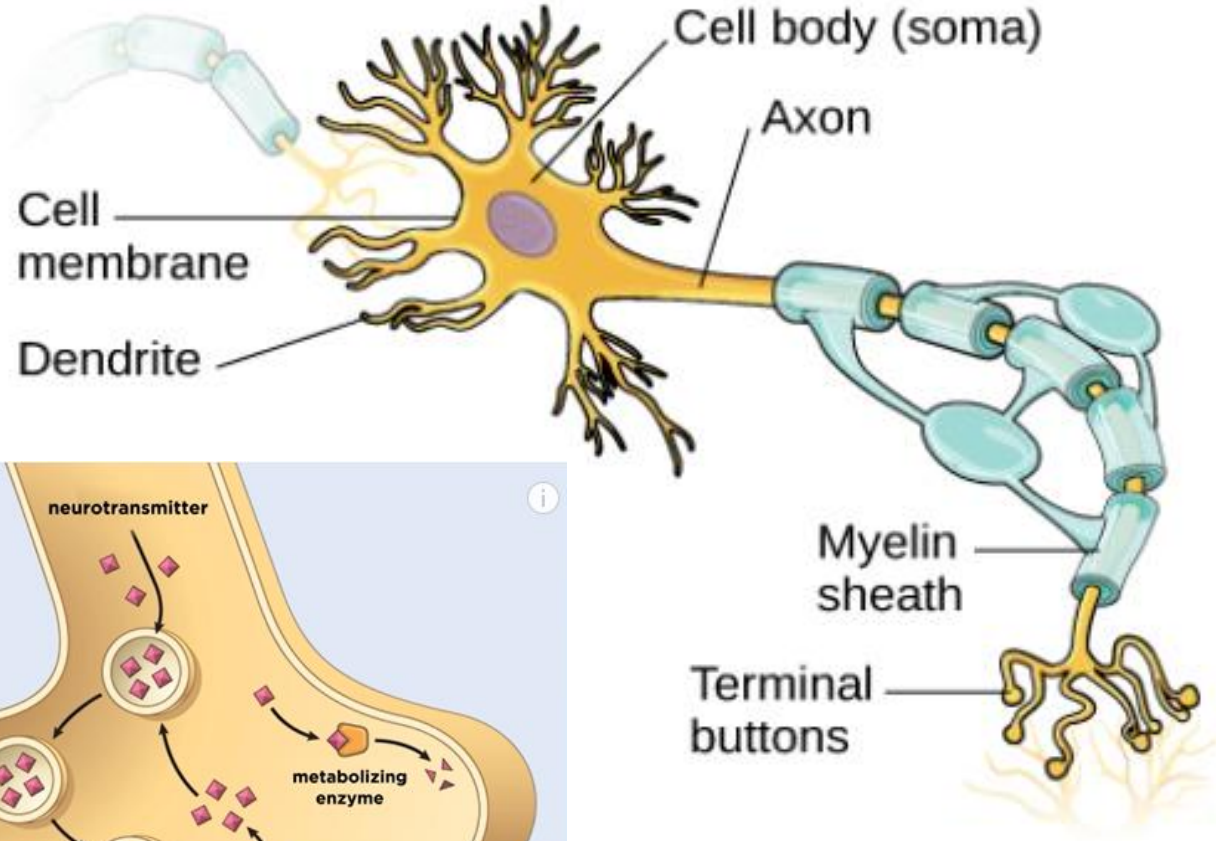
Round 20:
Synaptic Transmission &
Intro to Neural Networks

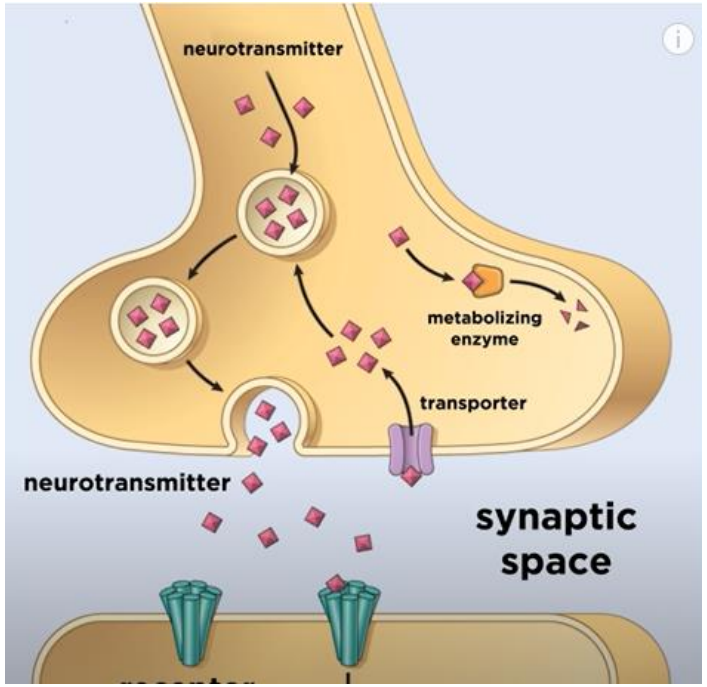
05/06/2021

Kristy Snyder Colling, PhD

Neuron

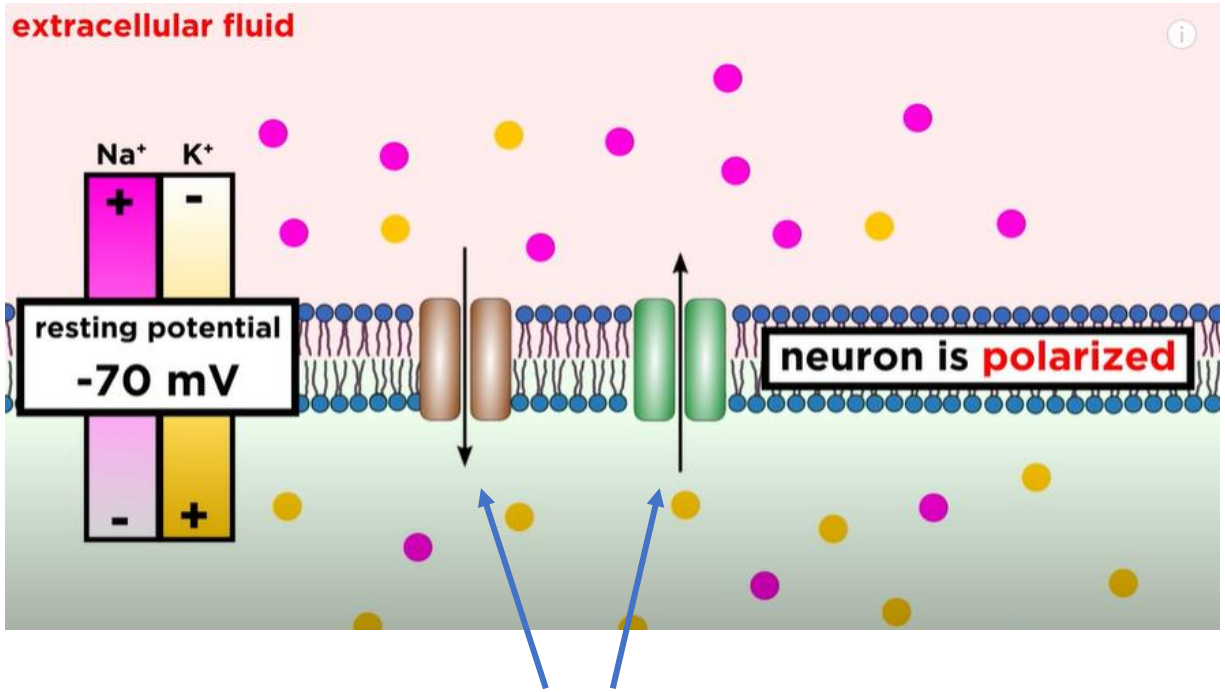
- Cell body or Soma – information processors
- Dendrites are input devices
- Axons convey information from the soma to the terminal buttons
- If it is myelinated, signals are transferred more quickly
  - Loss of myelination disrupts communication
  - Multiple Sclerosis
- Synaptic Vesicles - Store neurotransmitters
  - Released by action potentials
  - Received by receptors on post-synaptic dendrites
  - Facilitates electrical activity of the post-synaptic neuron





Action Potential/ Neural Transmission

- Electrical potential – the amount of work necessary to separate two opposite charges particles
- In neurons potential exist by virtue of the charge that exists on either side of the cell membrane
  - For a resting neuron there is more sodium (Na+) on the outside in the extracellular fluid and more potassium K+ on the inside in the cytoplasm



