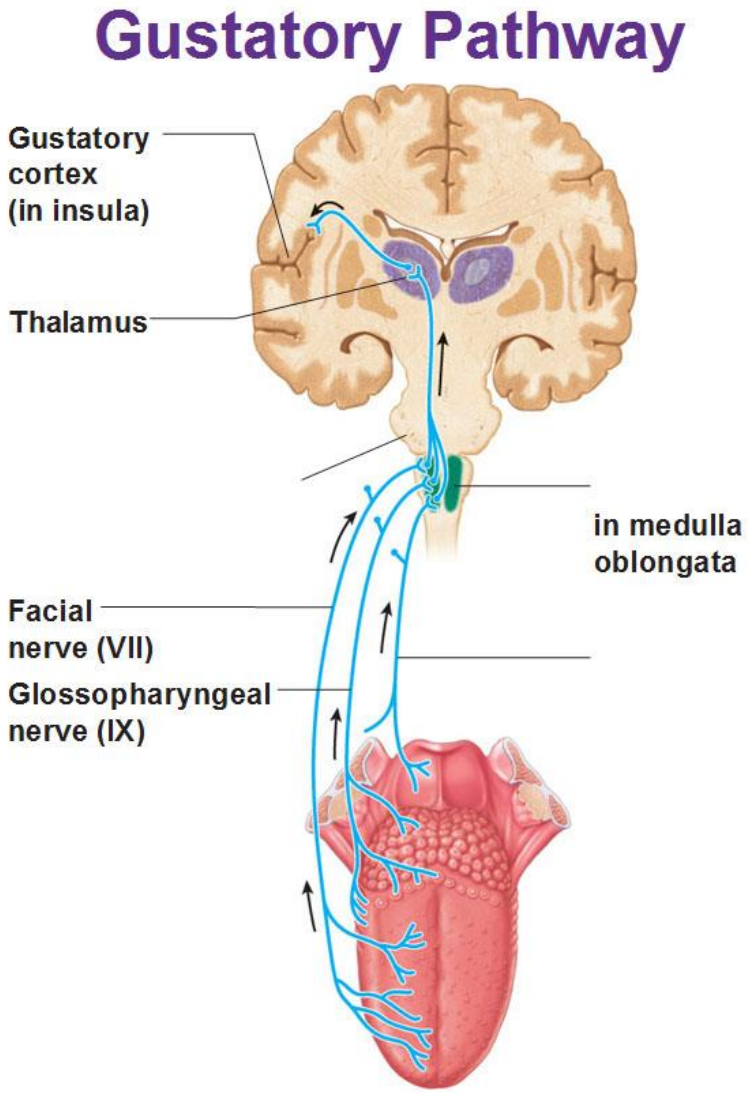
Secondary Motor Cortex Areas

- Involved in the planning and preparation of movement
- Parietal region for visually planning spatial movements
- Supplementary motor cortex for planning and coordinating complex movements
- Premotor area for sensory guidance and control of trunk areas



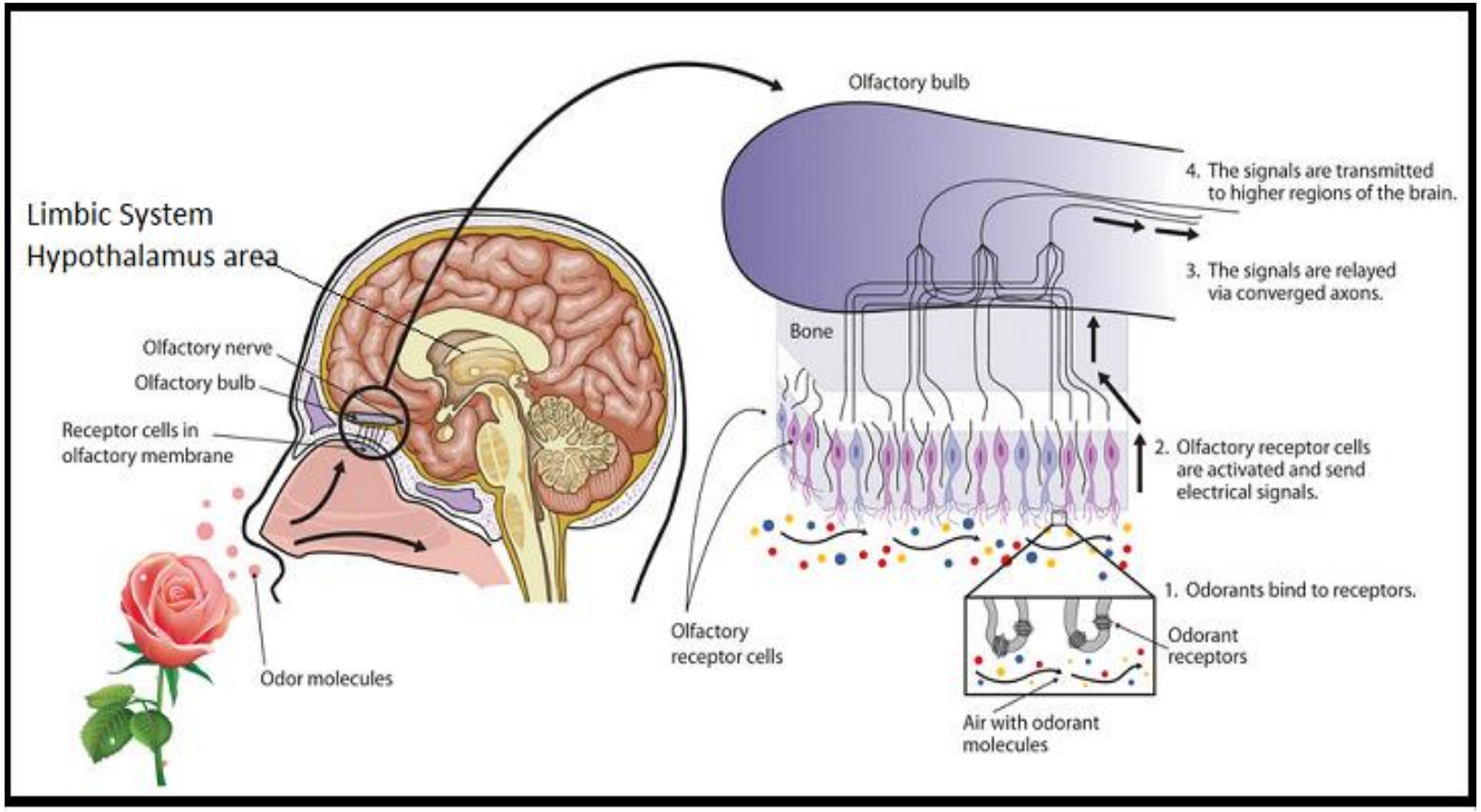
Taste (Gustatory Cortex)

- Taste buds on the tongue detect flavor (chemosensory system)
- Converted to an electrical signal
- From the tongue to the gustatory cortex
- Gustatory cortex is contained in
  - The anterior insula on the insular lobe, and in
  - The frontal operculum on the inferior frontal gyrus of the frontal lobe.



