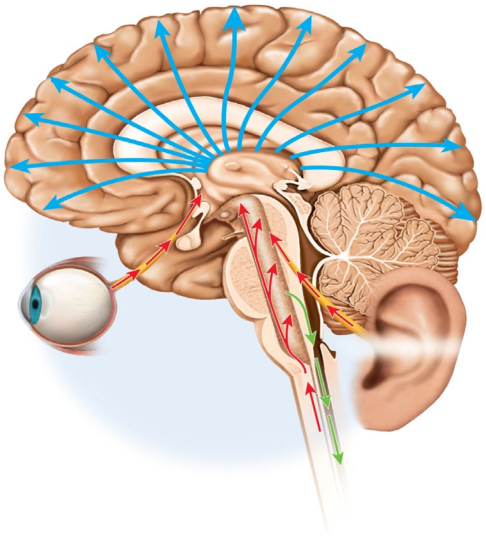
Chapter 14.4

Brain Function



Medulla Oblongata, Pons, Mid-Brain, Reticular Formation, Diencephalon, Thalamus, Epithalamus, Hypothalamus, Cerebellum, Cerebrum, Limbic System, Basal Ganglia, Language Centers, Claustrum, Anterior Cingulate Gyrus and other structures listed in C14 Chapter Study Guide.

(15 test questions)

During the first two years of life, the total number of neurons do not increase but brain density increases. This is caused by the formation of new terminal knobs. The end of axon split and forms new synaptic connection between existing neurons.

During the first two years of life, the human brain produces 20 million new synaptic connection per second .

This creates a "confused network". But as the brain is exposed to stimuli and starts to store information, the brain "prunes the synaptic connections" (reduce the total number of synapses) to strengthen and improve the efficiency of the neuronal pathways. The cortical mass becomes denser as this occurs.

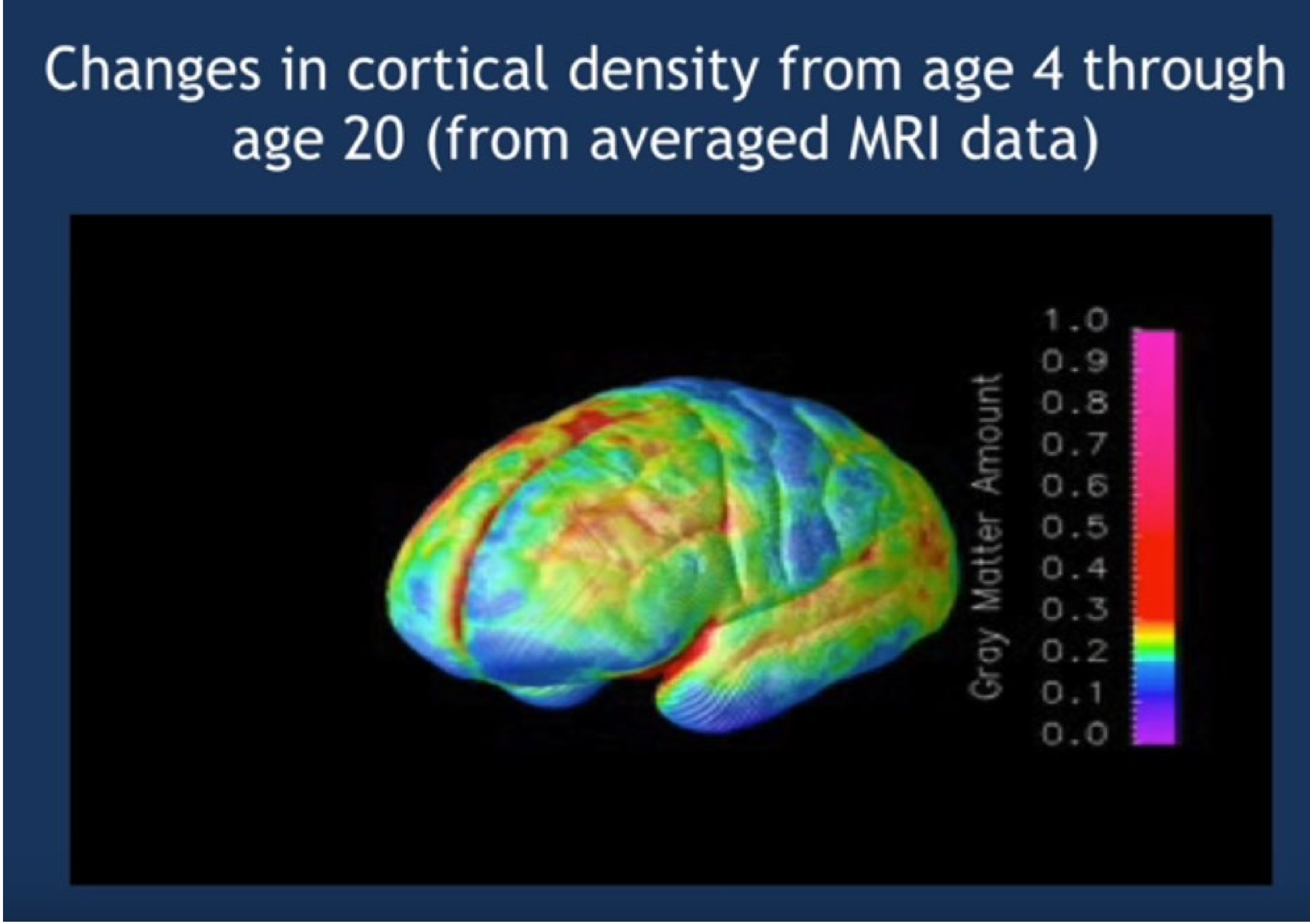
Developing a Mind...

