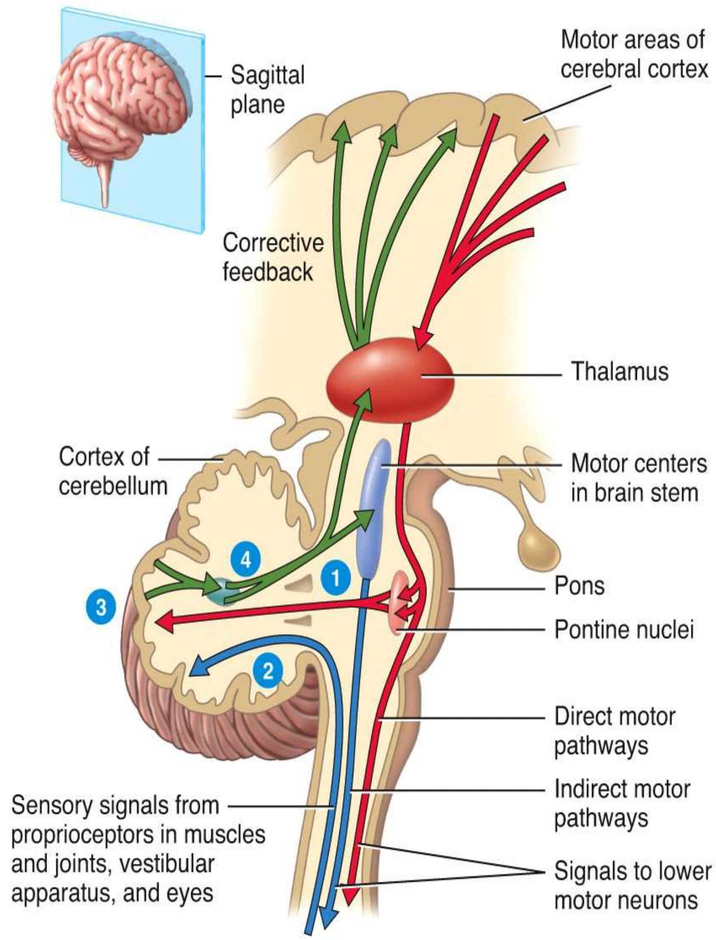
Chapter 14.5

Motor Control



Sagittal section through brain and spinal cord

Motor Control Is An Example of a Higher Brain Function

- Motor control describes how we regulate our skeletal muscles

- Motor control requires bidirectional neural networks to connect the <u>cerebral cortex, basal nuclei, cerebellum, and nuclei in brainstem</u>

- Central pattern generators in the anterior horn also play a role in regulating the sequential contraction of skeletal muscles

  - central pattern generators are also called local motor neurons

  - these nuclei control groups of skeletal muscle (e.g. regulate the muscle contraction which occur during walking)

  - CPG are located in the spinal cord's anterior horns

Motor Control
Intent VS Performance

- The thought to contract a skeletal muscle originates in the prefrontal cortex
  - prefrontal cortex will send an action potential that eventually ends up in the precentral gyrus (i.e. motor strip) by way of the motor association area in the frontal lobe, basal nuclei, and thalamus.
  - frontal cortex is where we plan our behavior (the origin of our idea to move)
  - motor association area = one of the areas where neurons compile and store motor programs (neural circuits for different learned motor program – e.g. tie your shoes) // basal nuclei also have stored motor programs

More About Motor Control

- Many learned motor programs (directions for specific muscle contractions) are located in motor association area. Signals are relayed to neurons in precentral gyrus (the primary motor area --- also called the “motor strip”)

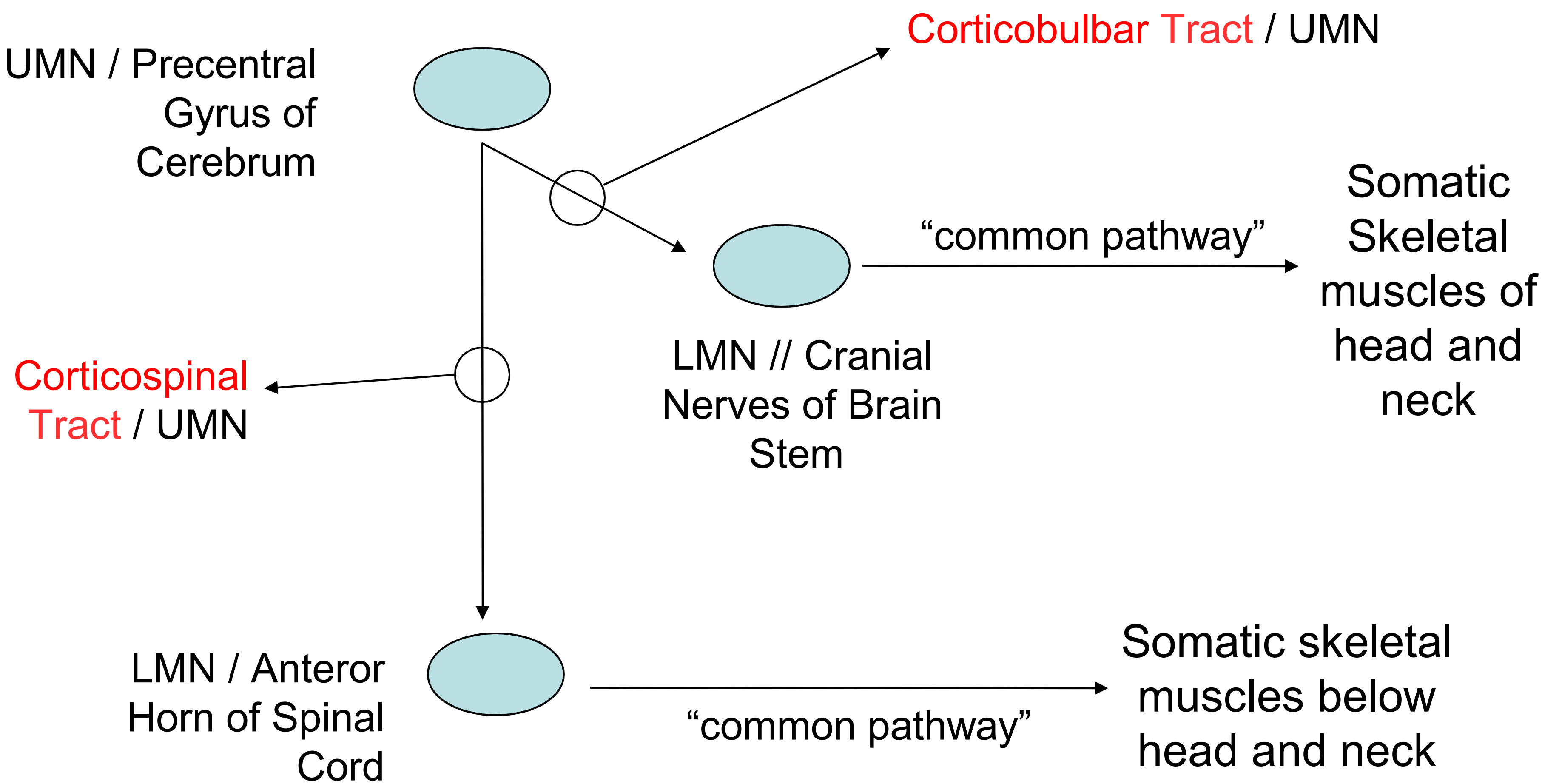
- Precentral Gyrus (Primary Motor Area) is where soma of the corticospinal tract originate (the upper motor neurons) /// these axons descend to synapse on lower motor neurons (soma in anterior horns of spinal cord) // LMN = common pathway to skeletal muscles

- Precentral Gyrus also have somas which form the corticobulbar tract (also upper motor neurons) // they descend to synapse on motor nuclei in brain stem (crainial nerves) // these cranial nerves are the lower motor neurons that innervate skeletal muscles in head and neck

- Both CST & CBT synapse with LMN // LMN are the pathways or circuits that connect CNS to skeletal muscles (see next slides)