Olfactory System

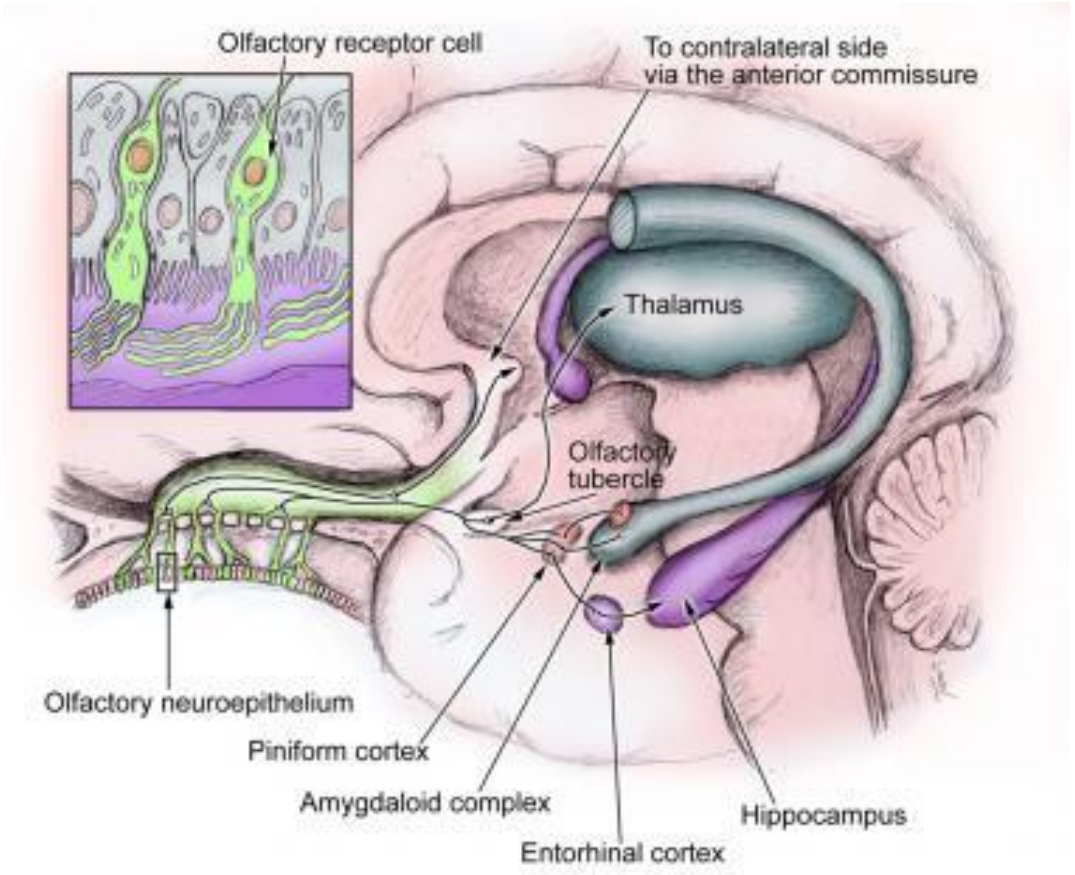
- Odorant detection by the nose (chemosensory system)
- Olfactory sensory input is converted to electrical impulses and is sent through the olfactory bulb
- Olfactory bulb is part of the limbic system



Primary Olfactory Cortex

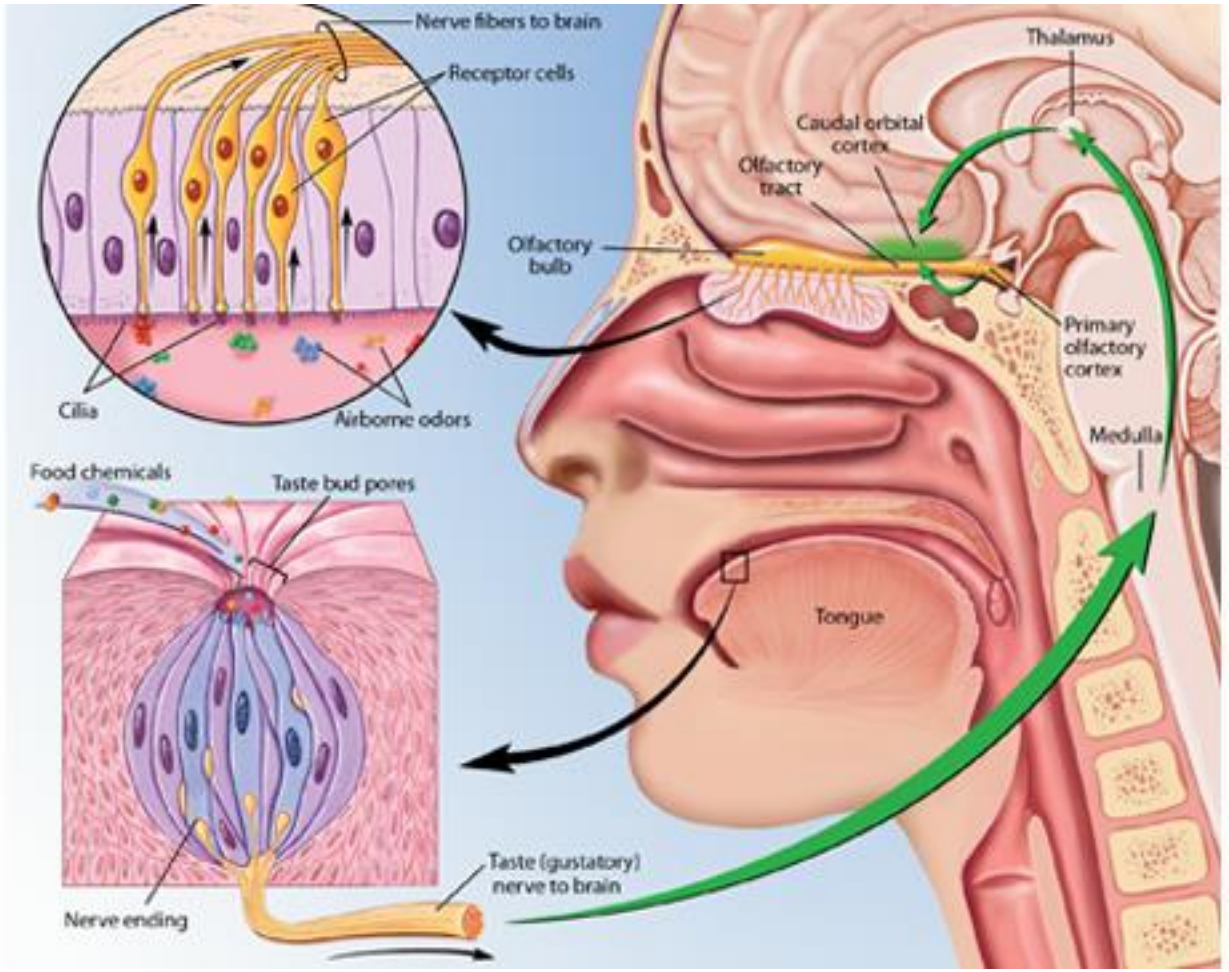
- The information travels through the olfactory tract towards the primary olfactory cortex in the limbic system

- This cortex transfers the information to the thalamus, hypothalamus, the amygdala, hippocampus, and orbitofrontal cortex



Smell and Taste (often go together)

- Both chemosensory systems
- Olfactory bulb shares an area associated with emotions and memories
- Thalamus integrates with other sensory input
- Orbitofrontal cortex integrates sense of smell and taste

