Section 8
Learning
Language & Lateralization

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COGS 17 A04

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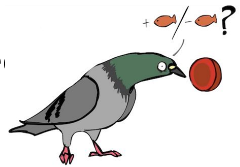
Learning

- Generic Definition: Development of a permanent <u>change</u> in behavior based on <u>experience</u>

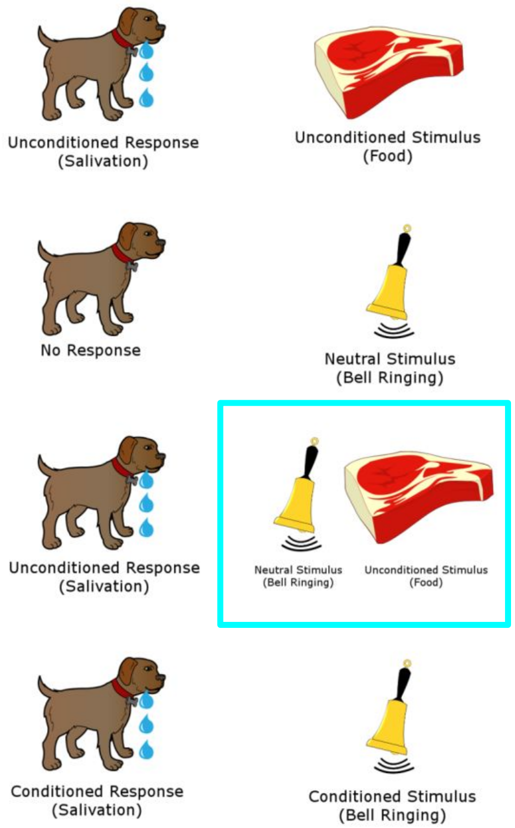
- **Law of Effect:** Any stimulus/action/context associated with <u>positive</u> reinforcement will tend to <u>repeat</u>

- **Classical** Conditioning
    - Learning happens when the two stimuli are linked together
    - Pavlov's Dog
    - Stimuli must co-occur for the conditioning to succeed

- **Operant/Instrumental** Conditioning
    - Learning happens through consequences of behavior
    - Pigeon presented with dot → gets food → pecks more



- **Temporal Contiguity**
    - Both types of conditioning require <u>co-occurrence</u> to become associated in the learner's mind
    - Proposed that co-occurrence leads to <u>neural co-activity</u> of the stimulated circuits, thus leading to learning

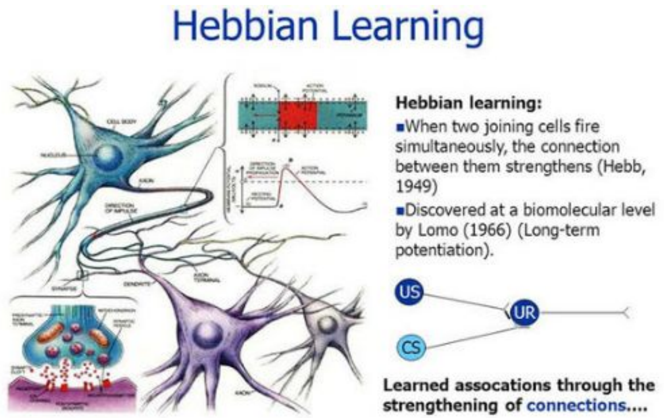


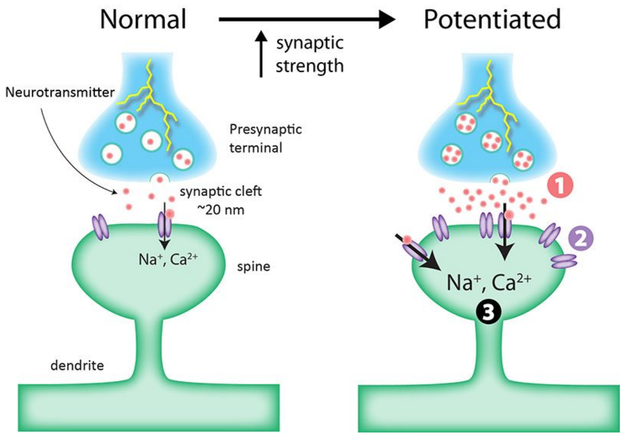
Hebbian Learning

- Proposed by Hebb as the fundamental neural process involved in learning

- *Neurons that fire together, wire together*
    - <u>Repeated co-activated</u> neural circuits, involved in learning and retrieval of associations, are reinforced and increases the likelihood of circuits co-firing. **“Hebbian Synapse”**
    - by structural/metabolic changes in NT availability, release, and reception

- **Long-Term Potentiation (LTP)**
    - Key mechanism underlying learning
    - Over time, LTP can lead to (Semi-) Permanent structural and connectivity changes among neurons
    - Increases the likelihood of activity along repeated circuits





Long-Term Potentiation (LTP)

- Semi-Permanent structural and connectivity changes
- Typically changes occur on the <u>post</u>-synaptic neuron
    - Changes to # of receptor sites
    - Dendritization (building new dendritic branches), etc.

