Movement & Sensory Processing

SPICE 2024

Neuroscience & Computational Psychiatry Module

Class V

3rd of July 2024

Mount Sinai

Center for Computational Psychiatry

Sensory processing - taste

- **Chemical consistency & taste**: The raw sensory data detected by taste buds and touch receptors in the mouth.
- **Perception**: The brain interprets and organizes sensory input, creating a unified experience of flavor.
- **Thought**: Higher-order cognitive processes analyze the flavor experience, triggering memories, emotions, and judgments.

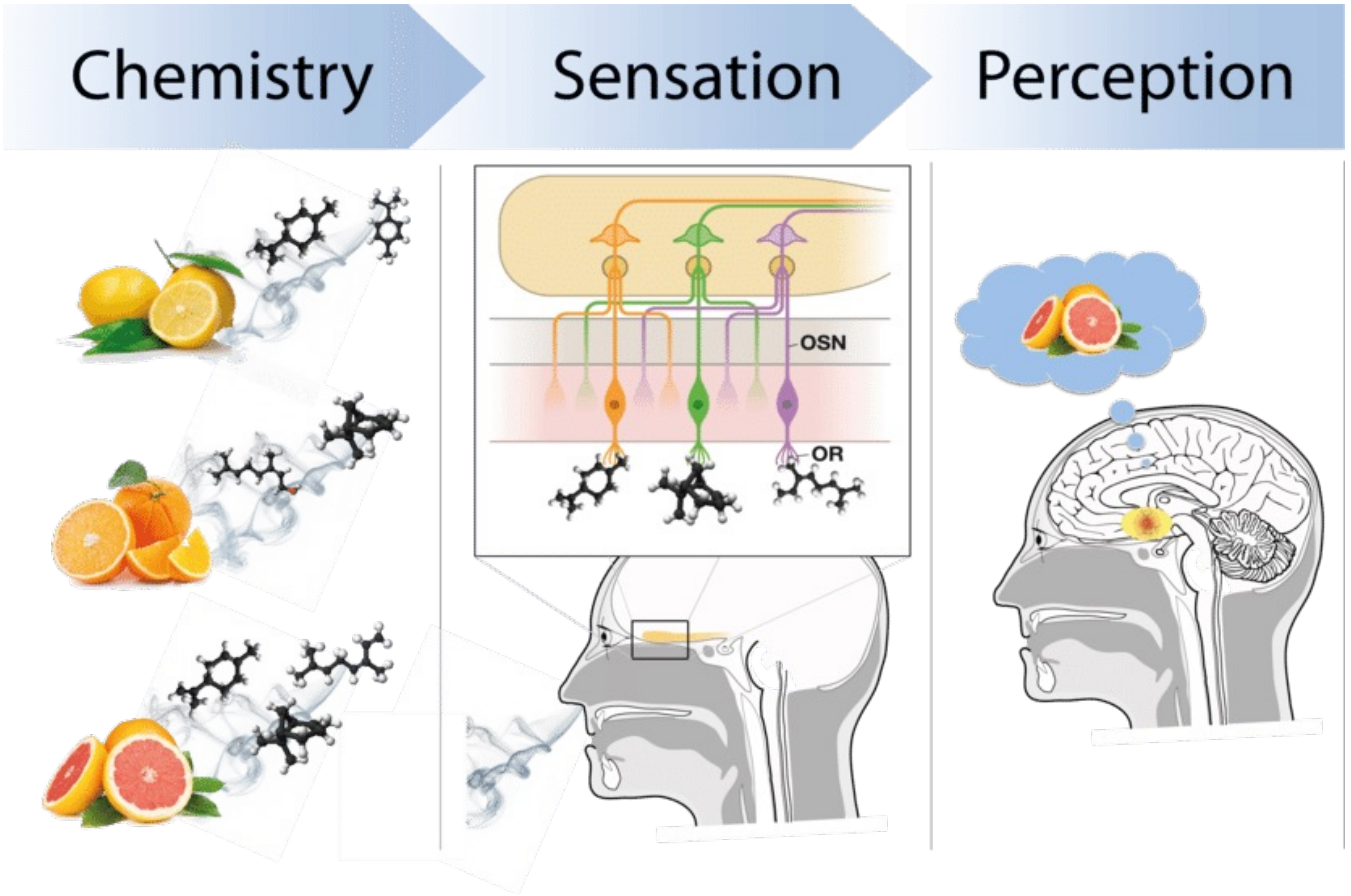


Image: Fiaeldstad, Petersen, & Oversen (2017)

Sensory processing (e.g., olfactory pathway)

- **Sensory receptors**: Specialized cells that detect stimuli like light, sound, touch, temperature, and chemicals.
- **Sensory transduction**: Conversion of stimuli into electrical signals by receptors.
- **Sensory pathways**: Routes of information from receptors to the brain (thalamus as relay station).
- **Sensory coding:** Brain's interpretation of stimulus intensity, duration, and location.
- **Perception**: Organization and interpretation of sensory information to create meaningful experiences.