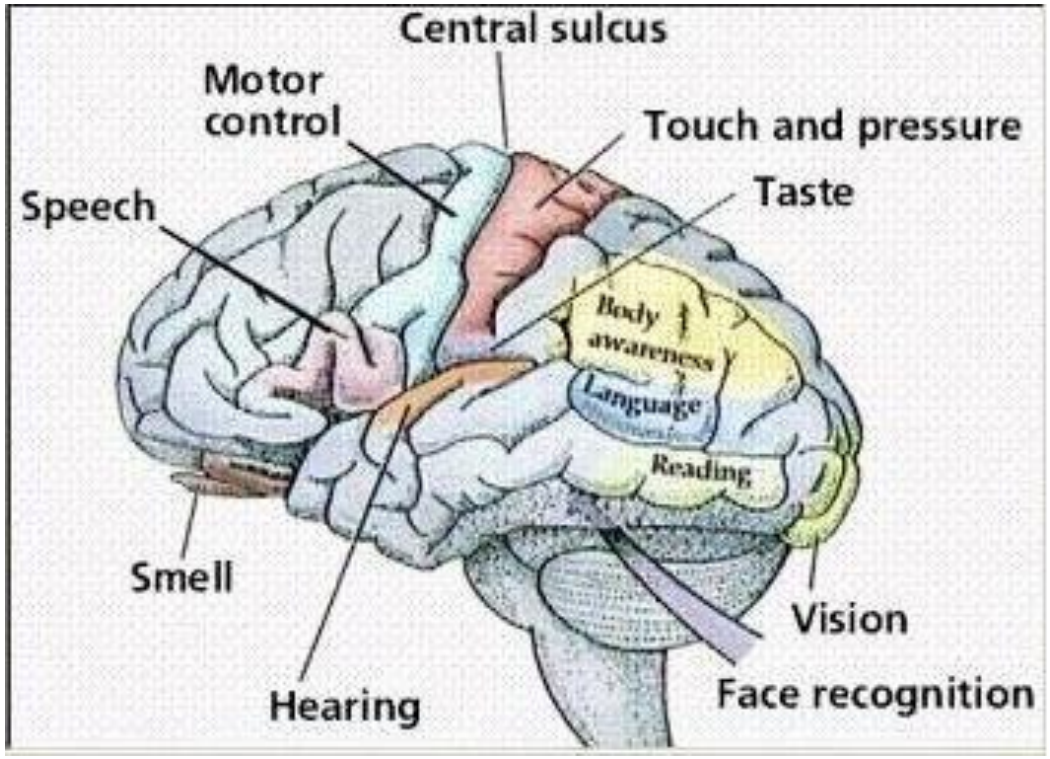


http://www.brainfacts.org/sensing-thinking-behaving/senses-and-perception/articles/2012/taste-and-smell/

Summary of Sensory Systems

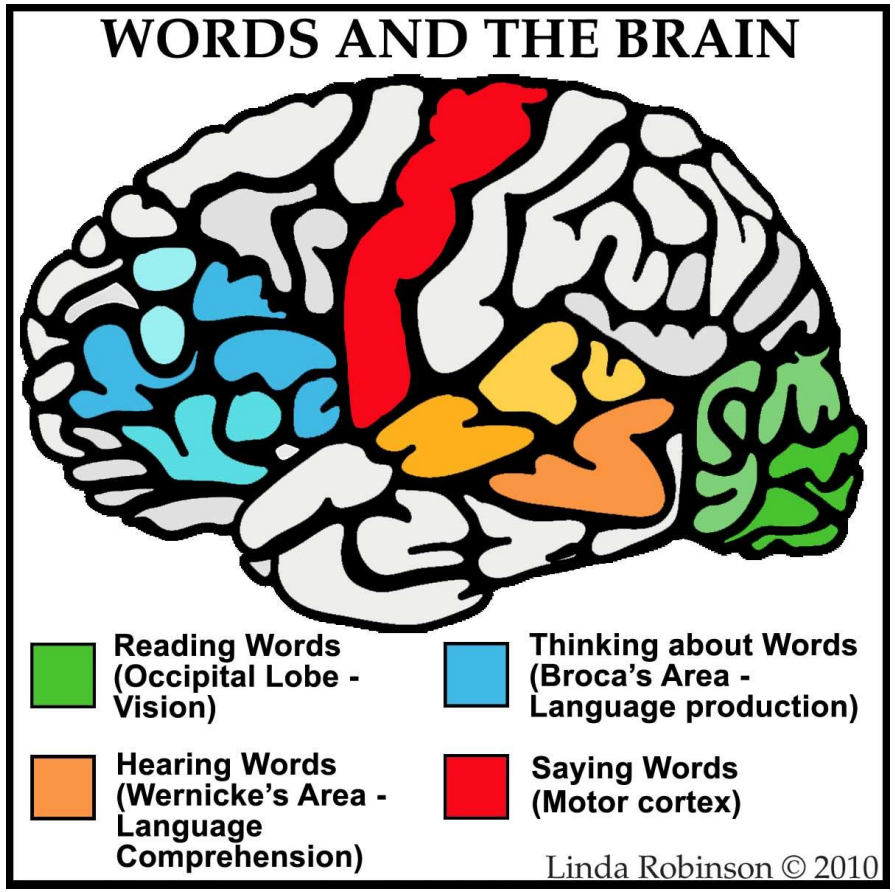
- Most in the occipital, parietal, and temporal lobes

- Integration of information for awareness of surroundings and making sense of the universe



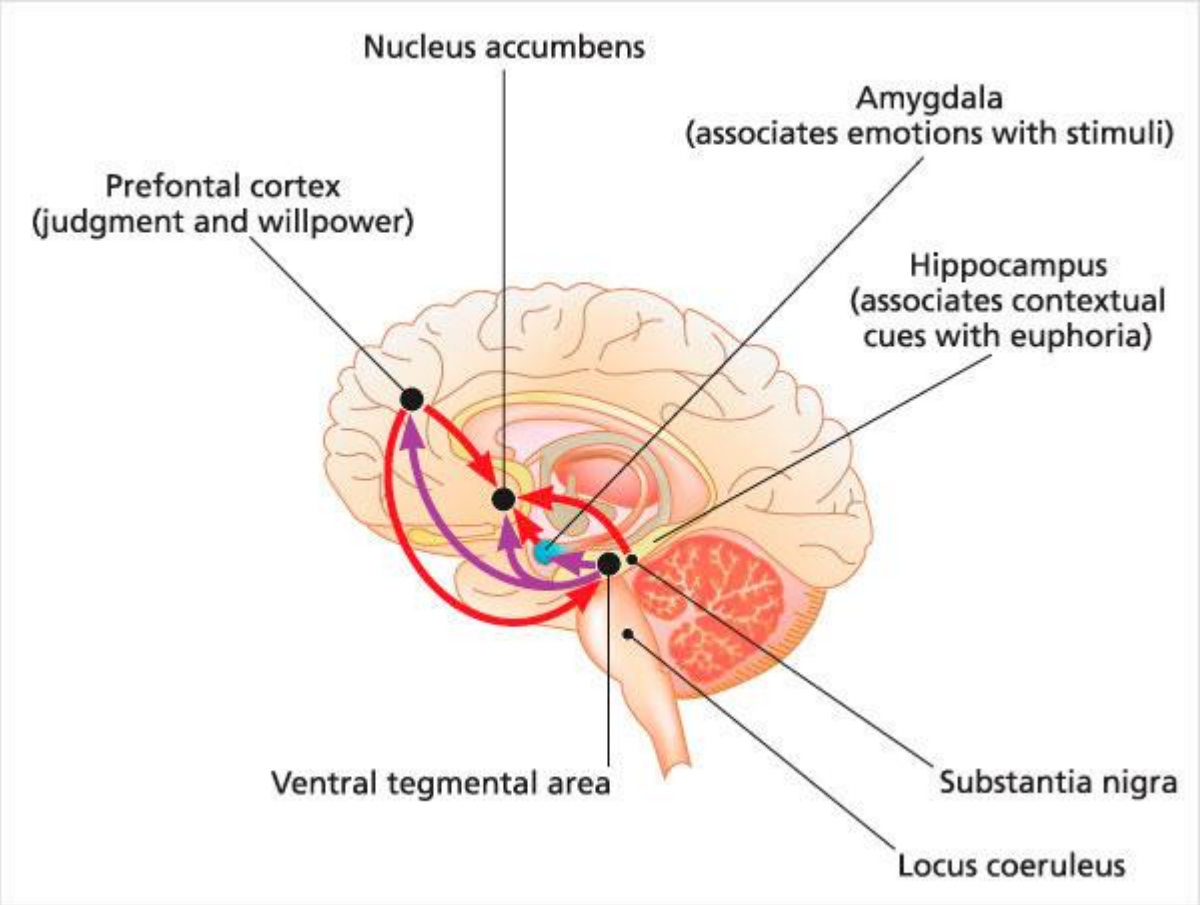
Speech and Language

- Wernicke's area = between auditory and visual cortex, language comprehension
- Broca's area = inferior frontal gyrus, production of speech
- Angular gyrus = associate a perceived word with different images, sensations, and ideas