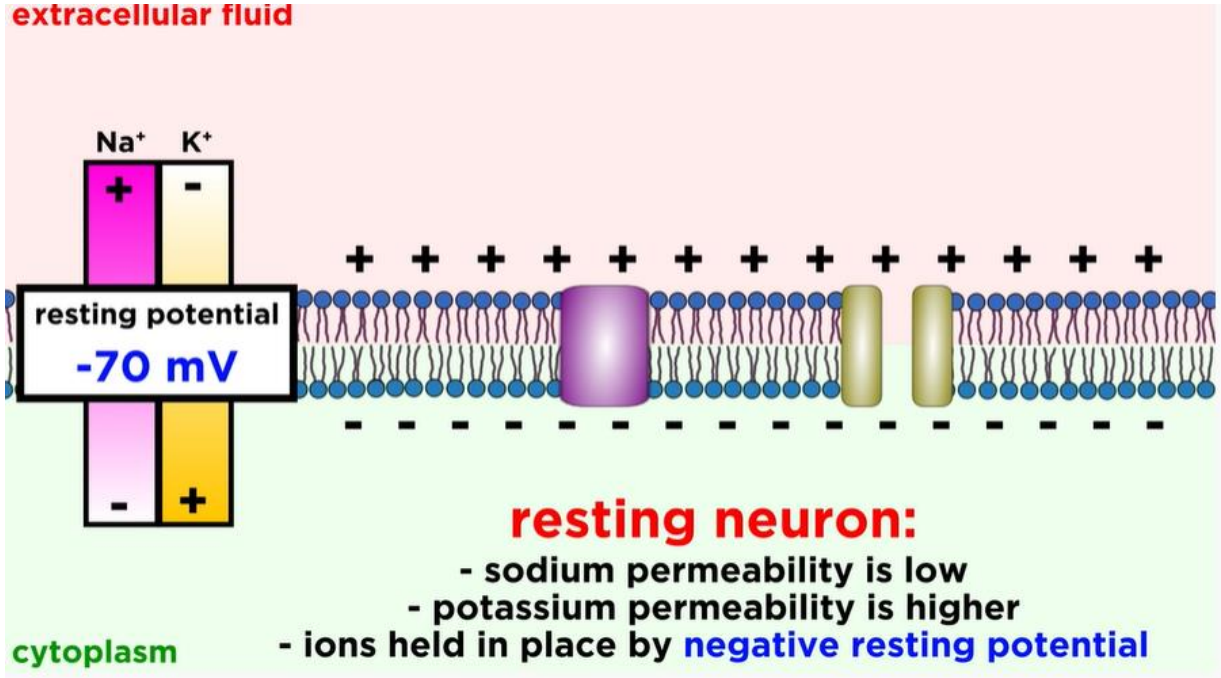
Ion channels

Ions only have the potential to move through the channels - resting potential

Action Potential/ Neural Transmission

- Sodium channels are usually closed
- Potassium channels are usually open, allowing for potassium to leave the cell making the charge on the inside negative
- The result is increasing pressure on sodium to enter the cell to level out the concentration gradient and electrostatic charge

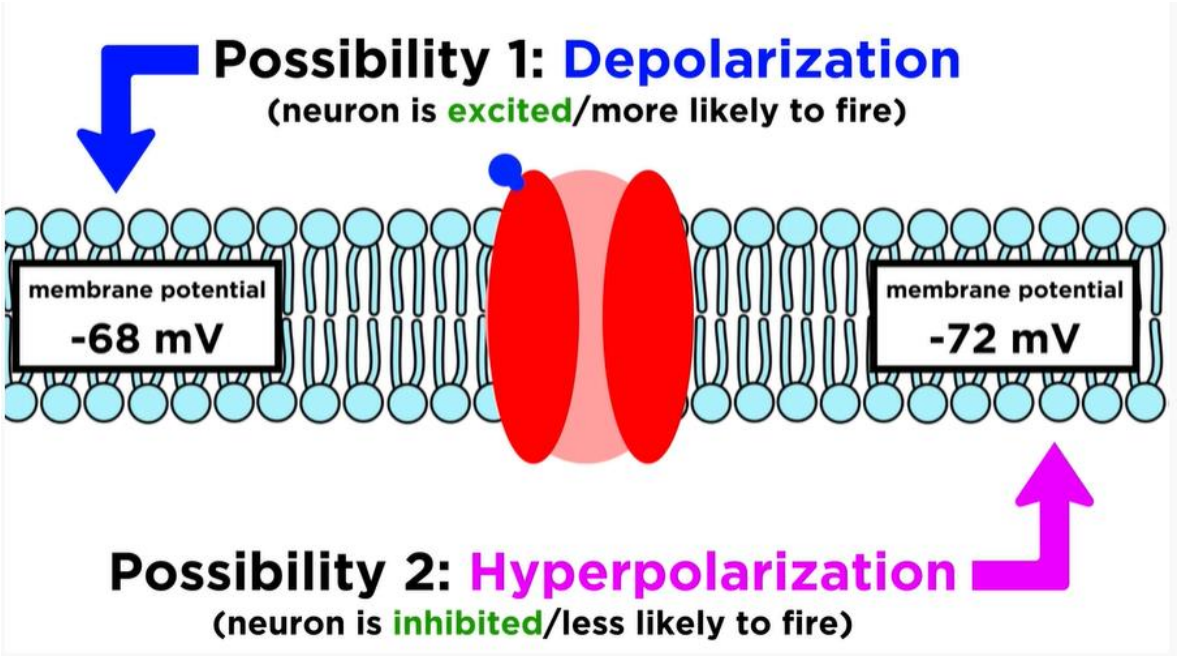
- However, the status of these channels is mediated by signaling molecules -> Neurotransmitters



Action Potential/ Neural Transmission

- When neurotransmitters are released, they are received by ionotropic receptors
- Have one of two effects on the post-synaptic neuron:

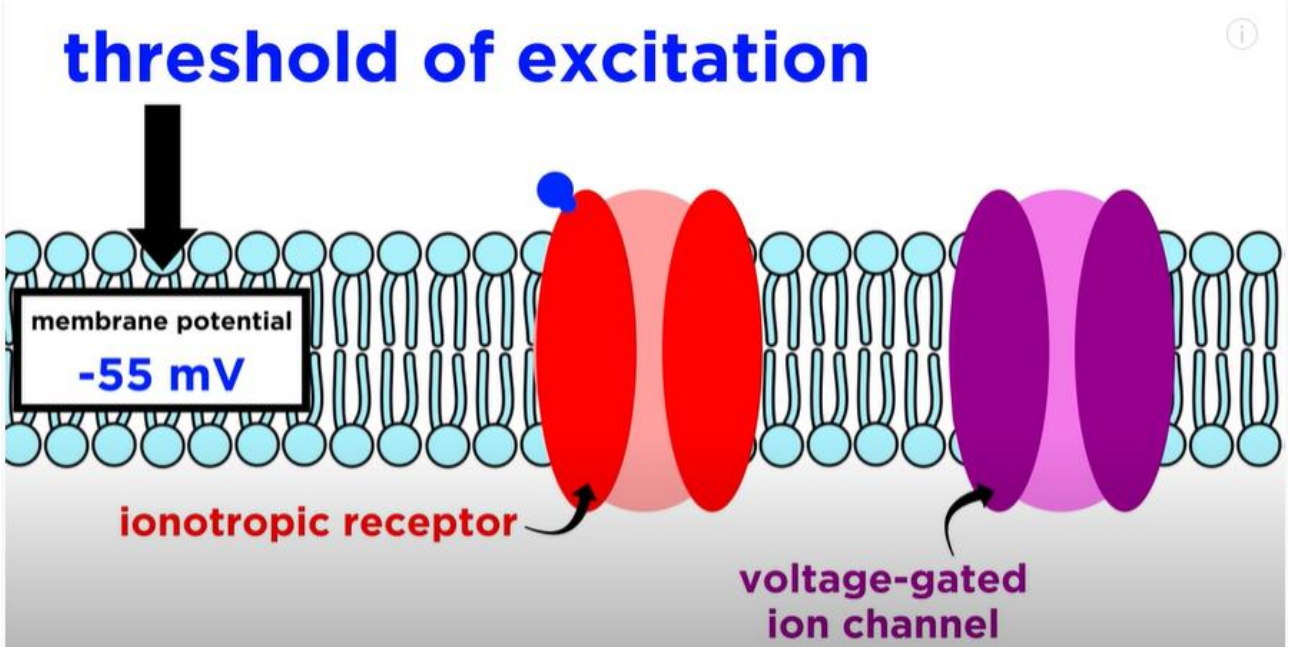
Makes inside of the cell **less** negative



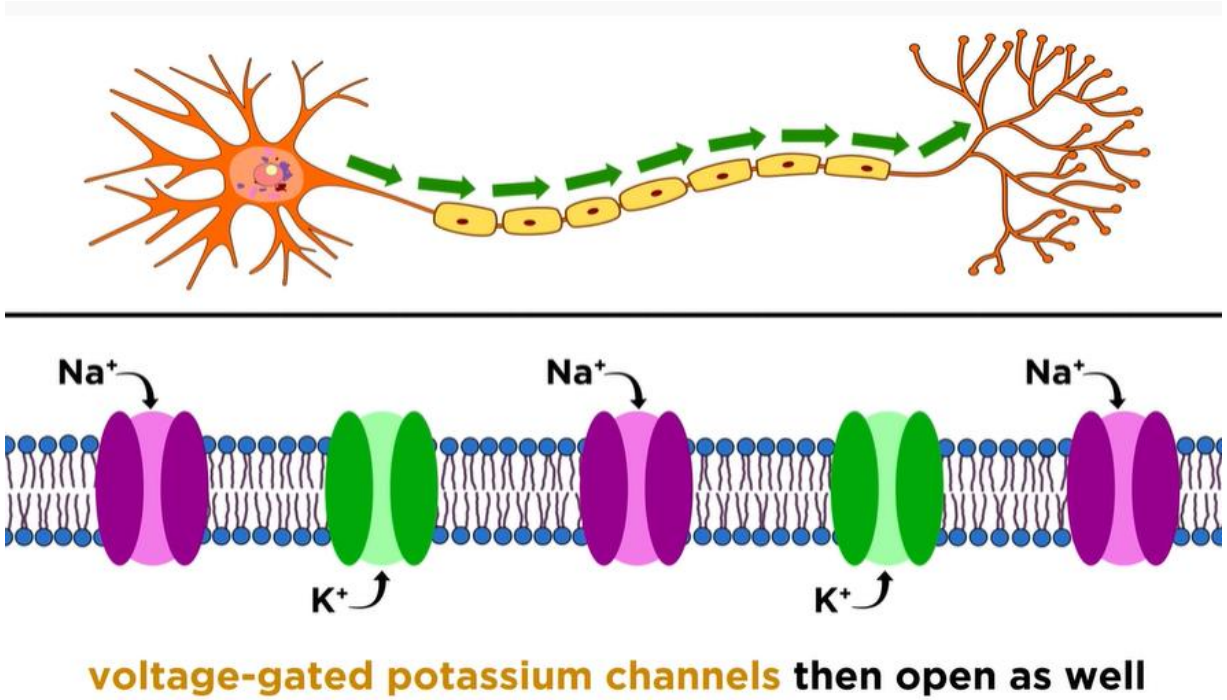
Makes inside of the cell **more** negative