Descending Direct Pathways

Pathways = Axon Tracts

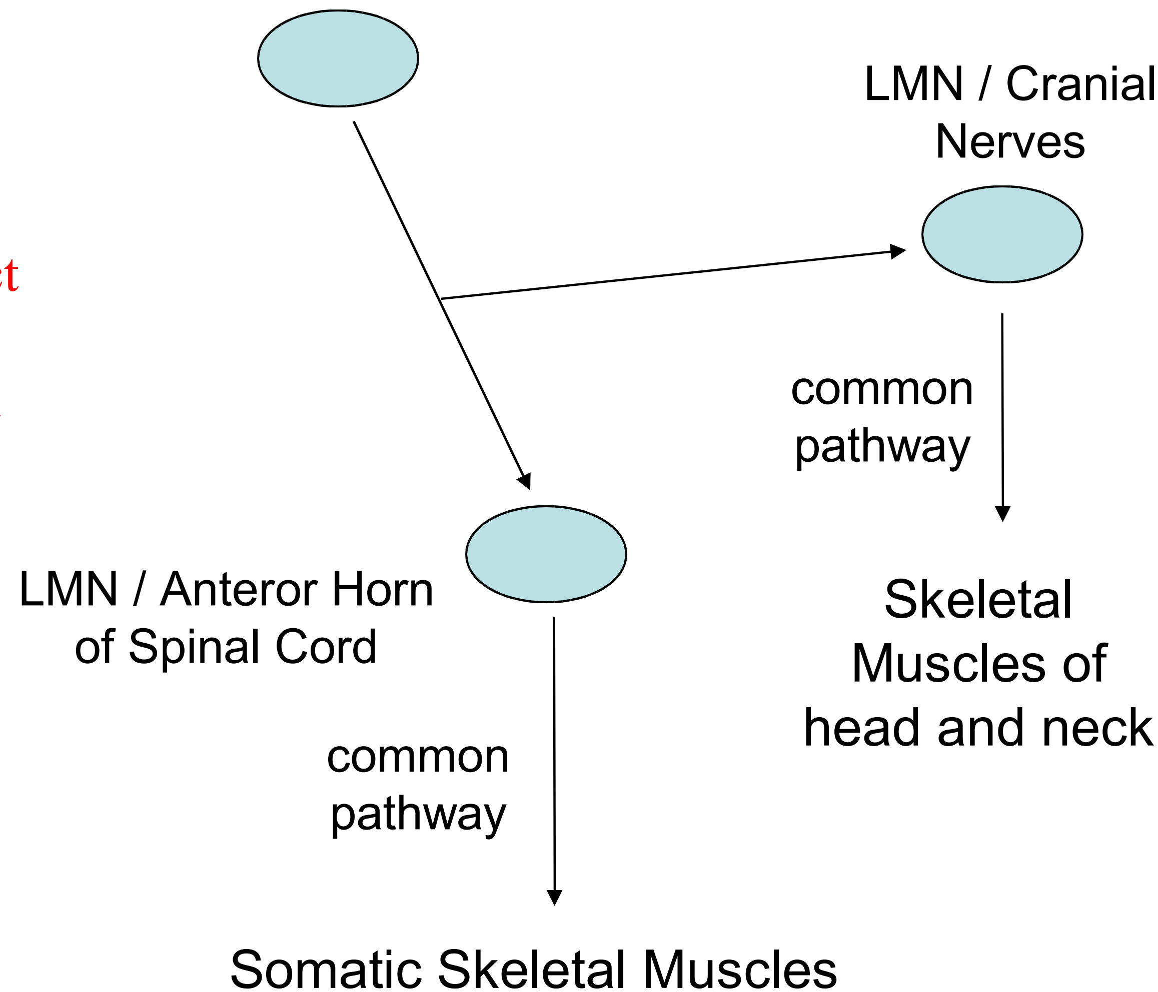


Descending Indirect Pathways

Pathways = Axon Tracts

UMN // These **nuclei originate in medulla oblongata**

1. tectospinal tract
2. vestibulospinal tract
3. rubriospinal tract
4. reticularspinal tract



Motor Control

- Motor control is a complex phenomena

- There are several different models that can be used to illustrate how our brain integrate information in order to regulate skeletal muscle's voluntary contractions

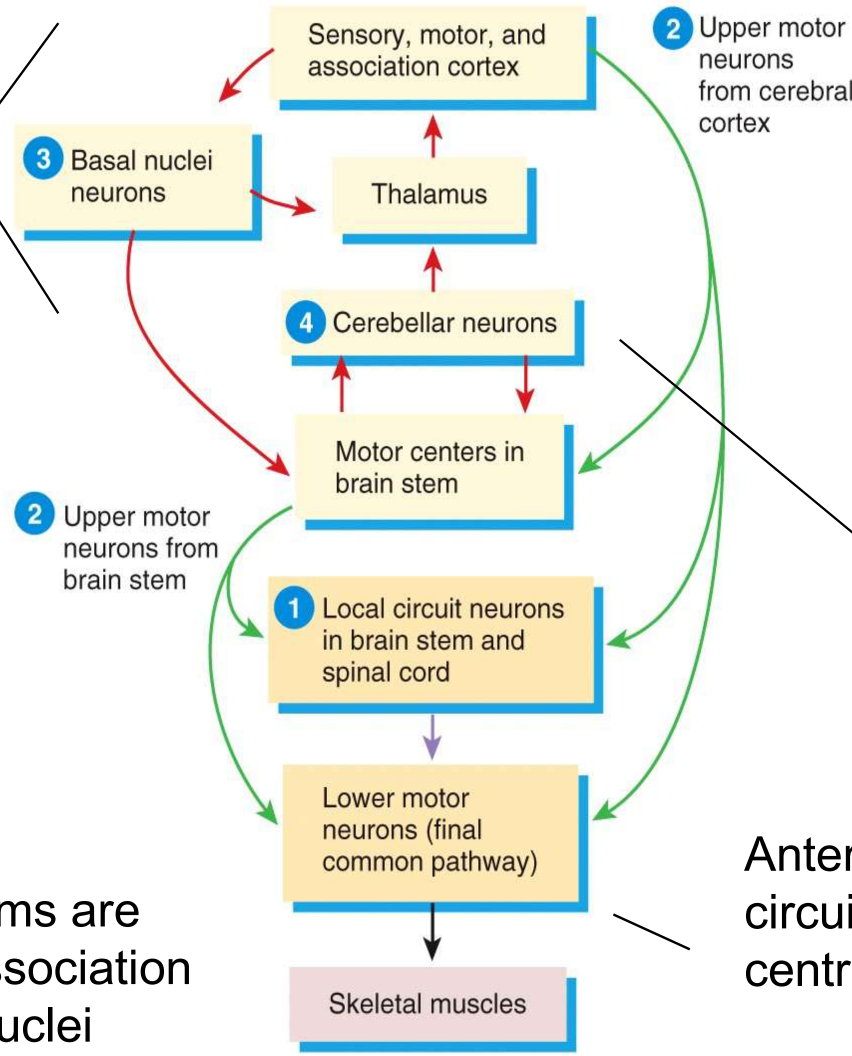
- Motor control is an example of a “higher brain functions”

- Language, learning and memory, and sleep are also examples of higher brain functions. Motor control is the only higher brain function that will be cover in this course.

Motor Control

Feedback loop / between cerebrum – basal nuclei - cerebellum

Indirect Pathway / brainstem nuclei / unconscious control on LMN

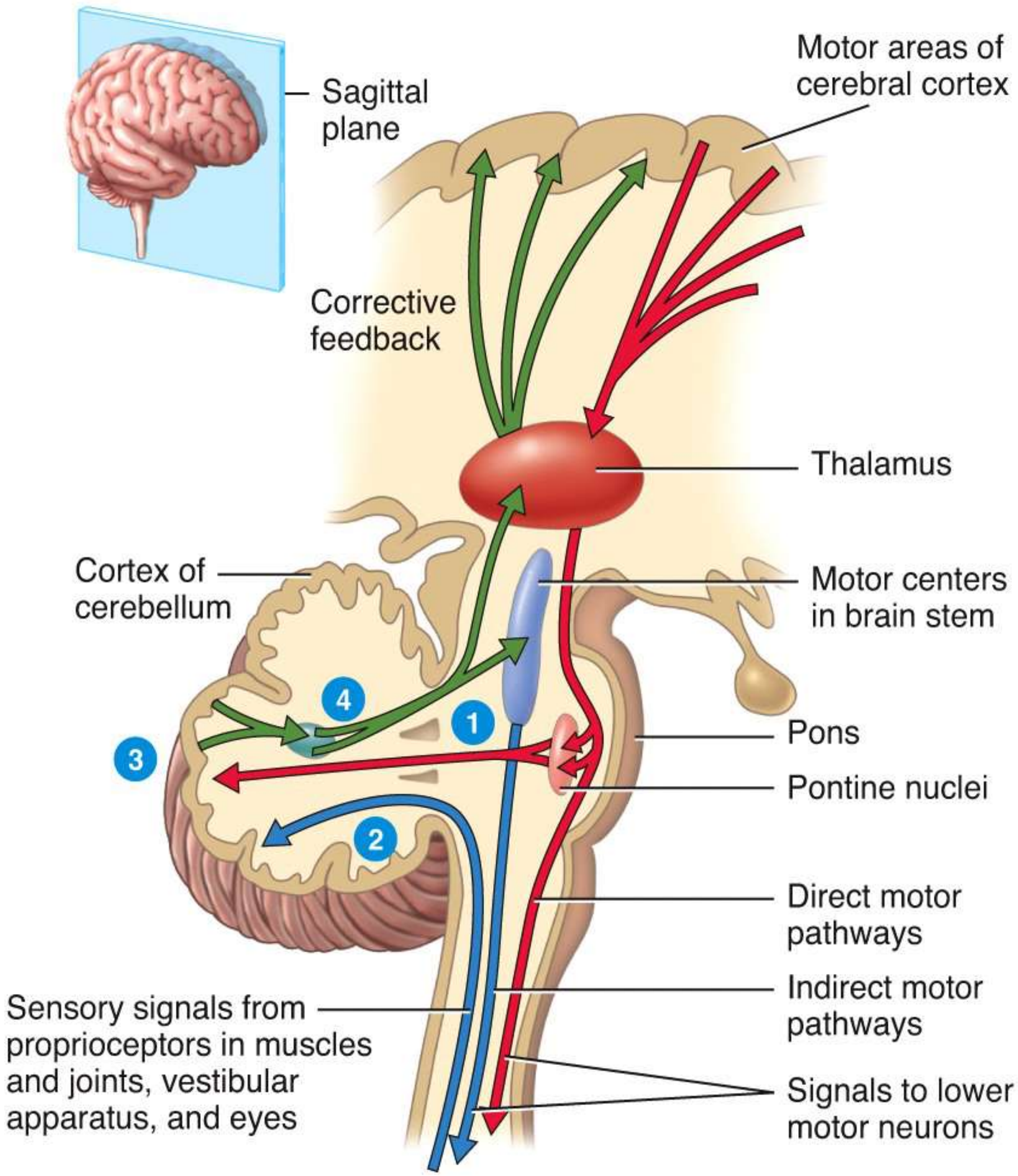


Direct Pathway = two pathways – corticospinal and corticobulbar / conscious control