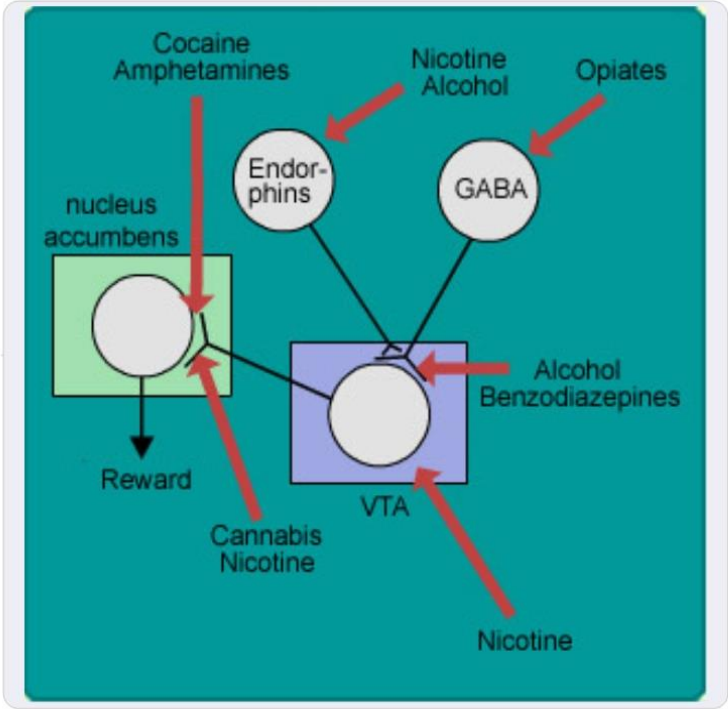
Reward System

- Responsible for incentives, desires, pleasure, and positive reinforcement
- Mid-brain, between executive and sensory centers
- Mesolimbic dopamine pathway - includes VTA and nucleus accumbens (dopamine rich areas), prefrontal cortex, amygdala, hippocampus



Reward system and drug abuse

- Many drugs (cocaine, amphetamine, heroin, marijuana) mimic the effects of a neurotransmitter
- Can tap into the brain's communication systems and interfere with normal processing
- Others flood the reward system with dopamine
  - This gives the feeling of reward or well-being in the brain
  - Can produce euphoric feelings, strongly reinforcing the behavior of drug use

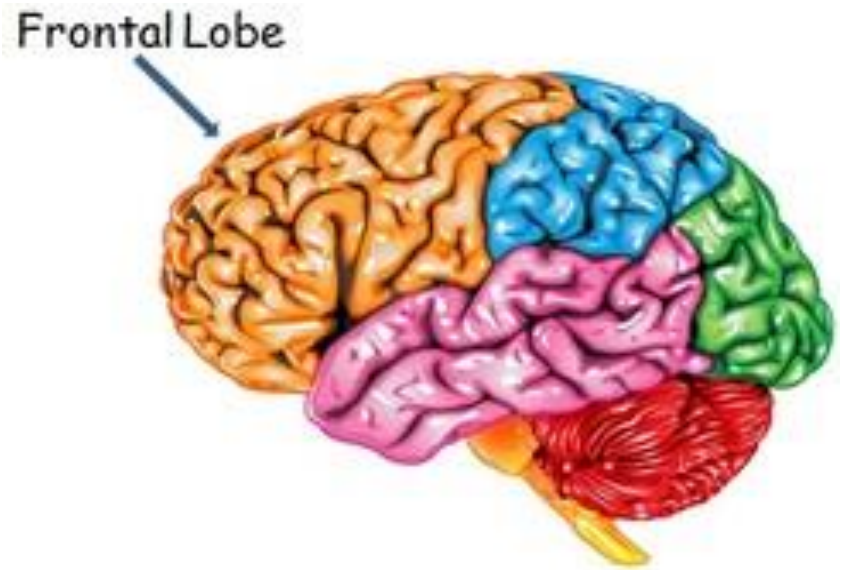


Understand the Addiction Pathways

What about the Frontal Lobe?

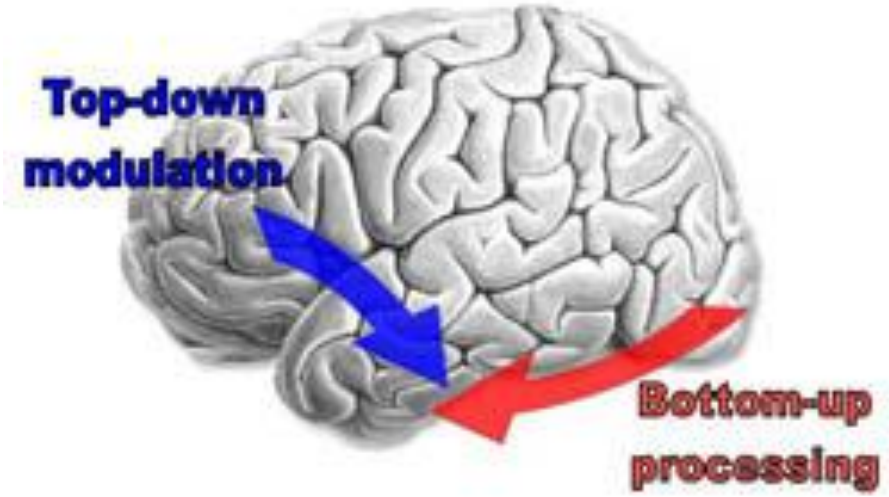
- Contains most of the dopamine sensitive neurons

- Reward, attention, short-term memory, planning, motivation



“Top down” vs “Bottom up” Processing

- Bottom up processing refers to processing sensory information as it comes in
  - Some emotion and fear processing
  - Externally driven
- Top down refers to perception driven by cognition
  - Executive functioning and control
  - Internally driven



Example of Top-Down vs Bottom-up

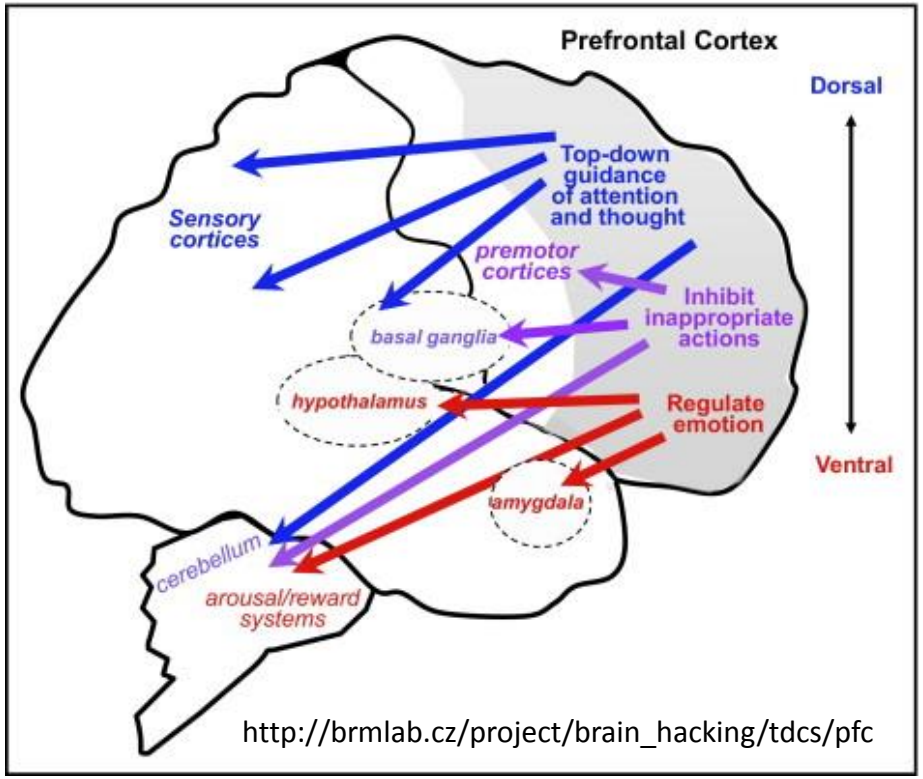
- What do you see?