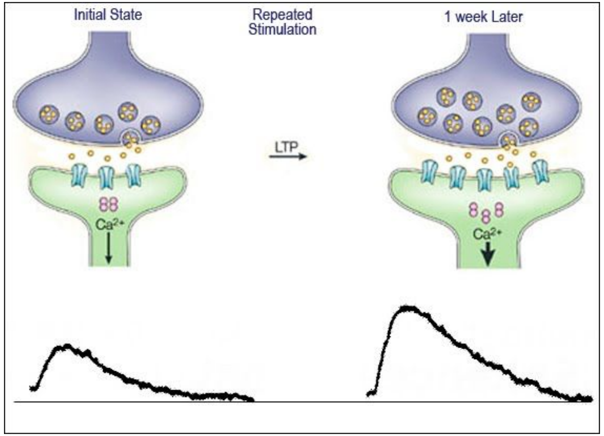
- The best-studied mechanisms of LTP use Glutamate as the primary NT

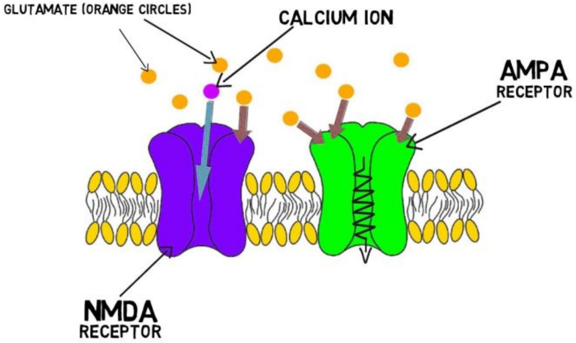
- 2 types of Receptor Sites for Glu

1. **AMPA** Receptors
    - Glu attaches → ion gates open to admit Na+ and CA ++
    - Pumps Mg++ out of the cell/receptor sites

2. **NMDA** Receptors
    - Mg++ blocks the NMDA channel unless…
        - AMPA is activated first and let Na+ (depolarize) → pushes Mg++ out from NMDA → Ca++ and Na+ enter the cell

- As circuit repeats, more Na and Ca enter the post-synaptic cell → causes metabolic processes in cell to eject Mg
- **Result:** NMDA receptors are converted into AMPA, increases dendritization





Long-Term Potentiation (LTP)

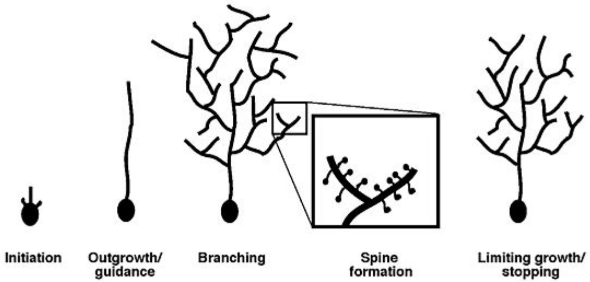
Dendritization

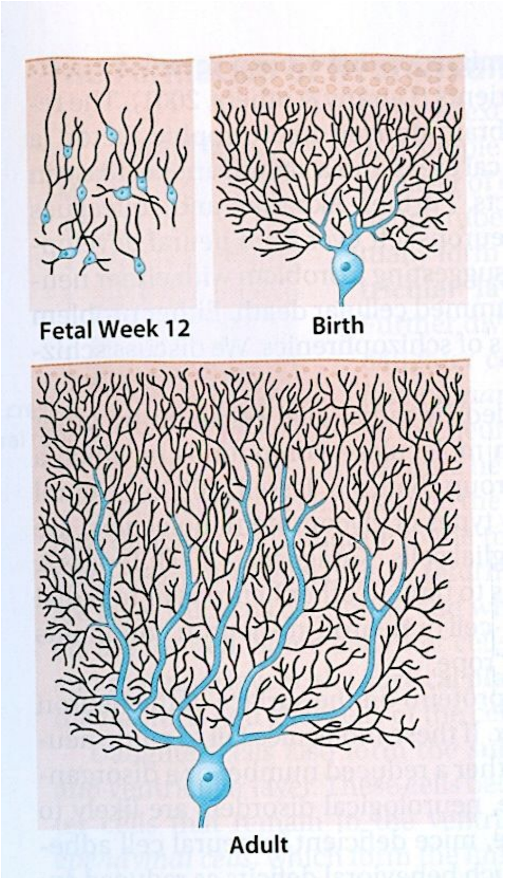
- Significant experiences (e.g., learning new languages, how to play guitar etc) over time changes how neuron looks like

- How? It introduces physical changes in cells: increasing **number of branches** which increase the **number of receptor sites**

- Repetition is the key: Continued activity along circuit → growth of new dendritic branches

- In some memory circuits, **retrograde messengers** (e.g., Nitrous oxide) are released by **post-synaptic cells**, throughout life, to create a positive feedback loop and prolong release of NTs by pre-synaptic cells
  - exceptional case which does not usually happen after birth





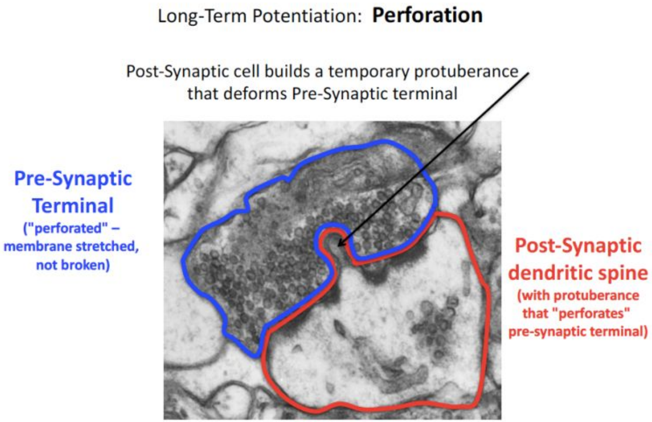
Perforation (Splitting of Synapses)

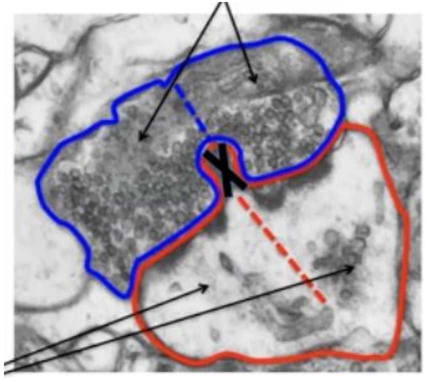
- Occurs where the terminal button meets the axons of the next cell