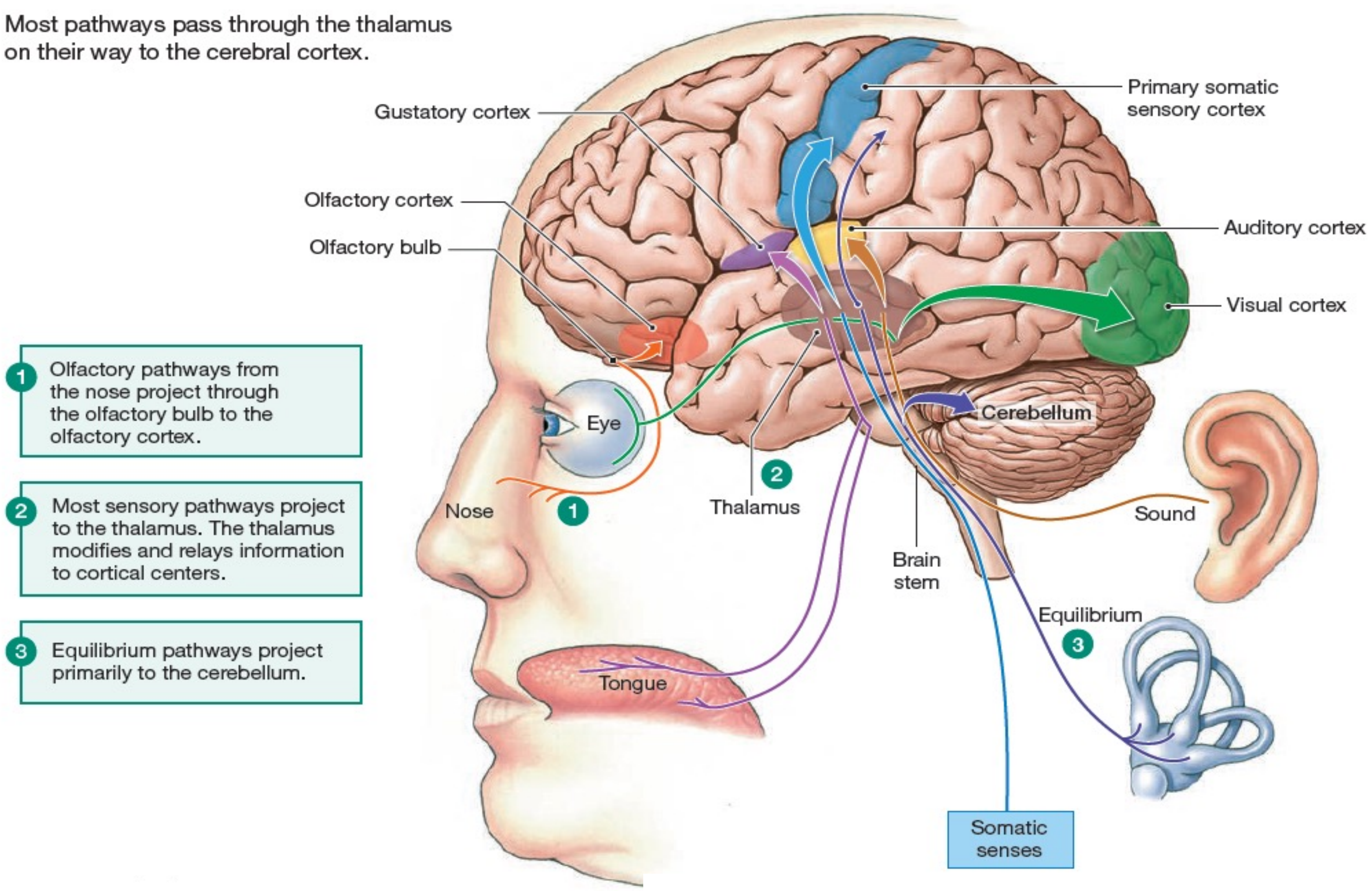
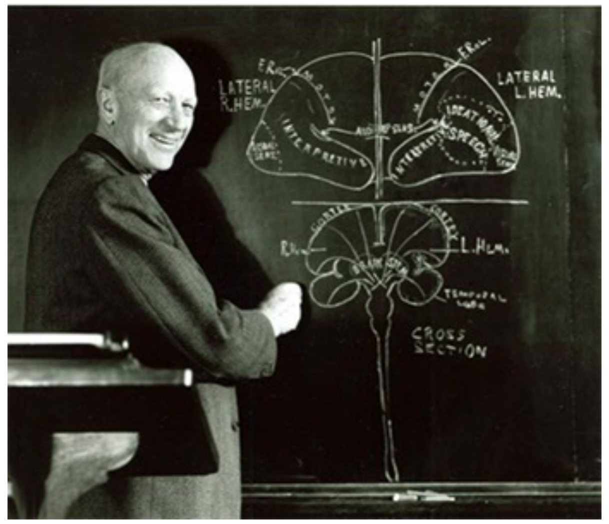


Image: scientistcindy.com

Sensory processing – touch & sensation

- Somatosensory system, a network of neural structures in the brain and body that produce the perception of touch, as well as temperature, body position, and pain (nociception)
- Paty of the sensory system
- Somatosensory cortex posterior to the central sulcus
- Topographical representation pf the homunculus arranges in an anatomical fashion