Development / learning =
Synaptic growth + synaptic pruning

- Synaptic growth → novelty, new associations, increasing knowledge and skills

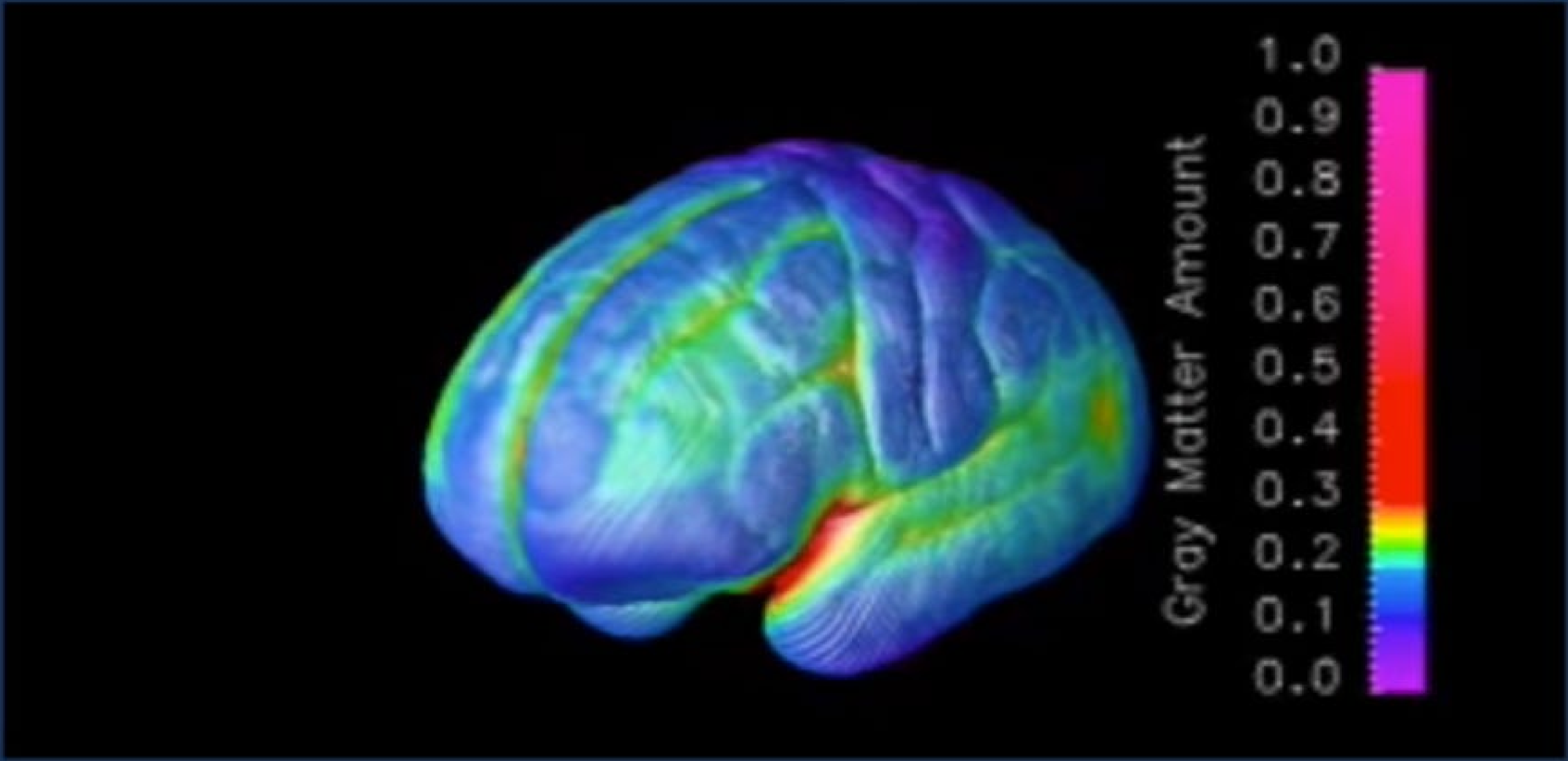
Synaptic pruning

Consolidation, efficiency, habit formation

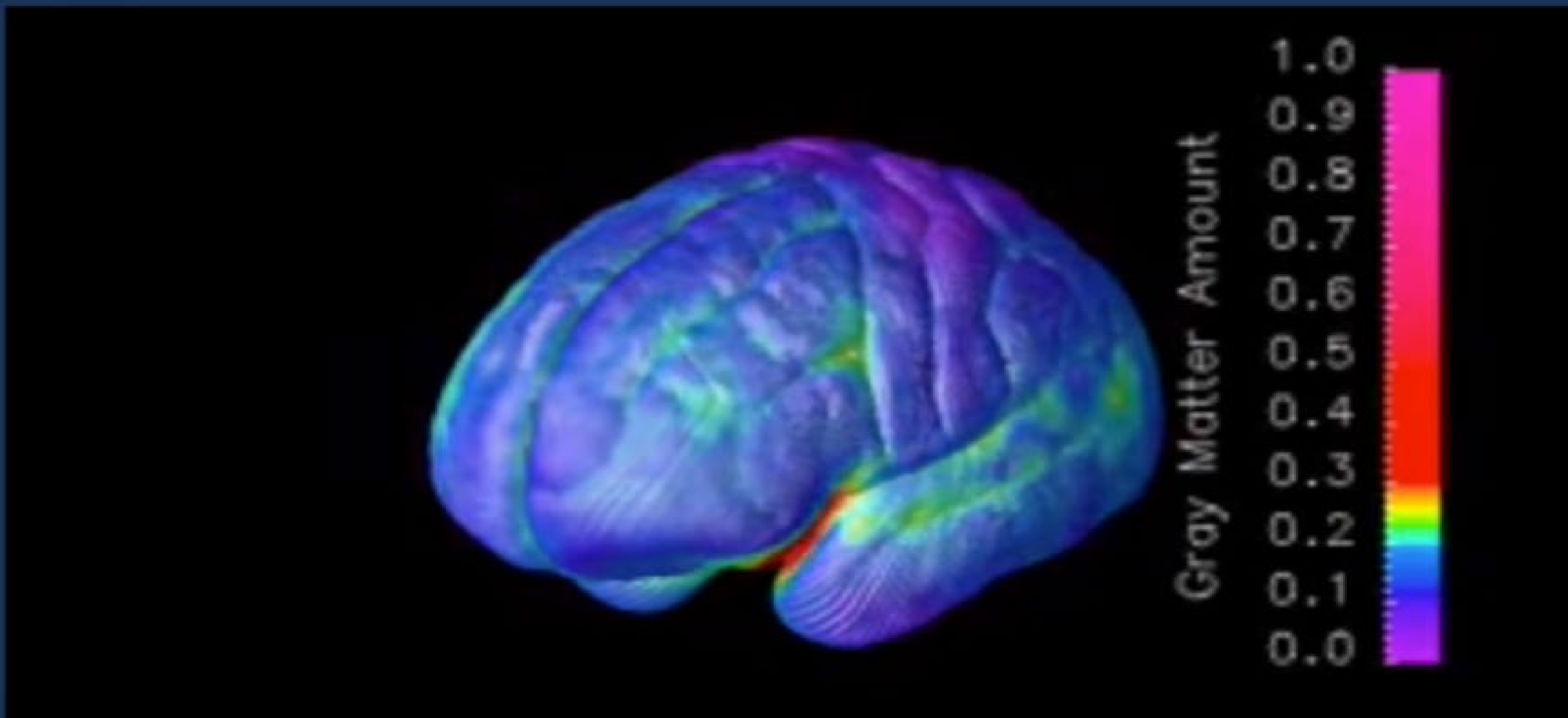


The next three slides show the how the cortical density changes as a result of “pruning”. The dark blue areas show where pruning has already occurred. The somatosensory areas are the first to be pruned.