- What if we add additional information?

http://openpsyc.blogspot.com/2014/06/bottom-up-vs-top-down-processing.html

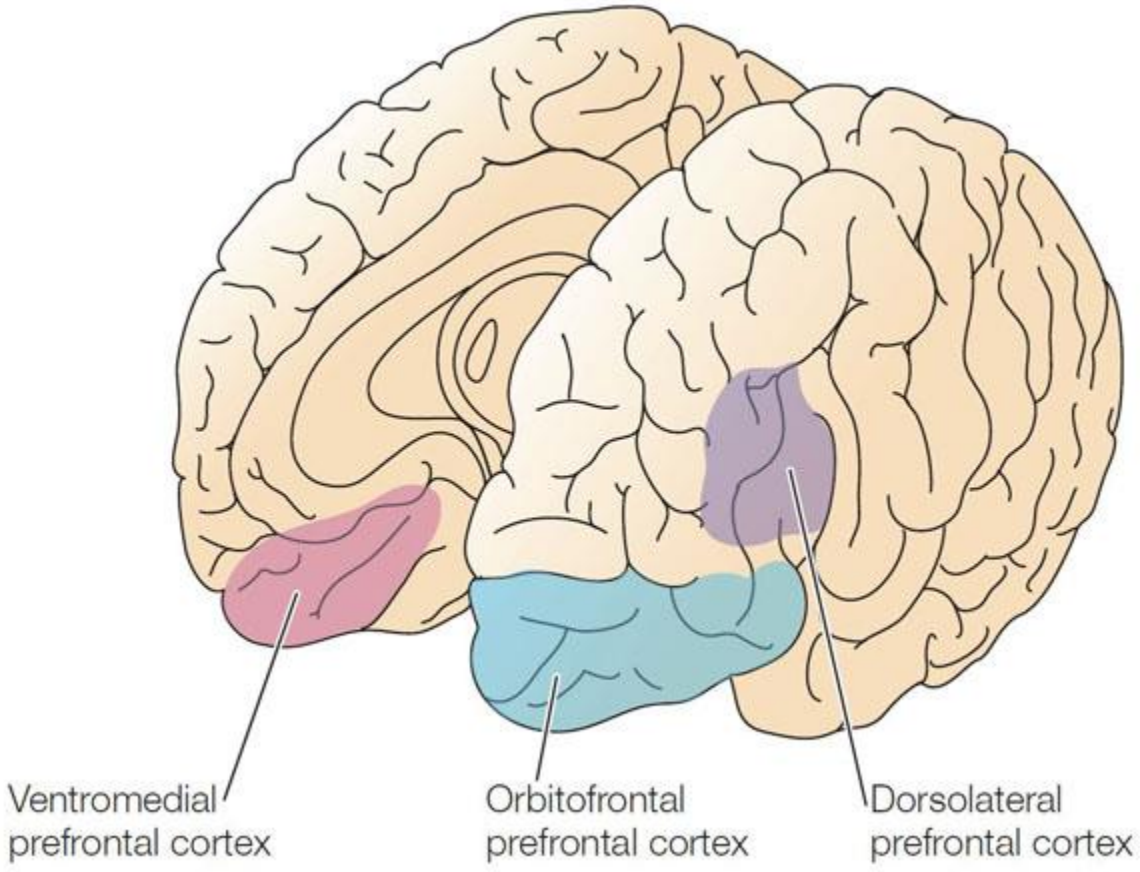
Executive Cognitive Functioning

- Set of cognitive processes including
  - Attentional control
  - Inhibitory control
  - Emotional regulation
  - Working memory
  - Problem solving
  - Planning and effort
- Essential for aspects of daily living
- Prefrontal cortex



Prefrontal Cortex

- The front part of the frontal lobe
- Executive functioning center
- Well developed in humans compared to other animals



http://sites.sinauer.com/animalcommunication2e/chapter08.07.html

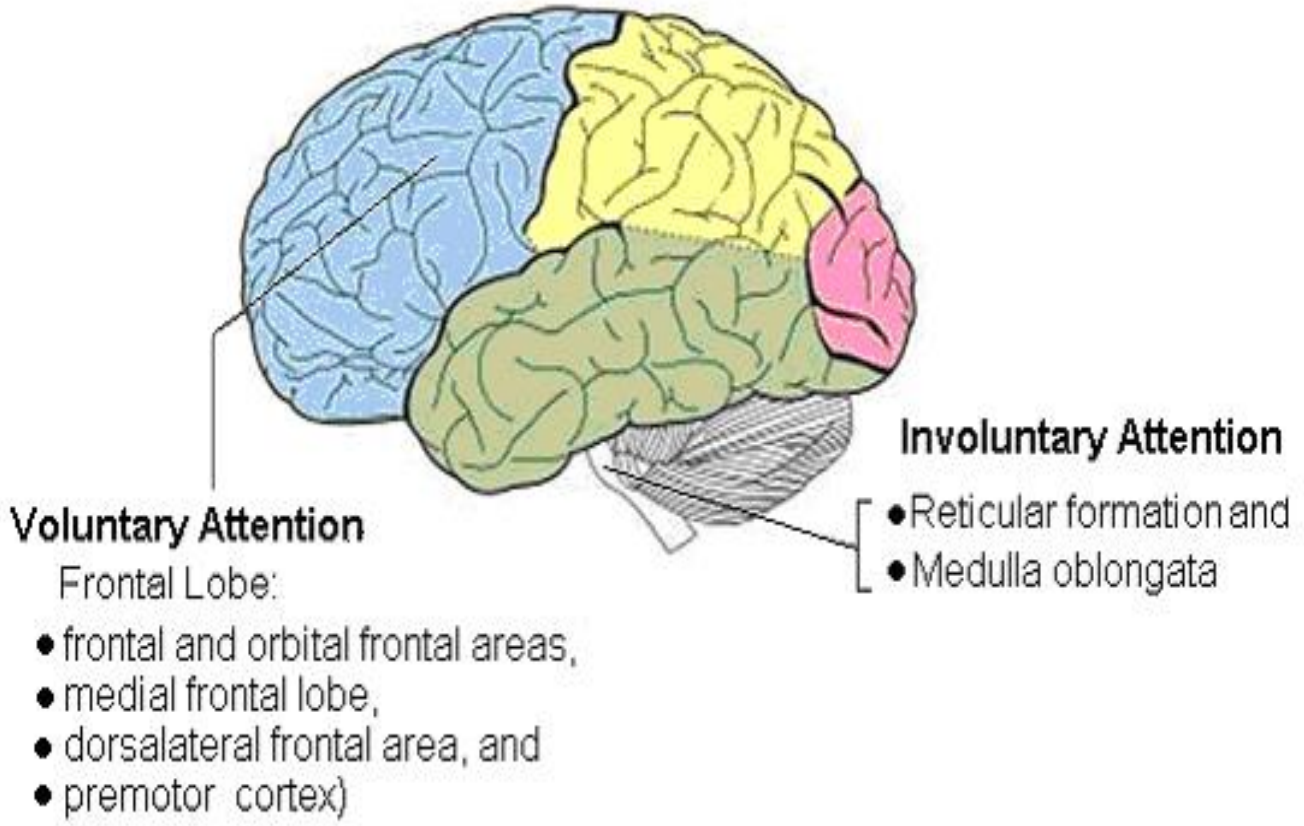
Executive functioning is required for:

1. Planning or decision making
2. Trouble shooting or error correcting
3. Novel sequence of actions (not rehearsed)
4. Dangerous or difficult situations
5. Resisting temptation or overcoming habits

Norman and Shallice (1992)

Attention

- Voluntary, selective, focused, divided, sustained (tonic, can be minutes to hours)
- Involuntary, conscious mind changes focus due to sudden changes in the environment (phasic)