Wilder Penfield

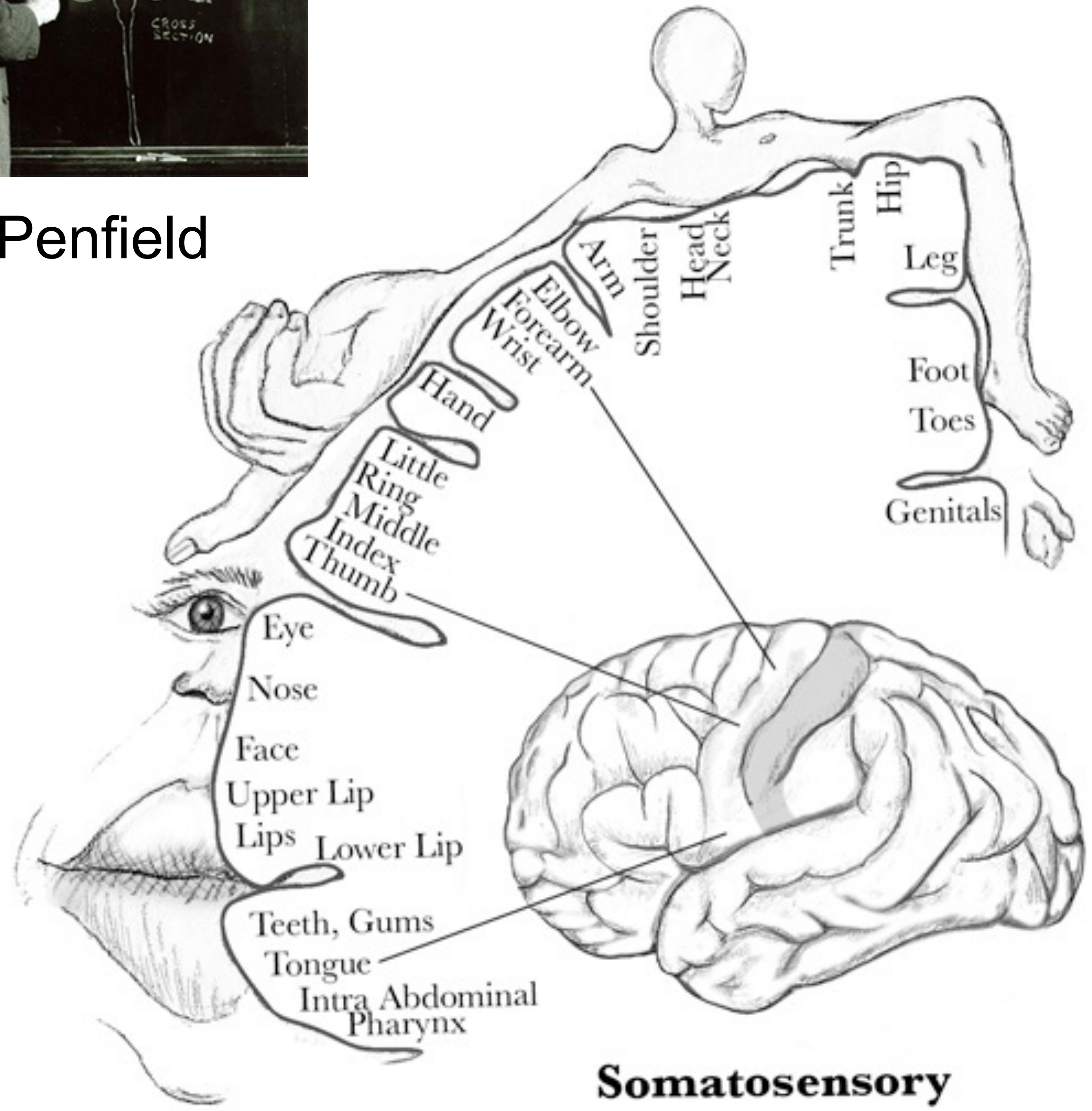


Image: EMB Consult

Sensory & motor integration

- **Sensorimotor integration**: The interplay between sensory input and motor output.
- **Reflexes**: **Automatic responses** to sensory stimuli (via the spinal cord as a control centre)
- **Voluntary movements**: Consciously controlled actions.
- **Motor learning and adaptation**: Modification of motor programs through practice and experience.
- **The Feedback Loop**: Sensory information informs motor planning and execution

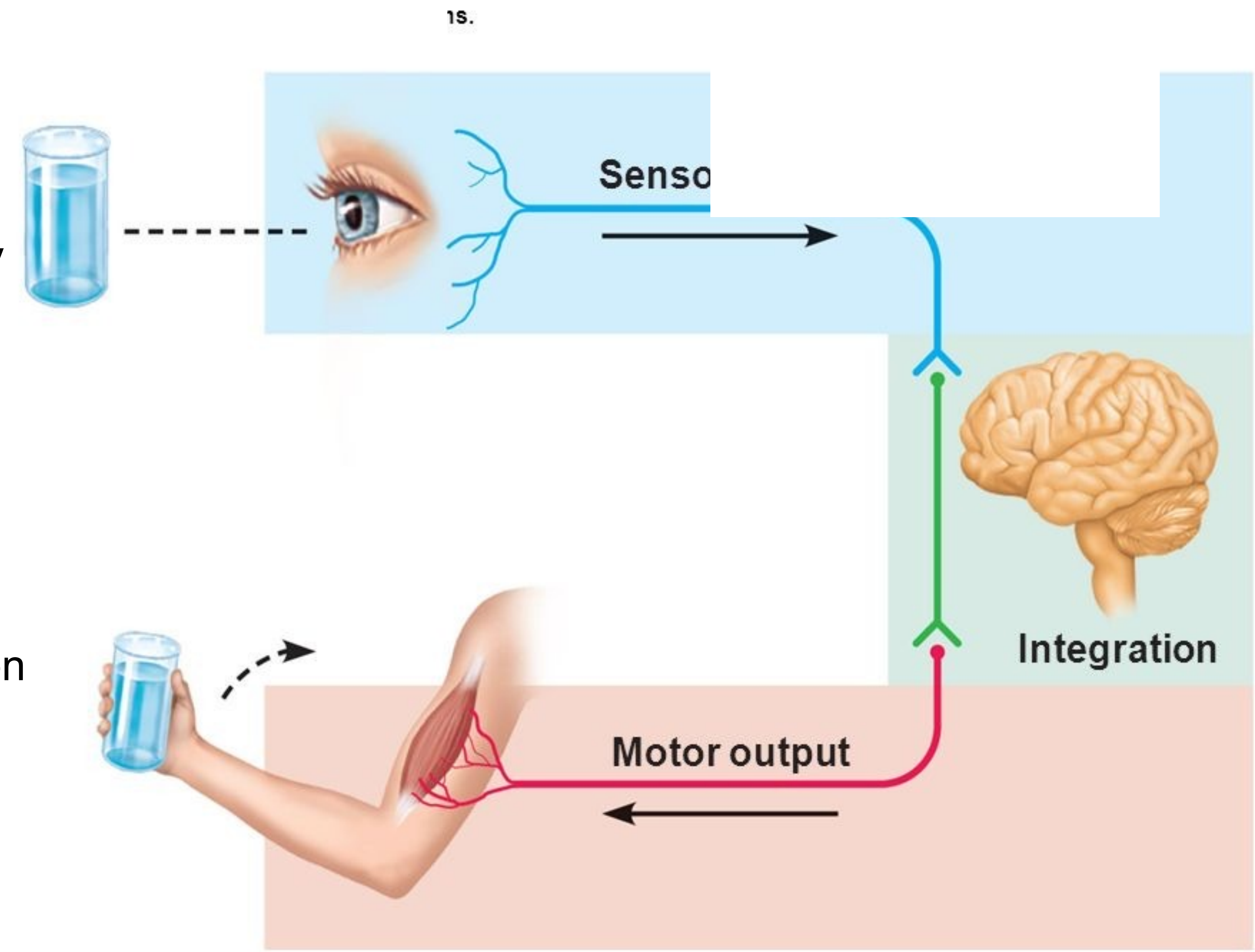


Image: Pearson Education 2010

Precision in motor coordination

- **Motor neurons and pathways**: Transmission of signals from the brain to muscles for movement.
- **Types of motor control**: Voluntary (conscious) and involuntary (reflexive) movements.
- **Motor cortex**: Planning and initiation of voluntary movements.
- **Basal ganglia and cerebellum**: Fine-tuning movement, coordination, balance, and skill learning.
- **Proprioception**: Sensory feedback that allows the brain to monitor and adjust movement.

Motor system

- **Motor Cortex:** The motor cortex is crucial for initiating and planning voluntary movements.
  - **Primary Motor Cortex**: Directly controls muscle contractions.
  - **Premotor Cortex**: Involved in the planning and preparation of movements.
  - **Supplementary Motor Area**: Coordinates complex movements and sequences.