Action Potential/ Neural Transmission

- The polarization opens or closed voltage-gated ion channels
- If the membrane potential changes as a result of the influx or outflux of ions such that it reaches threshold, it will trigger an action potential

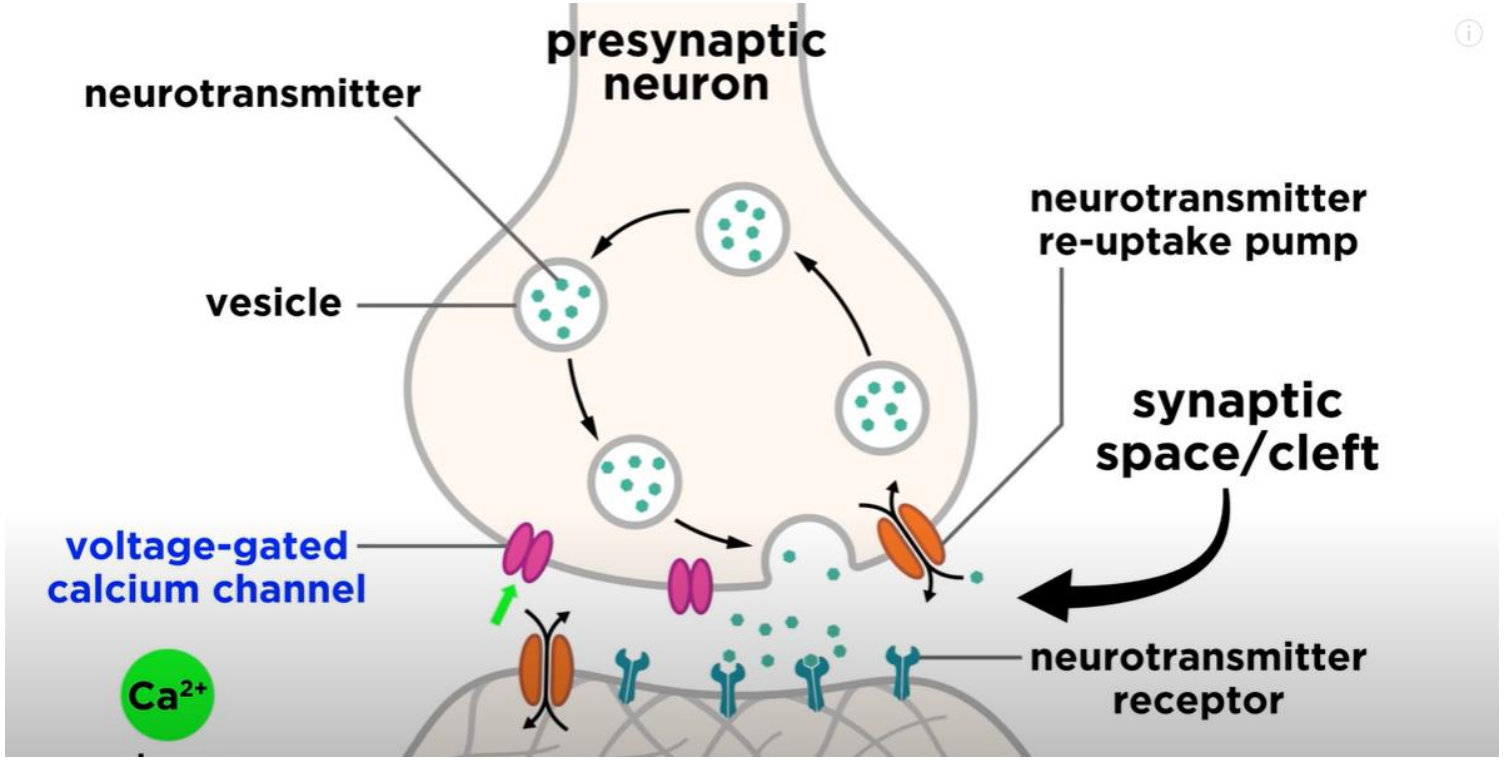


Action Potential/ Neural Transmission



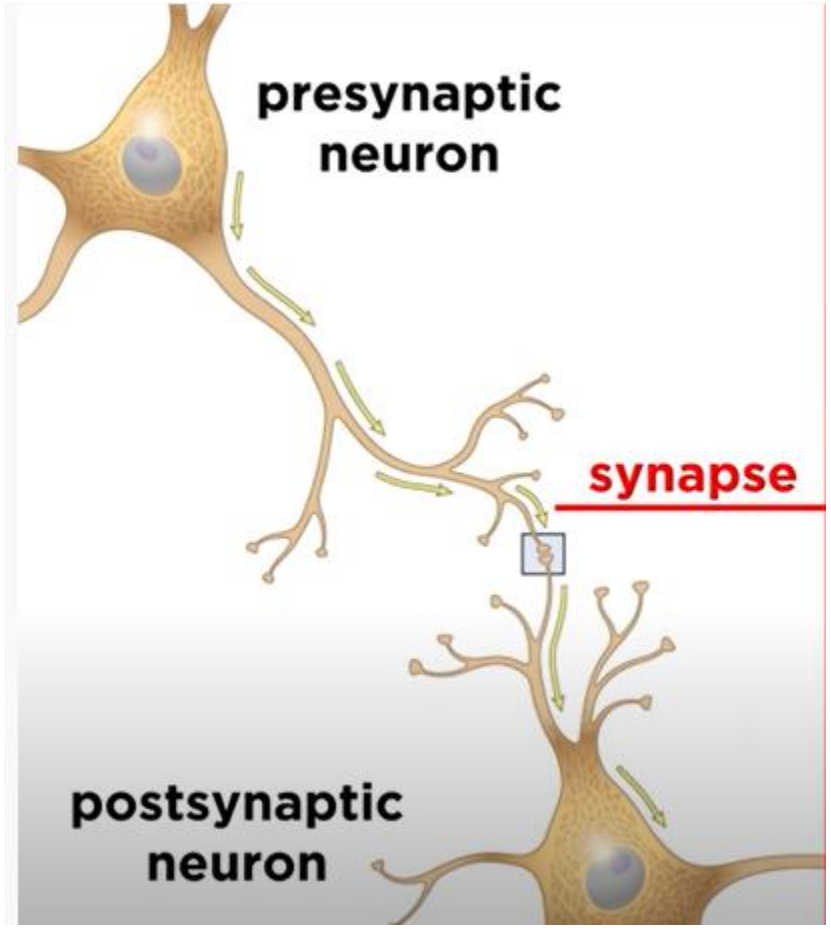
Action Potential/ Neural Transmission

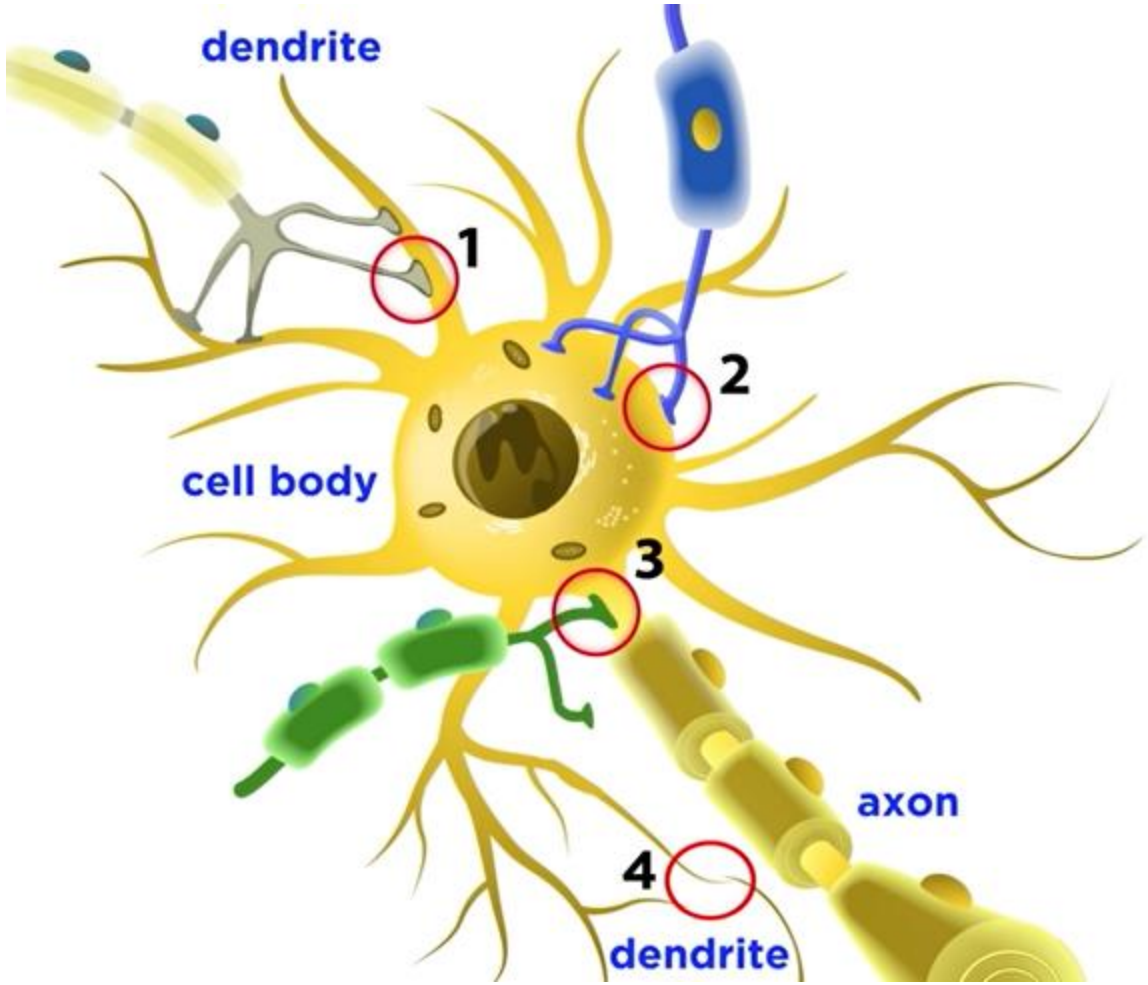
- The result of the action potential is to open voltage gated calcium channels
- Calcium is a messenger that trigger vesicles to bind with membrane and release neurotransmitters