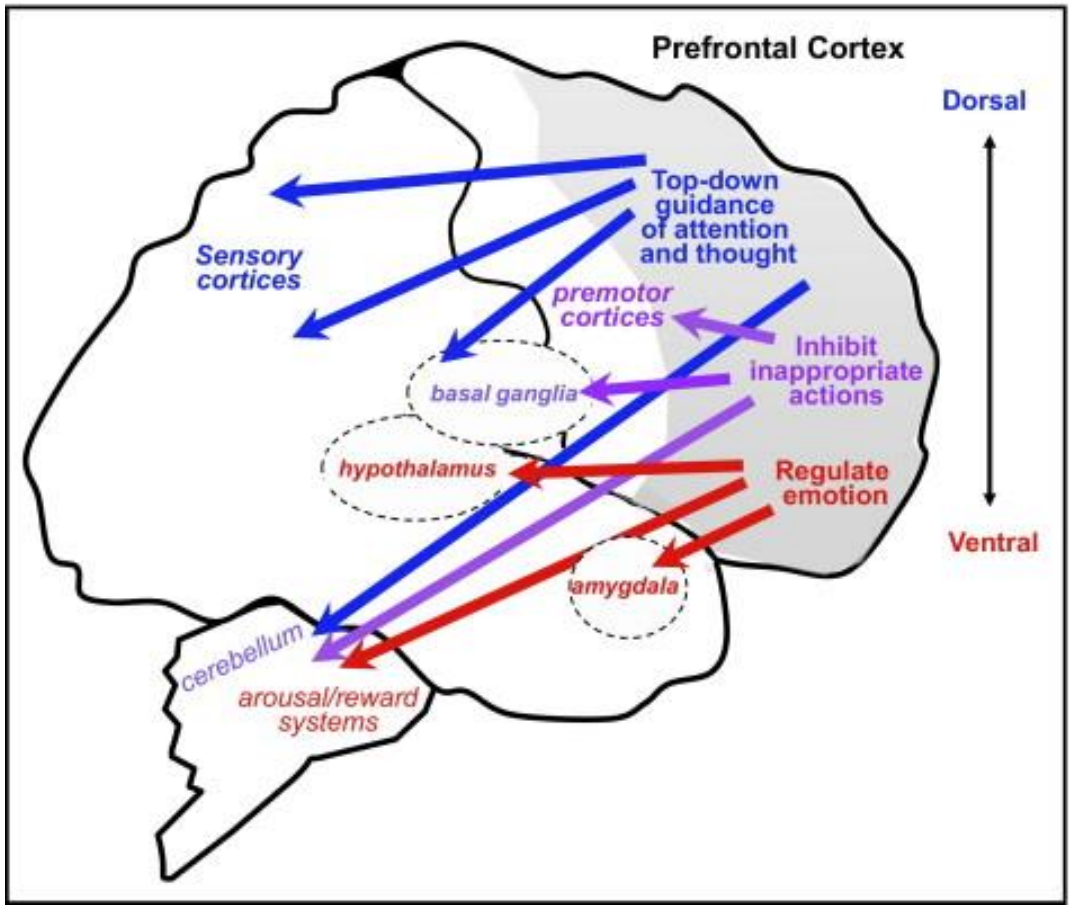
http://www.brainbehavioroptimization.com/simple.php?f=_spec_Attention.php&t=Attention

Attention (continued)

ATTENTION	
Voluntary	Involuntary
Top-down brain pathways	Bottom-up brain pathways
The result of effort	A response to a stimulus
Builds self-regulation	Builds a dependence on the stimulus

Inhibitory Control

- Ability to prevent motor acts, behaviors, habits
- Parts of brain include dorsolateral and dorsomedial frontal cortex, inferior frontal cortex

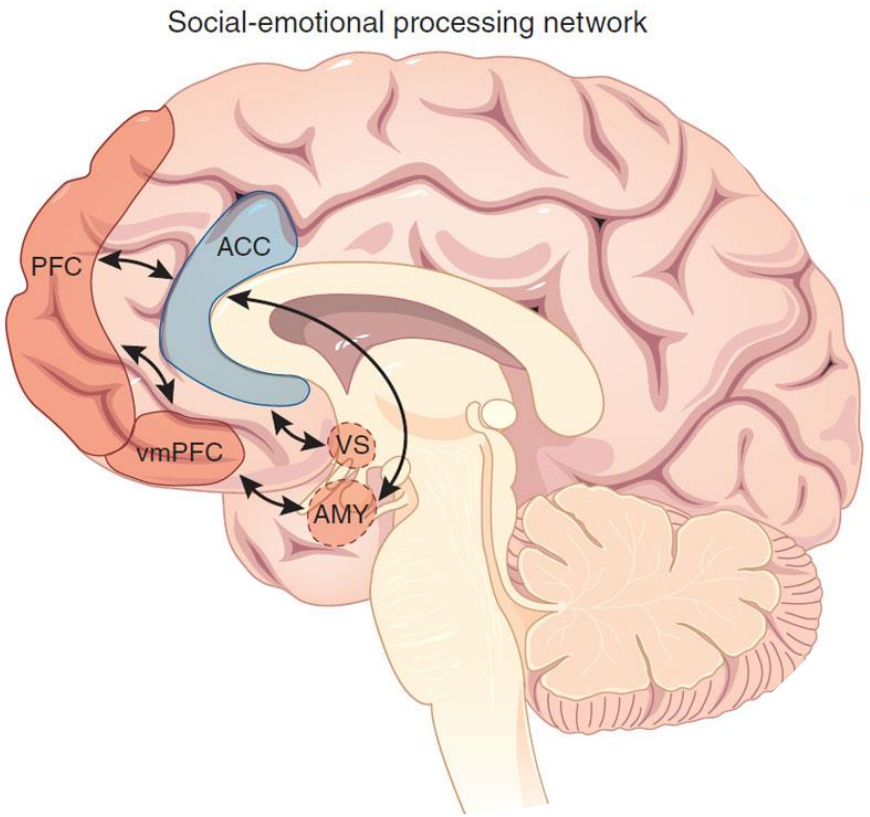


Attention Deficit Hyperactivity Disorder (ADHD)

- In children and adults, difficulty maintaining attention, impulsiveness
  - (6-9% of children, 3-5% adults in US)
- Structural differences from controls – delayed development, reduced volumes of grey & white matter
- Reduced activity in various frontal regions of the brain
- Lower levels of dopamine in ADHD brains

Emotions and Emotional Regulation

- Affective system
- Limbic system – **amygdala**, thalamus, hippocampus, hypothalamus, dorsal anterior cingulate cortex (dACC)
- Orbitofrontal cortex



http://sites.tufts.edu/emotiononthebrain/2014/11/19/impairment-in-emotion-regulation-in-schizophrenia-patients/

Fear Network

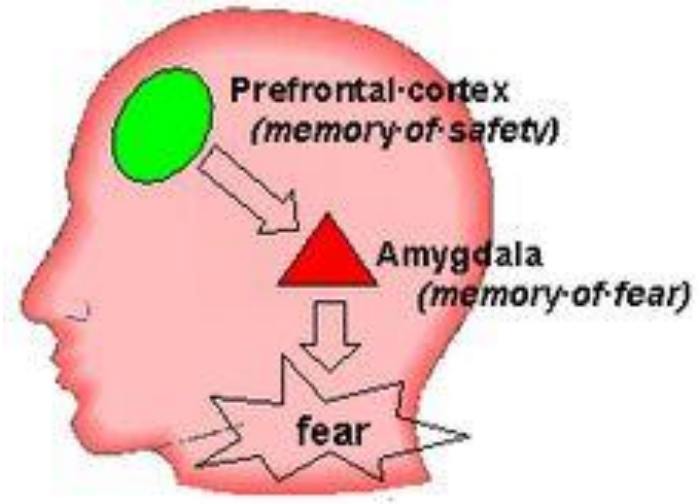
- Amygdala, ventromedial prefrontal cortex (vmPFC), dorsal ACC, thalamus, hippocampus

- Classical fear conditioning is when a conditioned stimulus is associated with an unconditional stimulus (shock and colors)

- Fear memories can be strong and can have a large bottom-up effect

Post Traumatic Stress Disorder (PTSD)