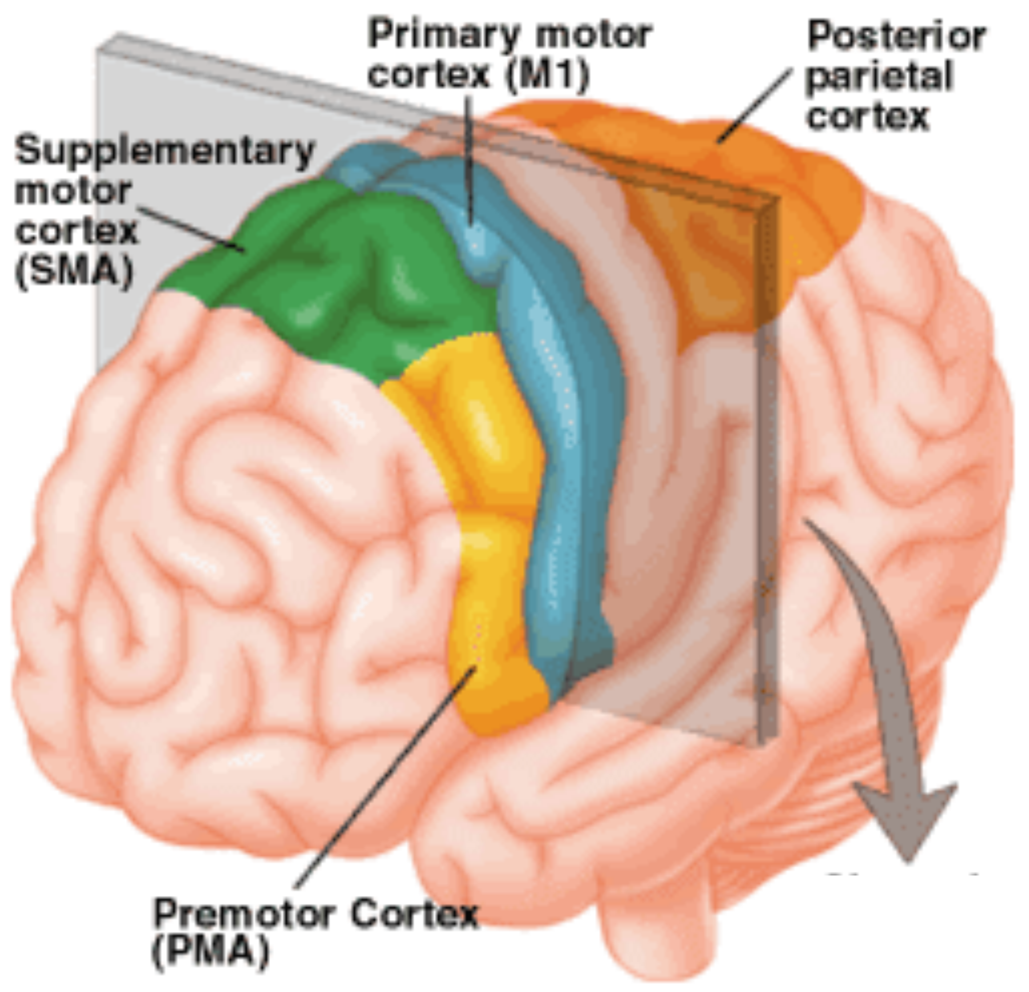


Image: BrainHQ

Motor system - the homunculus

- Primary motor cortex is somatotopically organized
- Different regions control different body parts.
- Areas controlling precise movements (hands, face) are larger.

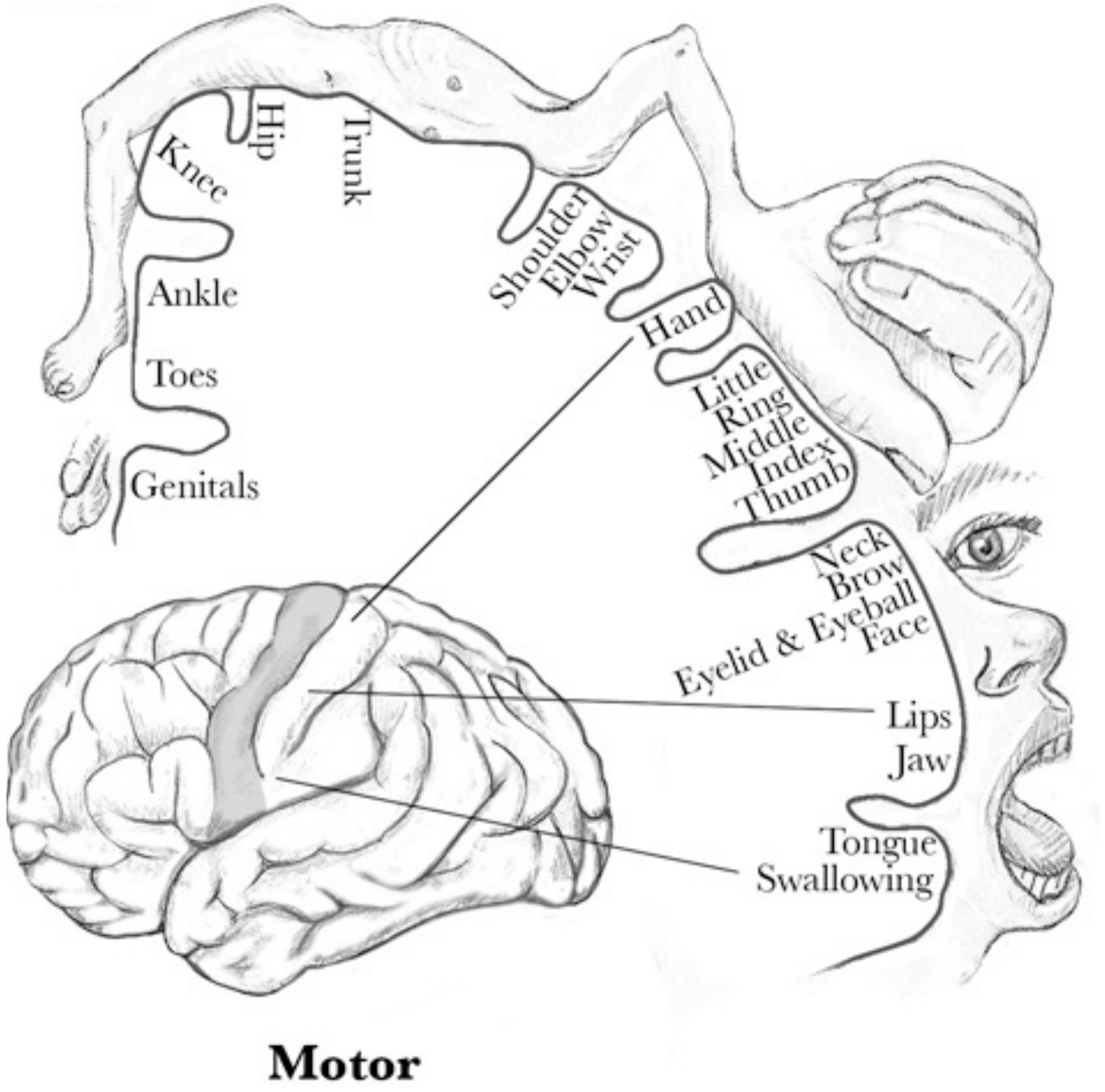


Image: EMB Consult

Motor system – two pathways

Motor Pathways: Connect brain to muscles for voluntary movement

- **Corticobulbar Tract**:

  Motor cortex → Brainstem → Cranial Nerves

  - Controls muscles of face, head, neck
  - Functions: Facial expressions, speech, swallowing

- **Corticospinal Tract**:

  Motor cortex → Spinal Cord → Spinal Nerves

  - Controls muscles of limbs and trunk
  - Divided into lateral (limbs) and anterior (trunk) tracts

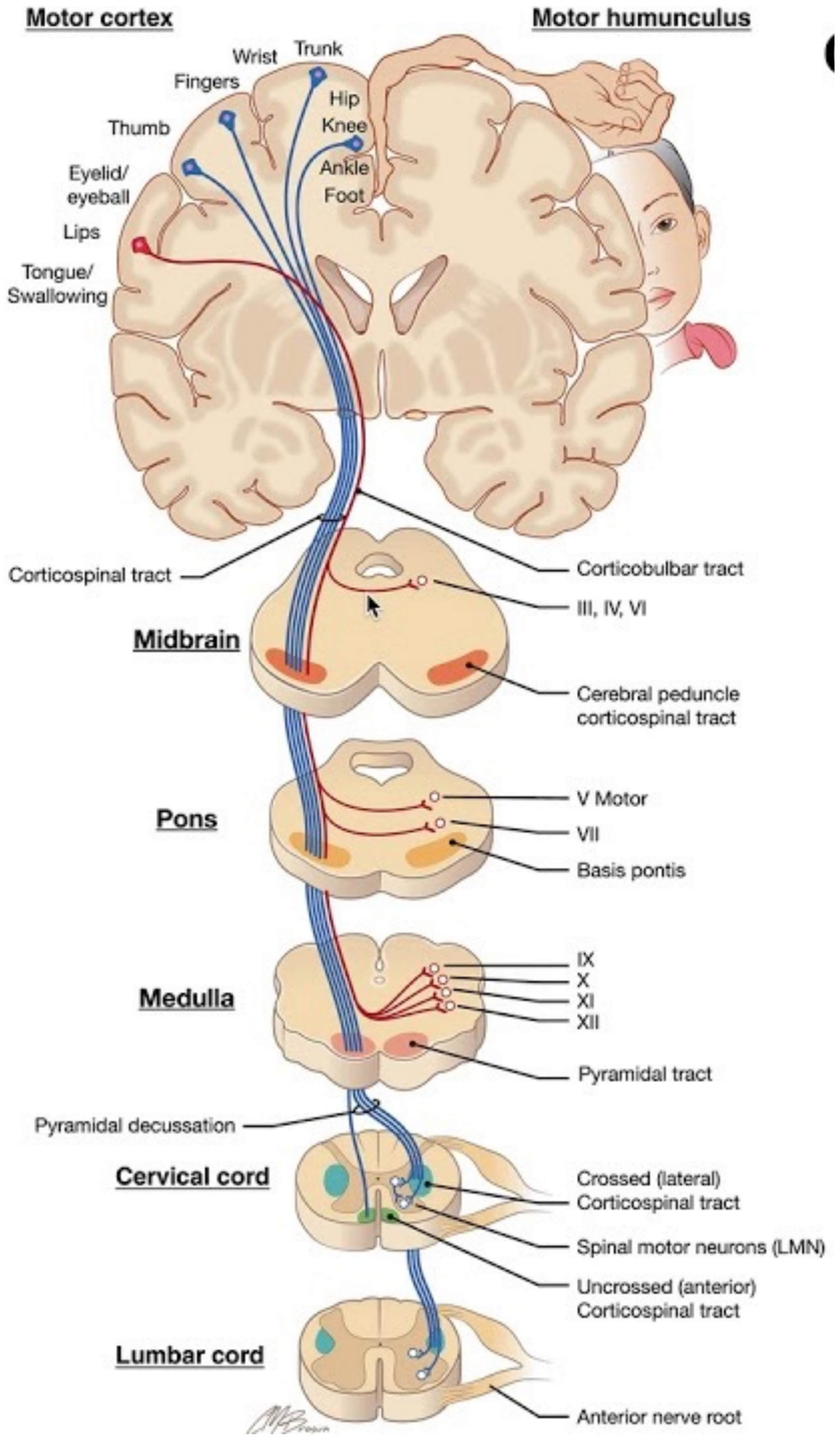
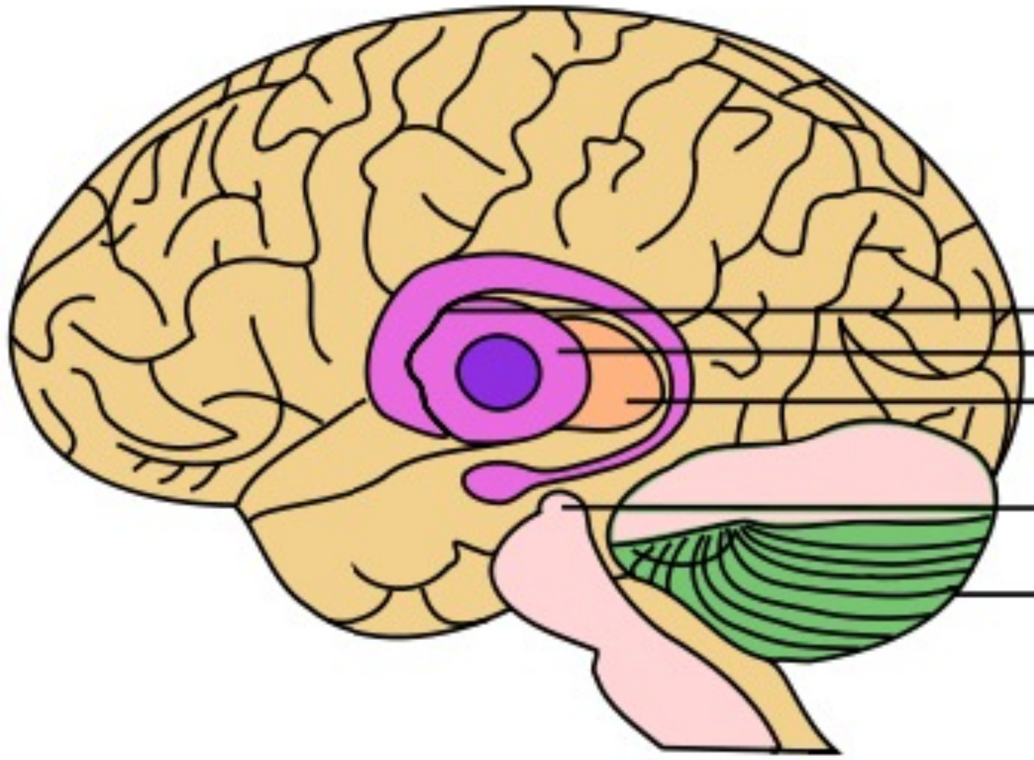


Image: Markand, O.N. (2020)

Motor system – the basal ganglia

- **Basal Ganglia**: Initiates and regulates voluntary movements, maintains muscle tone, and suppresses unwanted movements.
- **Substantia Nigra**: Crucial component of the basal ganglia, produces dopamine, a neurotransmitter vital for smooth movement.
- **Thalamus**: Acts as a relay station, filtering and directing sensory and motor information between the brain and the body.
- **Cerebellum**: Coordinates and fine-tunes movement, ensuring precision and balance.