Changes in cortical density from age 4 through age 20 (from averaged MRI data)

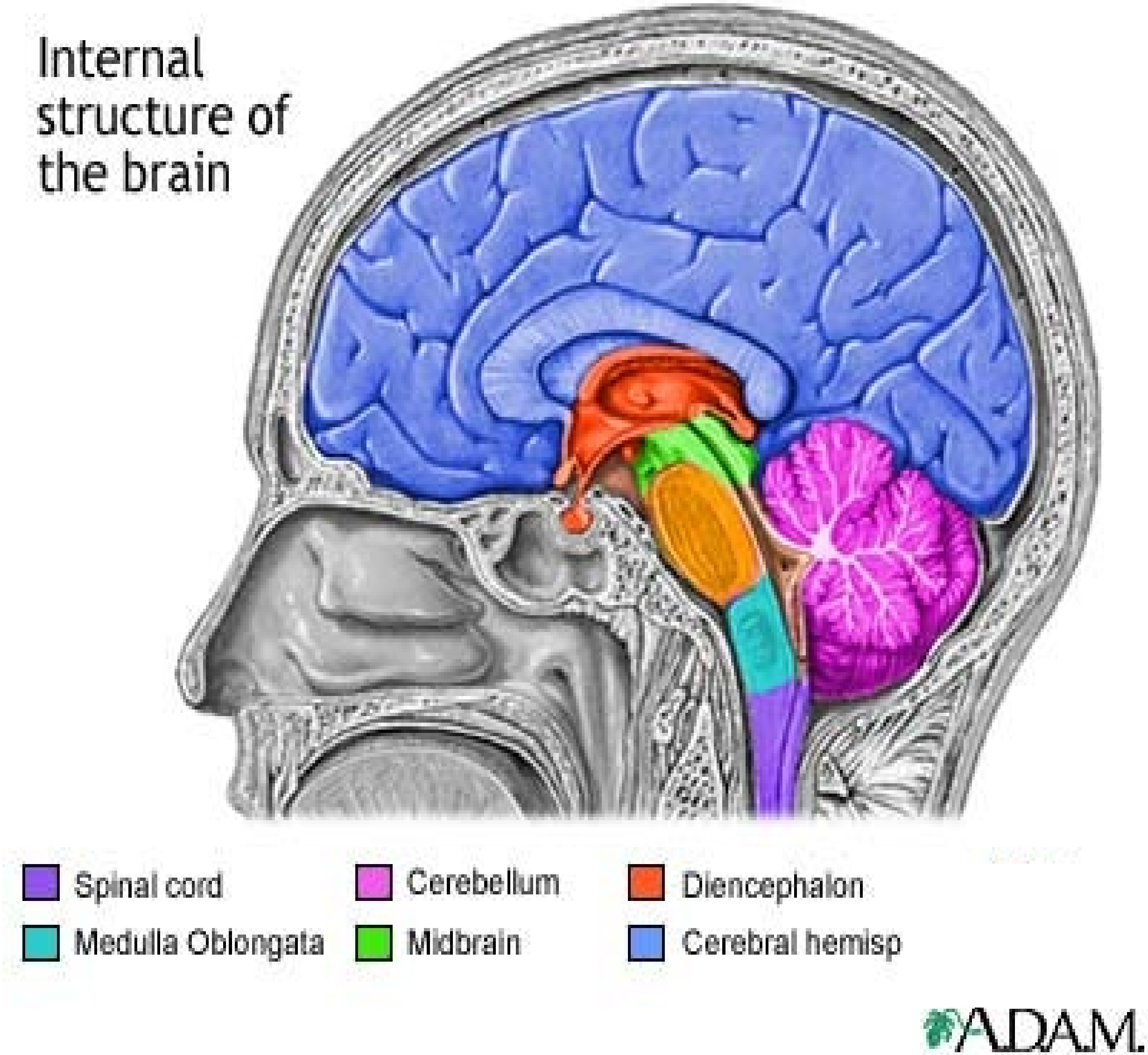


Changes in cortical density from age 4 through age 20 (from averaged MRI data)



The last region o the brain to mature (hard wire) is the prefrontal cortex.

We will start at the brain stem
and move towards the cerebral hemispheres.



Medulla Oblongata

First segment of the brain stem

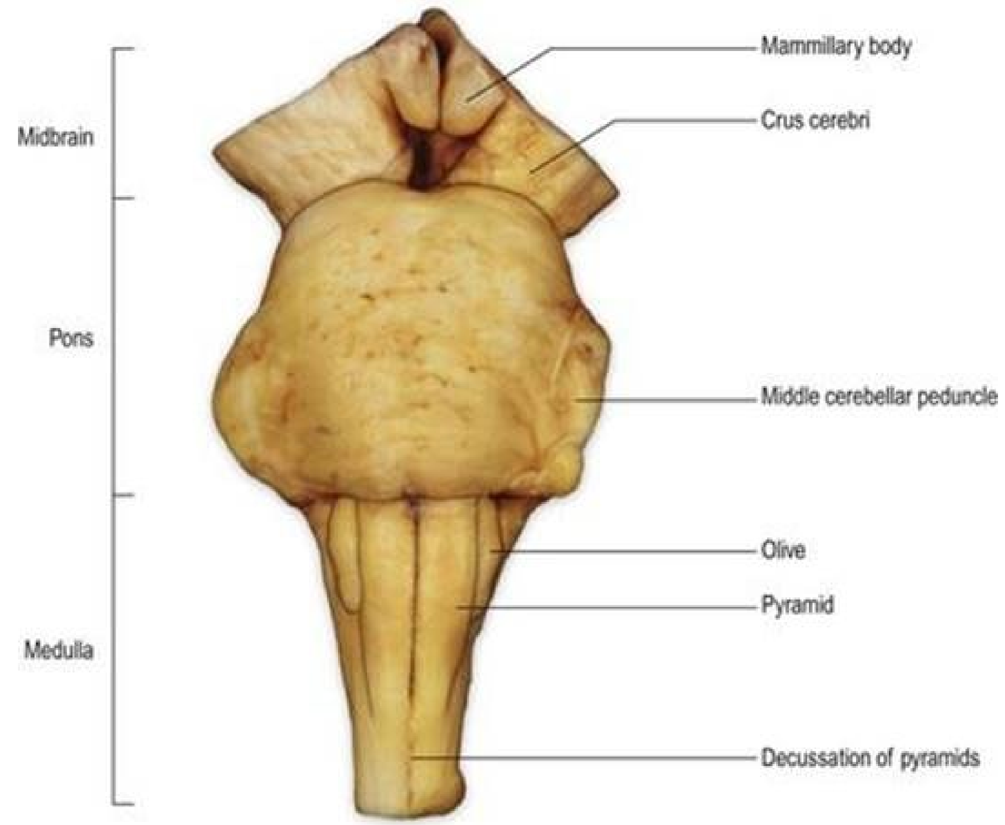
The medulla oblongata begins at the foramen magnum of the occipital bone and is approximately 3 cm long