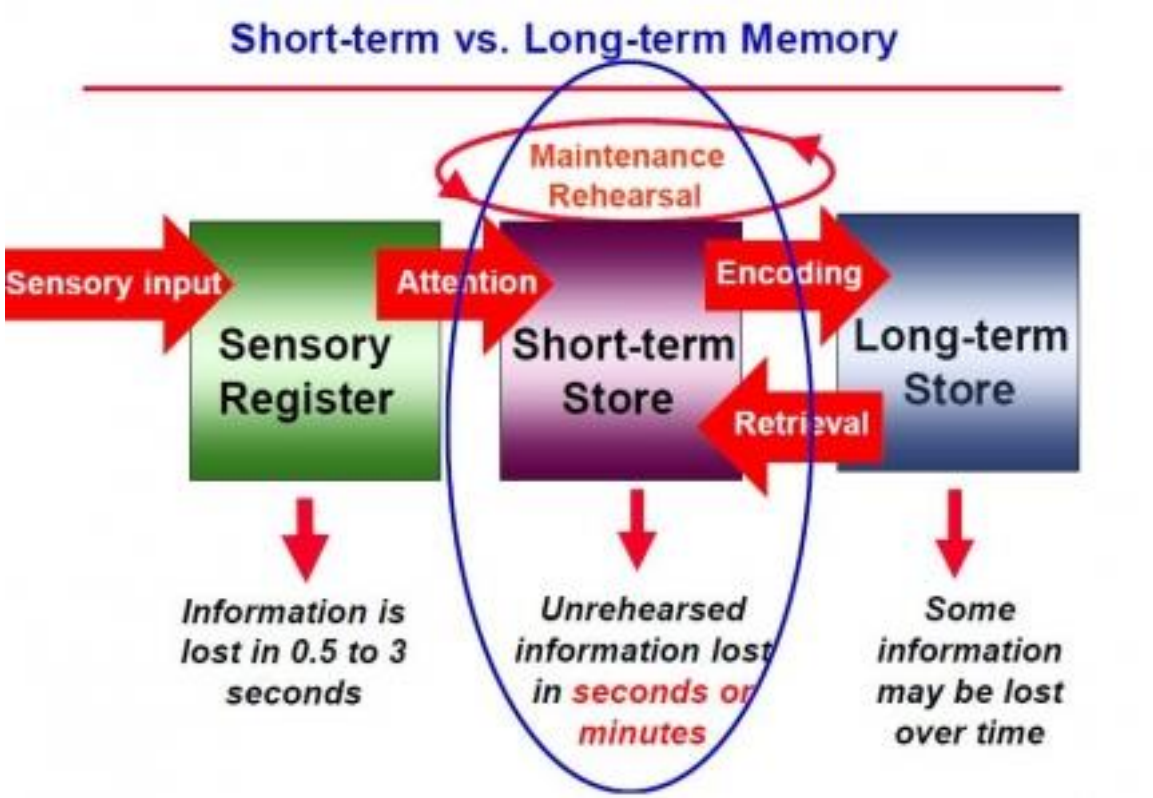
- Conditioned fear from a trauma
- Nightmares, flashbacks, avoidance of situations, negative feelings and beliefs
- Irritable, trouble concentrating, trouble sleeping
- Failure to extinguish fear in the presence of safety
- Hyperarousal of fear areas in the brain



Types of Memories in the Brain

- Long term vs short term (working) memory
- Declarative vs non-declarative
- Episodic vs factual
- Emotional memories
- Fear memories

Short-term vs. Long-term Memory



http://studydroid.com/printerFriendlyViewPack.php?packId=334821

- Sensory infomration is quickly lost
- Short term memory can hold about 7 items for about 20-30 seconds
- Strategies to help with memory
- Important information is gradually transferred to long term memory

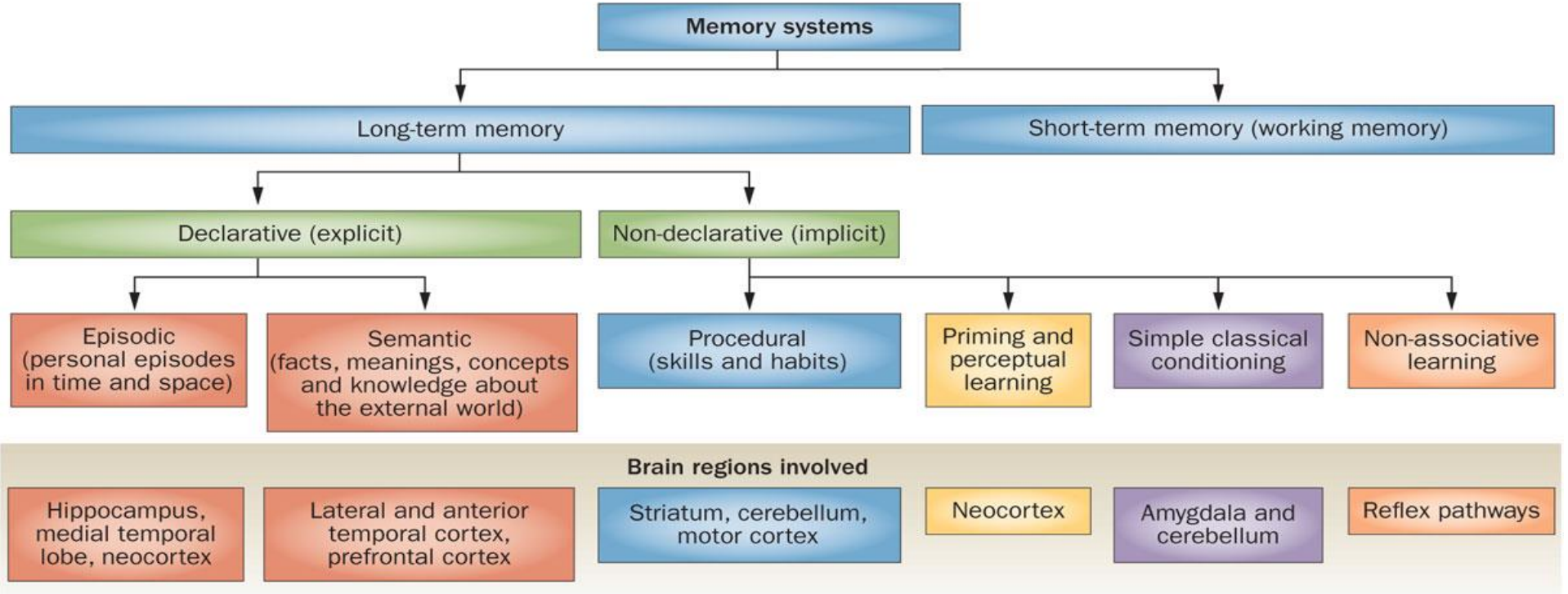
Long-term Memories

- Many types of memories, multiple brain systems for memory

1. Cognitive/Declarative memory – explicit, facts and events
   a. Information that is stored and retrieved
   b. Memories that can be consciously recalled
   c. Example, history lesson, facts, dates

2. Non-declarative – implicit, skills, habits, emotional, skeletal
   a. Does not require conscious thought to recall
   b. Procedural memory
   c. Example, driving a car, tying your shoe

Figure 1 Classification of memory systems in the human brain



Bartsch, T. & Butler, C. (2013) Transient amnesic syndromes
Nat. Rev. Neurol. doi:10.1038/nrneurol.2012.264

Memory

- An organism's ability to store, retain, and recall information and experiences.

- **Sensory memory** corresponds approximately to the initial 200–500 milliseconds after an item is perceived

- **Short-term memory**
  - allows recall for a period of several seconds to a minute without rehearsal.
  - Limited capacity
  - Can store 4–5 items
  - Can be increased through a process called chunking For example, in recalling a ten-digit telephone number a person could chunk the digits into three groups (the area code, then a three-digit chunk, and lastly a four-digit chunk)

Long-Term Memory

- Long-term memory can store much larger quantities of information for potentially unlimited duration (sometimes a whole life span)
- Its capacity is immeasurably large
- Maintained by more stable and permanent changes in neural connections widely spread throughout the brain
- The hippocampus is essential (for learning new information) to the consolidation of information from short-term to long-term memory, although it does not seem to store information itself
- Hippocampus may be involved in changing neural connections for a period of three months or more after the initial learning

Forming Memories

- How do we create long-term memories, and where do we store them?

- One of the primary functions of sleep is thought to be improving consolidation of information, as several studies have demonstrated that memory depends on getting sufficient sleep between training and test.

- Data obtained from neuroimaging studies have shown activation patterns in the sleeping brain which mirror those recorded during the learning of tasks from the previous day, suggesting that new memories may be solidified through such rehearsal.

