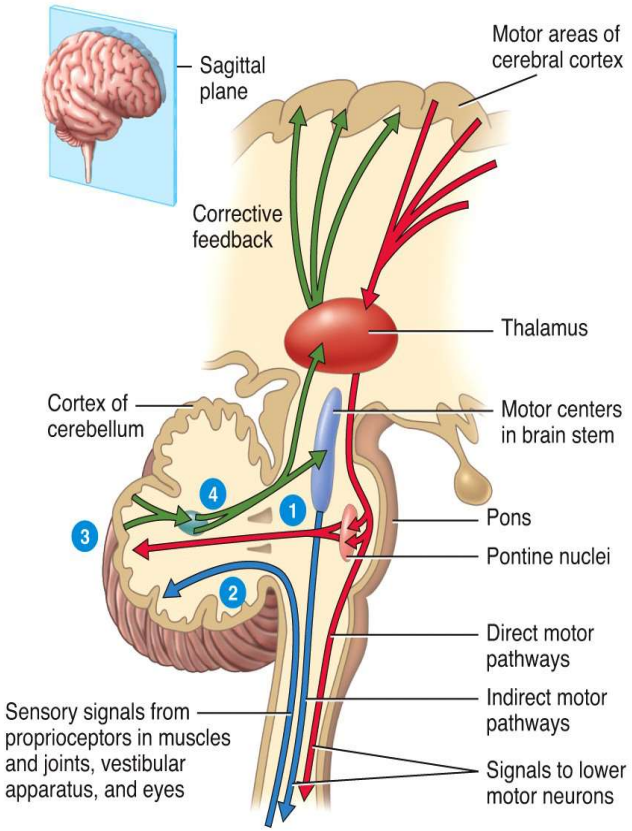
Chapter 14.6

Motor Control

(Review / Covered in Previous Slides)



Sagittal section through brain and spinal cord

Motor Control Is An Example of a Higher Brain Function

- Motor control describes how we control the contraction of our skeletal muscles

- Motor control requires the simultaneous bi-directional movement of action potentials between neural networks that interconnect the *cerebral cortex, basal nuclei, cerebellum, thalaus, and several other nuclei in the brain stem*

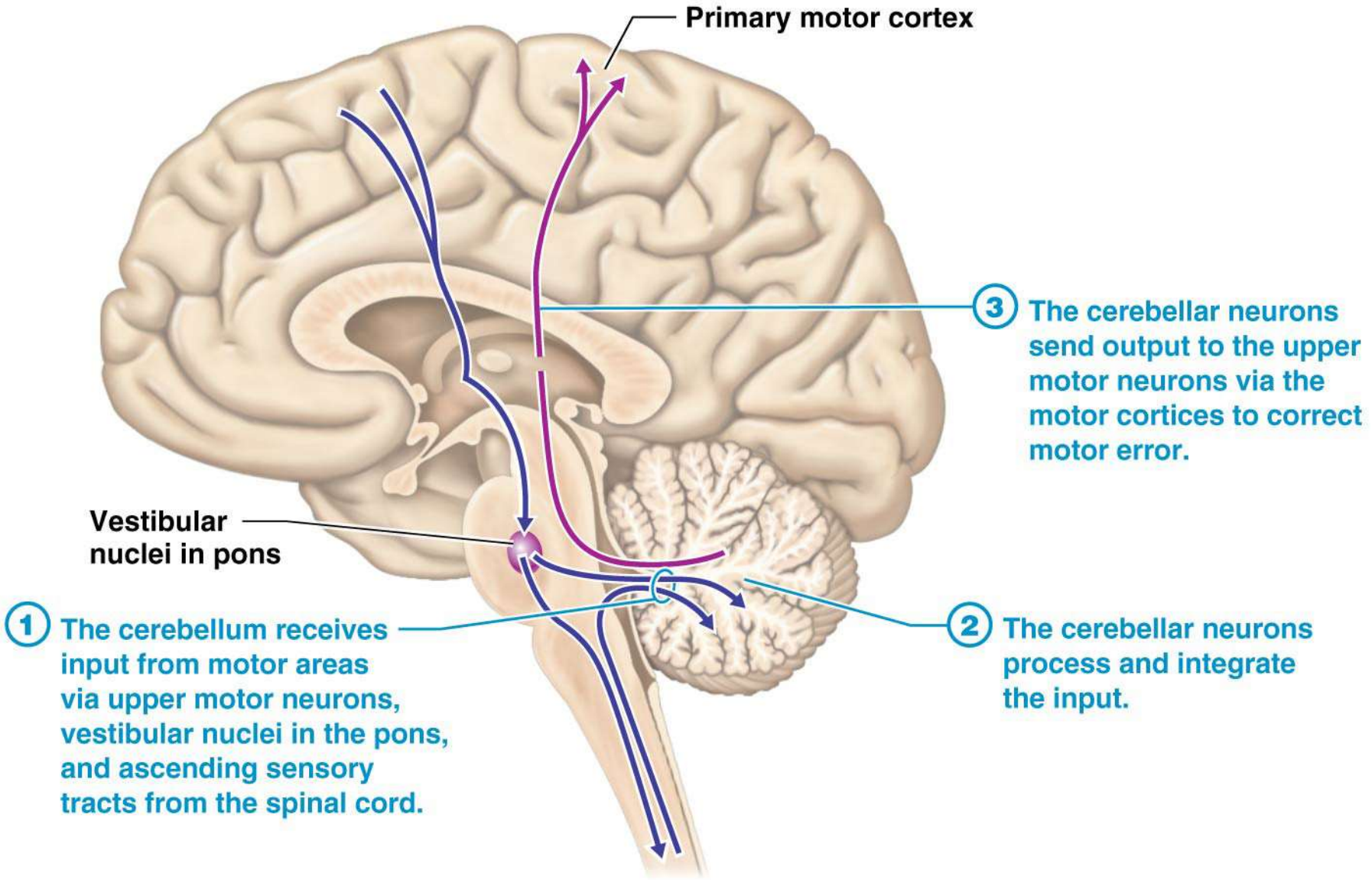
- Central pattern generators (also called local curcuit neurons) also play a role in regulating the sequential contraction of skeletal muscles

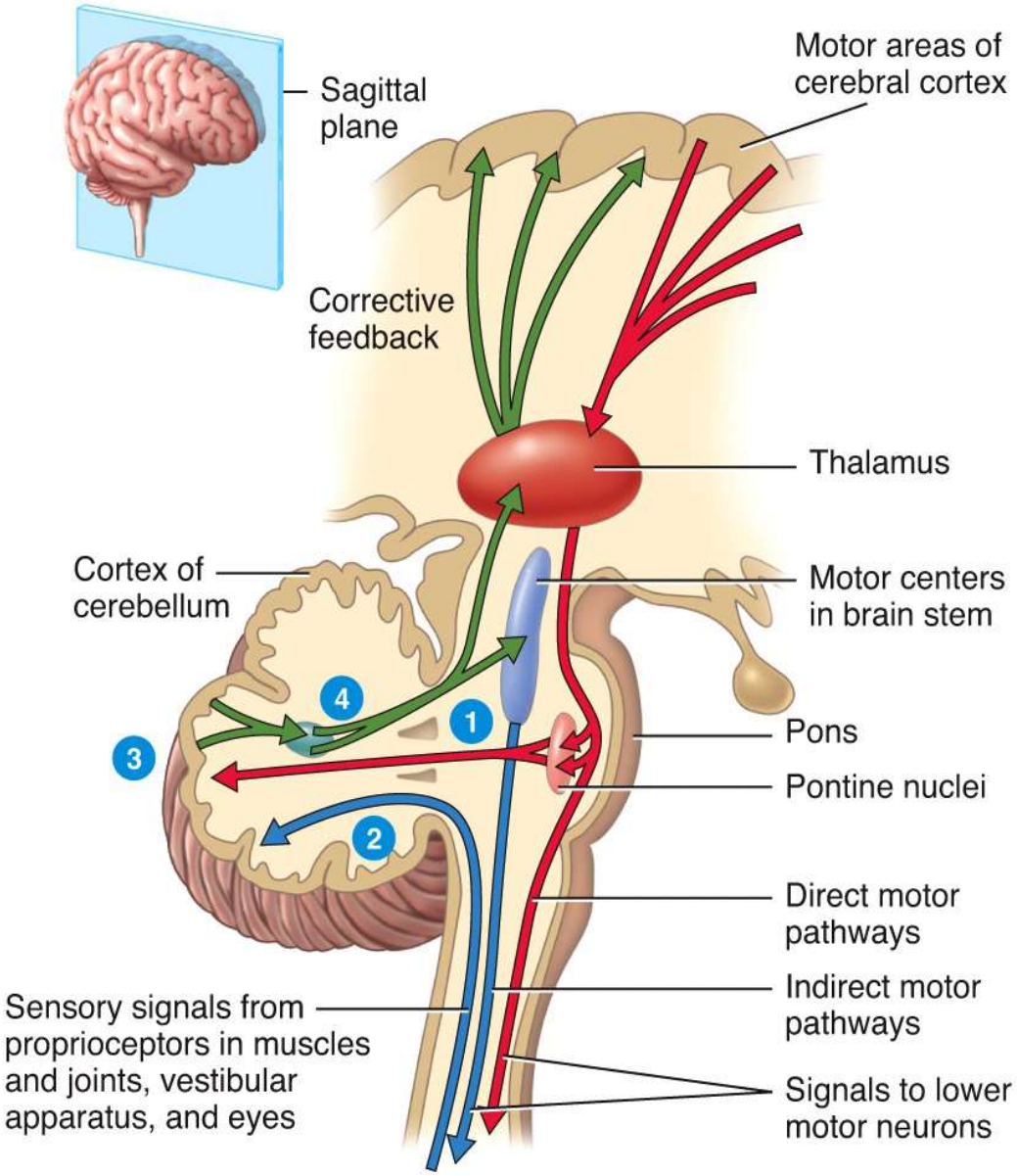
  - These nuclei control groups of skeletal muscle (e.g. regulating the muscle contraction which occur during walking)

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

Cerebellum function in voluntary movement.

The cerebellum compares the intent with performance.