Ends at a groove between the medulla and pons

Slightly wider than deep

The pyramids – pair of external ridges on anterior surface of medulla oblongata

- resembles side-by-side baseball bats
- pathway for the corticospinal track (motor strip to skeletal muscles)



olive – a prominent bulge lateral to each pyramid

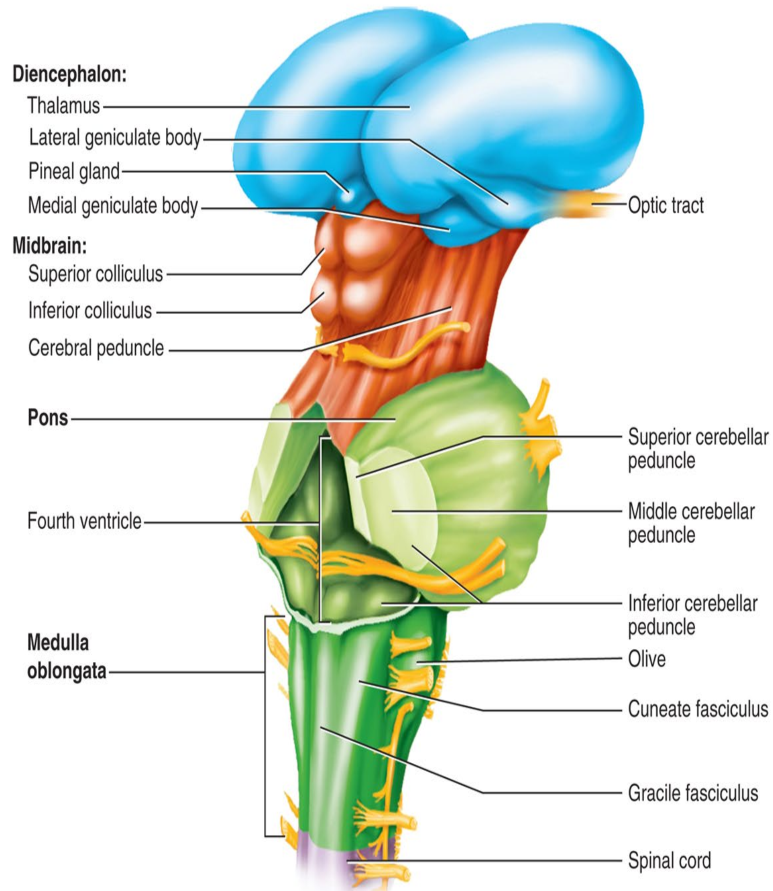
Medulla Oblongata

Contain all the nerve fibers that connects the brain to the spinal cord

All nerve tracts must pass through the medulla oblongata

Posteriorly, **gracile** and **cuneate fasciculi** of the spinal cord continue as two pair of ridges on the medulla

Four pairs of cranial nerves begin or end in medulla - IX, X, XI, XII



(b) Dorsolateral view

Medulla Oblongata
Location of Many Nuclei

(Each Nuclei Regulates a Different Function)

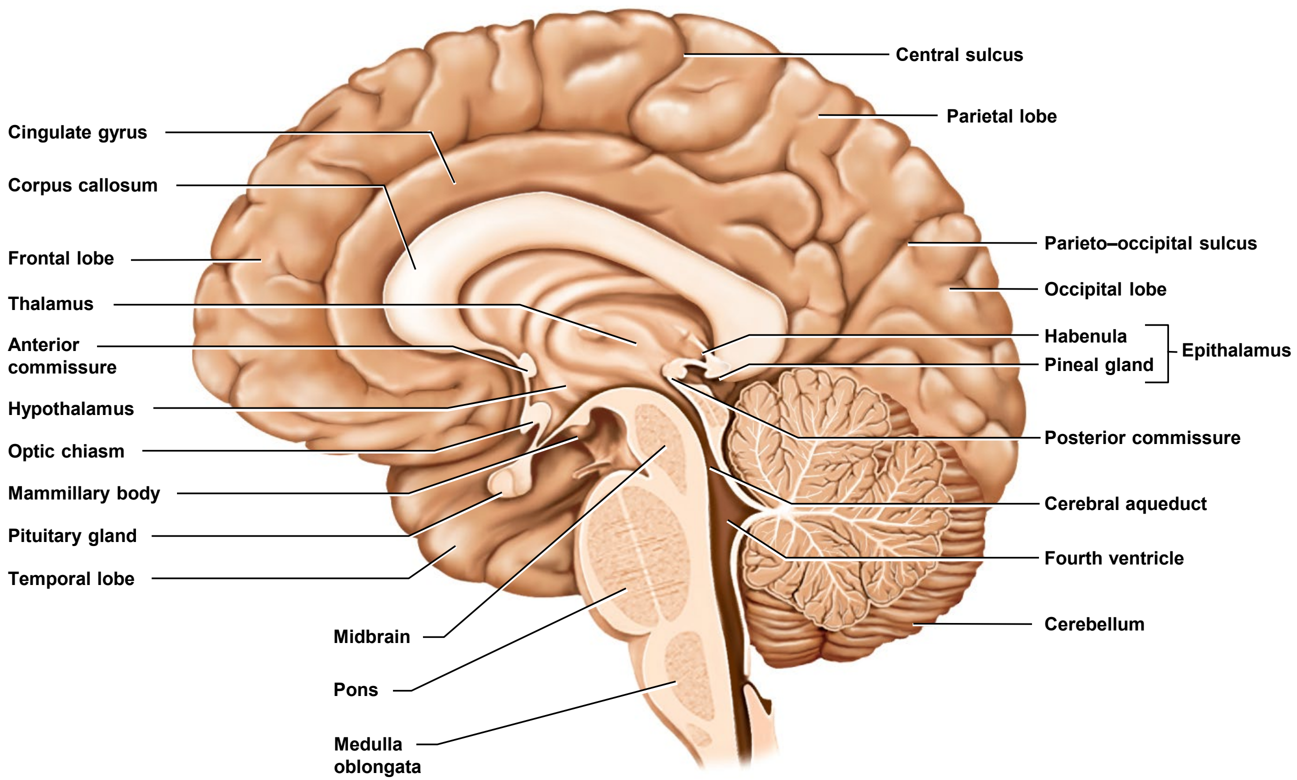
cardiac center // adjusts rate and force of heart

vasomotor center // adjusts blood vessel diameter

respiratory centers // control rate and depth of breathing

reflex centers // coughing, sneezing, gagging, swallowing, vomiting, salivation, sweating, movements of tongue and head