- **Post-synaptic** (red) **branch will grow protuberance** pokes into the pre-synaptic (blue) terminal (membrane of the pre-synaptic terminal is stretched but not broken)

- Results of Perforation
  1) duplicates the metabolic mechanisms in both sides
  2) promotes the **division of the pre-synaptic terminal into two terminal buttons**

- The dendrites then dismantles the protuberance and divides into two dendritic spines that each receive NT from one of the new terminal buttons

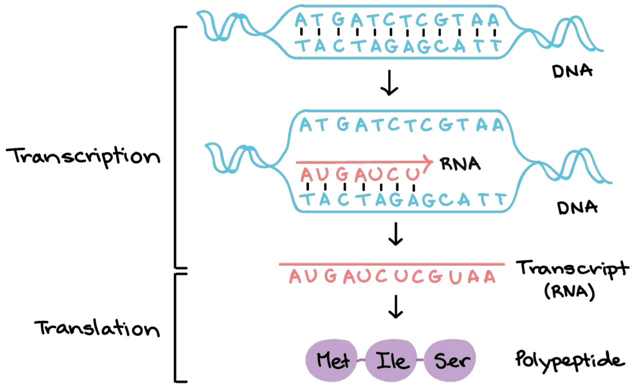




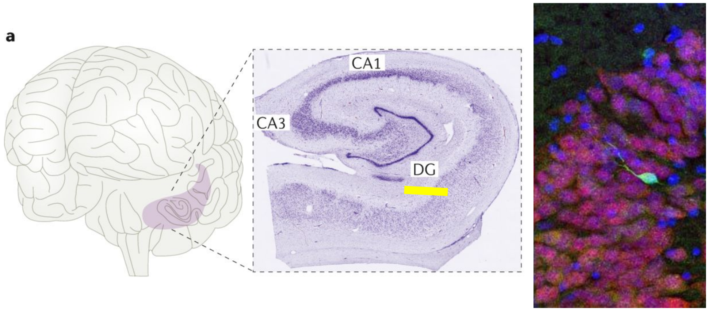
Other Factors

…that modify function based on experience

- **Genes**
  - Have impact through gene transcription (makes copies of segment of DNA (=RNA) to code for protein production and transport it to ribosome to build protein)
  - These proteins can change the # of available NTs, the size and distribution of vesicles, and metabolic processes in the cells



- **Neurogenesis**
  - The growth of new neurons in the adult brain
  - Very rare and is only known to occur in sparse regions
    - Subgranular Zone (SGZ) in the dentate gyrus (DG) of the hippocampus
    - Subventricular Zone (SVZ) of the lateral ventricles



Left: Young neurons (green) in the human hippocampus and more mature neurons (red). Image credit: Sorrells *et al.*

Memory

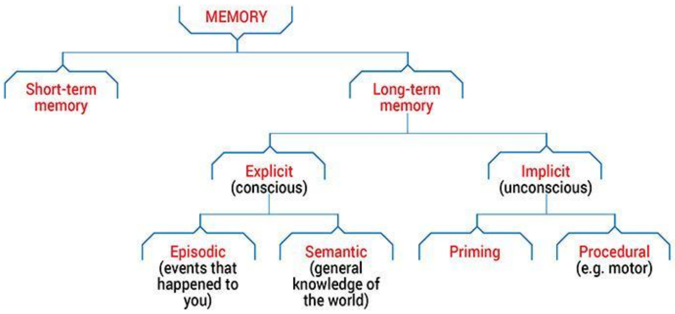
- Often divided into 3 classes with critical brain regions for each type (though very loosely defined and not always localized to one region)

Very Important! Memories are not stored in these regions, but are vital for their retrieval and consolidation

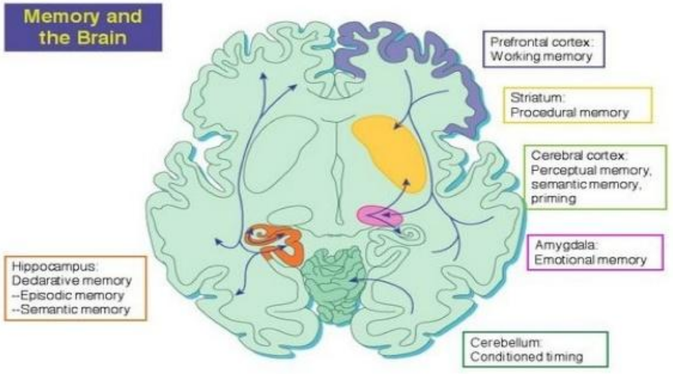
1. **Hippocampus**
   - <u>Spatial</u> Memory (e.g., “where is my phone, where is York Hall”)
   - Develops <u>place cells</u> over the course of spatial learning → cognitive maps of where the animal is in space and where locations are relative to the animal
   - Damage can impair navigation, map reading, recall of locations

2. **Cerebellum and Basal Ganglia**
   - <u>Procedural</u> memory: Sequences of behavior that you’ve learned how to do (e.g., riding bicycle)

3. **Hippocampus, Medio-dorsal Thalamus, Prefrontal Cortex**
   - <u>Declarative</u> memory: facts or personal episodes (e.g., rules for tennis game, what I did during the last weekend)