Compares Intent to performance

Anterior horns have local circuit neurons / also called central pattern generators

Note: motor programs are stored in the motor association area and basal nuclei



Sagittal section through brain and spinal cord

Intent VS Performance

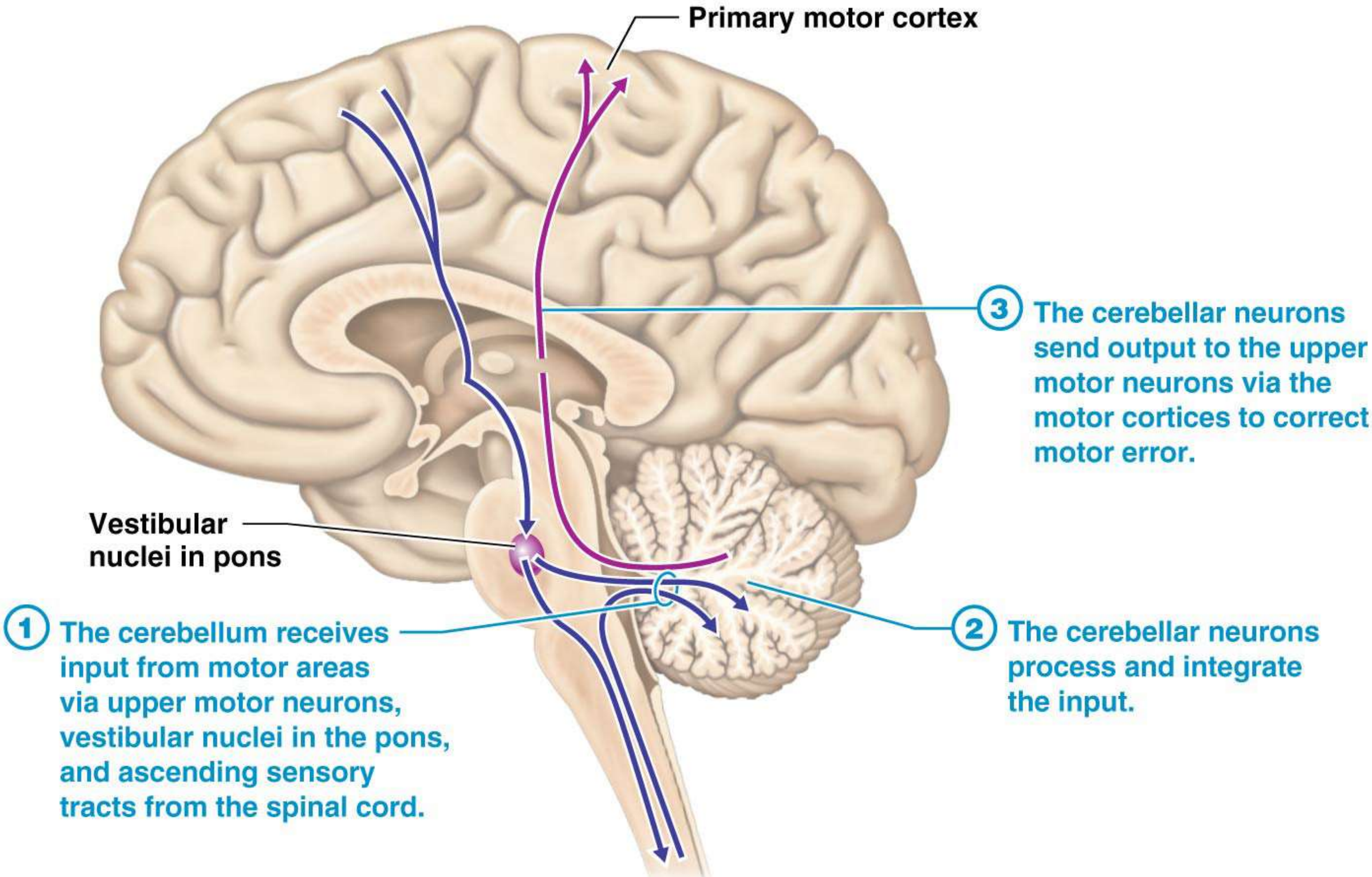
1 - Monitoring intentions for movement // get impulses from motor cortex and basal nuclei via pontine nuclei

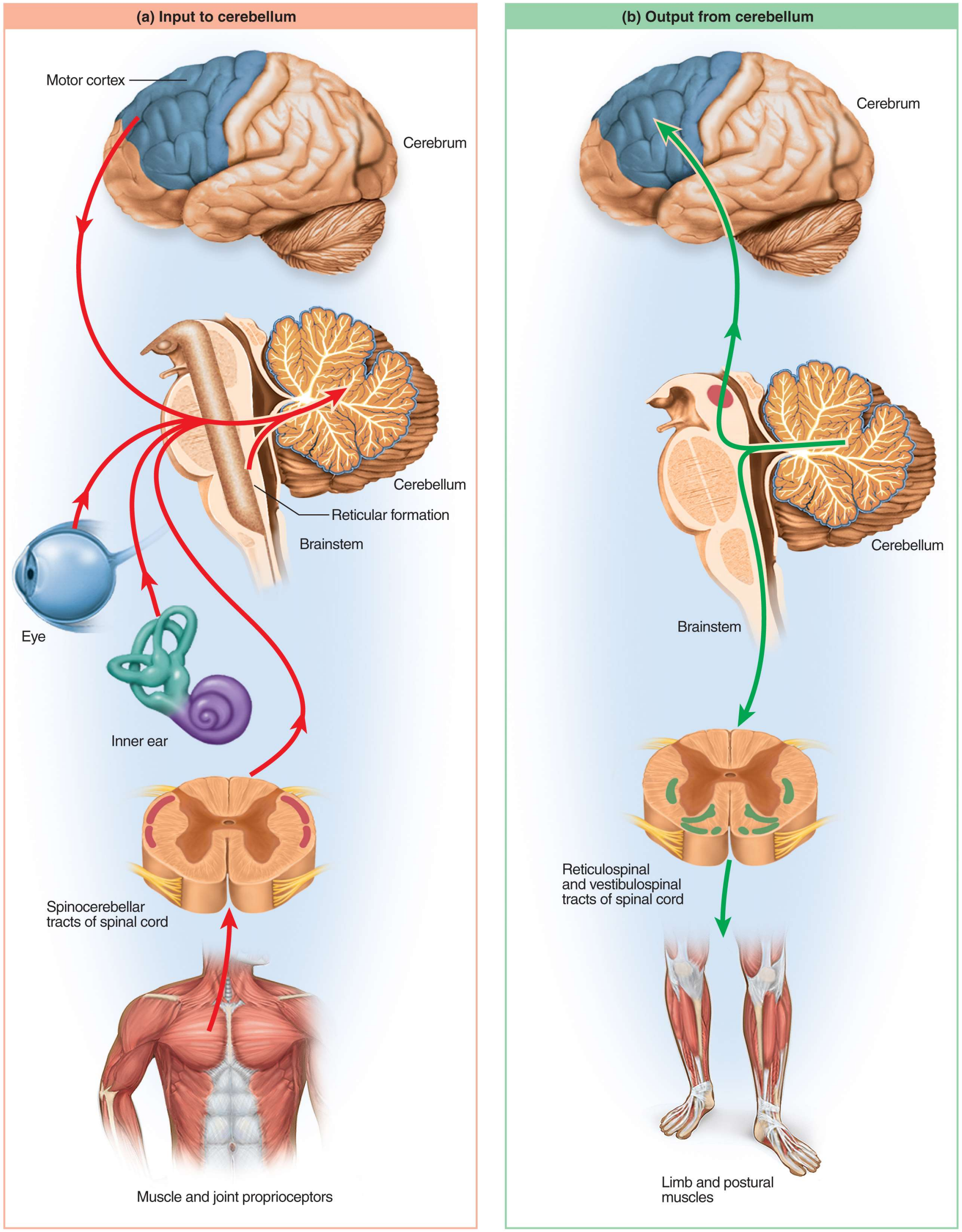
2 – Monitoring actual movement

3 – Comparing command signal with sensory information

4 – Sending out corrective feedback // via thalamus to cerebral cortex upper motor neurons as well as to indirect UMN

Role of the cerebellum in voluntary movement.