The Pons



Pons – anterior bulge in brainstem, rostral to medulla

Cerebellar peduncles – tracts that connect cerebellum to brainstem at the pons /// peduncle fiber tracks play key role in "motor control" = how skeletal muscles compare the intent vs actual muscle contraction and adjust results to match intent (to be covered in later slides)

- inferior peduncles
- middle peduncles
- superior peduncle

Pons

- ascending sensory tracts to cerebrum
- descending motor tracts to cerebellum and spinal cord
- pathways in and out of cerebellum

- **cranial nerves V, VI, VII, and VIII originate within Pons**

– **sensory roles** – hearing, equilibrium, taste, facial sensations

– **motor roles** – eye movement, facial expressions, chewing, swallowing, urination, and secretion of saliva and tears

- Pons also contain part of the reticular formation

- Additional nuclei concerned with // *sleep, respiration, analgesic descending tract, and posture*

Midbrain

Short segment of brainstem that connects the thalamus to the pons

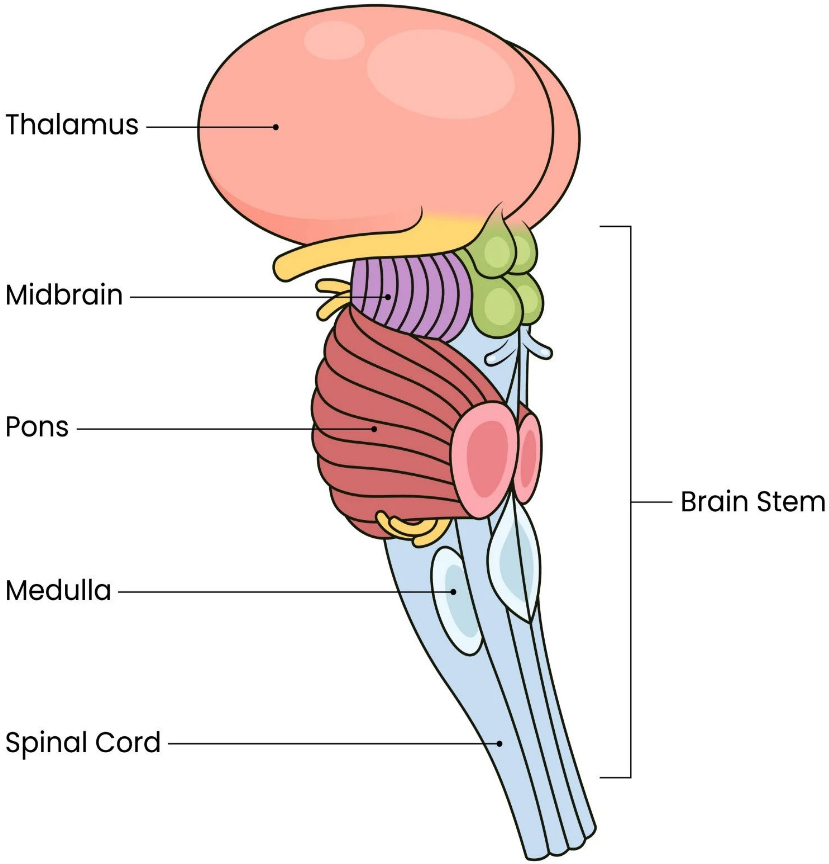
the cerebral aqueduct runs through the length of the midbrain

contains continuations of the medial lemniscus and reticular formation

contains the motor nuclei for two cranial nerves that control eye movements – CN III (oculomotor) and CN IV (trochlear)

periaqueductal gray – this surrounds cerebral aqueduct // very ancient part of the brain // project to raphi nucleus – role in blocking pain

the midbrain is the origin of addiction pathway (reward or pleasure pathway) // **ventral tegmental** area projects dopamine nerve tracks to the nucleus accubens



Midbrain's Structures

Tectum – roof-like structure at top of the midbrain /// posterior to cerebral aqueduct

Corpora quadrigemina (superior and inferior colliculi)

four bulges, positioned under the occipital lobe

upper pair = superior colliculi /// visual reflexes /// function in visual attention, tracking moving objects

lower pair = inferior colliculi /// auditory reflexes /// receives signals from the inner ear /// relays them to other parts of the brain, especially the thalamus //

Sensory input from eyes and ears, generate motor response to skeletal muscles in head/neck /// responsible for the startle reflex

Cerebral peduncles – fiber tracts passing through midbrain // two stalks that anchor the cerebrum to the brainstem anterior to the cerebral aqueduct

Midbrain

Important midbrain structures: tegmentum, substantia nigra, and cerebral crus

Tegmentum: dominate structure is red nucleus // pink because of high denisty of blood vessels // works with cerebellum in fine motor control

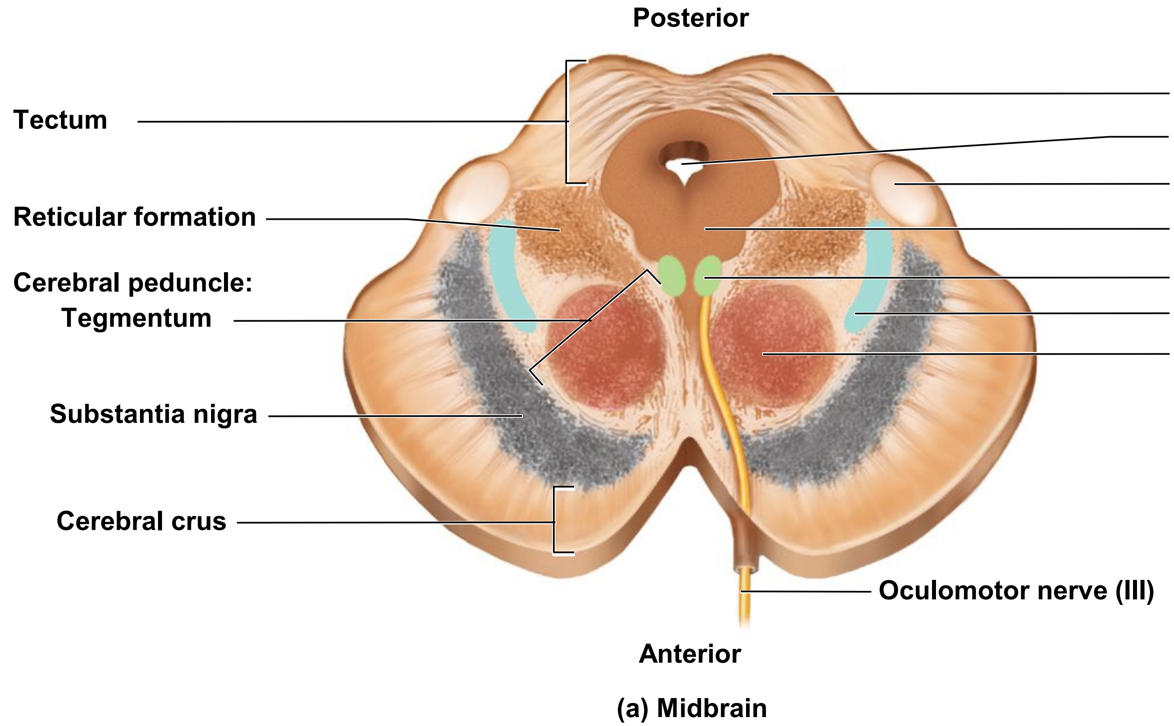
Substantia nigra: dark grey to black nucleus pigmented with melanin // *motor center that relays inhibitory signals to thalamus and basal nucleus – inhibits muscle contractions*