Basal Ganglia and Related Structures of the Brain



Motor system – Basal Ganglia Direct Pathways

- **Facilitates movement:** accelerator, increasing thalamic activity, which leads to increased excitation of the motor cortex and promotes movement initiation.
- **Key structures:** Striatum (caudate nucleus and putamen), internal globus pallidus (GPi), and substantia nigra pars compacta (SNc).
- **Neurotransmitters:**
  - Striatum releases GABA (inhibitory) onto GPi.
  - SNc releases dopamine (excitatory) onto striatum, modulating its activity.
- **Net effect:** Disinhibition of the thalamus, leading to increased cortical excitation and movement.

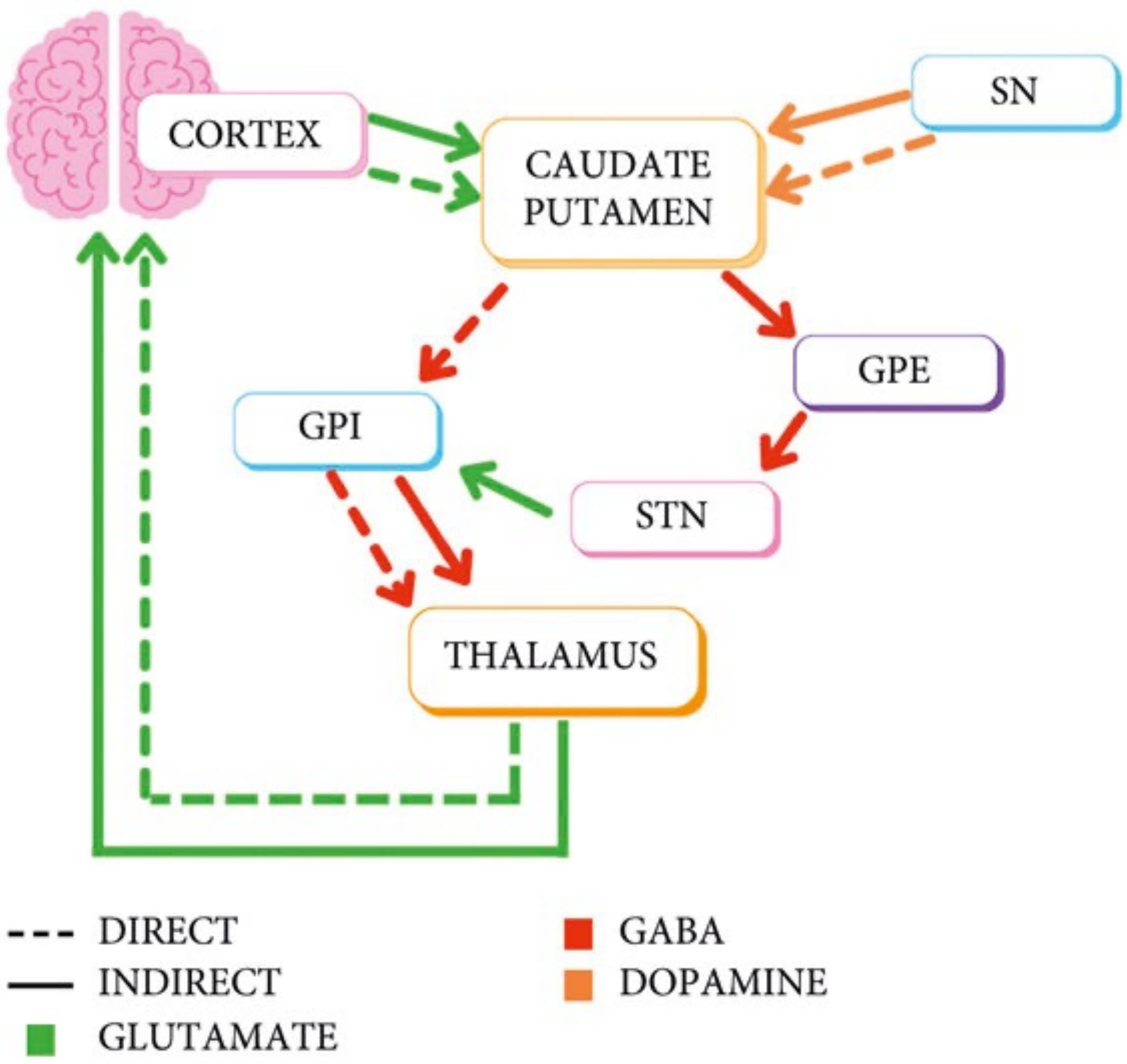


Image: Audi, Cunningham & Newey (2023)

Motor system – Basal Ganglia Indirect Pathways

- **Inhibits movement:** acts like a brake, decreasing thalamic activity, which reduces excitation of the motor cortex and suppresses unwanted movements.
- **Key structures:** Striatum (caudate nucleus and putamen), external globus pallidus (GPe), subthalamic nucleus (STN), and internal globus pallidus (GPi).
- **Neurotransmitters:**
  - Striatum releases GABA (inhibitory) onto GPe.
  - GPe releases GABA (inhibitory) onto STN.
  - STN releases glutamate (excitatory) onto GPi.
  - GPi releases GABA (inhibitory) onto thalamus.
- **Net effect:** Increased inhibition of the thalamus, leading to decreased cortical excitation and movement suppression.