Sagittal section through brain and spinal cord

Intent VS Performance

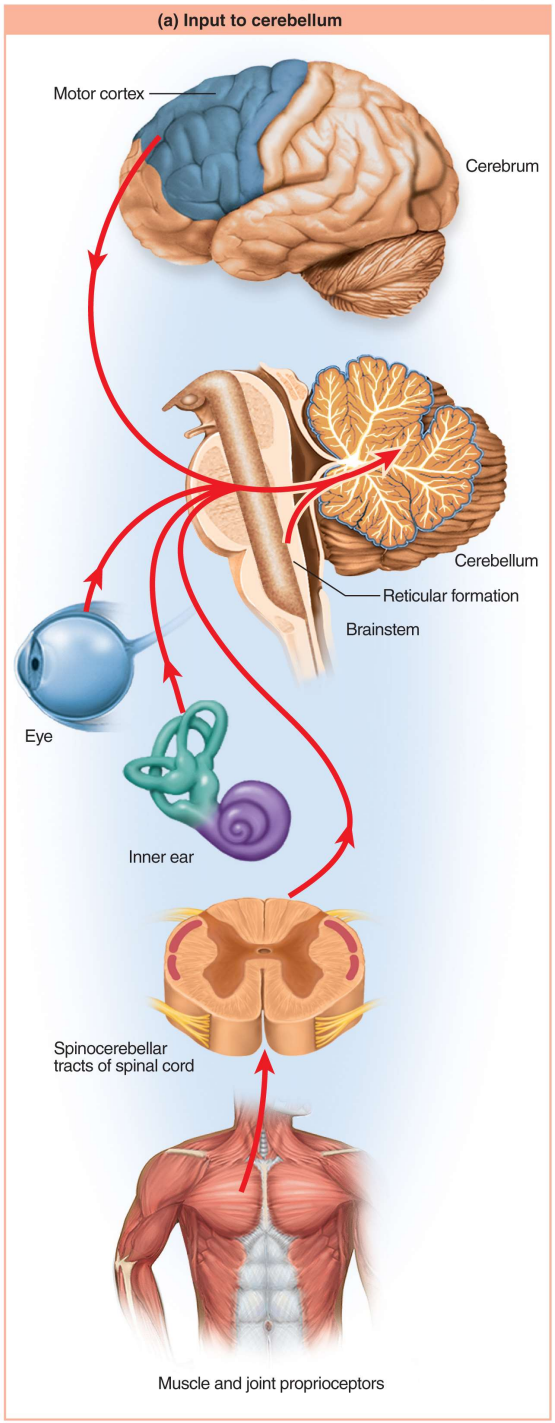
1 - Monitoring intentions for movement // get impulses from motor cortex and basal nuclei via pontine nuclei

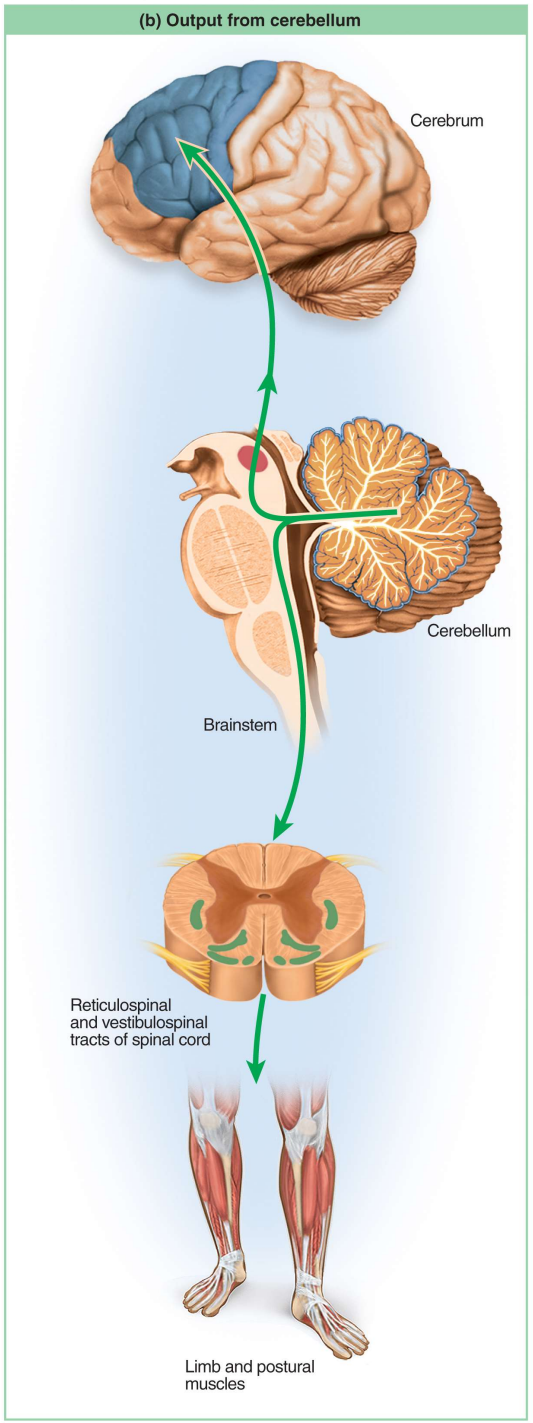
2 – Monitoring actual movement

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

These events occurs in the the pyramidal pathway.





Input and Output of the Cerebellum

Note: motor control requires constant comparison by the cerebellum of stimuli not only from proprioceptors but also from other sensations (e.g. vision and equilibrium)

This explains in part why the cerebellum have so many neurons and each neuron has over 100,000 unique synapses!

Motor control is only of the many functions of the cerebellum, however. In general, all of the cerebellum's function involve "comparing" (e.g. time, texture, like sounding words, etc.)

Motor Control
Intent VS Performance

- The conscious thought to contract a skeletal muscle originates in the prefrontal cortex (i.e. executive function)
  - prefrontal cortex starts an action potential that will eventually signal the precentral gyrus (i.e. motor strip send action potentials via UMN)
  - before this happens, the pathway must transits through the motor association area, then to the basal ganglia then to the thalamus before it reaches the precentral gyrus (i.e. motor strip).
  - prefrontal cortex is where we plan our behavior (the origin of our idea to move)
  - motor association area = where we compile a program for the skeletal muscle contractions requested by the frontal cortex /// if a skeletal muscle even is often used then it is saved in the motor association area as a motor programs /// just like computer apps (eg. how to tie your shoes or typing your password)
  - *Note: basal ganglia play a critical role in motor control /// we will study this later // Note: BG can take charge and control skeletal muscles when we lose conscious control of motor control // e.g . When you drive your car for a distance without awareness!*

More About Motor Control

- Learned motor programs are located in the motor association area. These local curcuit neurons may be destroyed by a stroke which would result in loss of function. These motor skills may be “relearned” with physical therapy.

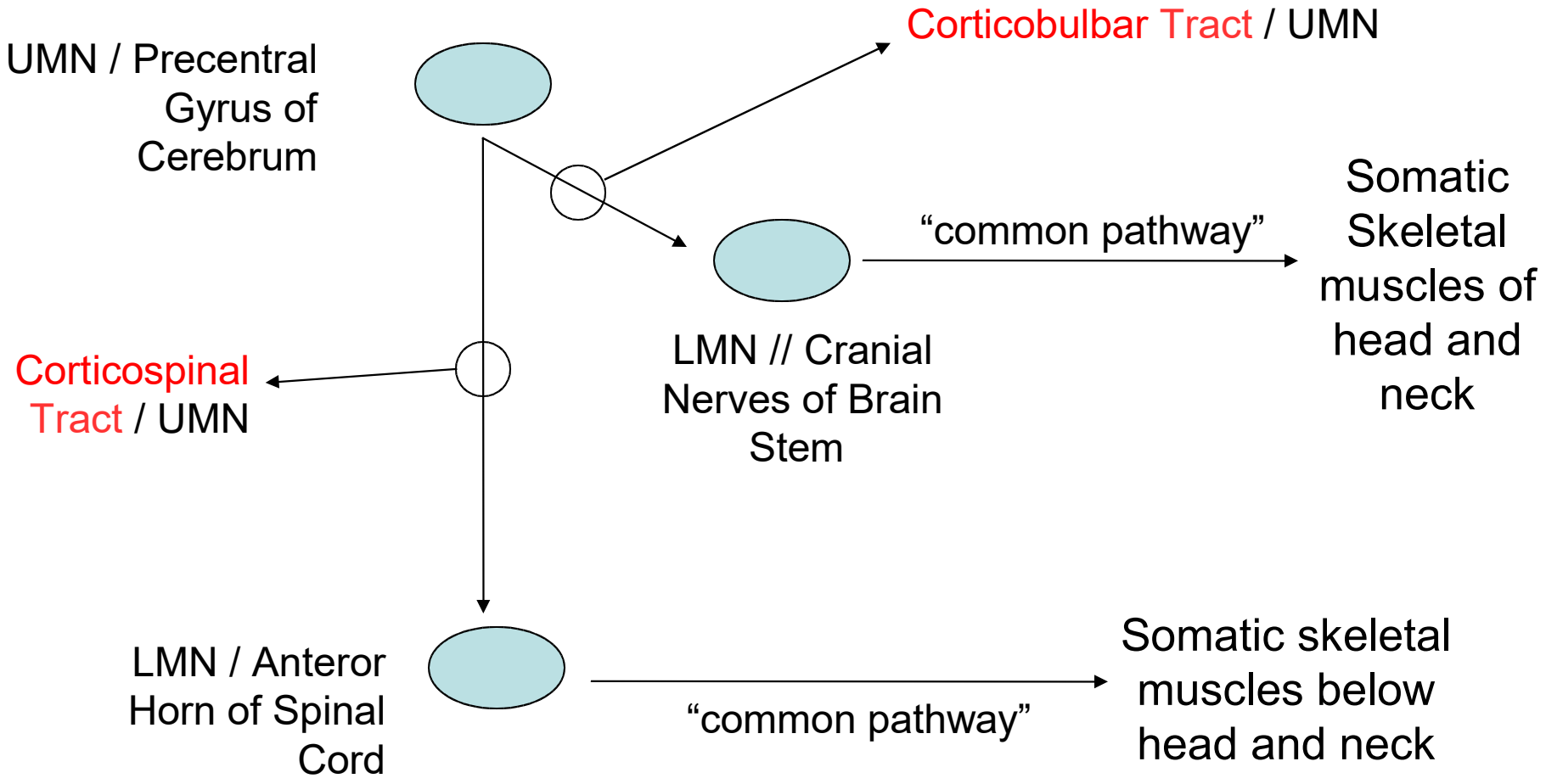
- Precentral Gyrus (Primary Motor Area) is where soma of the corticospinal tract originate (the upper motor neurons) /// these axons descend to synapse on lower motor neurons (soma in anterior horns of spinal cord) // LMN = common pathway to skeletal muscles

- Precentral Gyrus also has neurons which form the corticobulbar tract (also upper motor neurons) // they descend to synapse on motor nuclei in brain stem (cranial 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 common pathway that connect CNS to skeletal muscles (see next slides)

Descending Direct Pathways

Pathways = Axon Tracts



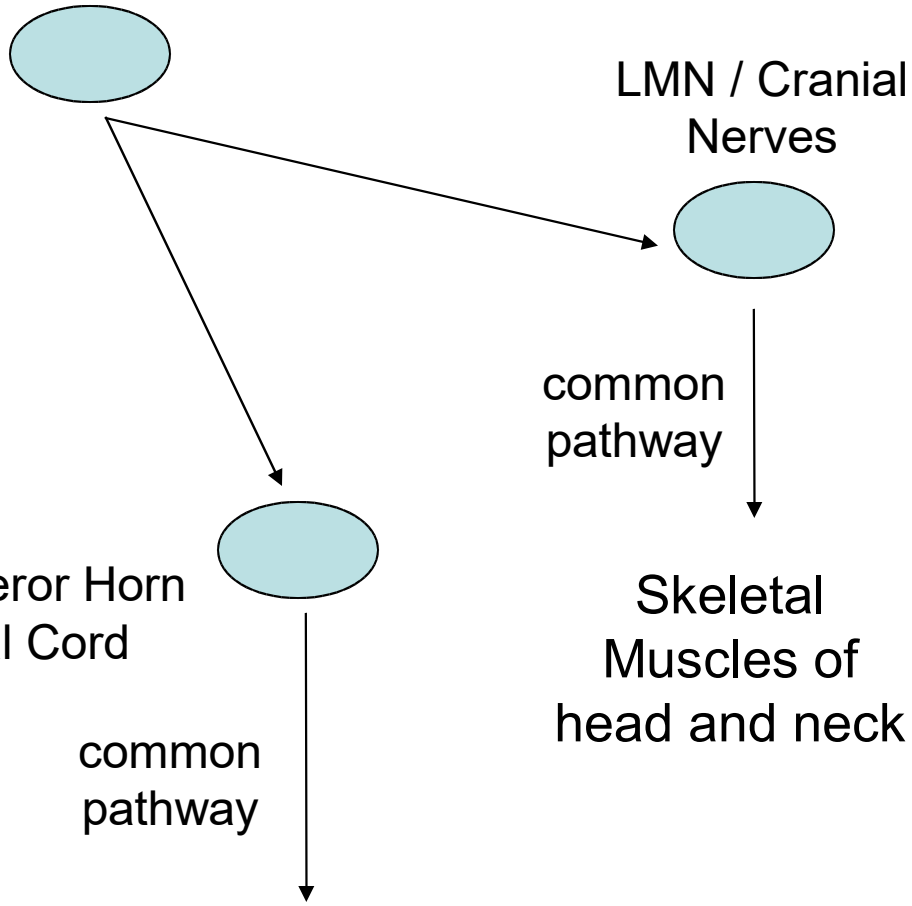
Descending Indirect Pathways

Pathways = Axon Tracts

UMN // These n**uclei originate in medulla oblongata**

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

Note: Nuclei #1 and #2 are responsible for reflexes from eyes and ears.