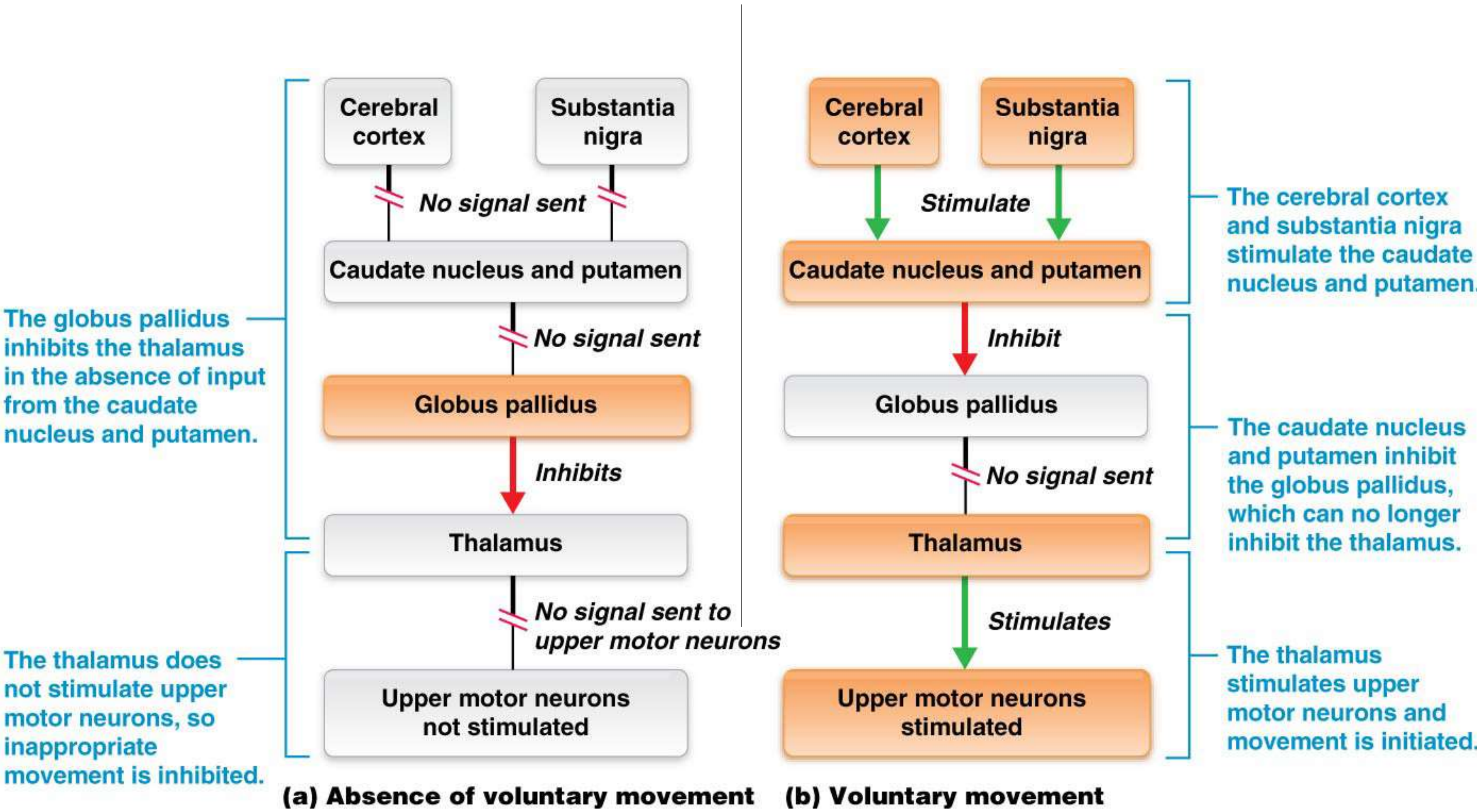




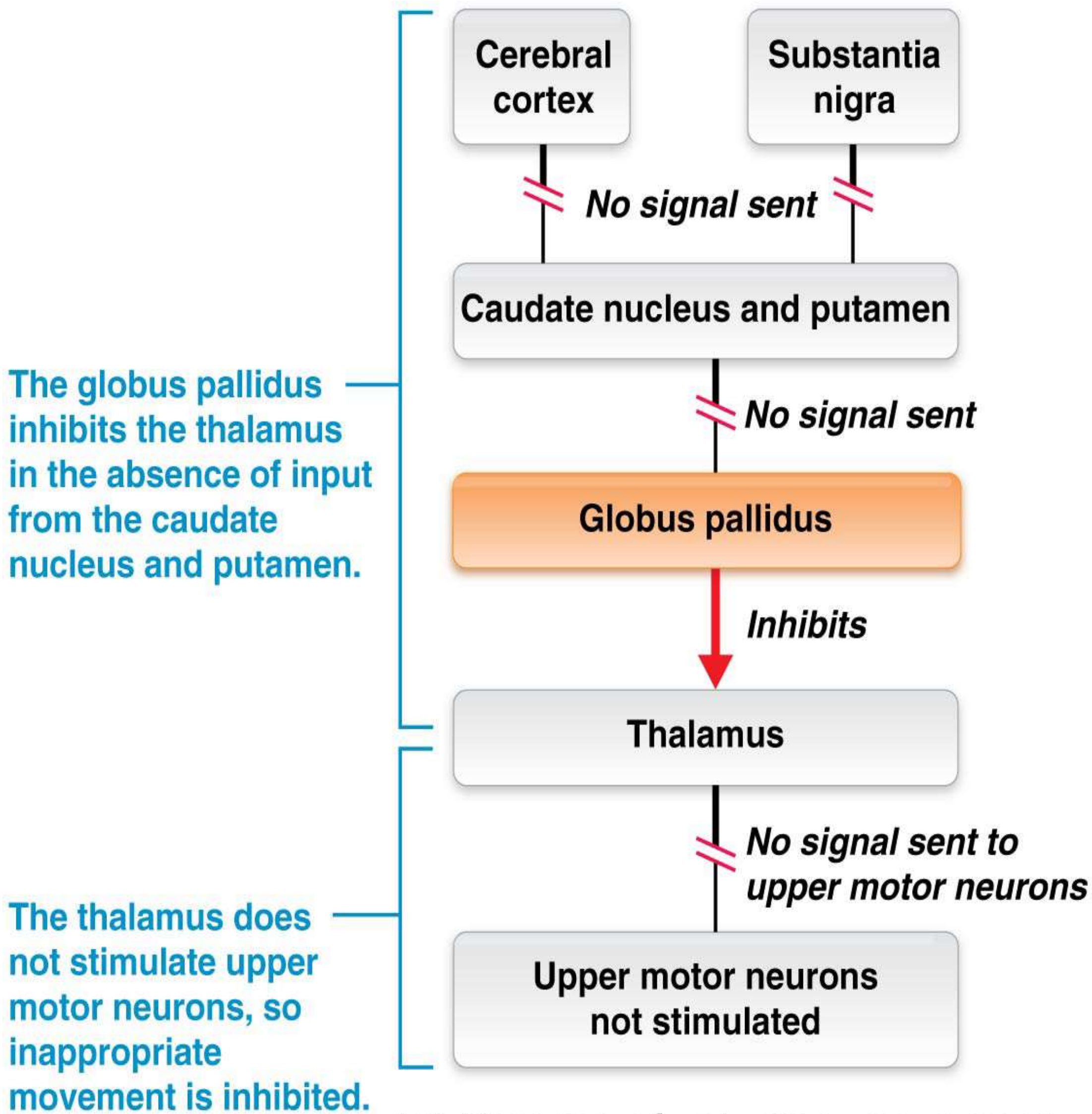
Input and Output to Cerebellum

Note: differentiate between direct and indirect motor pathways as related to function of the cerebellum

Role of the basal nuclei in voluntary movement.



Role of the basal nuclei in voluntary movement.