Action Potential/ Neural Transmission

- This occurs neuron by neuron to convey a message
- Chemistry occurs in picoseconds (trillionths of a second)





1) axodendritic

axon terminal connects to a dendrite on the postsynaptic neuron

2) axosomatic

axon terminal connects to the cell body on the postsynaptic neuron

3) axoaxonal

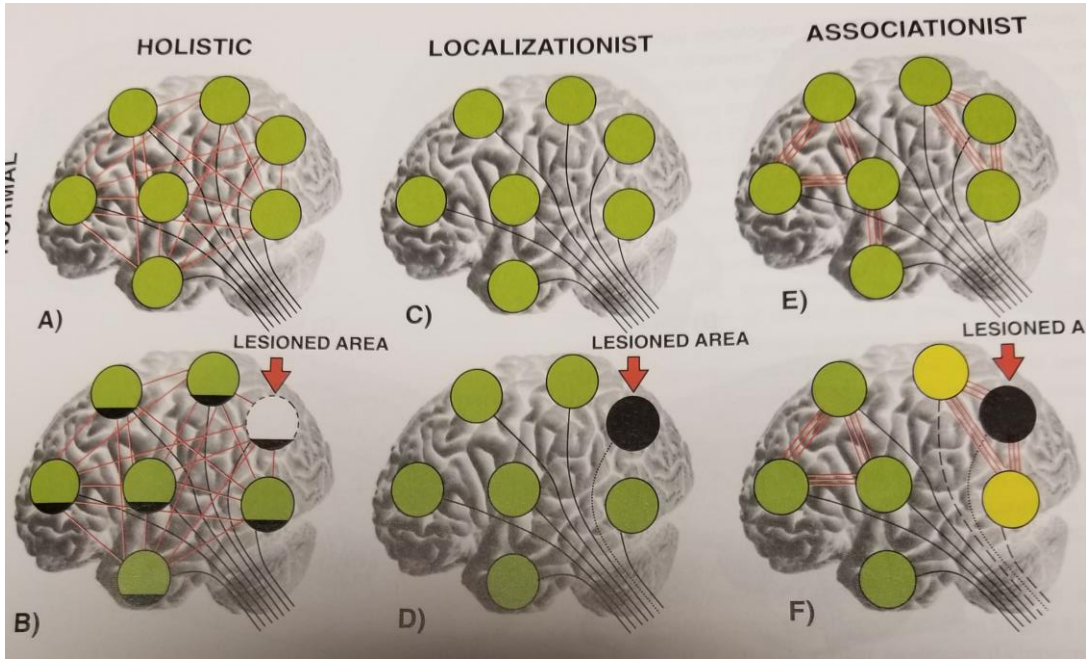
axon terminal connects to the axon on the postsynaptic neuron

4) dendrodendritic

dendrite connects to a dendrite on the postsynaptic neuron

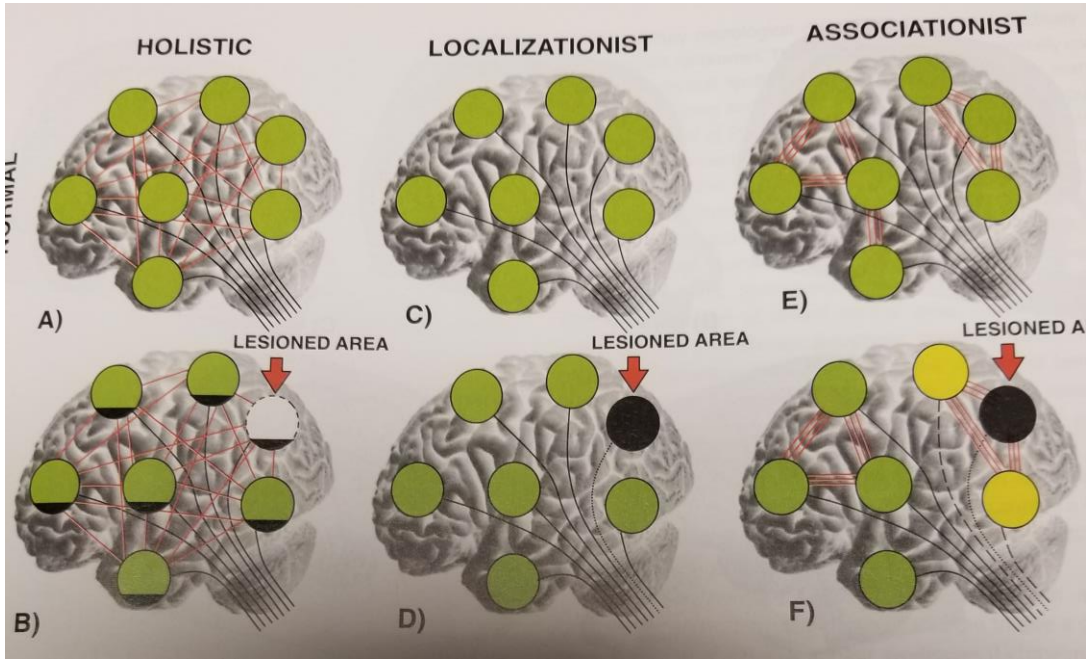
Brain Function Theories

- Holistic Models
  - All regions are mutually interconnected and have equipotentiality
  - Cognition results from simultaneous activity among all regions acting as a whole
  - Damage to one area, the network redistributes workload
    - But the quantity of work accomplished is reduced
  - Evidence against from brain injury/lesions demonstrating localization of some functions



Brain Function Theories

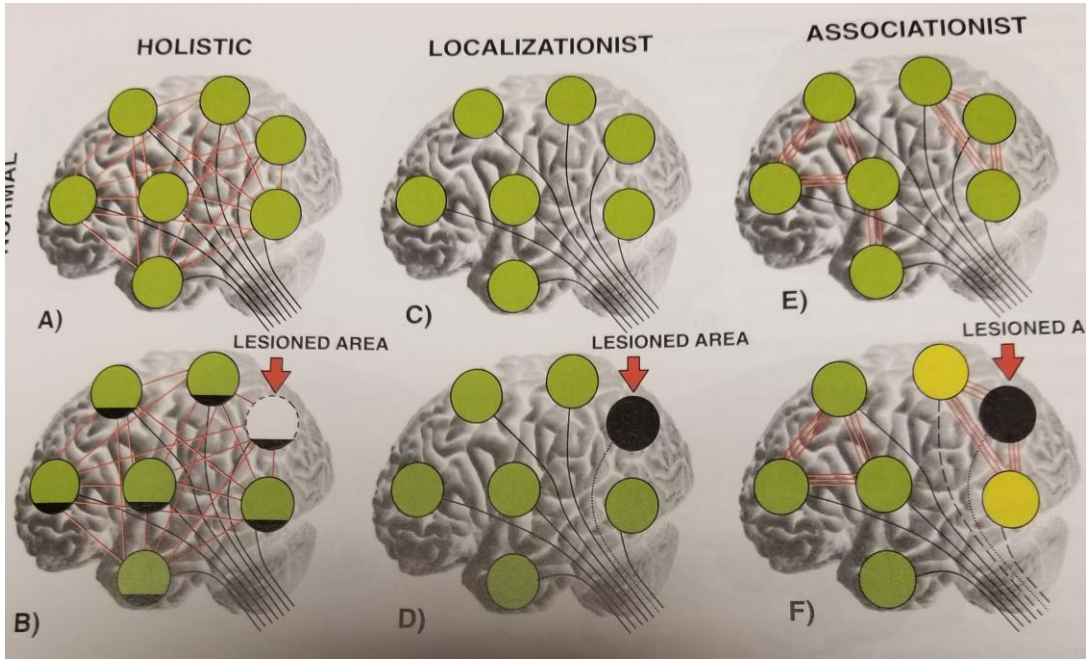
- Localizationist Models
  - Various functions are carried out by discrete independent regions
  - Damage to one area results in complete lost of the associated function



Brain Function Theories

- Associationist Models
  - Brain is organized into parallel distributed networks around cortical epicenters
  - Primary & motor functions are largely localized (blue areas)
  - Higher functions are distributed within large-scale networks (peach areas)