Basal Ganglia Functions

- Before the motor strip can send an action potential to an UPM, the motor association cortex directs the AP through the basal ganglia.

- BG is responsible for initiating a voluntary skeletal muscle contraction (BG direct pathway / excitation) while also preventing unwanted contraction (BG indirect pathway / inhibitory). The BG also plays a role in visual perception and other functions.

- Think about the rhythmic muscle contraction and relaxation that occurs when you walk. You must initiate and stop contractions but you must also inhibit other skeletal muscle unwanted contractions

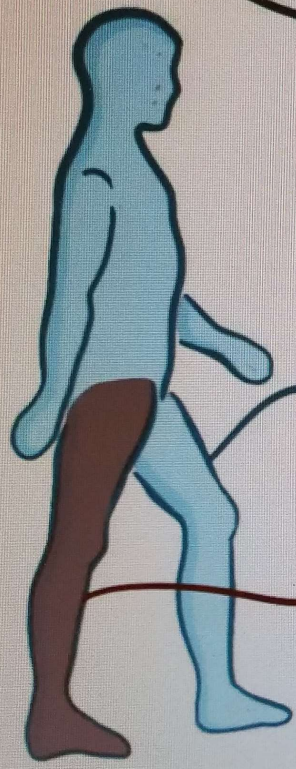
- Motor association area sends AP into striatum (cadate and putamen nuclei) // results in globus pallucidum passing AP through thalamus and eventually the AP arrives at the motor strip // the AP may now move down UMN to LMN and cause the skeletal muscle to contract.

- Basal ganglia also play a roll in vision. Perception is limited by BG so we can only see one image at a time (see next slide)

BASAL GANGLIA

- START, STOP, AND CONTROL MOVEMENTS
- INHIBITS UNDESIRED MOVEMENTS

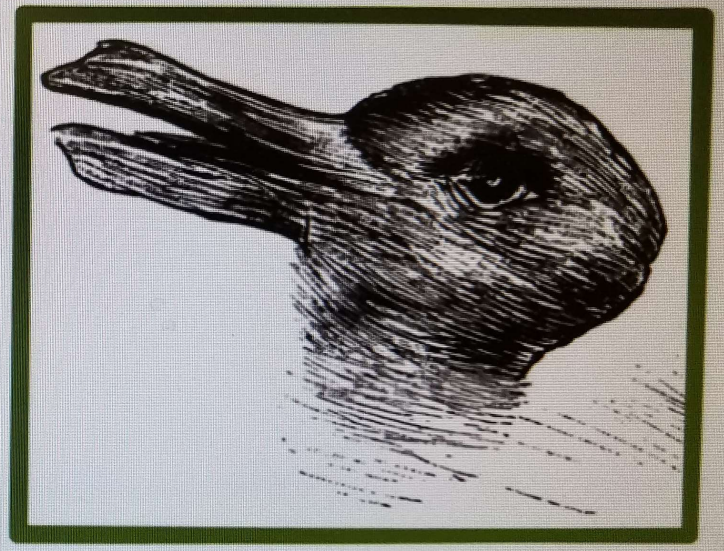
WALKING



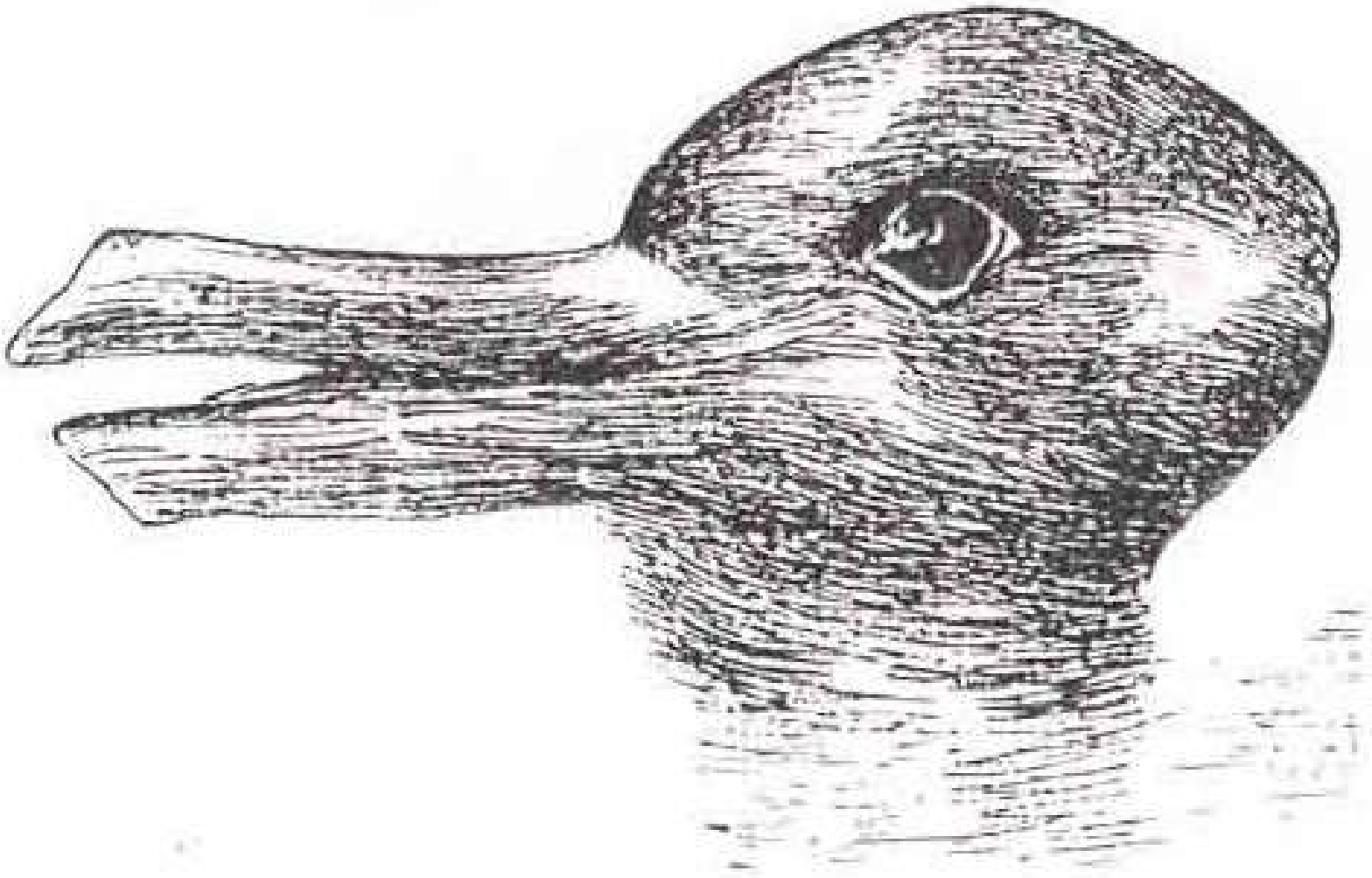
ACTIVE LEG
(STEPPING FORWARD)

INHIBITED LEG
(STATIONARY)