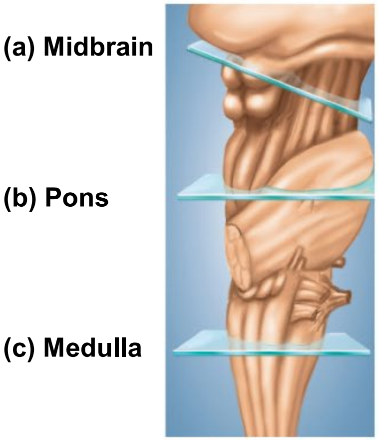
Note: Parkinson disease – degeneration of substantia nigra neurons reduces dopamine secretion to basal nuclei // **less inhibitory signals** to anterior horns LMN and therefore more unwanted contractions which results in an increase in muscle tremors

Cerebral crus // bundle of nerve fibers that connects cerebrum to the pons // corticospinal tracts pass through the cerebral crus

Midbrain

Cross Section





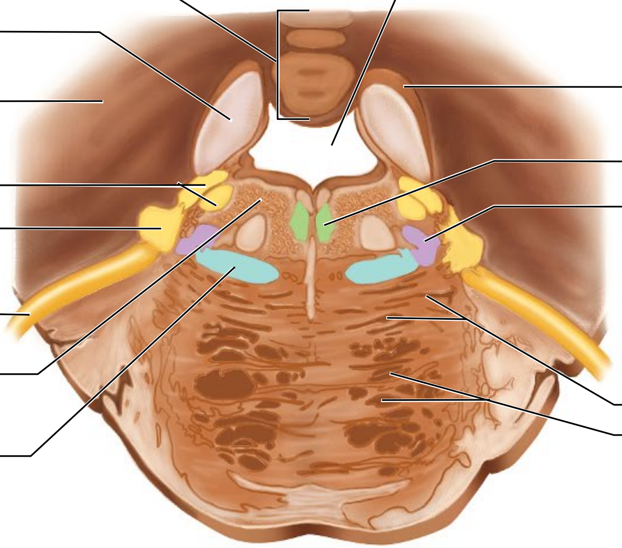
What is the function of tegmentum? It is a motor center that relays inhibitory signals to the thalamus and nuclei of the basal ganglia // preventing unwanted body movement

What is the tectum? A structure serving as a roof of the midbrain.

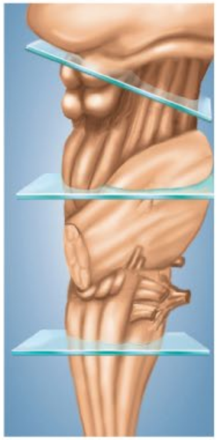
The dorsal part of the midbrain is the location of the corpora quadrigemina.


May cause stiffness and tremors
Normal midbrain
Parkinson’s midbrain

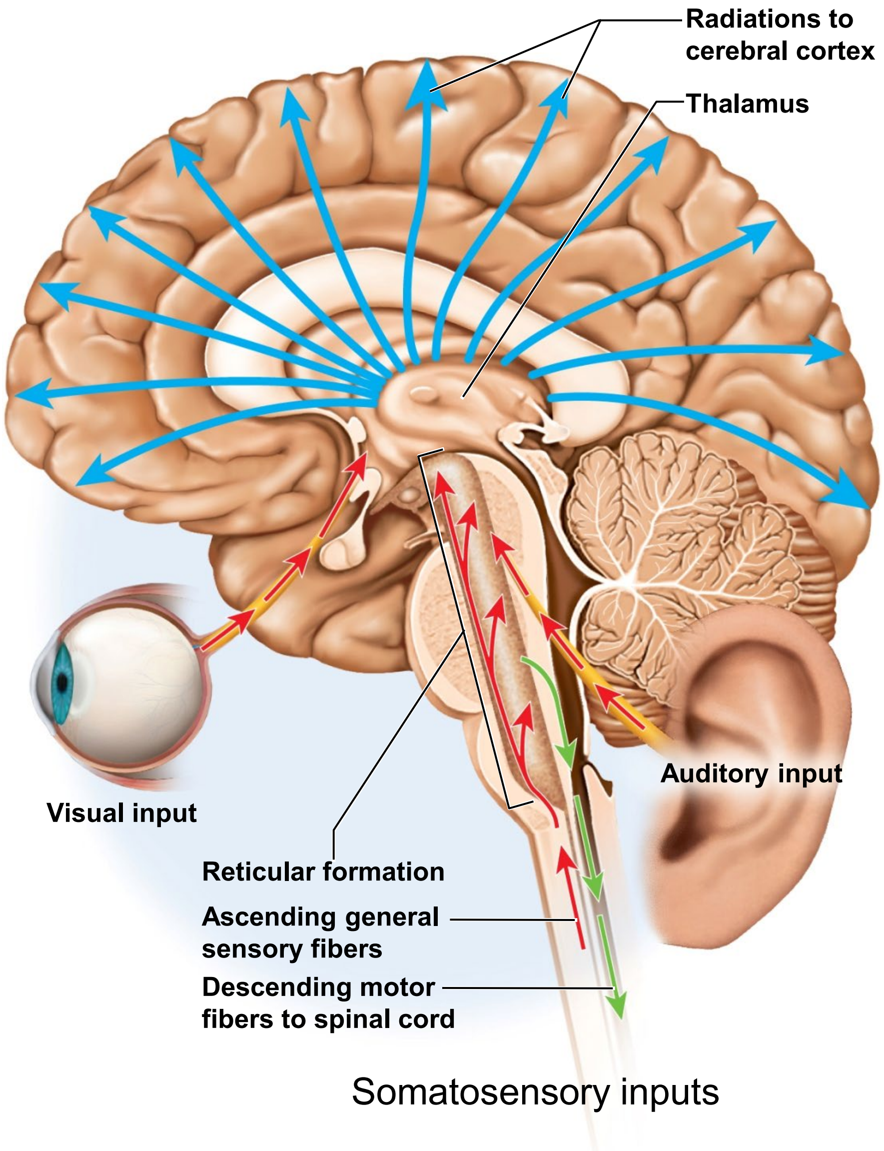
Cross-section of Pons



(b) Pons



Reticular Formation



Loosely organized web of nuclei (i.e. gray matter)