Different regions of brain involved in specific memory



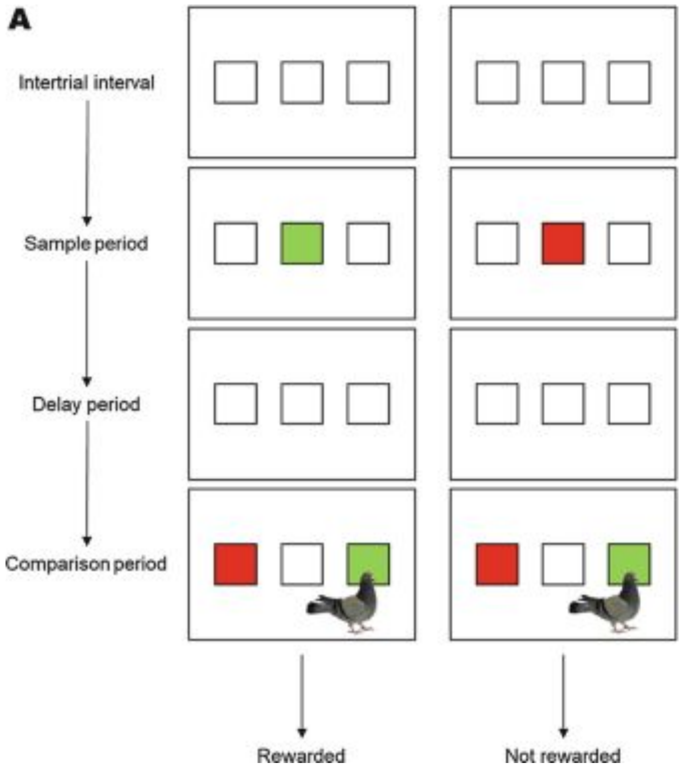
Declarative Memory

- Memory of “facts”, abstract “rules”, and “episodic memory”
- Involves the Prefrontal Cortex, Hippocampus, and Medio-dorsal Thalamus (Medio-dorsal Nucleui, MDN)

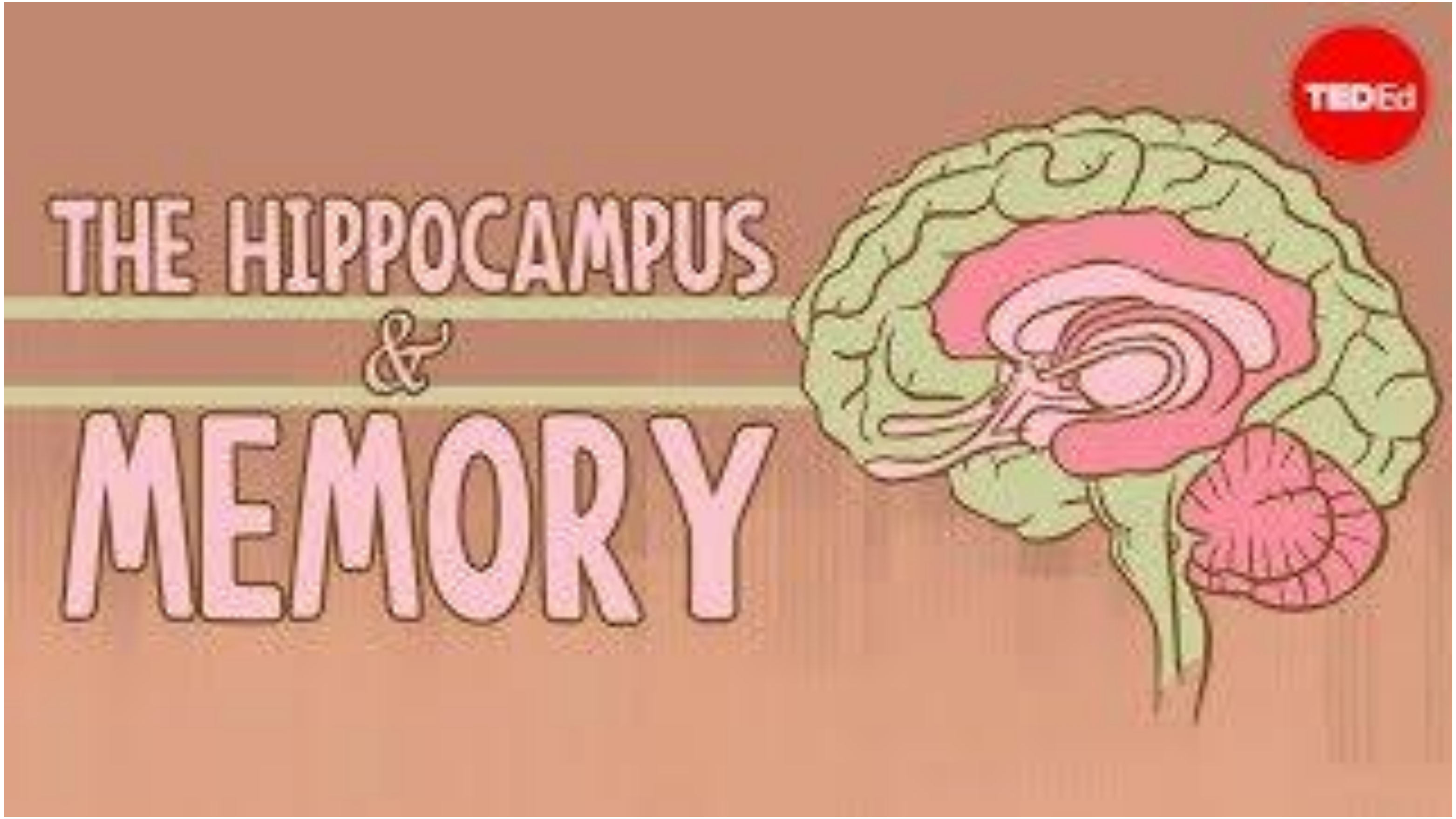
- **Match-to-Sample Task:** a declarative memory task that doesn’t require language
  - A cue is given and give a reward when animal matches the choice to the sample in a task phase
  - Performance is impaired if the hippocampus is lesioned after the learning the rule

💡 Hippocampus plays a vital role in forming and retrieving memories

- If connections from the MDN to the PFC are damaged (as in B1 deficiency from chronic alcoholism) Korsakoff’s Syndrome develops
  - Suffers from anterograde amnesia (difficulty in forming new memories after specific accident or injury) and confabulation (can’t remember → make up a story)



Patient H.M.



Patient H.M.