PERCEPTION

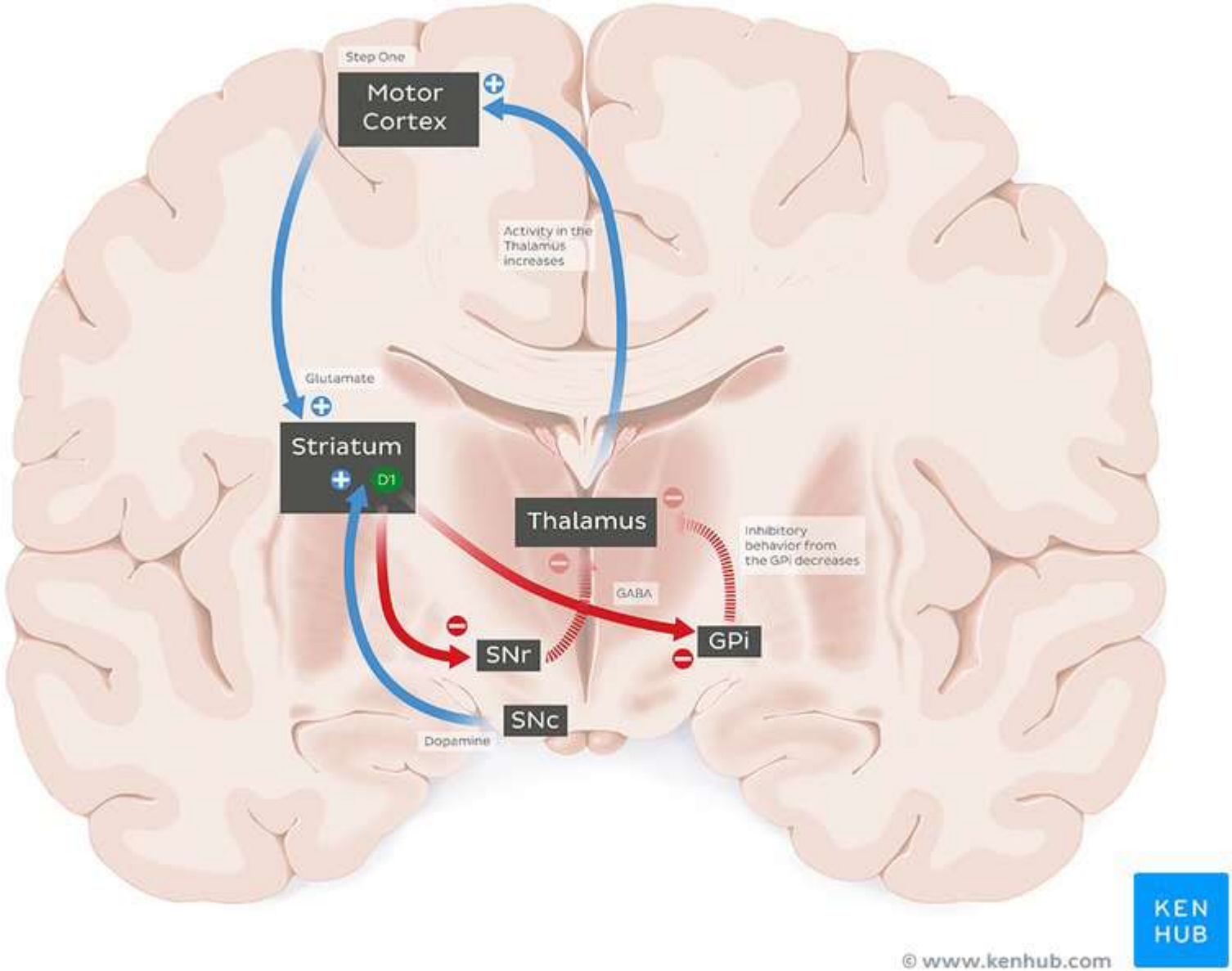


STIMULATES VISION OF ONE
INHIBITS THE VISION OF OTHER



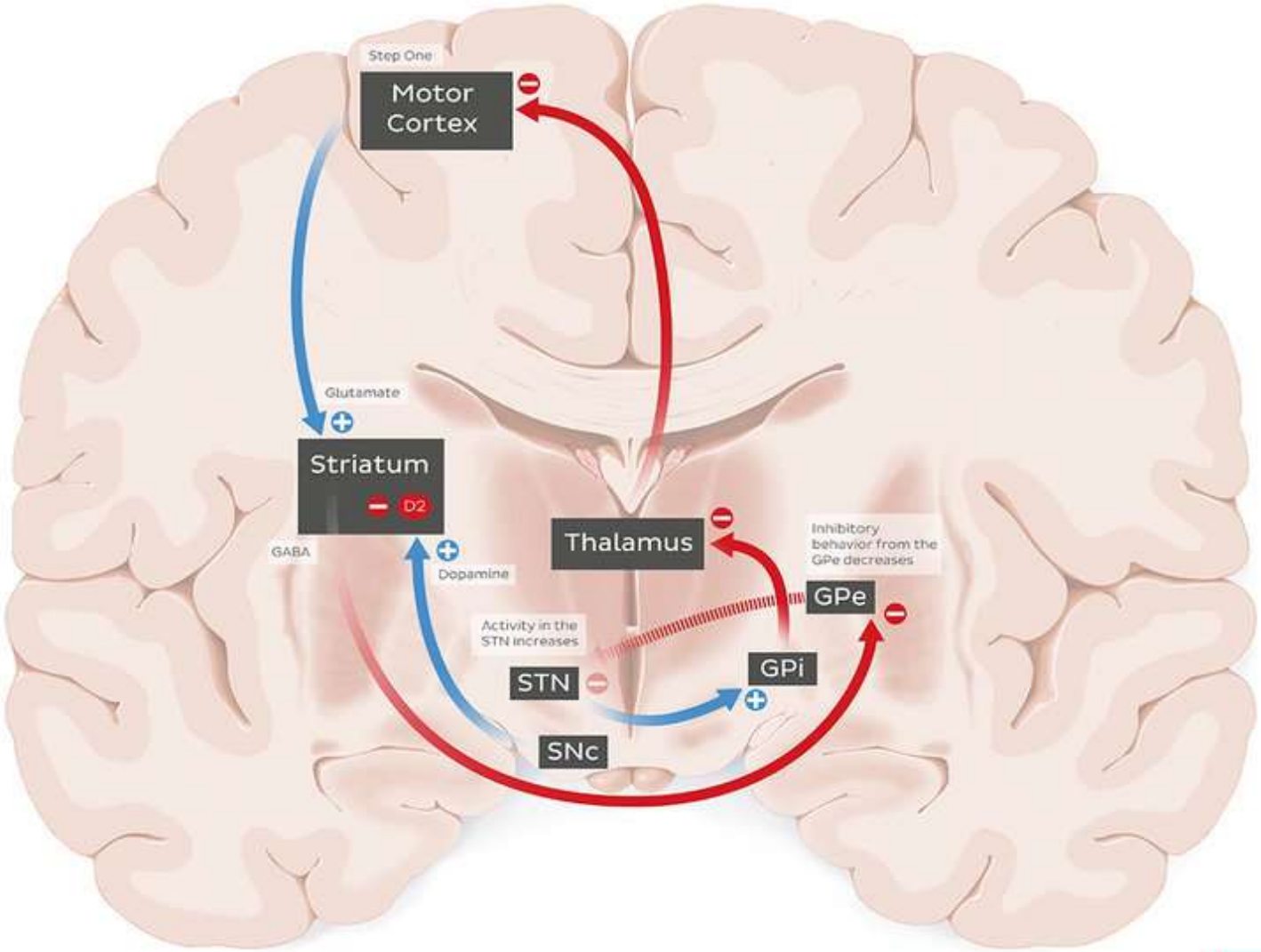
The following slides examine the function of the the Basal Nuclei in greater detail. This information is not a learning objective for this class. If you are curious and want to know more about motor control then you may want to study these slides.

Direct Pathway of the Basal Ganglia



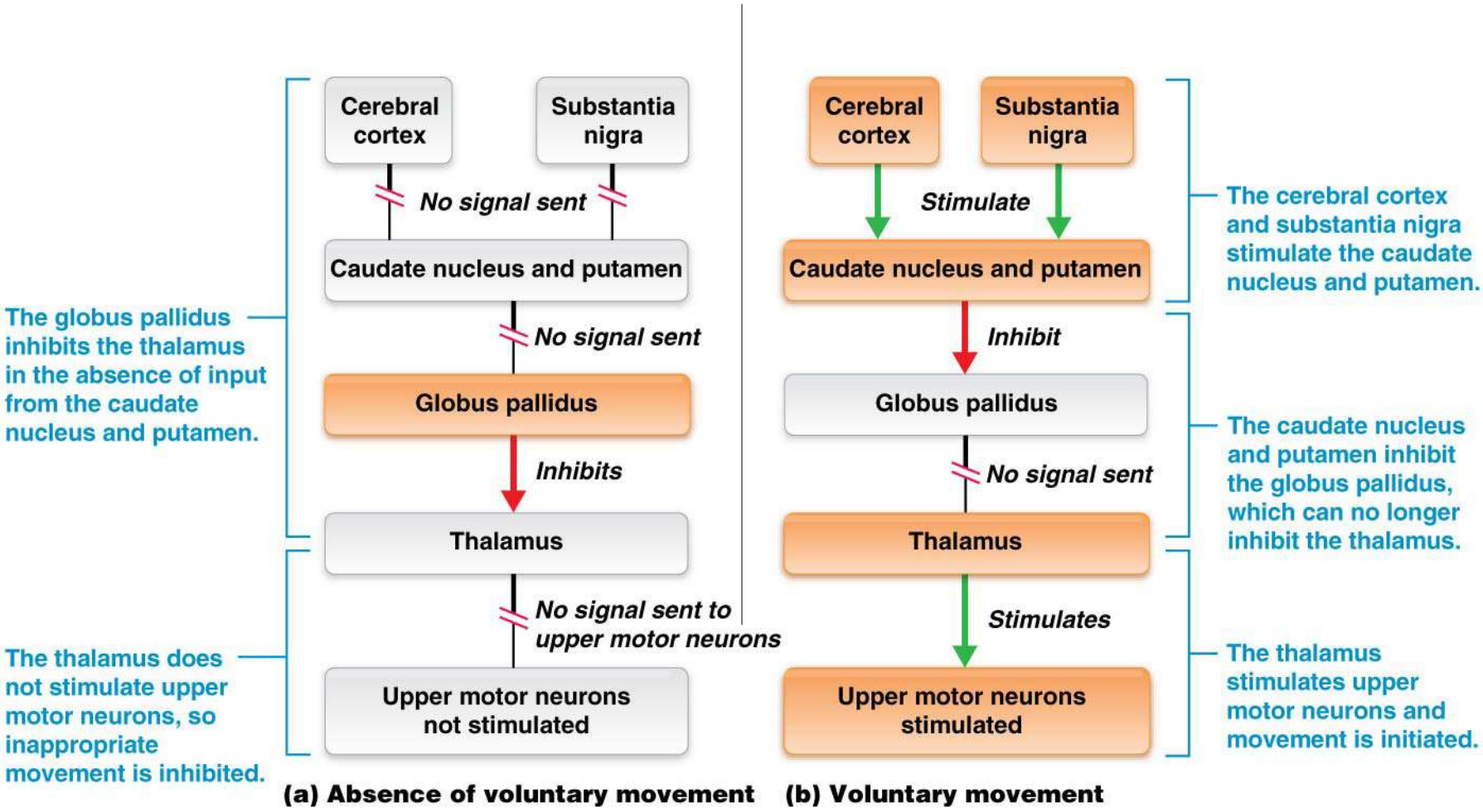
KEN HUB

Indirect Pathway of the Basal Ganglia

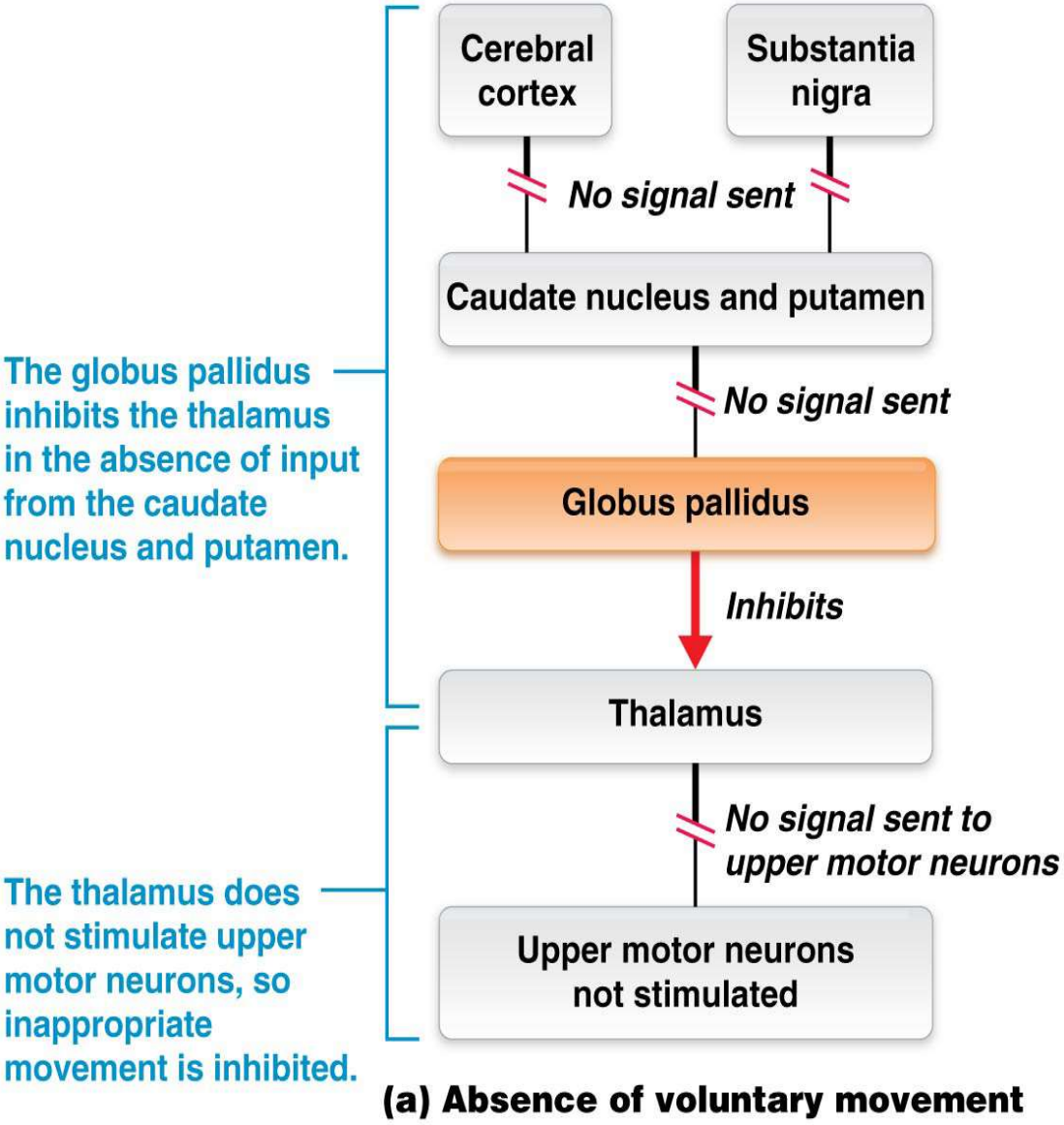


KEN HUB

Role of the basal nuclei in voluntary movement.