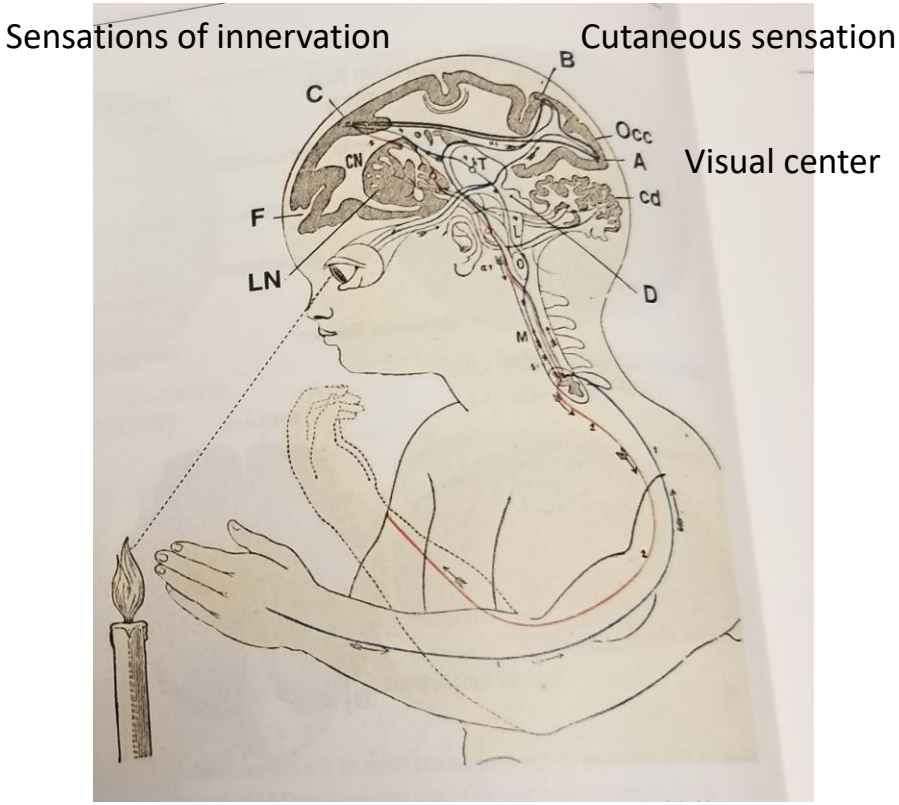
  - Lesion causes functional loss of the damaged area and partial dysfunction to connected regions



Neural Networks

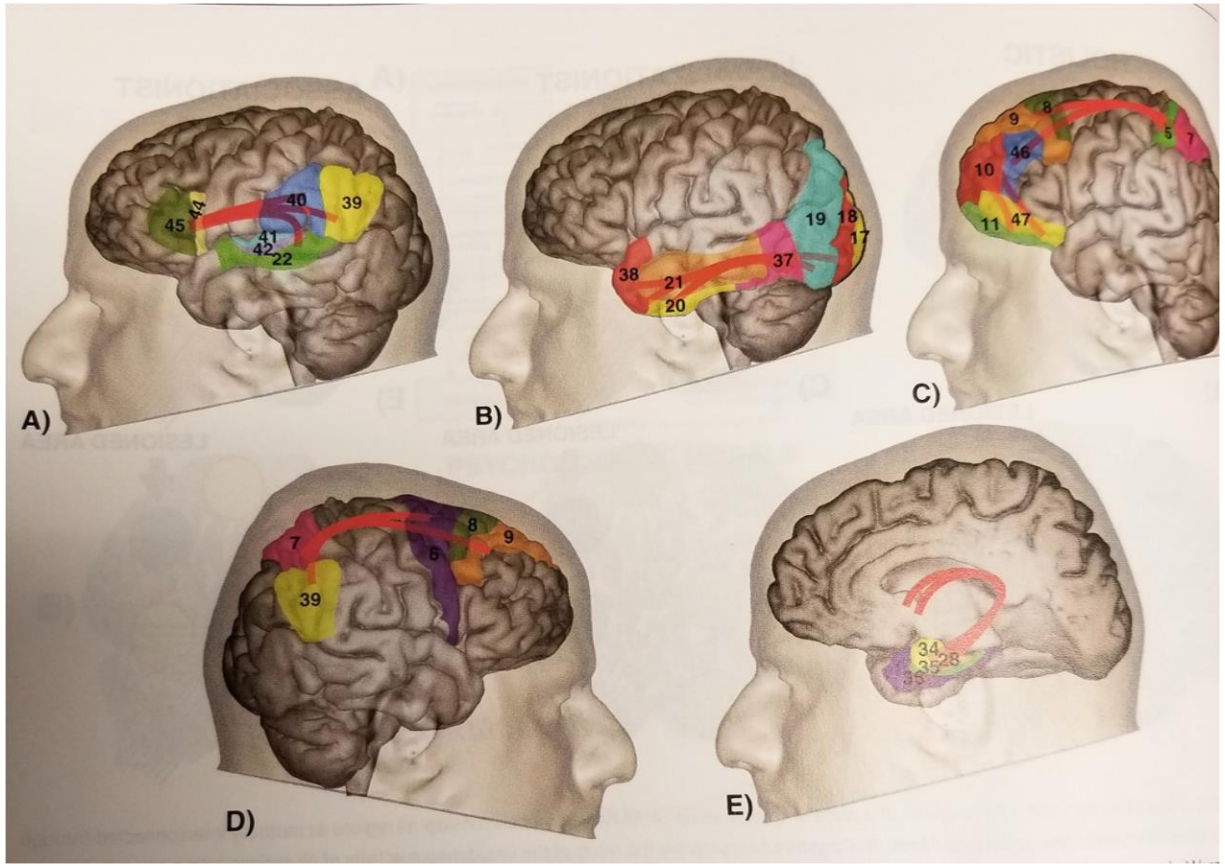
- Meynert (1885)

- Proposed a network involved in learning to avoid burning oneself
- Child touches a flame, the sensation of burning triggers a spinal reflex to withdraw the hand
- The sight of the flame, the pain experienced, and the hand withdrawal is then conveyed to cortical centers (A & B)
- Area C - believed to be an associative center convergence of sensory inputs & translation into motor planning
  - Just seeing a flame will trigger memory of the event -> avoiding flame in the future



Mesulam's Large-scale Networks

- A – Language Network connecting Broca's & Wernicke's
- B – Face-Object Identification Network connecting occipito-temporal & temporopolar regions
- C – Executive Function Network connecting lateral prefrontal, orbitofrontal, & posterior parietal cortex
- D – Spatial Attention Network connecting dorsal posterior parietal cortex, frontal eye field, & cingulate gyrus
- E – Memory-Emotion Network connecting hippocampal-entorhinal & amygdaloid complex



Pathways

- Association Fibers
  - Connect brain regions within a hemisphere
  - Play a role in language, visuo-spatial processing, memory, emotion, praxis
    - Praxis – enactment of a complex motor skill (apraxia - inability to perform learned /familiar movements on command)
- Commissural Fibers
  - Connect brain regions between hemispheres
- Projection Fibers
  - Connect cortex and subcortical regions