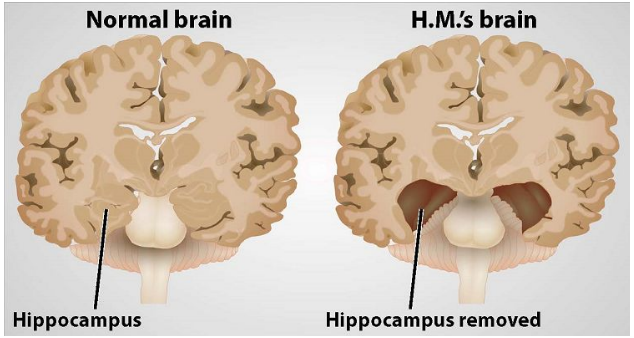
- Bilateral Hippocampus, amygdala, and partial regions of the temporal cortex were removed to treat H.M.'s epileptic seizures

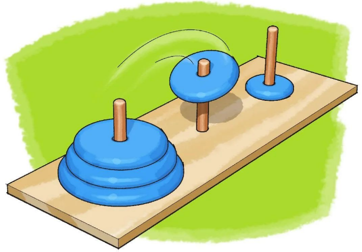
- Results led to reduction of epilepsy but other symptoms arose

- H.M.'s IQ and personality was intact, but suffered from severe anterograde amnesia (e.g., after meeting a new people, no memory of having met them)

    - Was unable to form new episodic memories after his hippocampal resection, but Procedural Memory and Working Memory was largely intact

    - With repetitive training, H.M. learned new skills (like solving the "Tower of Hanoi" puzzle) but was not able to recall having learned them





Long-Term Memory

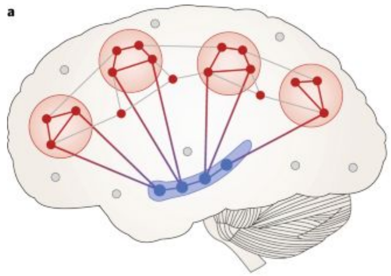
- Declarative memory is **not** stored in the Hippocampus, Thalamus, or Prefrontal Circuits

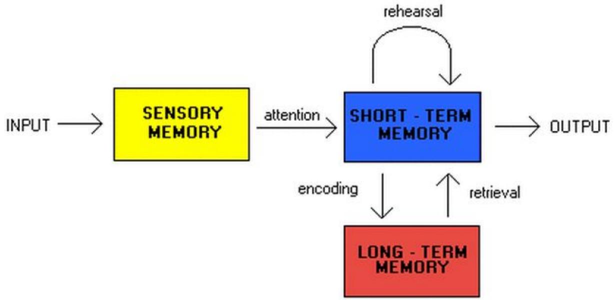
- However these circuits are required for the consolidation and retrieval of information that are stored elsewhere in the cortex
  - Area of ongoing research, it is generally believed that memories are distributed to various circuits throughout the cortex

  - Fusiform Gyrus of the Inferior Temporal Cortex is active in recognizing faces (Fusiform Facial Area, FFA)

  - Dorsal Temporal Cortex including Wernicke's Area is used for recognizing words and voices

  - Posterior Parietal has some spatial memory for how you engage with the world from an egocentric POV





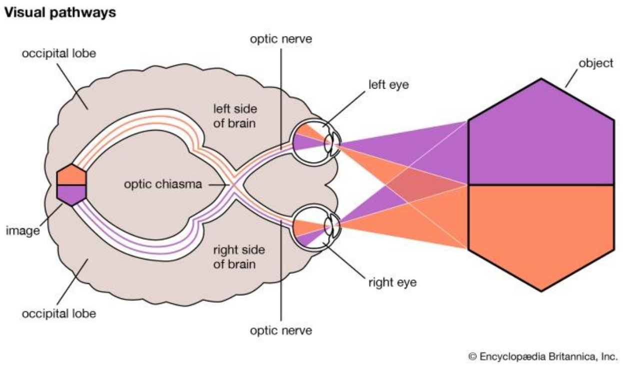
Bilateral Crossover

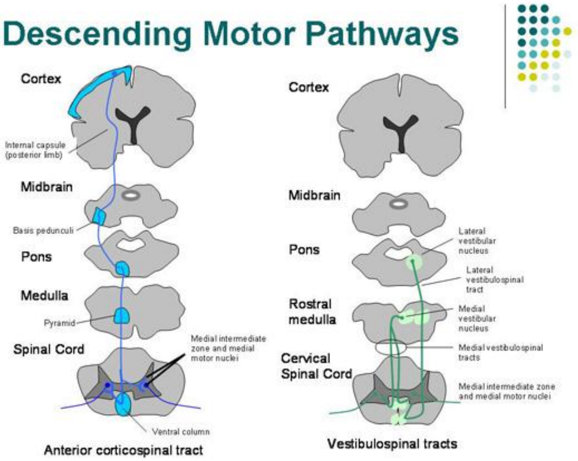
- Crossover of perceptual and motor pathways plays a role in some dominance patterns

- **Visual Pathway:** Right visual ctx receives input form Left visual field & vice versa

- **Somatosensory Pathway:** Right somatosensory ctx receives input from left half of body & vice versa. Facial senses are shared more

- **Motor Pathway:** Right hemisphere controls Left half of the Body & vice versa. Both hemispheres control the facial muscles although contralateral hemisphere is more dominant