Role of the basal nuclei in voluntary movement.

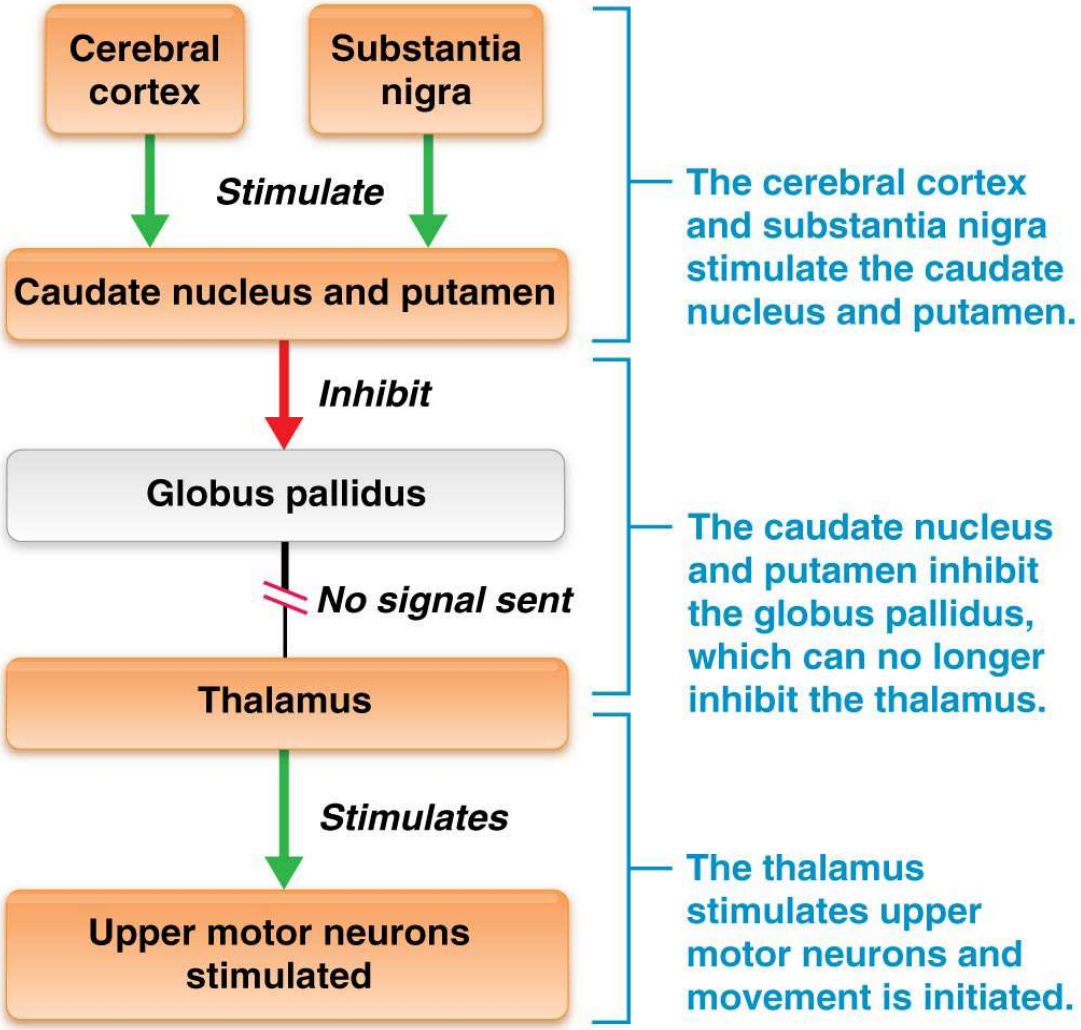


(a) Absence of voluntary movement

Role of the basal nuclei in voluntary movement.

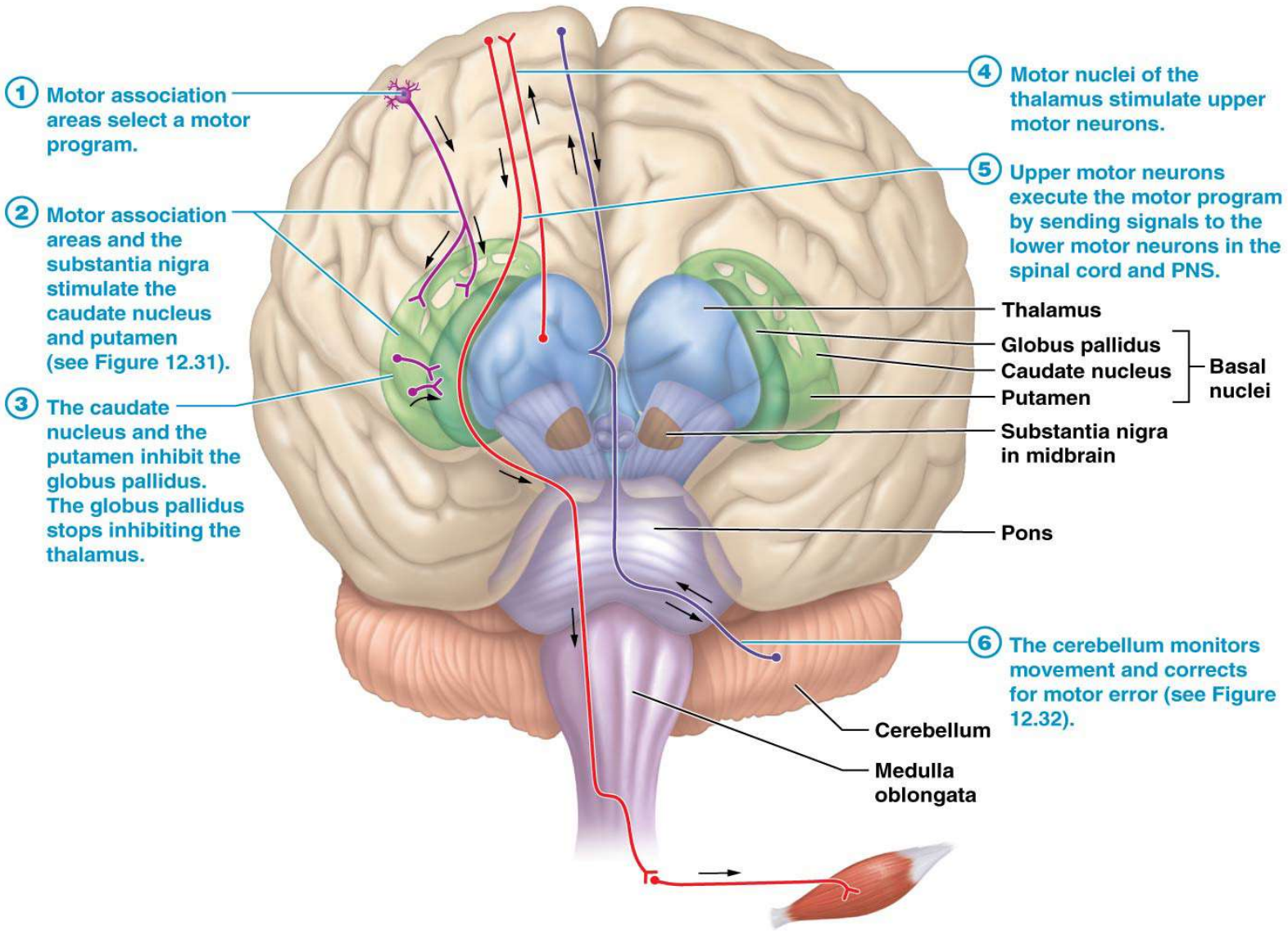
Globus pallidus function is to prevents motor programs from reaching UMN by blocking the AP at the thalamus.

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.



More Information About Motor Control

For More Information About the Basal Ganglia Function
Go To Unit Four Lecture
See Articles of Interest - Basal Ganglia

More Information About Motor Control

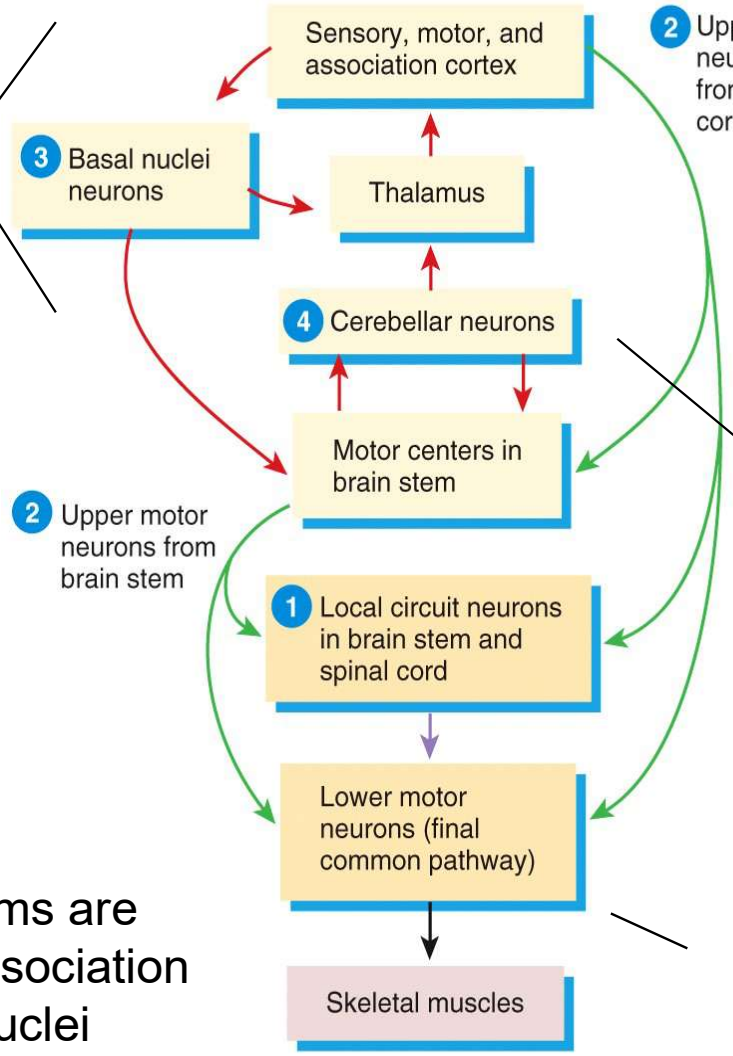
Students are not required to review the rest of these slides.

If you do decide to view these slides then you will get a more detailed perspective about motor control.