Improving Memory (5 simple techniques)

1. **Chunking**

   Organize the material as meaningfully as you can and think out relationships among each group. This not only improves learnability and retention but also aids in faster and effortless recollection.

- Limit chunks to include 5 to 9 items. (short-term memory capacity)
- Example: The list Apple, cucumber, paper, ink, cabbage, banana, grapes, beans, stapler, orange can be better learned by rearranging and applying chunking as :-
  Apple, banana, grapes, orange, cucumber, cabbage, beans, paper, ink, stapler
  -- 4 fruits, 3 vegetables and 3 stationary items.

2. **Rhyming**

- One of the most popular and oldest methods in memorization. This technique makes use of the fact that we have a natural tendency to remember rhymes and rhythms.
- *"Thirty days hath September; April, June, and November; Once short February's done'; All the rest have thirty-one"*

3. Mediation/Bridging

- In this method, a bridge is built in between the items given to be memorized. This technique is best suited for learning material involving word pairs or material that can be reduced to word pairs. An example often cited by memory experts is the learning of the capital of Poland. The capital of Poland is Warsaw. World War II started with Germany's attack on Poland. Thus it may be arranged as Poland SAW War first.

Improving Memory (5 simple techniques)

3. Bed-time Recital

- In this technique, you do your recital or rote learning just before going to bed. The mind in the process of sleeping would then arrange the information in a systematic and effective way when you are sleeping. Psychologists have also found that if you sleep after thinking about your problems there is a better chance that you arrive at a solution the next day.
- *Steps for Memory Improvement*
  - Be in a relaxed mood
  - Write down the things that you are supposed to remember in a piece of paper.
  - Read it aloud (if possible) once or twice and recite it two to three times.
  - Now go to sleep without worrying or thinking about anything.
  - You will surely retain the item longer and find it more easy to recall it when in need.

4. Trying by Not Trying

- All of us apply this method knowingly or unknowingly. Sometimes when you try to recall you may not be able to recall it at that time even if you are sure that you know it very well. You experience a blocking that prevents you from recalling it. Normally you tend to try again and again but in vain.
- To handle this situation you just keep away from trying to recollect it and do something else
- To your pleasant surprise that information automatically pops up into your mind after some time.
- This is because even if you stopped trying, the mind is searching for that information and brings it to awareness when it is found.
- Sometimes the information was blocked when you wanted, and mind brings it forward when the blocking is removed. This is where stress plays its role in hindering recall.

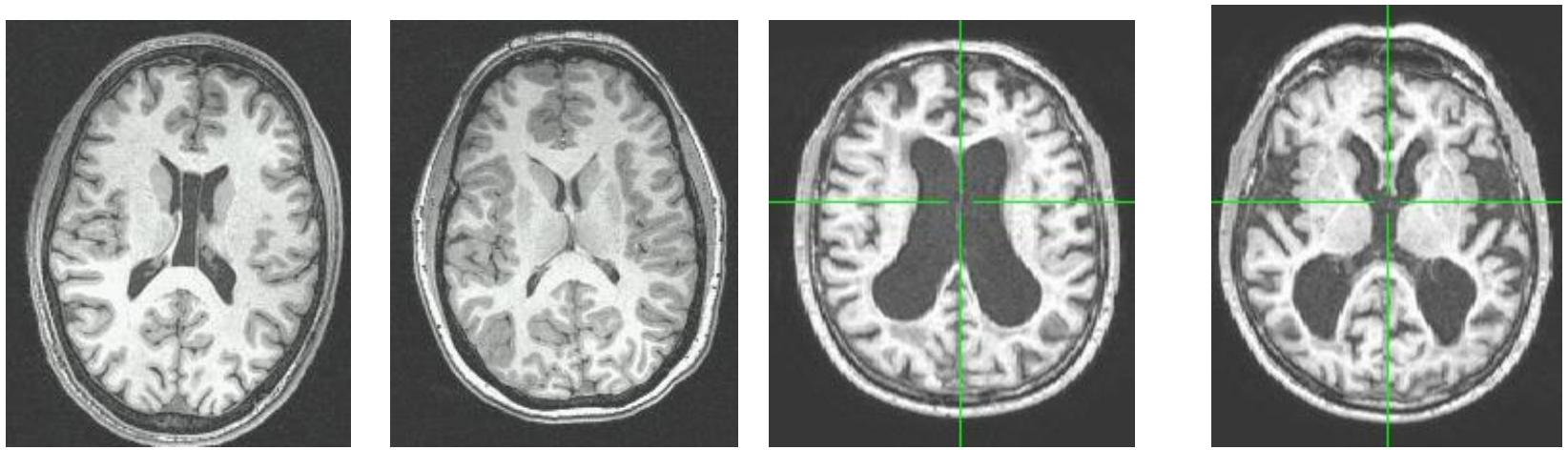
Alzheimer’s Disease

- **Alzheimer's is a brain disease that causes problems with memory, thinking and behavior.**

- Most common form of dementia
- Not a part of normal aging
- Worsens over time
- Has no cure, research continues

Alzheimer's Disease

- Characterized by loss of neurons and synapses in the cerebral cortex and certain subcortical regions.
- This loss results in gross atrophy of the affected regions, including degeneration in the temporal lobe and parietal lobe, and parts of the frontal cortex and cingulate gyrus



Normal

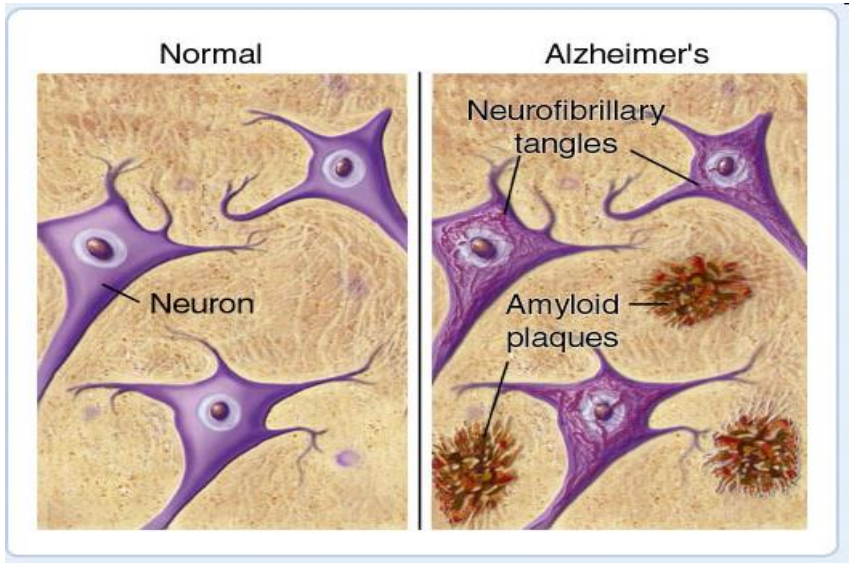
Alzheimer's Disease

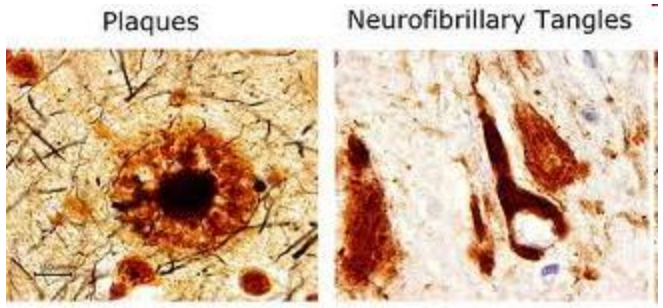
Alzheimer's Disease

- Both amyloid plaques and neurofibrillary tangles are clearly visible by microscopy in brains of those afflicted by AD

- Plaques are dense, mostly insoluble deposits of amyloid-beta peptide and cellular material outside and around neurons

- Tangles (neurofibrillary tangles) are aggregates of the microtubule-associated protein tau which has become hyperphosphorylated and accumulate inside the cells themselves





http://www.alz.org/alzheimers_disease_4719.asp