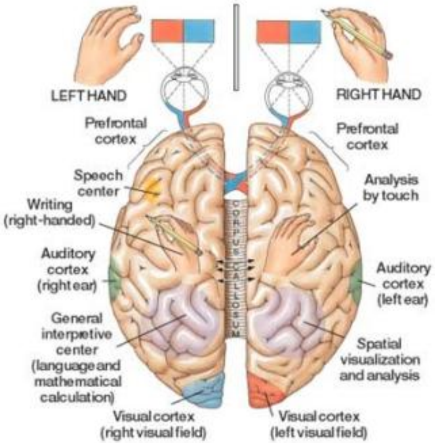


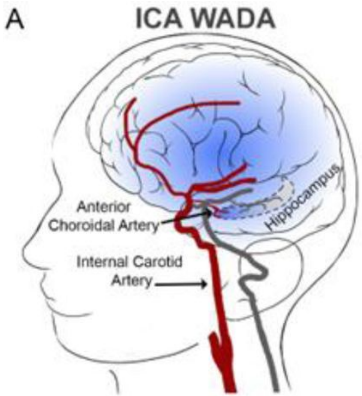
Lateralization

- Dominance of (an area in) one hemisphere of cortex over the other for <u>particular</u> functions

- **WADA Test**
  - Used to empirically test lateralization of functions
  - Inject Sodium Amytal into either L or R Carotid artery to anesthetize only the one hemisphere
  - Subject is given function specific tasks and test which hemisphere affects performance such as…

- R Hemisphere: Visuo-spatial tasks, Socio-emotional processes
- L Hemisphere: Speech, fine motor control





Lateralization

Lateralization

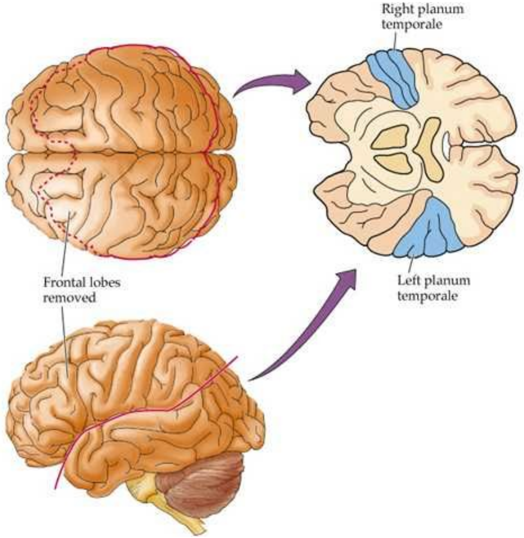
Interference: can happen when if similar parts of the brain are critical for two tasks where these tasks will interfere with each other

- Reading - language (mainly L hem)
- Listening to music <u>does not</u> interfere with reading (mainly on R hem)
- But listening to the lyrics <u>does</u> interfere with reading (+ L hem)

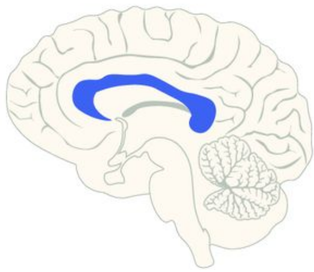
- Stuttering: may be linked to hemispheric competition for speech control
  - Most prevalent in Left-handers: often have less clearly lateralized brains (= both hem may try to handle speech, causing conflict)
  - Evidence: while talking, Left-handers may tap slower with R-hand (controlled by L hem), suggesting the L hem is busy with speech

Physical differences of Lateralization

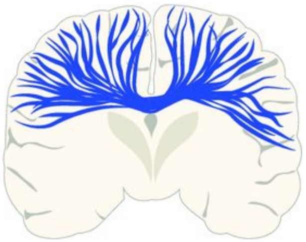
- **Corpus Callosum:** A bundle of axons connecting the cortical hemispheres
    - Typically thicker in Left-Handers and Females → less lateralization
    - Damage to one hemisphere is often compensated for by the other hemisphere
- **Planum Temporale:** An area in the Temporal Cortex (including Wernicke's Area) that is <u>larger in the L hem</u>
    - In non-human primates, relatively equal. Implicated in vocal communication and understanding of verbal language (speech comprehension)
- **Anterior Commissure:** Bundle of axons connecting the temporal lobes of the two hemispheres
    - Physically larger in females and homosexual males
    - Plays a role in pain sensation and contains fibers to the olfactory tracts
    - Implicated in the role of sensing of smells and chemoreception
    - Contributes to memory, emotion, speech, and hearing

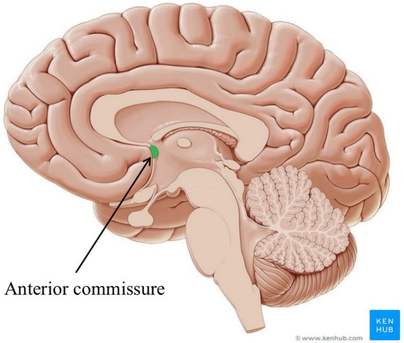


B Sagittal



C Coronal





Split-Brain Patients

Split-Brain Patients

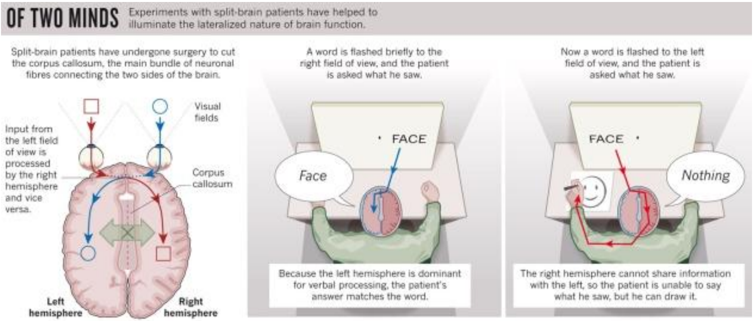
- Patients (post-surgery) presented with an image to one visual field are then tasked to find the matching unseen object by touch