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

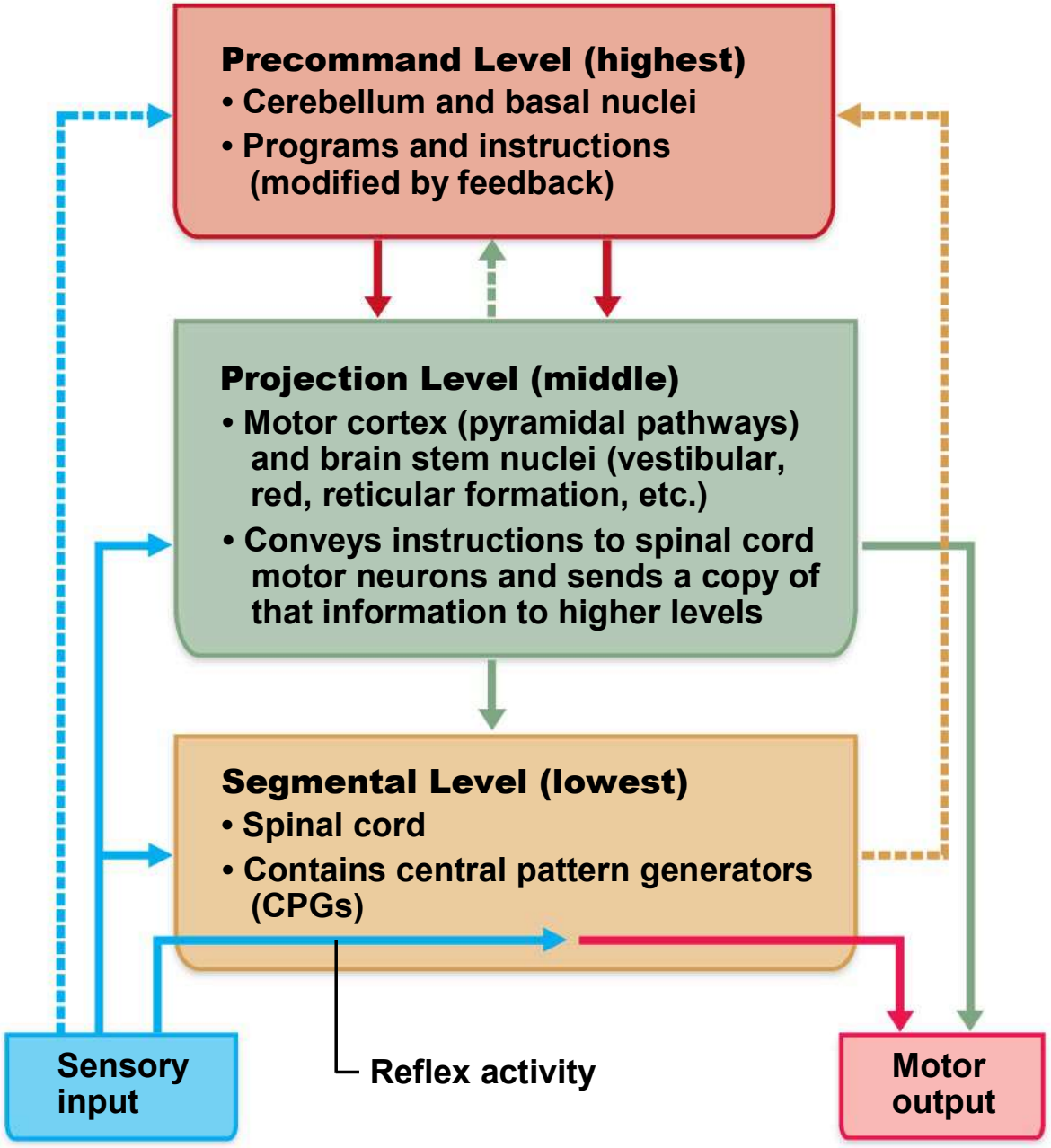
Hierarchy of Motor Control

The idea to move is generated in prefrontal cortex. This is where our conscious thought to move originates.

The action potential (AP) pathway then moves through basal nuclei to thalamus to motor cortex.

Projection level sends AP decending AP to skeletal muscles but also same signal back to Precommand Level.

Note: 1) Dotted lines show feedback pathways. 2) Reflex activity only involves segmental level.



(a)