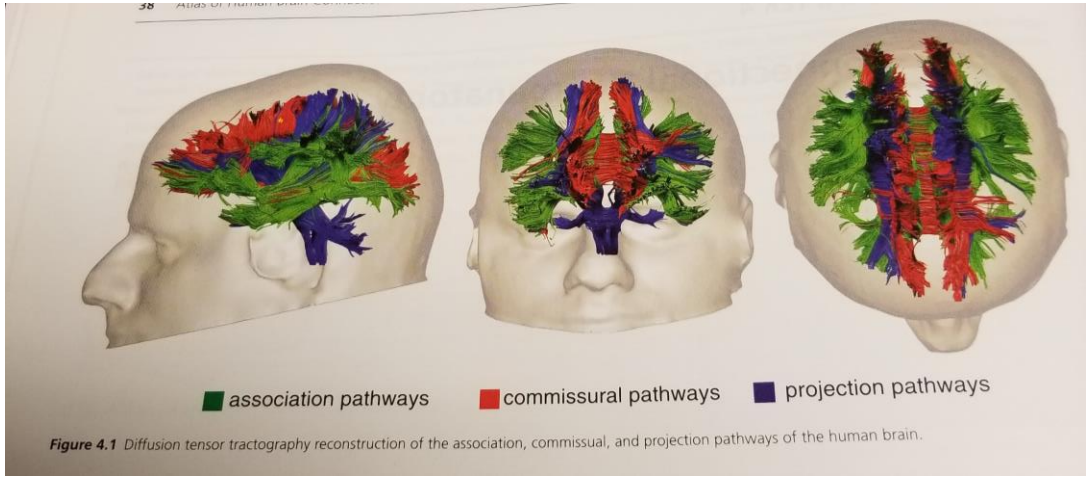
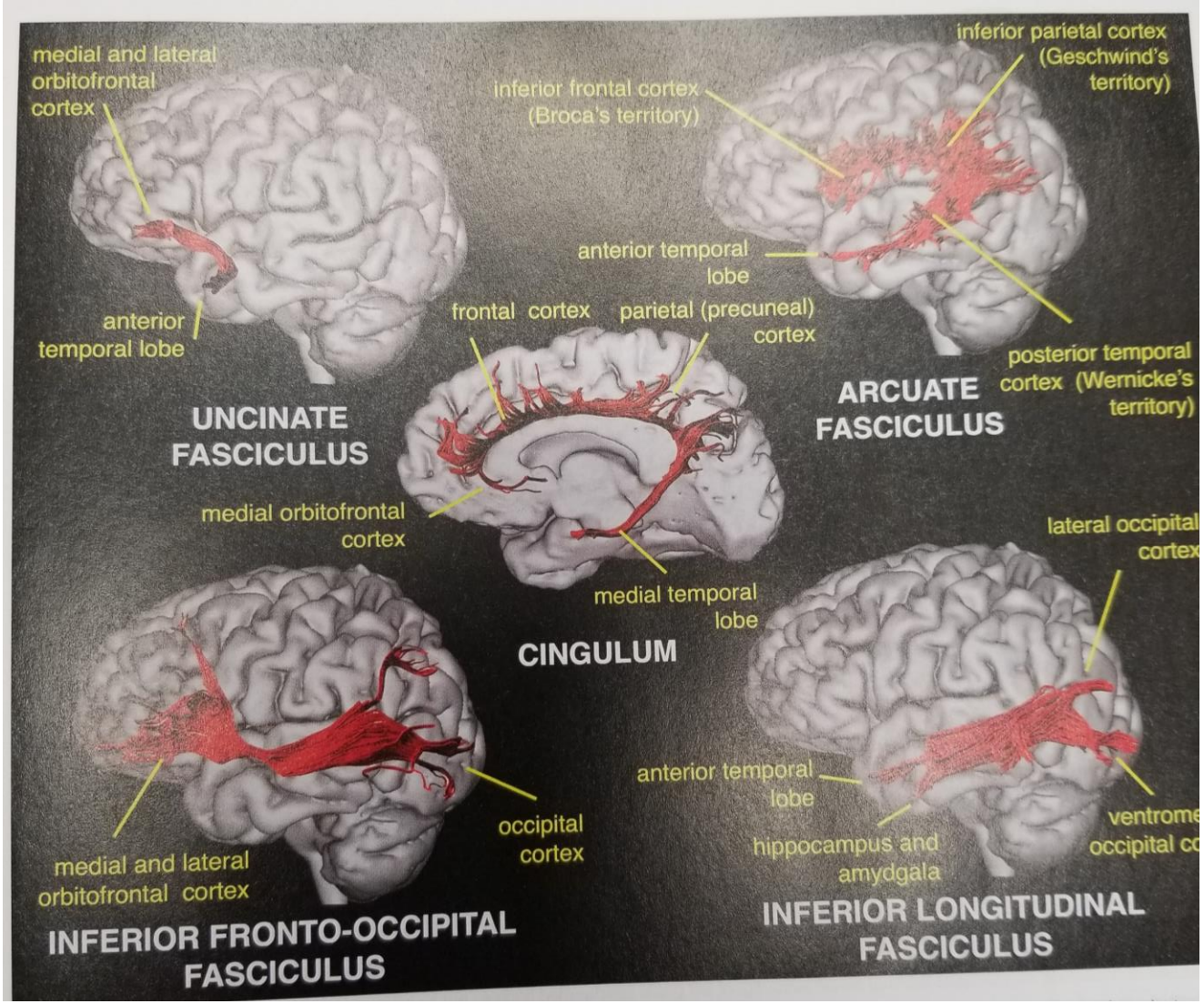


Figure 4.1 Diffusion tensor tractography reconstruction of the association, commissual, and projection pathways of the human brain.

Association Pathways

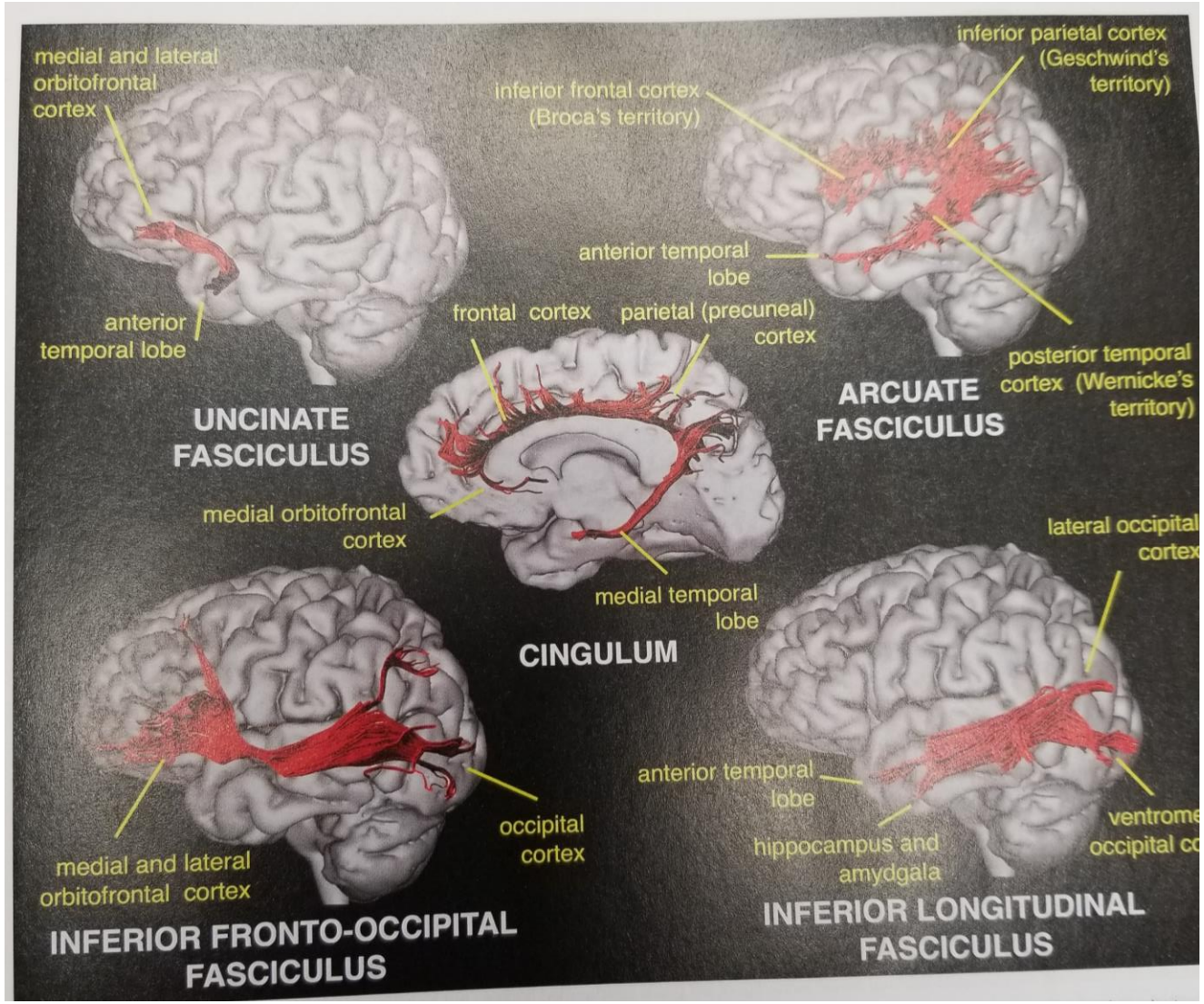
- Uncinate Fasciculus
  - Connects anterior temporal lobe with medial & lateral orbitofrontal cortex
  - Part of extended limbic system
  - Involved in memory, emotions, and language

- Arcuate Fasciculus
  - Left hemisphere connects Broca's & Wernicke's areas
    - Involved in language, praxis, and verbal working memory
  - Right hemisphere involved in visuospatial processing, prosody, semantics



Association Pathways

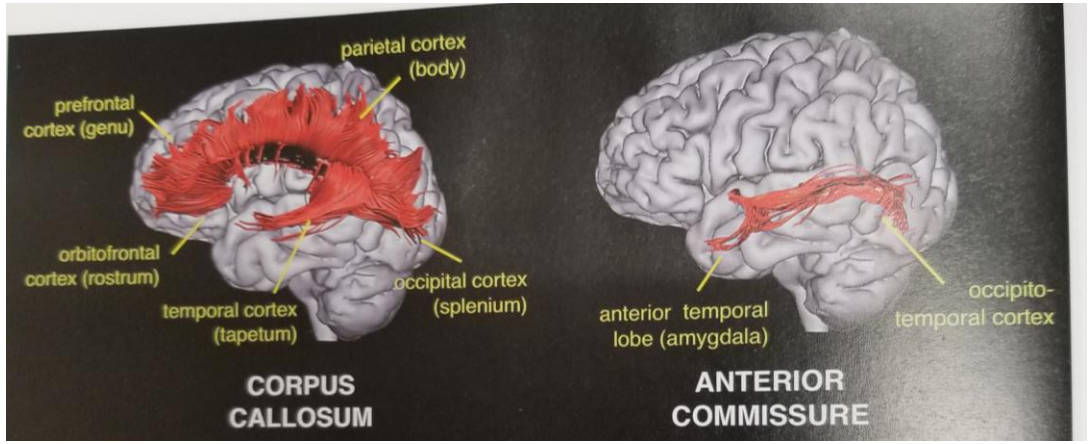
- Cingulum
  - Connects anterior temporal lobe to orbitofrontal cortex
  - Part of the limbic system
  - Involved in attention, memory, emotion
- Inferior Fronto-Occipital Fasciculus
  - May play a role in reading, attention, visual processing
- Inferior Longitudinal Fasciculus
  - Connects occipital and temporal lobes, connecting visual area to temporopolar, amygdala, and hippocampus
  - Plays a role in object & face perception, Reading, visual memory, and language