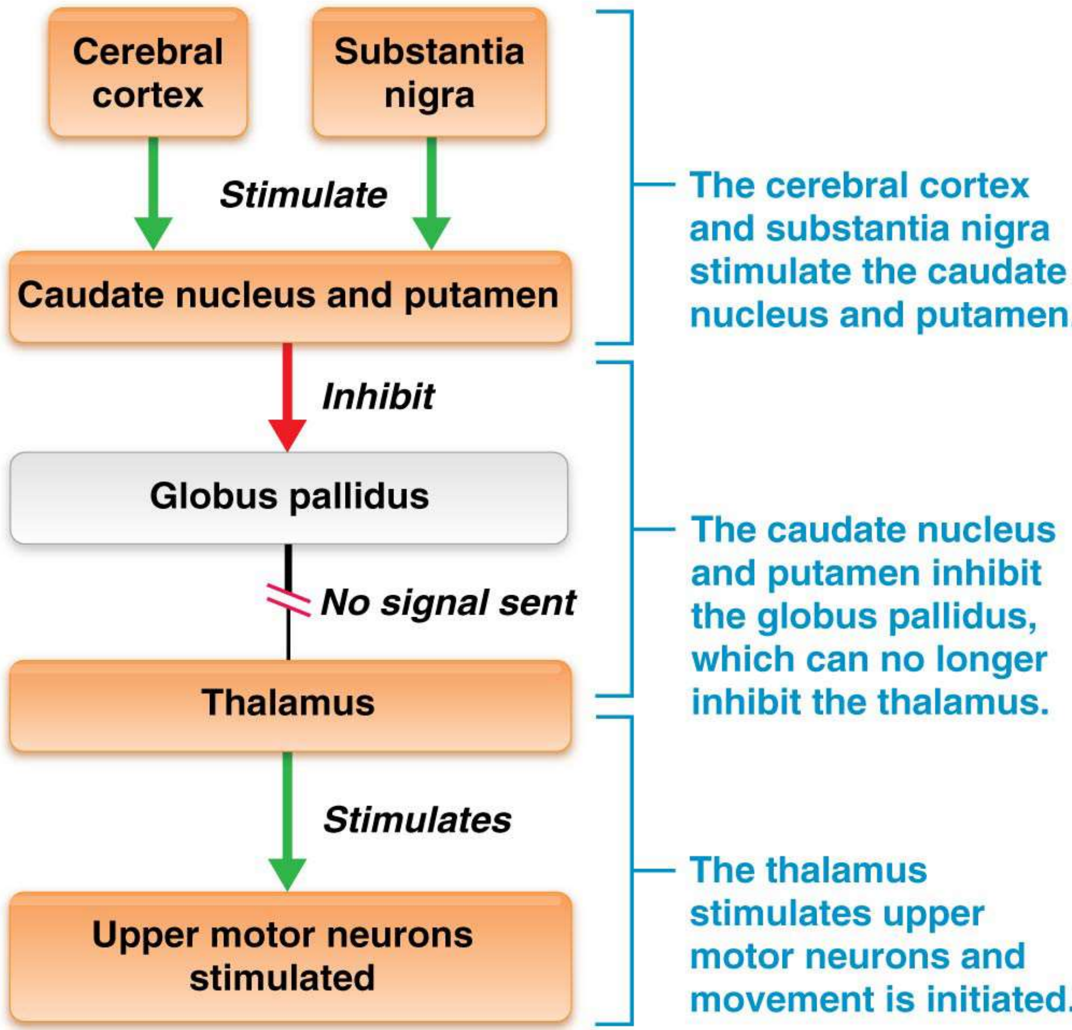


(a) Absence of voluntary movement

Role of the basal nuclei in voluntary movement.

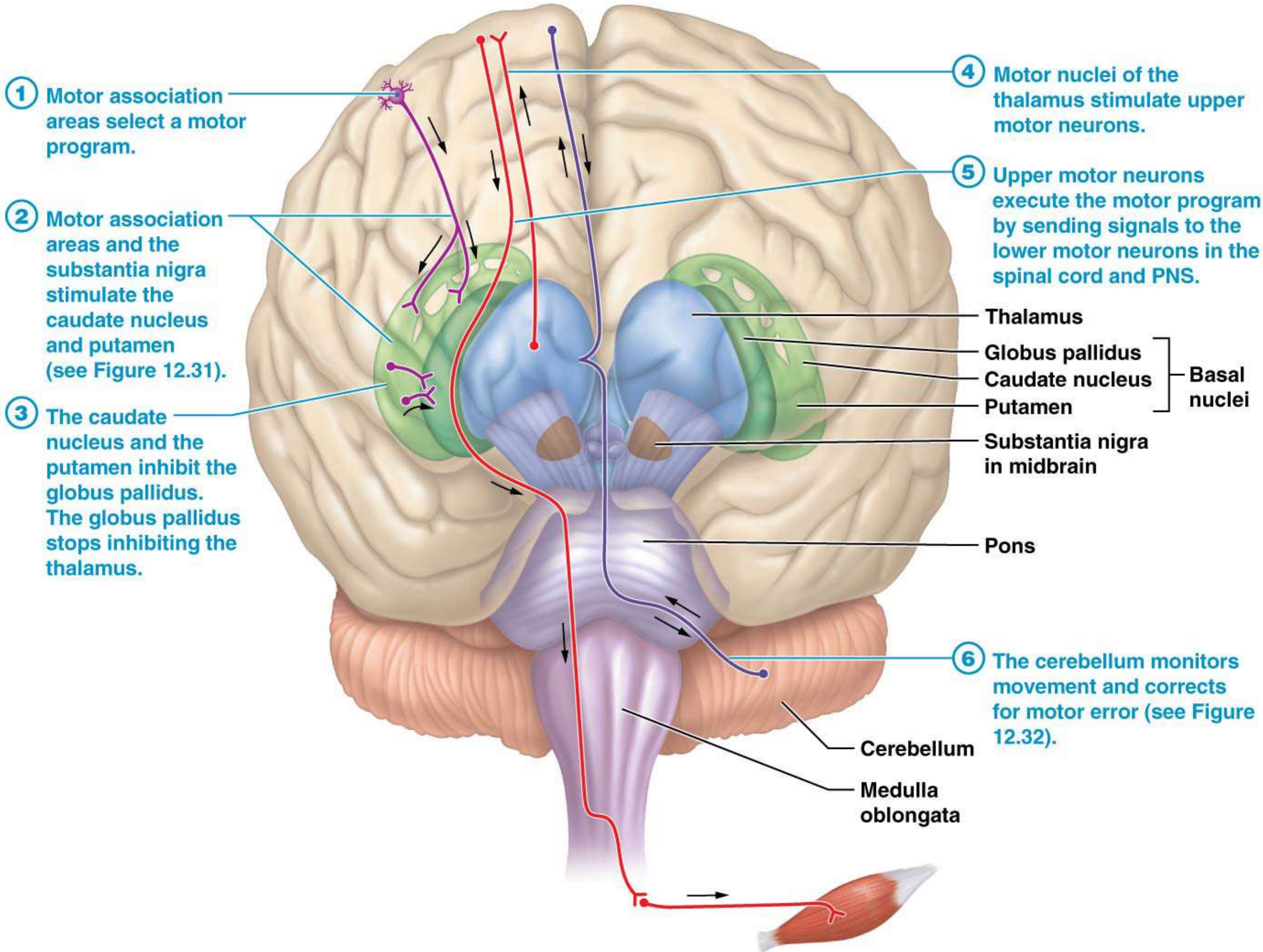
Globus pallidus function is to prevents motor programs from reaching UMN by blocking the AP at the thalamus.

The motor programs are stored in the basal nuclei, cerebellum, and motor association areas.



(b) Voluntary movement

The Big Picture of CNS Control of Voluntary Movement.



“The Three Levels of Motor Control”

(This is Another Model for Motor Control)

Students are not required to review these slides. If you do decide to view these slides then you will get a different perspective about the same phenomena, motor control. However, at this point, it may cause more problems for you as you try to integrate the different models.

"The Three Levels of Motor Control"

(This is Another Model for Motor Control)