Levels of motor control and their interactions

"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

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

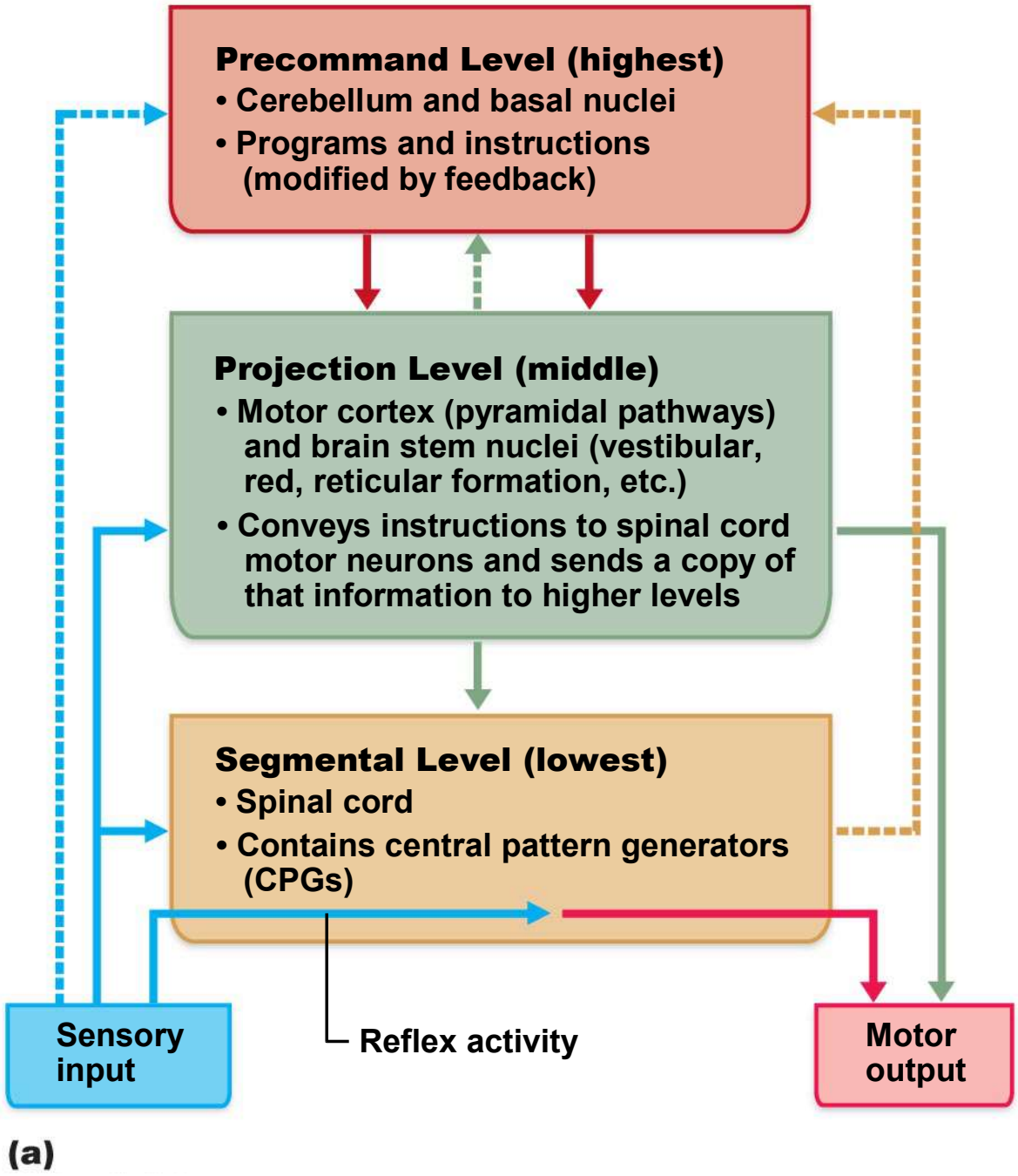
Pre-command Level

- 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

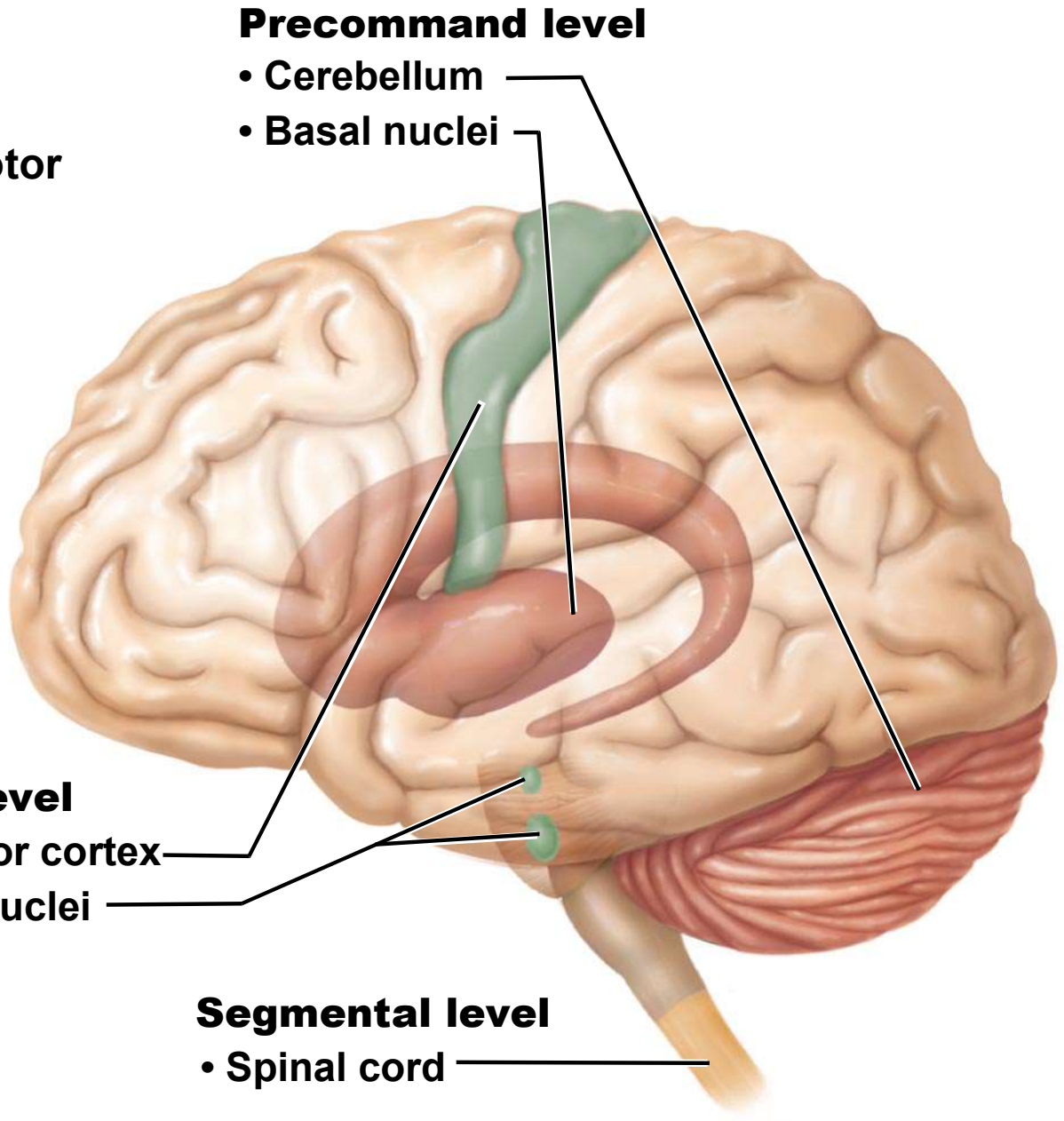
Pre-command Level

- **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**

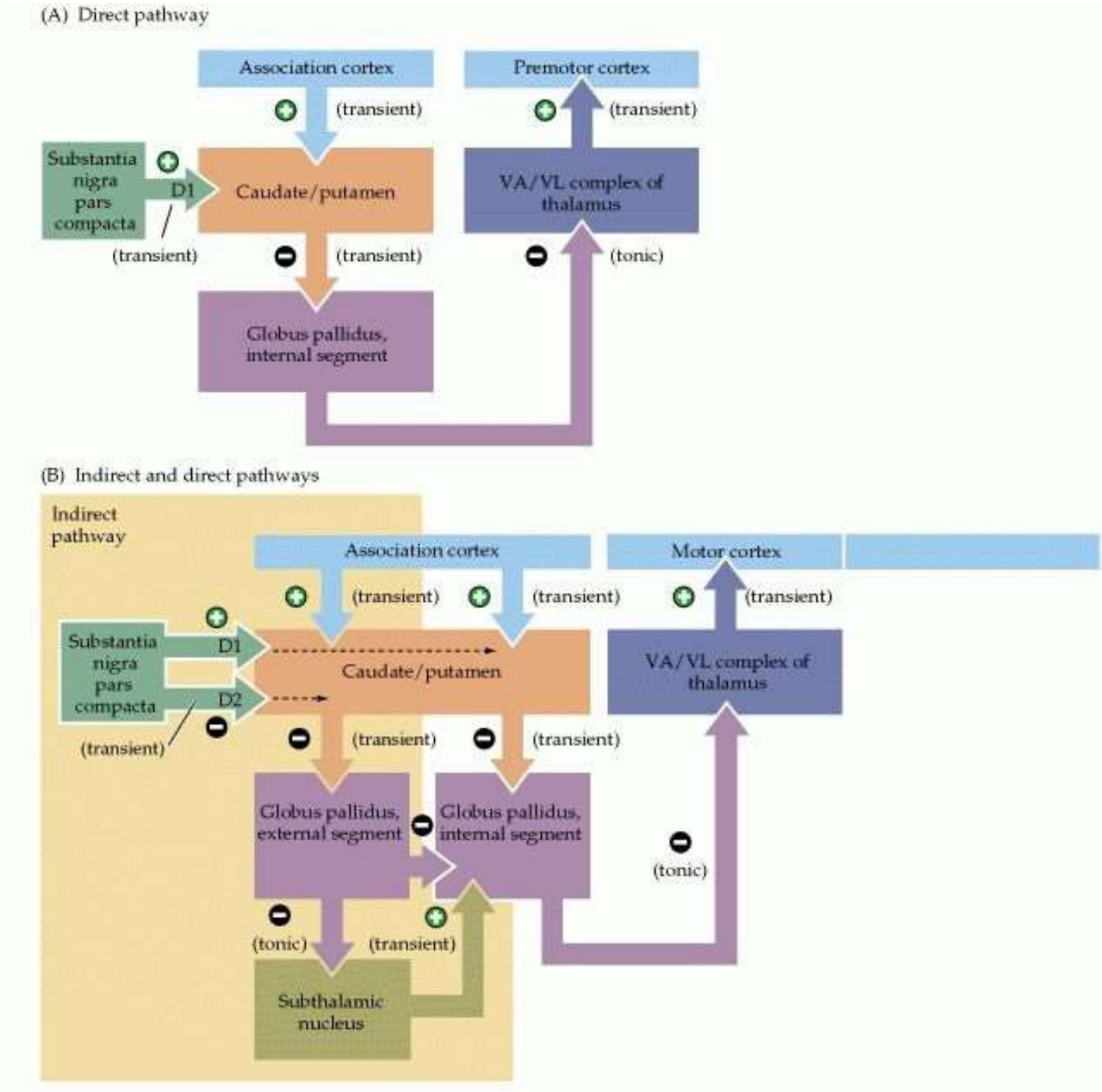
Hierarchy of Motor Control



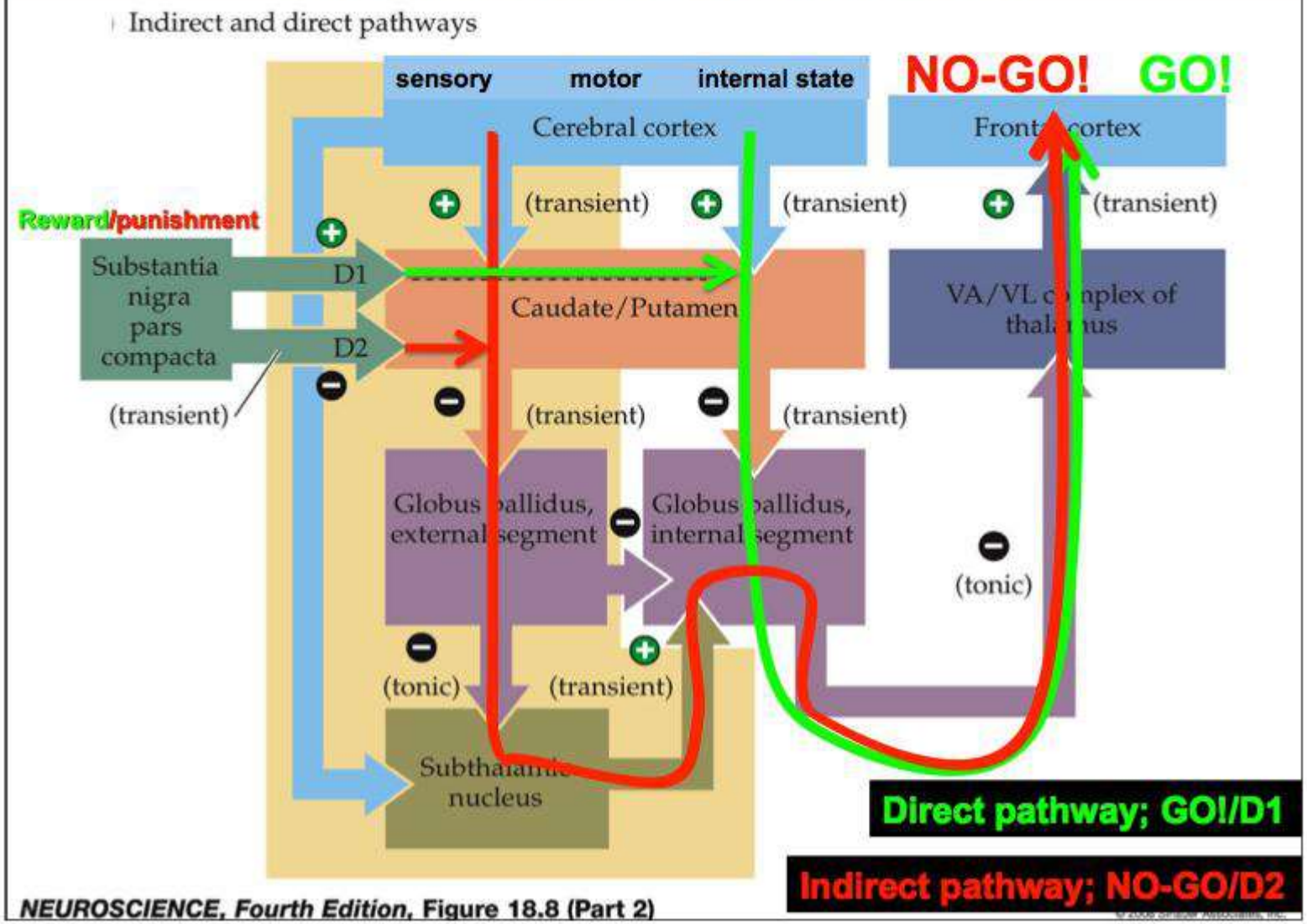
Hierarchy of motor control.



(b) Structures involved

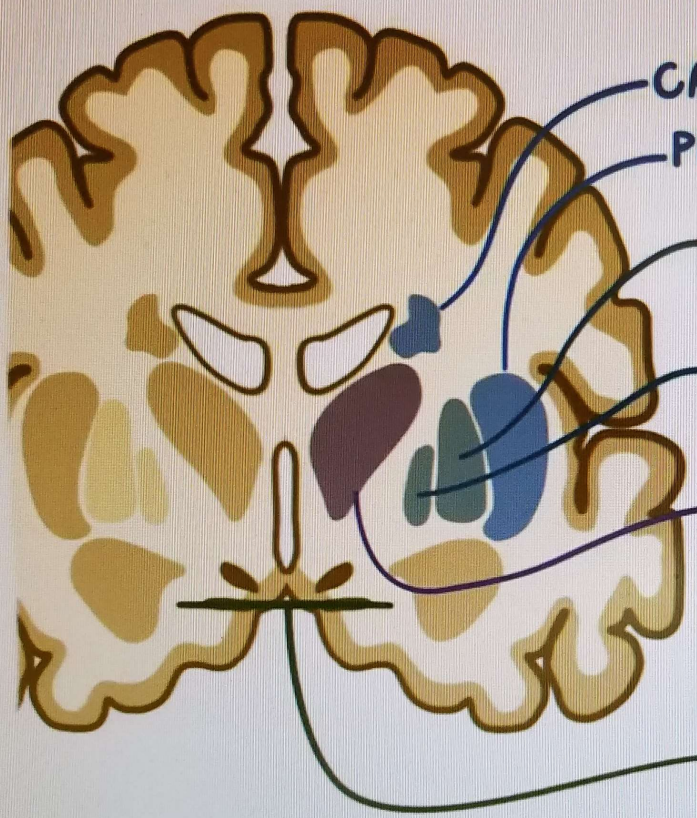

(A) Direct pathway
Association cortex
Premotor cortex
(transient)
(transient)
Substantia nigra pars compacta
D1
Caudate/putamen
VA/VL complex of thalamus
(transient)
(transient)
(tonic)
Globus pallidus, internal segment
(B) Indirect and direct pathways
Indirect pathway
Association cortex
Motor cortex
(transient)
(transient)
(transient)
Substantia nigra pars compacta
D1
D2
Caudate/putamen
VA/VL complex of thalamus
(transient)
(transient)
(transient)
Globus pallidus, external segment
Globus pallidus, internal segment
(tonic)
(tonic)
(transient)
Subthalamic nucleus

Direct and indirect pathways through the basal ganglia



NEUROSCIENCE, Fourth Edition, Figure 18.8 (Part 2)

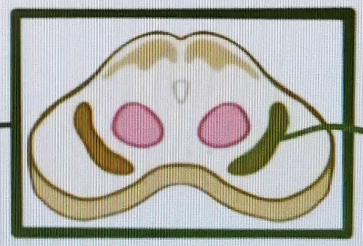
BASAL GANGLIA



CAUDATE NUCLEUS
PUTAMEN
} STRIATUM

EXTERNAL GLOBUS PALLIDUS
INTERNAL GLOBUS PALLIDUS
} GLOBUS PALLIDUS

THALAMUS
- VENTRAL ANTERIOR NUCLEI
- VENTRAL LATERAL NUCLEI



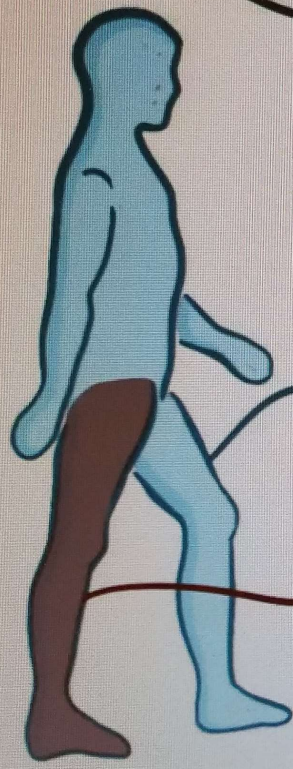
(MIDBRAIN)
SUBSTANTIA NIGRA

and ventral lateral nuclei of the thala

BASAL GANGLIA

- START, STOP, AND CONTROL MOVEMENTS
- INHIBITS UNDESIRED MOVEMENTS

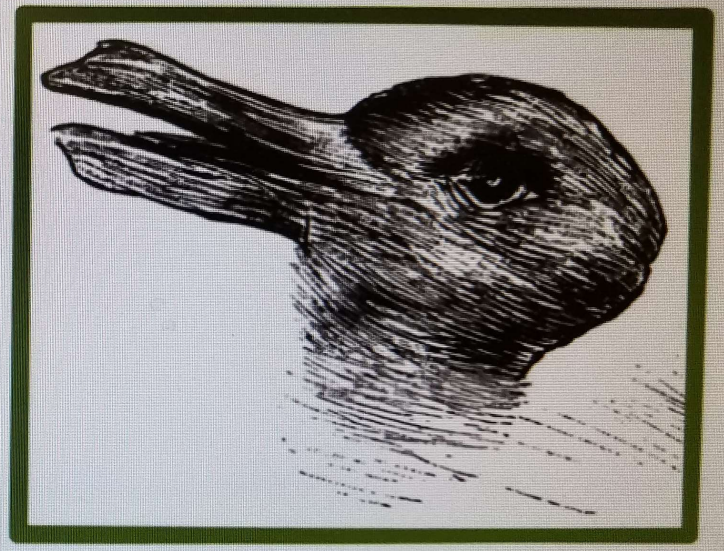
WALKING



ACTIVE LEG
(STEPPING FORWARD)