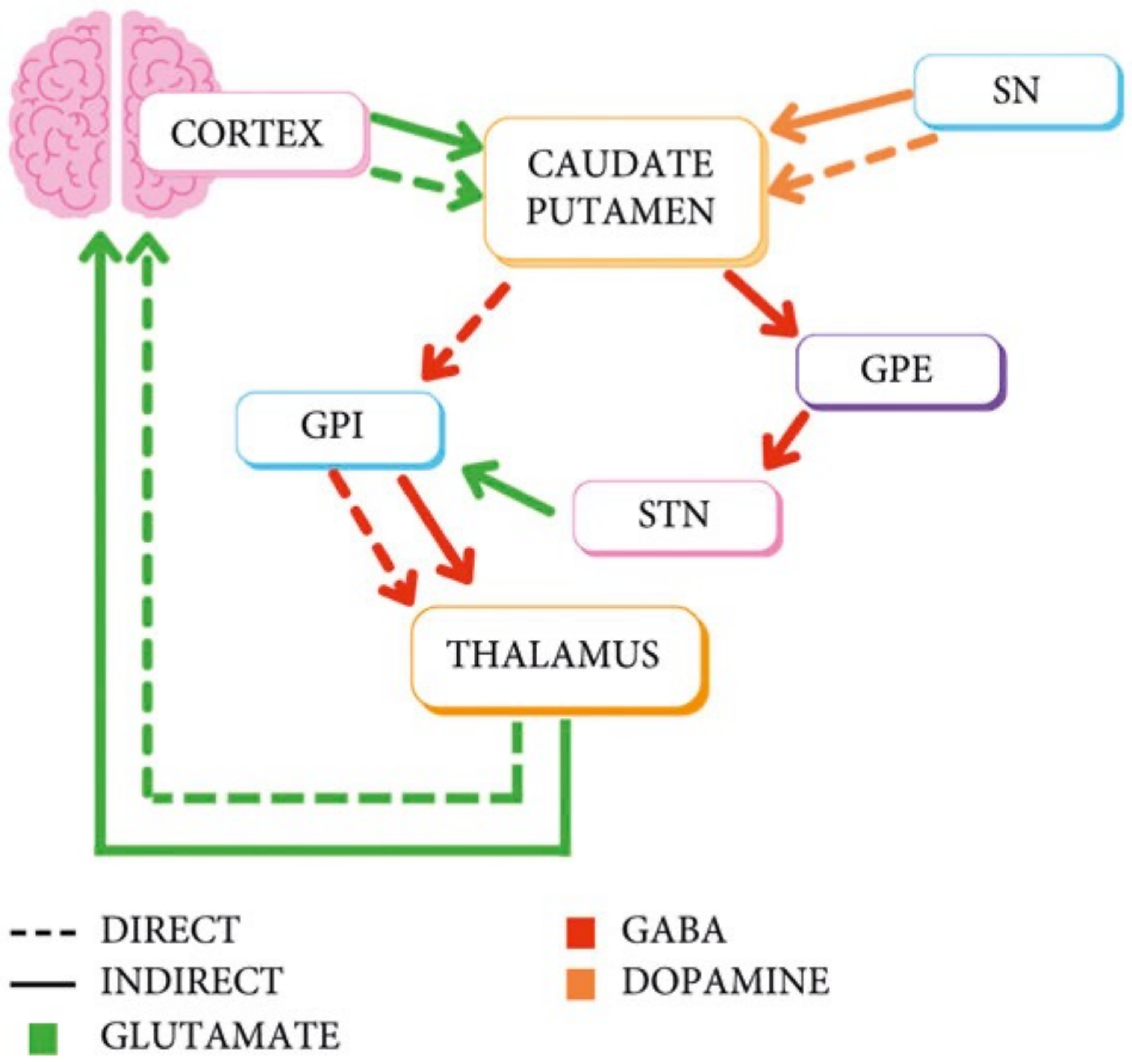


Image: Audi, Cunningham & Newey (2023)

Motor system – Basal ganglia pathways an intricate balance

- **Balance is key:** The optimal functioning of the motor system relies on a delicate balance between the direct and indirect pathways.
- **Direct pathway dominance:** Facilitates movement initiation and execution.
- **Indirect pathway dominance:** Suppresses unwanted movements and refines motor control.
- **Dysfunction and movement disorders:** Imbalance in these pathways can lead to various movement disorders, such as Parkinson's disease (hypokinetic due to decreased direct pathway activity) and Huntington's disease (hyperkinetic due to decreased indirect pathway activity).

Disruptions to the motor system

- Damage to the corticobulbar tract of one side anywhere (between precentral gyrus to the motor nucleus of the facial nerve) results in paralysis of muscles of the opposite lower half of the face.
- In **multiple sclerosis (MS**), the immune system attacks the myelin sheath protecting nerve fibers in the corticospinal tract
  - This damage leads to motor impairments such as muscle weakness, spasticity, ataxia, and gait abnormalities.
- **Parkinson's** disease is associated with damage to the substantia nigra, a region in the basal ganglia responsible for producing dopamine.
  - Dopamine deficiency disrupts communication within the basal ganglia and other brain regions, leading to motor symptoms in PD.

Disruptions to the motor system – deep brain stimulation (DBS)

- **DBS:** A surgical treatment that involves implanting electrodes in specific areas of the basal ganglia (e.g., STN or GPi).
- **Mechanism of Action:** DBS delivers electrical impulses that disrupt abnormal activity patterns in the basal ganglia.
- **Impact on PD:** DBS can significantly reduce motor symptoms like tremor, rigidity, and bradykinesia in individuals with PD, improving their quality of life.