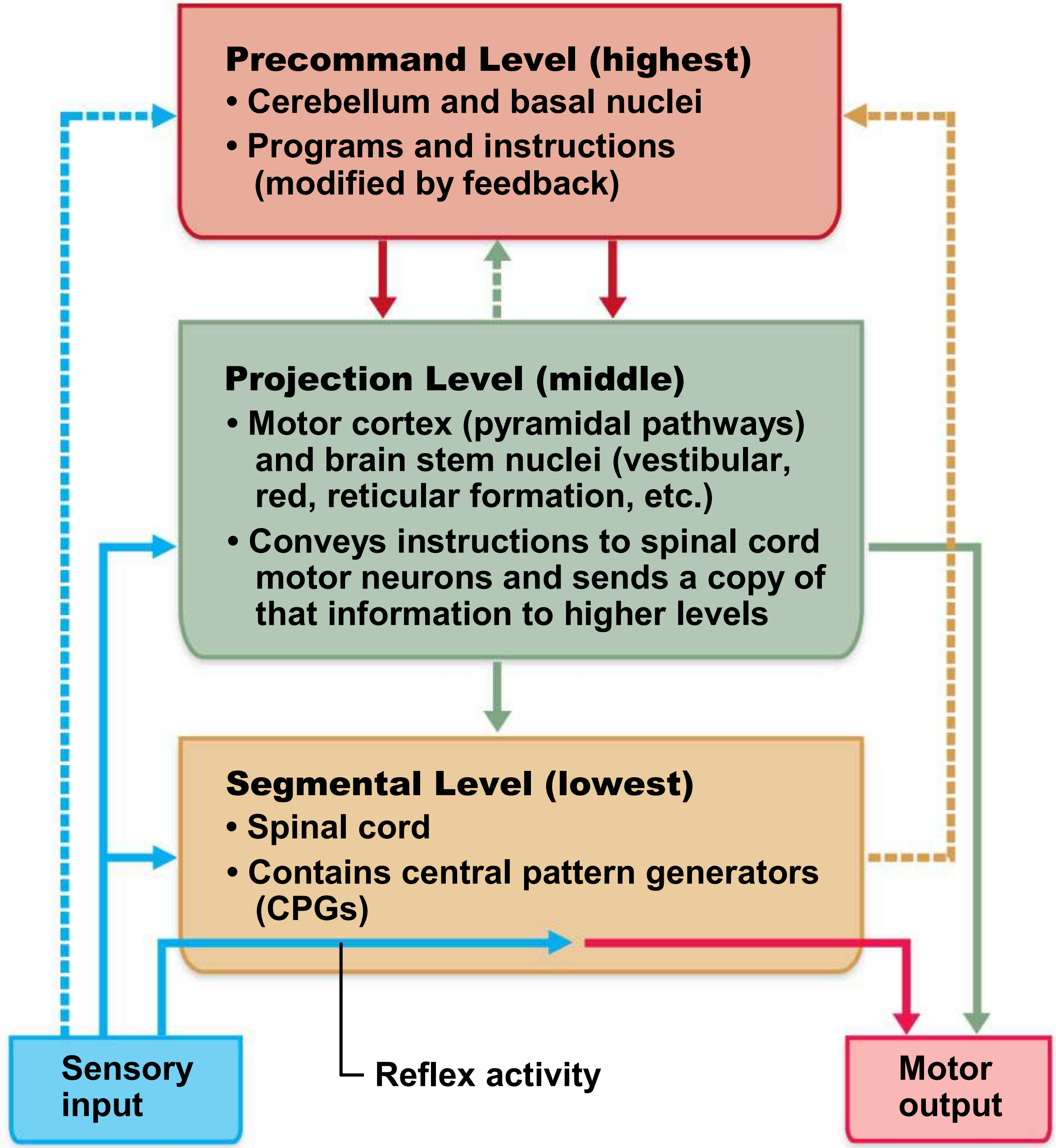
- Complex motor behavior depends on patterns of control from different "levels of command"
  - Precommand level (basal nuclei & cerebellum) - highest
  - Projection level (corticospinal & corticobulbar tracts) – mid level
  - Segmental level (LMN with local circuit neurons in anterior horms) – lowest level
- Cerebellum and basal nuclei are the ultimate planners and coordinators of complex motor activities
  - contain local circuit neurons / motor programs/ central pattern generators

Hierarchy of Motor Control

The idea to move is generated in prefrontal cortex.

This is the conscious thought to move.

This is sent to the pre-command level for processing. In the pre-command sites motor programs are stored.



(a)

Levels of motor control and their interactions

Segmental Level

- Lowest level of motor hierarchy
  - Reflexes and automatic movements
- Central pattern generators (CPGs): segmental circuits that activate networks of ventral horn neurons to stimulate specific groups of muscles
  - Controls locomotion
  - Specific, often-repeated motor activity

Projection Level

- **Consists of**
  - Upper motor neurons that initiate the direct pathway to produce voluntary skeletal muscle movements (also called the pyramidal tract // direct pathway)
  - Brain stem motor areas /// oversee the indirect pathway to modify commands of the direct pathway (also called the extrapyramidal tract // indirect pathway) // modify
    - Central Pattern Generators which controlled motor actions // also at segmental level of spinal cord
- Projection motor pathways send information to lower motor neurons, and keep higher command levels informed of what is happening

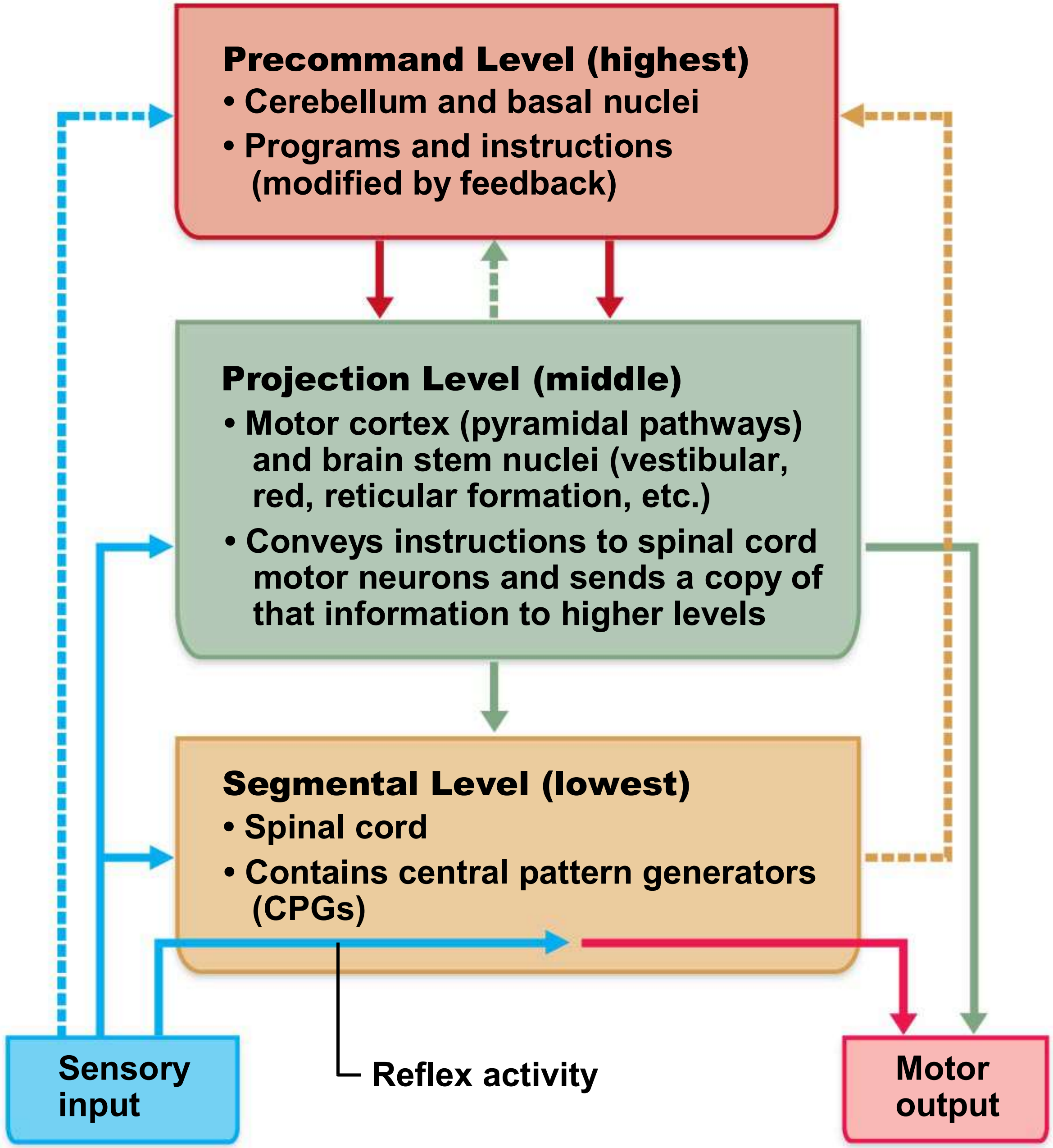
Pre-command Level

- Neurons in cerebellum and basal nuclei
- Neither cerebellum nor basal nuclei have direct synaptic contact with premotor association or primary motor cortex (thalamus lies between these loops)
  - Regulate motor activity
  - Precisely start or stop movements
  - Block unwanted movements
  - Perform unconscious planning and discharge in advance of willed movements
  - Coordinate movements with posture
  - Monitor muscle tone