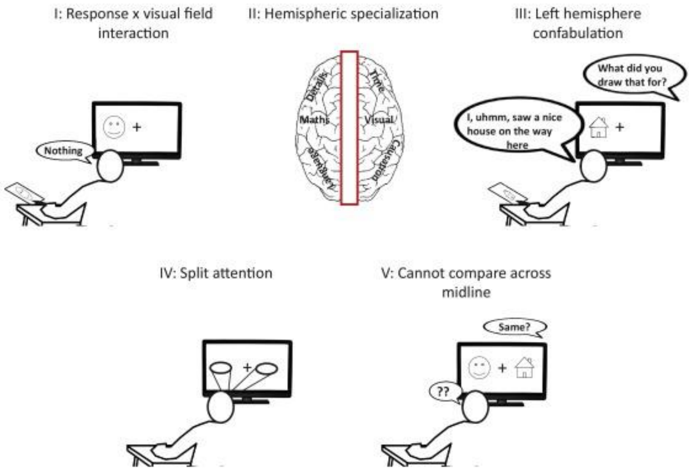
  - Visual information is presented in Left Visual Field (Right brain)
    - If reaching with the <u>Right</u> hand, <u>cannot</u> identify the object by feel
    - If reaching with the <u>Left</u> hand, <u>can</u> identify object by feel

  - **Note:** Visual information crosses over at the optic chiasm, not the CC. Visual input is intact in the Right Hemisphere, but Left Hemisphere lacks the visual input, which controls the Right hand

  - Can “cheat” by talking to self because the acoustic system crosses over in the medulla (essentially “telling” the Left Hemisphere the visual information)

- Some recovered patients show visual dominance for one visual field

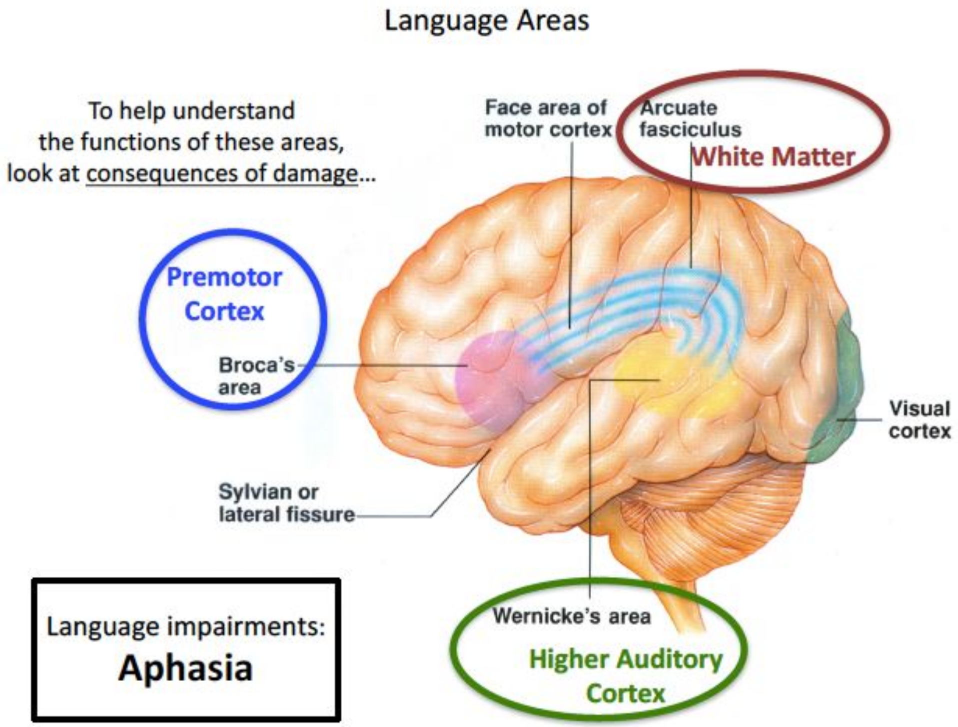




Trends in Cognitive Sciences

Language Areas

- **Broca's Area**
  - Part of the Premotor Cortex
- **Wernicke's Area**
  - Higher auditory cortex
- **Arcuate Fasciculus**
  - Bundle of axons (white matter tract) that connects Wernicke's Area with Broca's Area



Broca's Aphasia

aka "**Production** Aphasia" or "**Nonfluent** Aphasia"

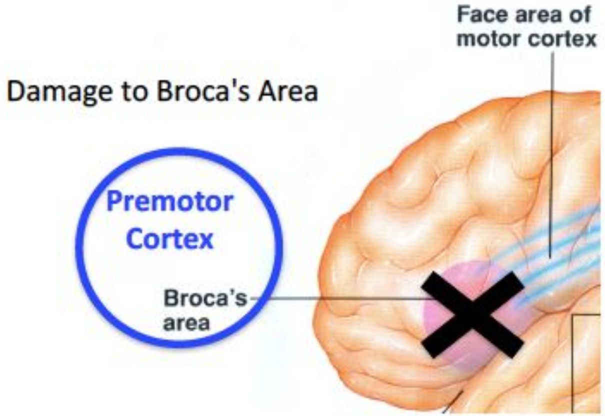
1. Articulation difficulty: Speech is slow, laborious, loss of prosody, and mispronounced words

2. Anomia for closed class terms
    - Forgets names for "closed class" terms (fixed set of terms in a given language that serves syntactical functions)
    - e.g., prepositions (of, by, for), articles (the, a), conjunctions (and, but), tense, and number markers (-ed, es)

3. Agrammatism
    - Difficulty in producing or understanding grammatical forms
    - Given "The boy that the girl is chasing is tall" – cannot say who is tall
    - Cannot follow sequential commands: "Put red block on green block"

- Can generally understand speech
- Still have deficits in producing sign language (not limited to spoken speech)
- Patients often suffer from depression and extreme frustration

speech tends to lack these terms:
say: I … go… store
instead of: I will go to the store