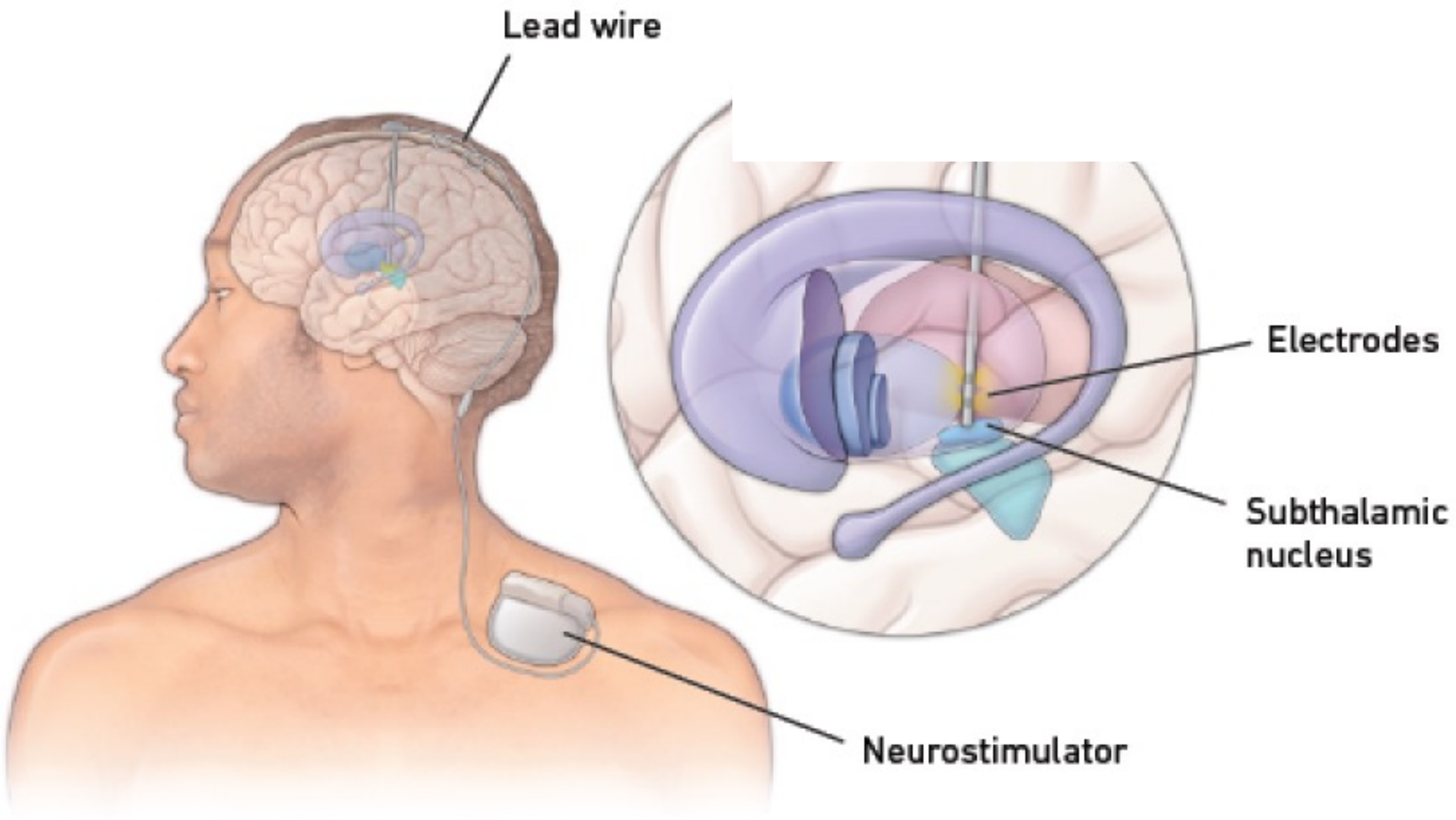
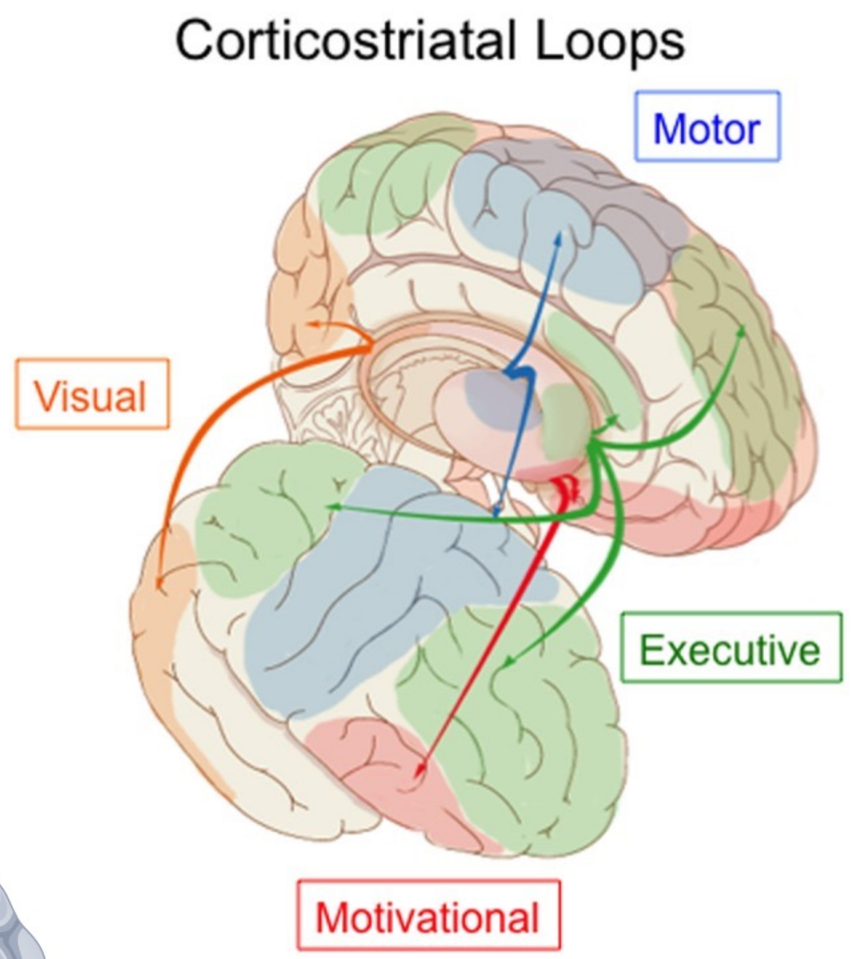
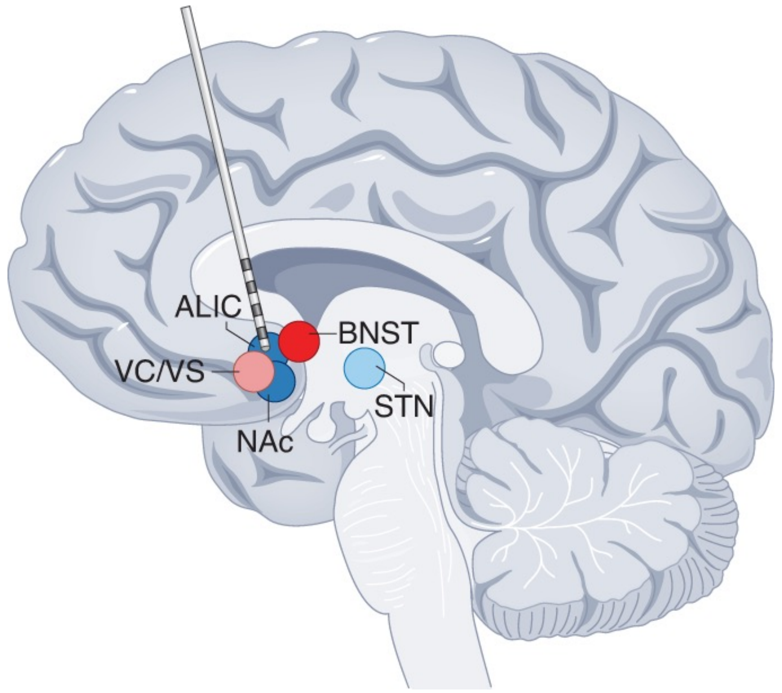


Image: Temple Health

Disruptions of the fronto-striatal loops – deep brain stimulation for OCD

- **Normalization of Circuit Activity:** OCD is thought to involve overactivity in certain brain circuits. DBS may help normalize this activity, reducing obsessions and compulsions.
- **Modulation of Neurotransmitters:** DBS may influence the release and uptake of neurotransmitters like serotonin and dopamine, which play a role in mood regulation and reward processing.





Images: Visser-Vandewalle et al., (2022) ; Segel & Miller (2010)

Thank you!

Any Questions?

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HAPPY 4TH OF JULY!

Next Class:

Monday the 8th of July

10:00am-11:00am