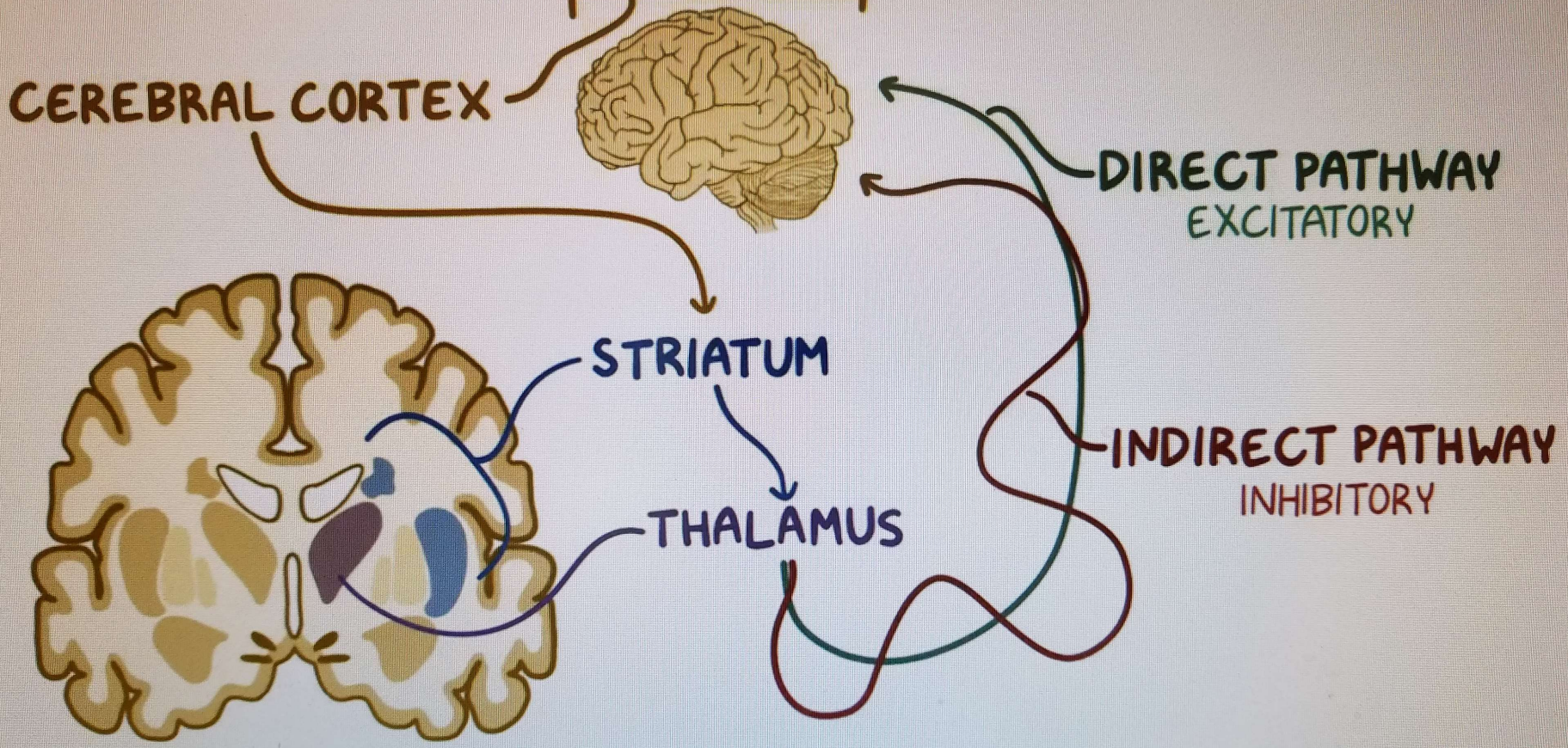
INHIBITED LEG
(STATIONARY)

PERCEPTION

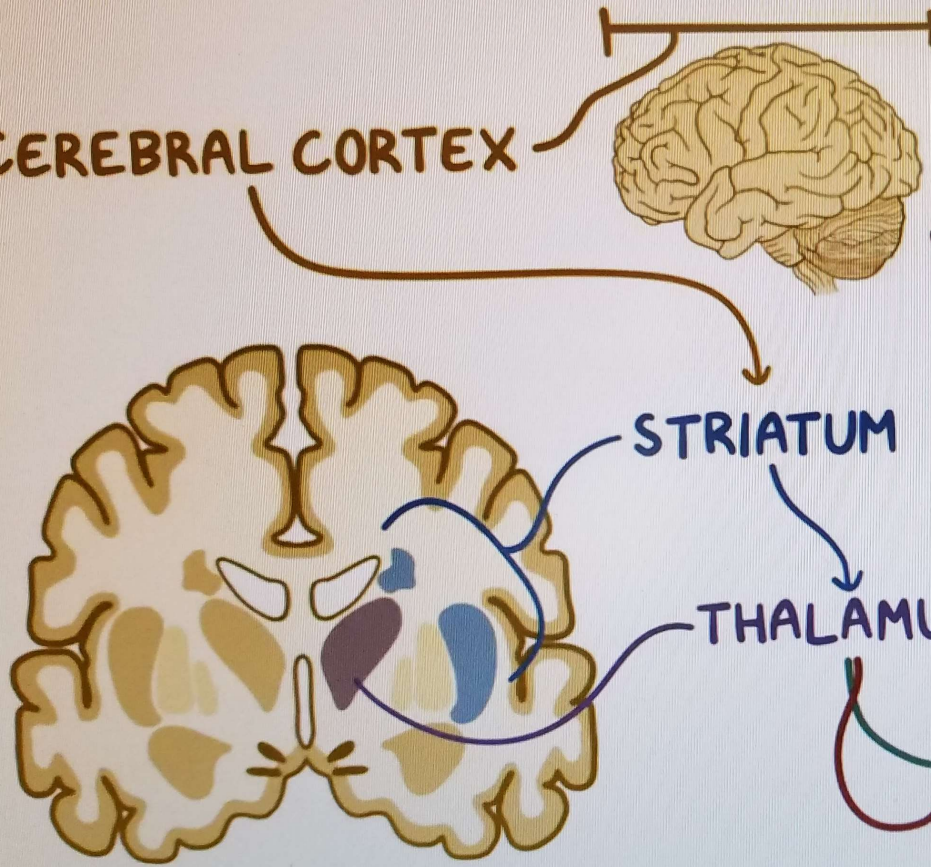


STIMULATES VISION OF ONE
INHIBITS THE VISION OF OTHER

BASAL GANGLIA



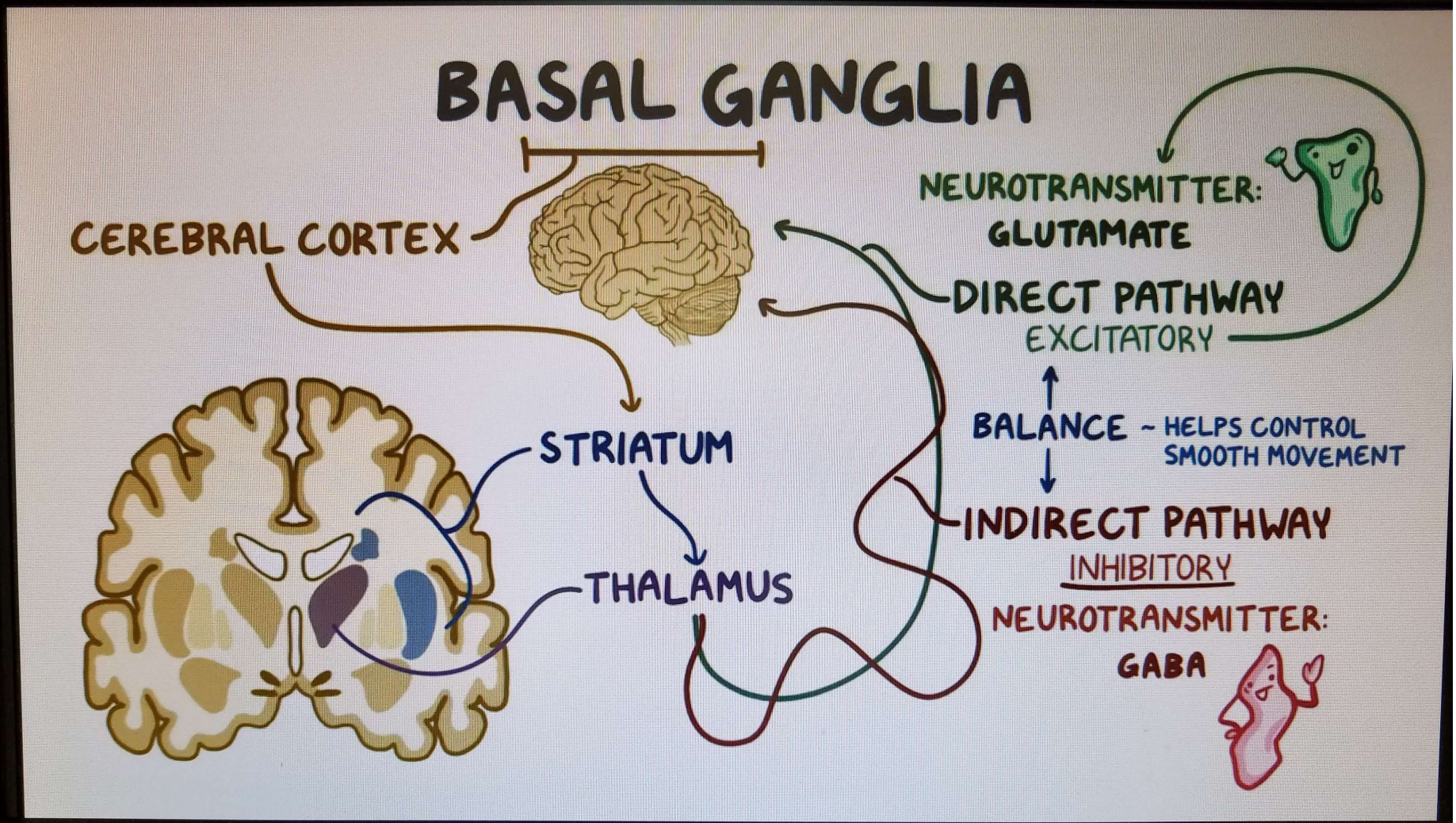
BASAL GANGLIA



DIRECT PATHWAY
EXCITATORY

BALANCE ~ HELPS CONTROL SMOOTH MOVEMENT

INDIRECT PATHWAY
INHIBITORY



neurotransmitter glutamate, and the inh
neurotransmitter GABA.