Commissural Pathways

- Corpus Collosum
  - Largest fiber tract connects the two hemispheres
  - Anterior portion (Genu)- connects prefrontal & orbitofrontal regions
  - Ventral portion (Body) connects precentral frontal & parietal regions
  - Posterior portion (Splenium) connects occipital lobes

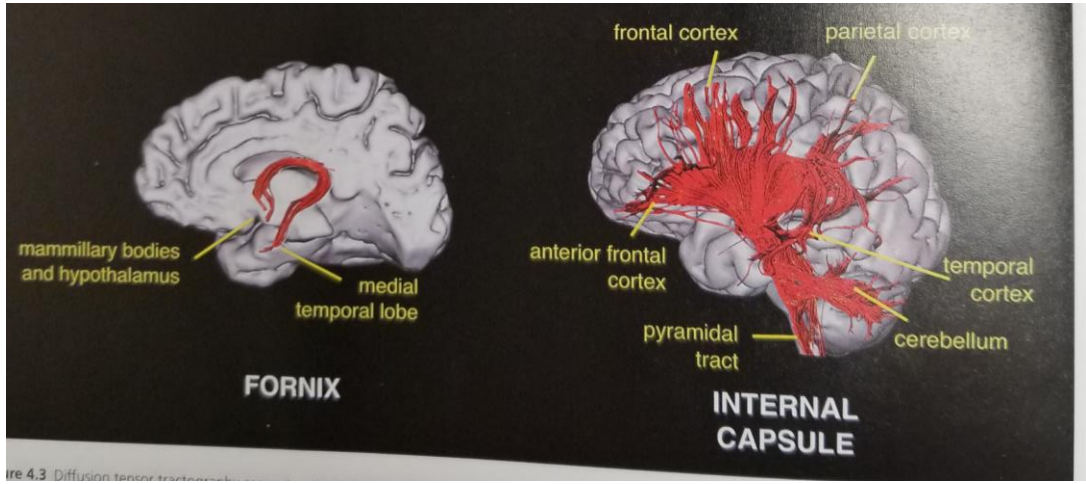
- Anterior Commissure
  - Connects the ventral temporal lobes, amygdala, and olfactory bulbs



Projection Pathways

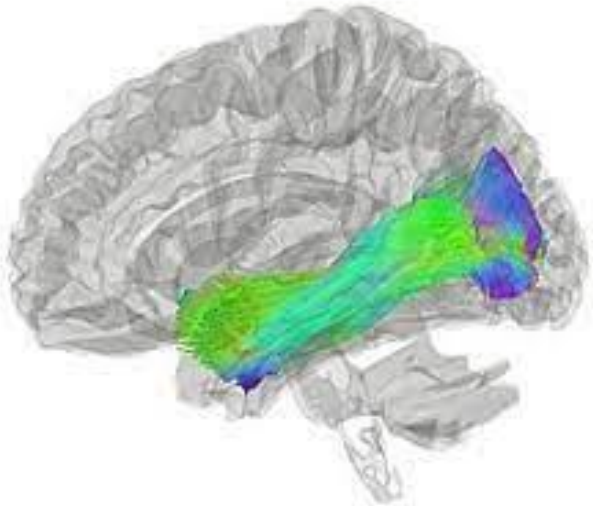
- Fornix
  - Connects medial temporal lobes, hippocampus, mamillary bodies, & hypothalamus
  - Part of the limbic system involved in memory

- Interior Capsule
  - Contains ascending fibers from the thalamus
  - Descending fibers from fronto-parietal cortex to subcortical nuclei including basal ganglia, brain stem, & spinal cord
  - Conveys sensory information to the cortex and control movement



Pathway Disorders

- Auditory hallucination in Schizophrenia
  - Hyperfunction locally in Broca's & Wernicke's but hypoconnectivity between them
- Visual Hypoemotionality
  - Visual-limbic disconnection affecting the inferior longitudinal fasciculus fibers
- Unilateral Neglect
  - Lesion of inferior parietal cortex, inferior frontal lobe, superior temporal cortex, occipital lobe connecting tracts

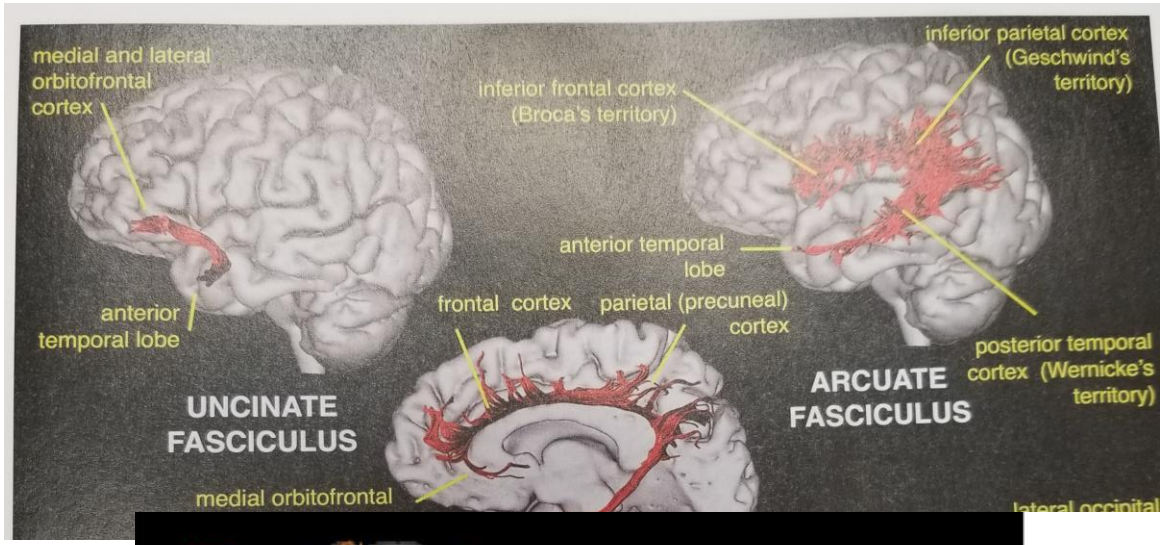


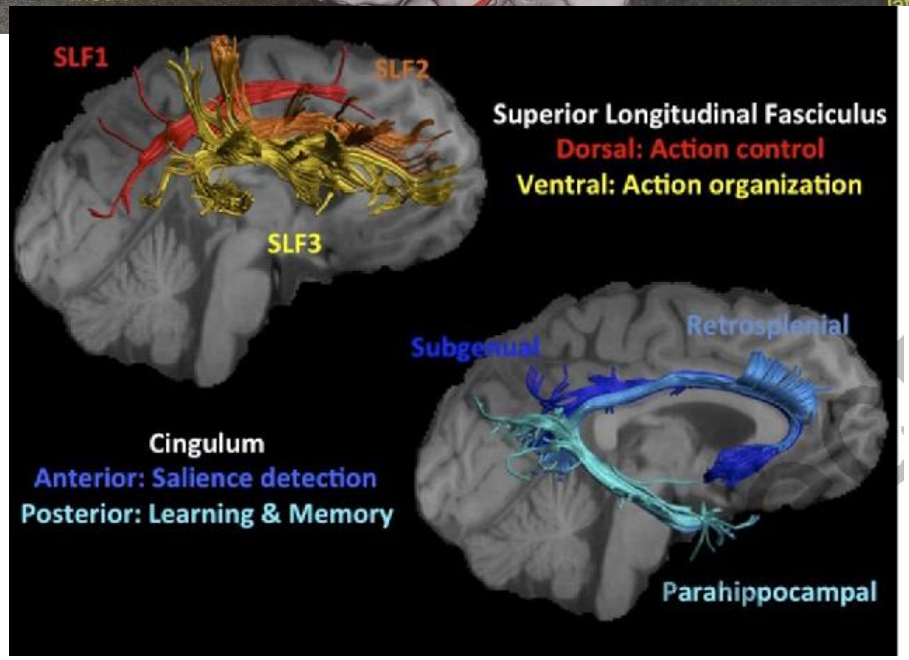
Pathway Disorders of Frontal Lobe

- Motor Syndrome
  - Lesions to primary motor cortex & its connections -> contralateral motor deficits of limbs or face
  - Lesion to arcuate fasciculus -> ability to execute learned purposeful movements
  - Lesions to frontal eye field and its connections -> gaze abnormalities
  - Lesions to medial frontal lobe and its callosal connections -> anarchic hand syndrome
    - one hand acts autonomously as if having its own will
  - Abnormalities along the precentral region can cause Jacksonian march
    - Partial seizure with succession of involuntary movements of fingers and arm as epileptic activity spreads along the motor homunculus

Pathway Disorders of Frontal Lobe

- Cognitive Syndrome
  - Dorsolateral prefrontal cortex connected to parietal cortex, temporal lobe, and basal ganglia by the cingulum, superior longitudinal fasciculus, arcuate fasciculus, and internal capsule
  - Lesions to dorsolateral
    - Memory deficit
    - Poor serial motor sequencing
      - Response inhibition
      - Abstract thinking
      - Goal-directed behavior (planning, rule learning, hierarchical organization, switching)
    - Easily distractable
    - Slowed mental flexibility





Pathway Disorders of Frontal Lobe

- Abulic Syndrome
  - Medial prefrontal cortex is connected to medial parietal, occipital, and temporal lobe by the cingulum and superior longitudinal fasciculus
  - Lesions manifest in apathy, loss of motivation, reduced goal-directed behavior, reduced ability to sustain effort