Wernicke's Aphasia

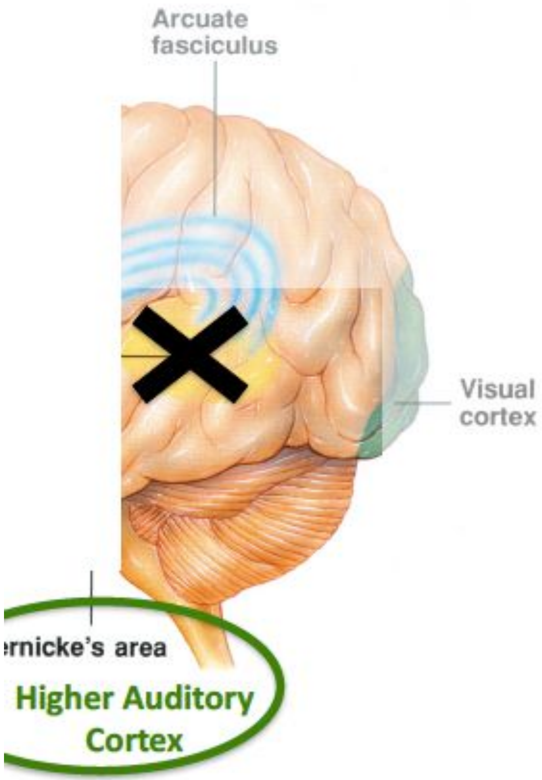
aka "**Receptive** Aphasia" or "**Fluent** Aphasia"

1. Fluent Articulation
   - Can speak fluently but the content is nonsensical

2. Anomia for content terms
   - For content terms (Nouns, verbs, adjectives, etc)
   - Deficits can be specific depending on the extent and location of damage (e.g., can name animate but not inanimate objects)

3. Incomprehension
   - Many cannot understand speech, may be able to read, write, and read lips, but cannot understand spoken language (=Pure word deafness)

- Suffer somewhat less than Broca's from depression, though tend to become withdrawn, detached

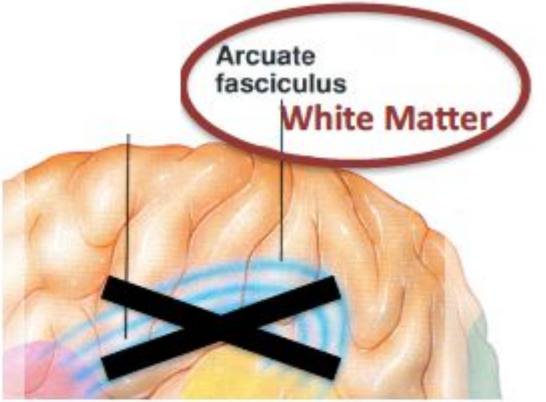


Conduction Aphasia

- Damage to the <u>Arcuate Fasciculus</u> (larger in the L hem) which connects Broca's and Wernicke's Area

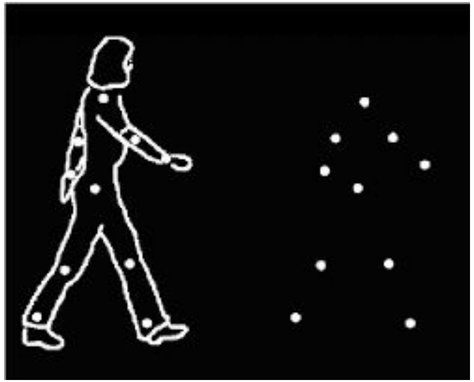
1. Difficulty repeating heard words: unable to establish a "Phonological Loop" (A "rehearsal" buffer of just-heard or about to be spoken words, e.g., when you are told a phone number and rehearse it until you store it)

2. May exhibit Phonemic Paraphasia: substitute the wrong phoneme into part of the word (e.g., say "hippy" instead of "happy")



- Can impair conversational exchange: cannot give a meaningful and relevant response and have difficulty carrying on a coherent conversation

- Impaired in lip reading and reading facial expressions
    - Involves connections with the Superior Temporal Sulcus (STS) for biological motion - typically R hem dominant

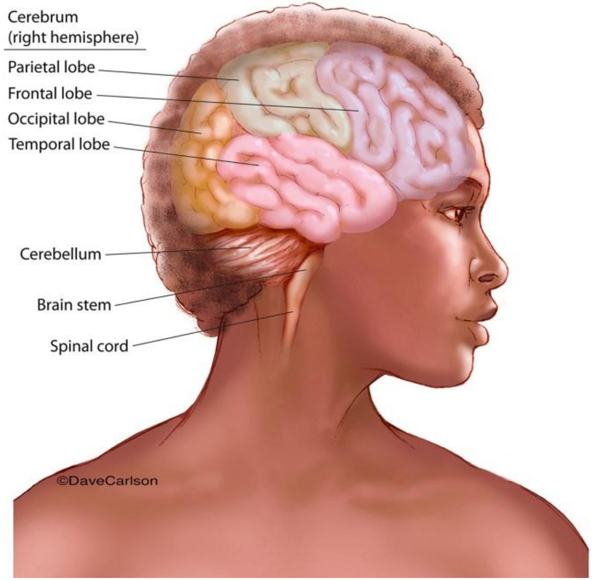


Right Hemisphere also plays a role

- Don’t forget about the RH! Not as well understood as the Left Hemisphere

- Right Hemisphere exhibits dominance for some cognitive functions

- **Global Processing**
  - Low-spatial frequency paths dominant over high-spatial frequency paths in the occipital lobe
  - Getting the “gist” of it (abstract knowledge verses keeping details concrete) e.g.: understanding a joke
  - Recognizing musical patterns (e.g.., melodies)
- **Spatial Abilities**
  - Damage to the Right Parietal Lobe → deficits in map reading, understanding spatial relationships, certain types of math, and solving puzzles
- **Socio-emotional processes**
  - Emotional expression both in face and in speech (e.g., tone of voice, facial expressions)
  - Recognize and correctly categorize others’ emotional expressions (e.g., recognizing sarcasm)



🍀 Good Luck on Your Middle Term 3 & Final Exam and Happy Spring Break!