Pre-command Level

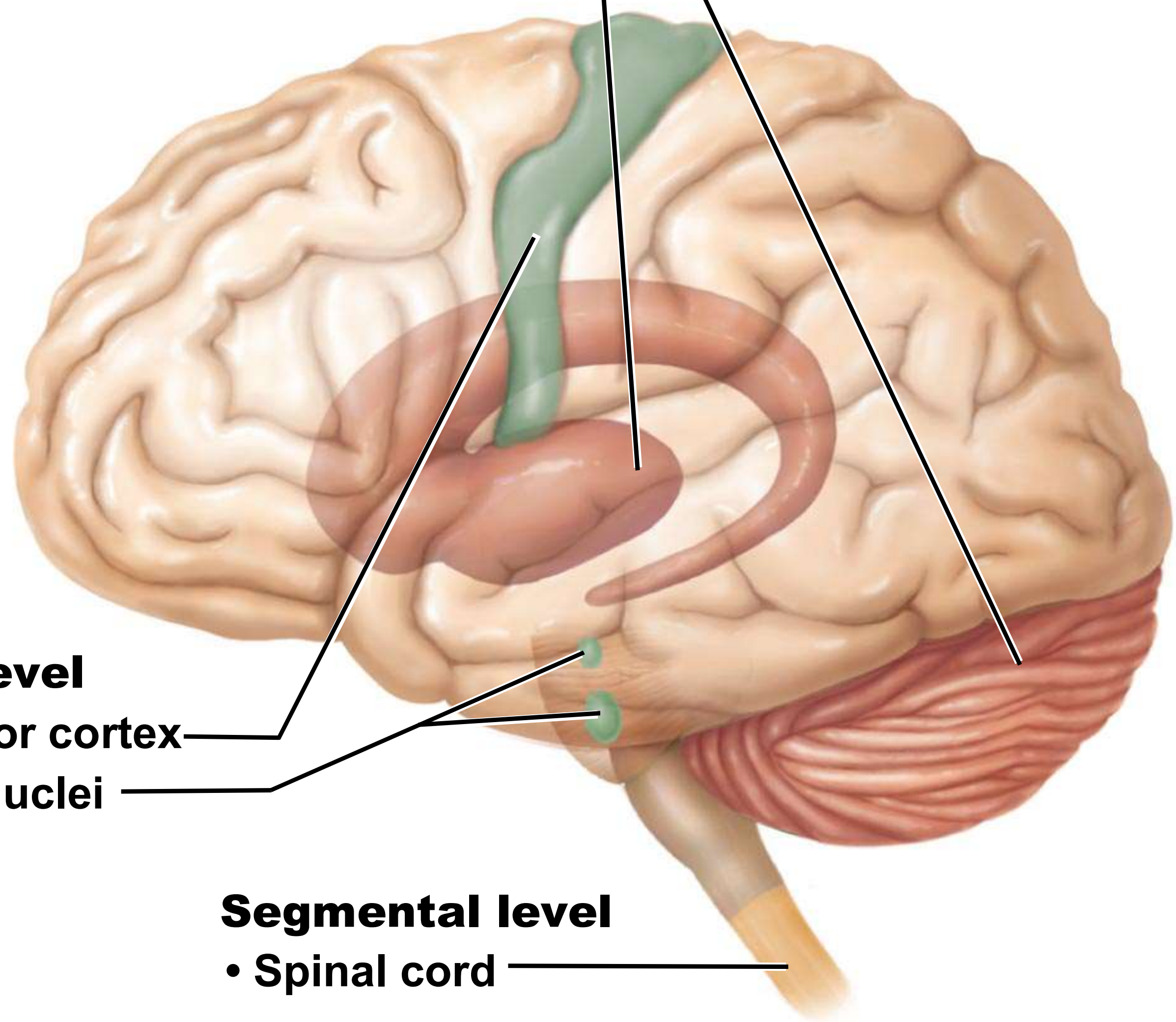
- Cerebellum
  - Acts on motor pathways through projection nuclei of brain stem
  - Acts on motor cortex via thalamus to fine-tune motor activity
- Basal nuclei
  - Inhibit various motor centers under resting conditions
  - Initiates and stops repetitive motor patterns (e.g. walking / swimming)
  - Remember! – influence of substantia nigra on basal nuclei

Hierarchy of Motor Control



(a)

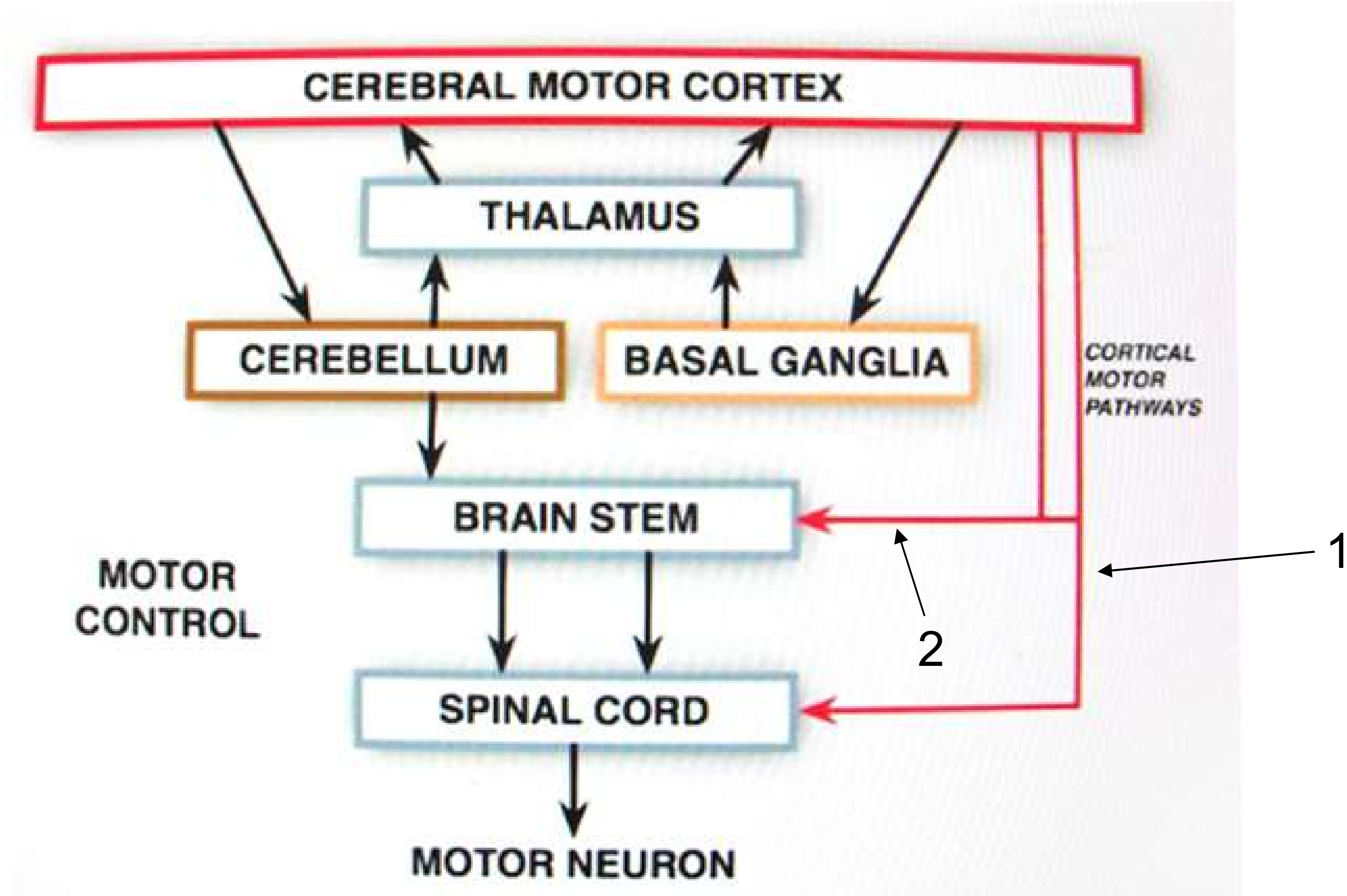
Hierarchy of motor control.



(b) Structures involved

More on Motor Control

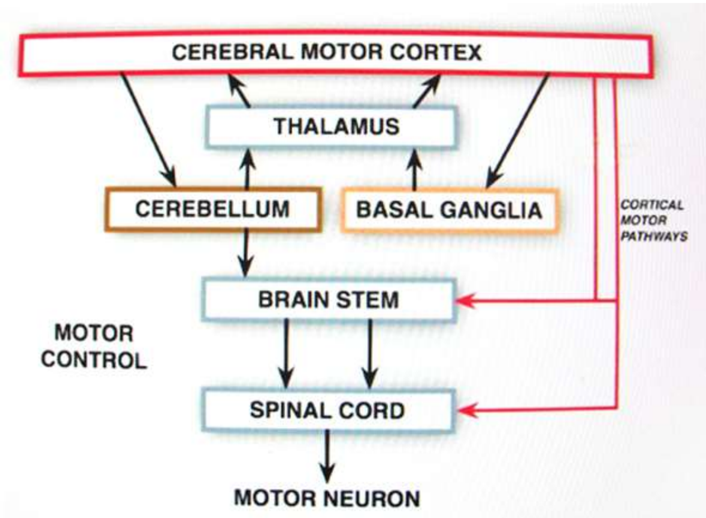
Understanding Motor Control Function



Notes:

1. Corticospinal tracts primarily innervate skeletal muscles of hand and feet
2. Corticospinal tracts have colateral fibers to Brain Stem Motor Nuclei
3. Brain Stem Motor Nuclei / muscle tone / modulate effects of gravity

Understanding Motor Control Function



Corticospinal tract sends Action Potentials to skeletal muscle (Direct pathway)