- Behavioral Syndrome
  - Orbitofrontal cortex is connected to the anterior temporal and ventral temoro-occipital cortices via uncinate and inferior fronto-occipital fasciculi
  - Medial portion of orbitofrontal connected to dorsolateral prefrontal via cingulum
  - Lesions manifest in personality changes, disinhibition, social inappropriateness, sexual preoccupation
    - Automatic imitate examiners movements without being told to do so
    - Reduced empathy, impulsivity, distractibility, depression, mania

Pathway Disorders of Parietal Lobe

- Disorders of Somatosensory and Tactile Function
  - Post-central gyrus (primary somatosensory) connected to thalamus
  - Lesions -> impaired pain sensation, temperature touch, vibration
    - May feel tingling, burning, numbness, pins & needles
    - Altered proprioception (ability to detect joint motion & limb position)

- Disorders of Motility
  - Parietal regions connect with occipital lobe & frontal lobes via superior longitudinal and arcuate fasciculus
  - Lesions of precuneus & superior parietal lobe may manifest as uncoordinated movements that lack speed, smoothness, appropriate direction
    - Inability to carry out complex visually guided movement, skilled movements, tool use
    - Unable to put together one- or two-dimensional objects

Pathway Disorders of Parietal Lobe

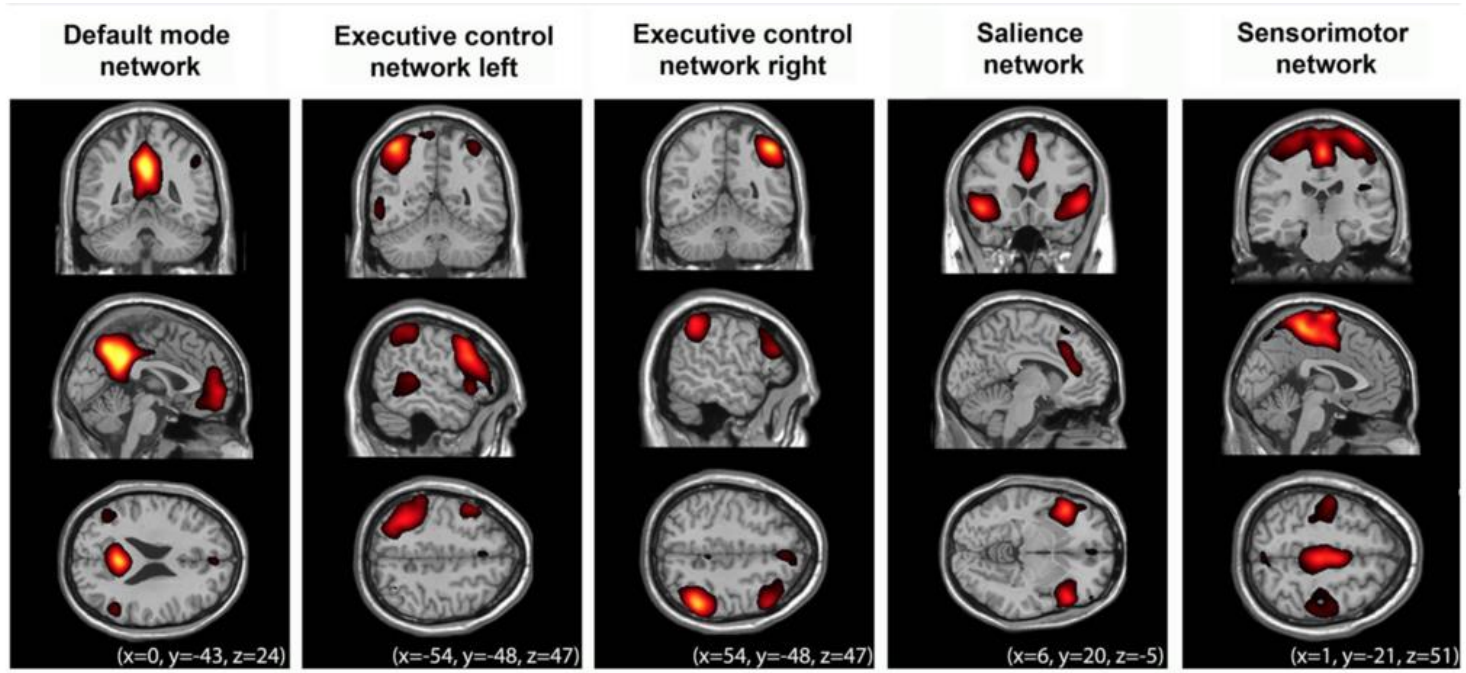
- Disorders of Spatially guided Attention – neglect

- Disorders of Symbolic Thought and Memory
  - Impaired manipulation of numbers in mathematical operations, impaired reading, writing

- Complex Visual Defects
  - Inability to recognize objects or scenes, derealization, out-of-body experiences
  - Balint syndrome (asomatognosia) optic ataxia

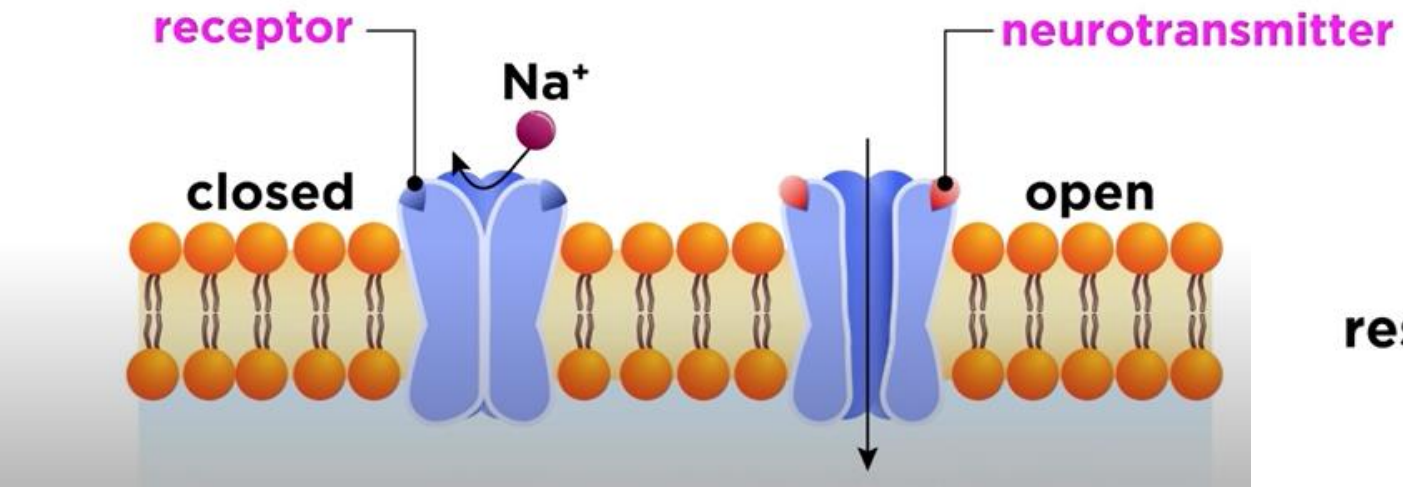
Thank You

(27) Neural Conduction, Action Potential, and Synaptic Transmission - YouTube


Default mode network
Executive control network left
Executive control network right
Salience network
Sensorimotor network
(x=0, y=-43, z=24)
(x=-54, y=-48, z=47)
(x=54, y=-48, z=47)
(x=6, y=20, z=-5)
(x=1, y=-21, z=51)

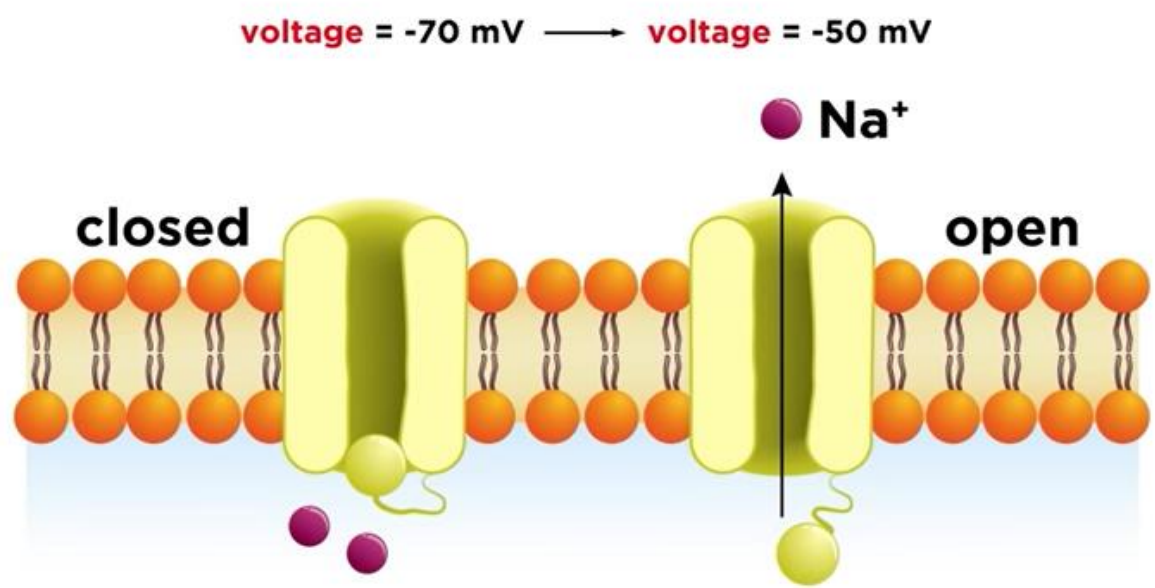
ligand-gated channels

open when a specific neurotransmitter binds



voltage-gated channels

respond to changes in membrane potential



Action Potential/ Neural Transmission