Runs vertically through all levels of the brain stem

RF - clusters of gray matter scattered throughout pons, midbrain and medulla oblongata

Occupies space between white fiber tracts of the brain stem // has connections with many areas of cerebrum

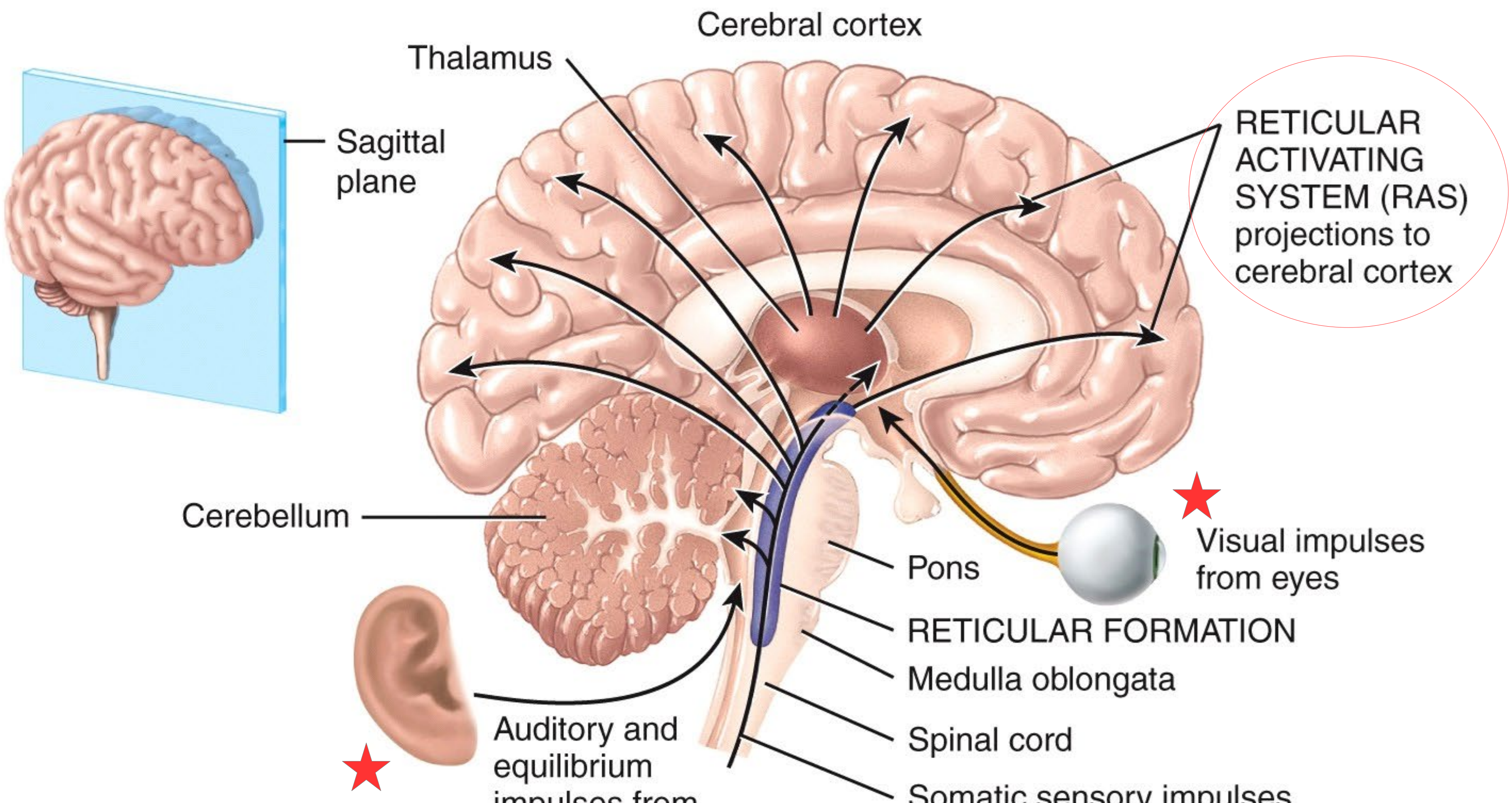
More than 100 small neural networks without distinct boundary

Action potentials from RF move through thalamus to “wake up” the cerebrum.

If action potentials into cerebrum are blocked then you are “asleep”

If these tracks are broken then you are in a “comma”.

Reticular Formation



(c) Sagittal section through brain and spinal cord showing the reticular formation

What types of stimuli activates the reticular formation?