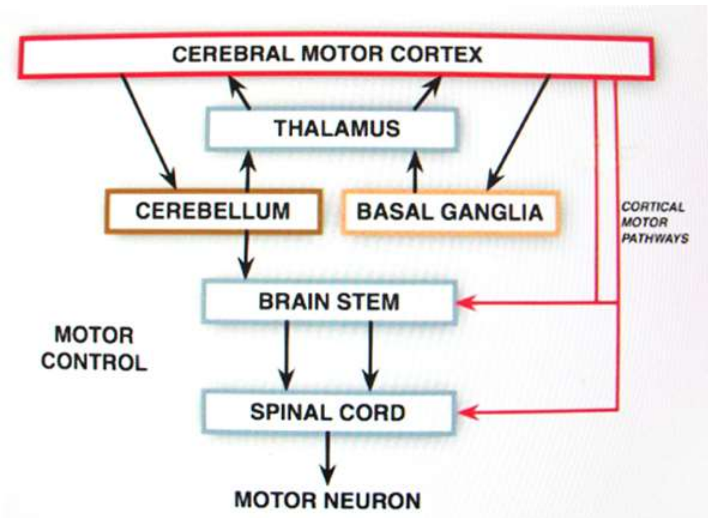
Corticospinal tract also influence brain stem's motor nuclei // these motor nuclei are the indirect pathway to skeletal muscles

Brain stem sends unconscious signals via indirect pathway to skeletal muscles to set muscle tone and inhibit skeletal muscle reflexes

Cerebellum able to communicate with both cerebrum and brain stem motor areas // compares intent and performance – provides corrective action

Basal nuclei also stores motor programs // e.g. regulate start-stop of rhythmic motions // stores implicit memory (procedural memory = the knowing how type of memory)

Understanding Motor Control Function



Somatic reflexes have their own circuits and if left unregulated they cause muscles to contract which would eventually result in a spastic contraction

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Indirect pathway (brain stem motor nuclei) must provide descending inhibitory signals to prevent reflex spastic paralysis

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Therefore – if you cut upper motor neurons you get spastic paralysis

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But – if you cut the lower motor neurons you get flaccid paralysis

More on Motor Control

- pyramidal cells of the precentral gyrus are called the upper motor neurons
  - their fibers project caudally
  - about 19 million fibers ending in nuclei of the brainstem
  - about 1 million fibers form the corticospinal tracts
  - most fibers decussate in lower medulla oblongata
  - form lateral corticospinal tracts on each side of the spinal cord
- in the brainstem or spinal cord, the fibers from upper motor neurons synapse with lower motor neurons whose axons innervate the skeletal muscles

Motor Control

- basal nuclei and cerebellum // areas of brain that play important role in muscle control
- together known as the Pre-command Level of motor control
  - form feedback loops which share information
    - between cerebrum – thalamus - basal nuclei
    - between cerebrum – thalamus – cerebellum
    - contain motor programs and instructions

Motor Control

- these <u>“loops” are independent of the corticospinal track</u>
  - *allows for constant adjustment between the intent and actual performance of muscle contraction.*
- <u>While descending signals within these “loops” are being processed</u>
  - ascending (proprioception) tracks pass signals into the cerebellum where so it can “compare” the performance with intent
- <u>Note: See Video on Web Site / Upper Motor Neuron</u>

Basal Nuclei & Cerebellum Play Important Roll in Motor Control

- **Basal nuclei**
  - determines the onset and cessation of intentional movements
  - E.g. the repetitive hip and shoulder movements in walking
  - Note: basal nuclei is Influenced by substantia nigra
    - SN makes and transports dopamine to basal nuclei
    - dopamine reduces the degree of contractions to skeletal muscles
    - deficiency of dopamine to basal nuclei results in condition known as Parkinson

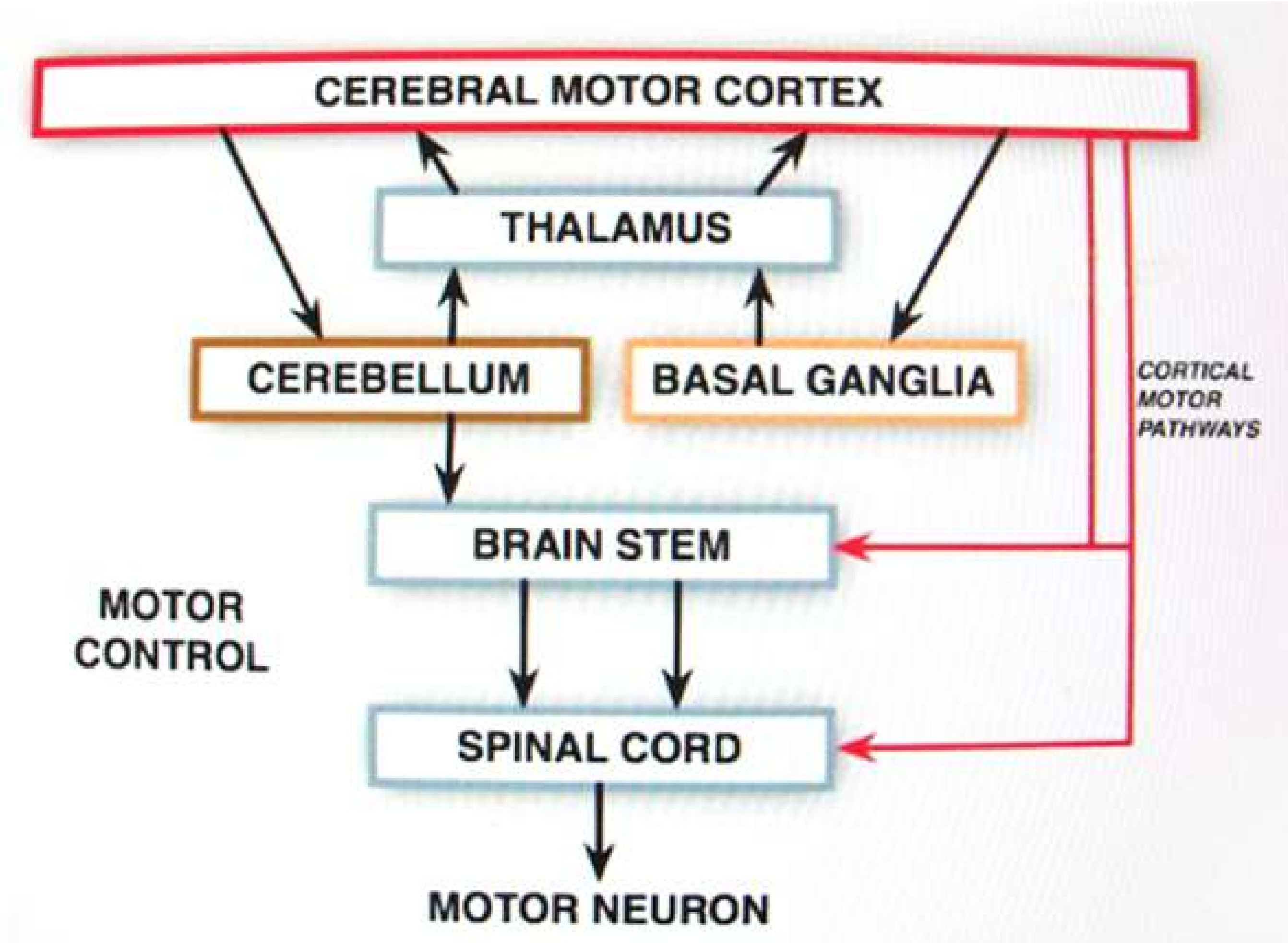
Basal Nuclei & Cerebellum Play Important Roll in Motor Control

- **Basal nuclei**
  - Another area in brain where motor programs are stored for highly practiced, learned behaviors
  - muscle contractions that one carries out with little thought // writing, typing, driving a car
  - lies in a feedback circuit from the cerebrum to the basal nuclei to the thalamus and back to the cerebrum
  - **dyskinesias** – movement disorders caused by lesions in the basal nuclei
  - Procedural memory (knowing how // implicit memory) is hippocampus independent memory which is encoded through the amygdala into basal nuclei and cerebellum.

Basal Nuclei & Cerebellum Play Important Roll in Motor Control

- Cerebellum // important role in motor coordination known for long time
  - aids in learning motor skills
  - maintains muscle tone and posture
  - smoothes muscle contraction
  - coordinates eye and body movements
  - coordinates the motions of different joints with each other
  - Lesion in cerebellum track results in ataxia – clumsy, awkward gait

Understanding Motor Control Function



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Intent vs Actural Performance

How the Cerebellum Regulates Motor Control

The cerebellum compares the intent (corticospinal tract) to the performance (proprioception from muscle spindles and golgi tendon organs as well as sensory info from vestibulocochlear and optic nerves).

- Middle peduncle: sends info into cerebellum from eyes, ears, and cerebrum (i.e. intent + performance).
- Inferior peduncle: sends info into cerebellum from proprioceptors in muscles and joints (i.e. performance).
- Purkinje cells of cerebellum compare info from middle and inferior peduncles….. /// If there is a discrepancy between intent and performance….
  - signal relayed to cerebellum's deep nuclei
  - signal relayed out of cerebellum by way of superior peduncle /// To motor association area (through thalamus).
  - Reticulospinal and vestibulospinal tracts (i.e. inderect pathways) provide corrective adjustments