Reticular Formation and the Sleep Cycle

Sleep and consciousness

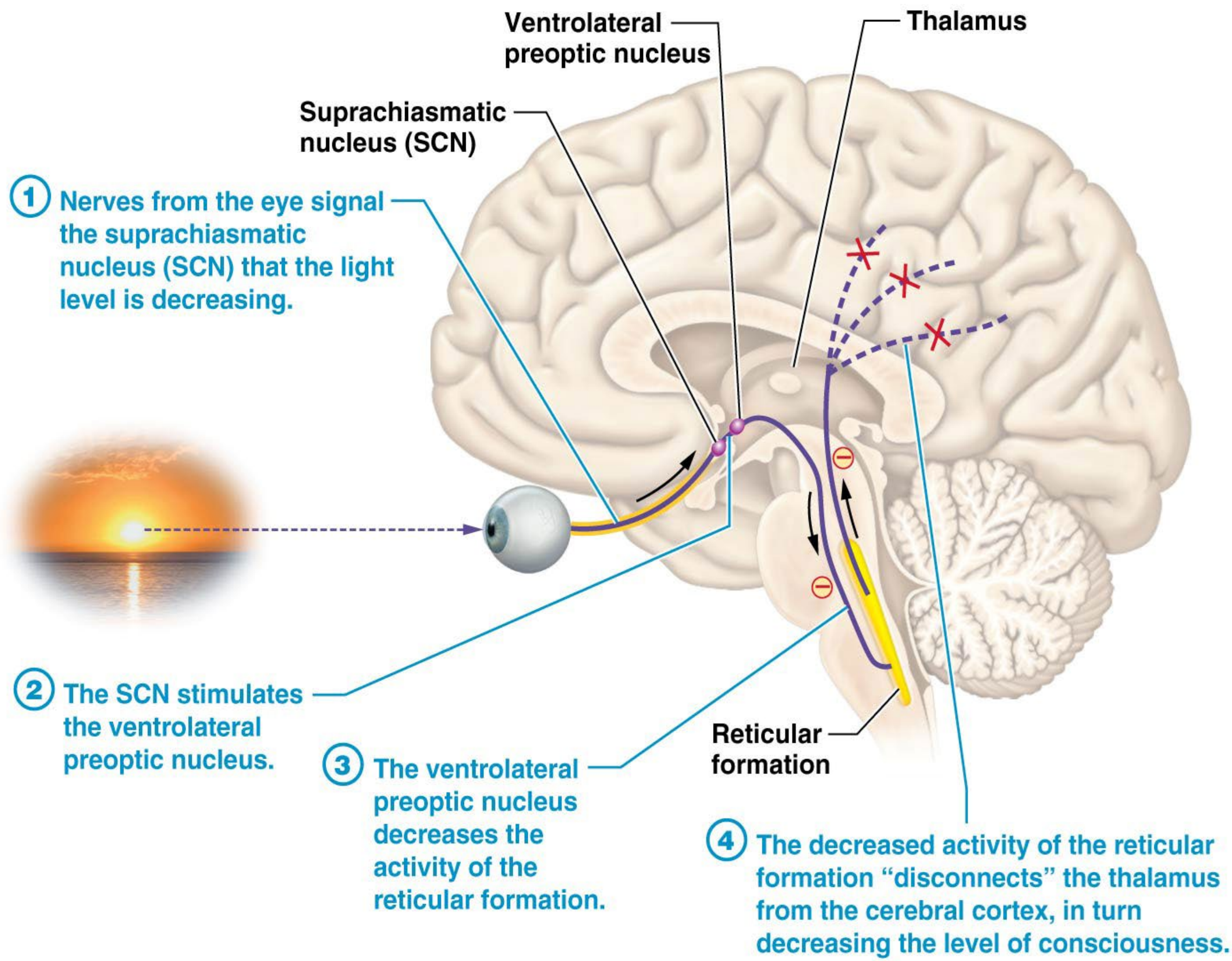
plays central role in states of consciousness, such as alertness and sleep

sleep or an unconscious state occurs when the reticular formation is disconnected from the cerebrum

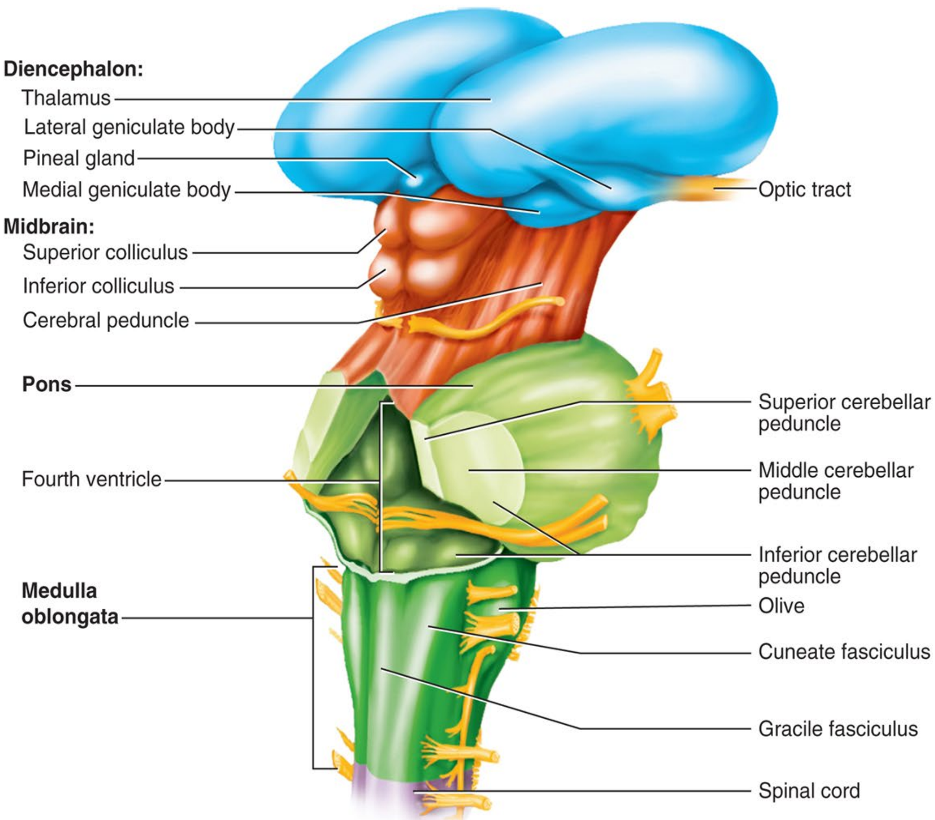
injury to reticular formation that breaks nerve tracks between RF and cerebrum can result in irreversible coma

Three mechanisms help to disconnect the thalamus from the cerebrum. This allows us sleep.

Falling Asleep – Step One



Melatonin – Step Two



(b) Dorsolateral view

The pineal gland (endocrine gland) produces melatonin which also plays a role in our mood and the process of falling asleep.

Melatonin's production is directly related to darkness: the longer the night (less sunlight), the more melatonin produced.

Melatonin receptors are located in the reticular formation. When melatonin binds to these receptors then the reticular formation disconnects the thalamus from the cerebral cortex.

Adenosine – Step Three

Adenosine in the brain is created by the breakdown of ATP.

There are adenosine receptors in the RF. When adenosine binds to their receptors then this disconnects the thalamus from the cerebrum and induces sleep.

The molecule structure of “caffeine” is similar adenosine. Therefore, they both complete for the same receptor.

Caffeine blocks adenosine from binding to the receptor

However, caffeine does not block action potentials from entering the cerebrum.

This is why drinking coffee can keep you awake!

More About the Reticular Formation

Habituation

–process that allows brain to learn how to ignore repetitive stimuli

–inconsequential stimuli ignored while remaining sensitive to other "important stimuli"

–your brain is "sensitive" to what is most important to you

–*How can this explain why some students like to study in a "busy cafeteria"?*

More About the Reticular Formation

About pain modulation

Spinalreticular tract is one of the routes used by pain signals from the lower body to reach the cerebral cortex. The spinalreticular tract first synapses with reticular formation before it reaches the cerebrum.

The reticular formation is also the origin for descending analgesic pathways (reticularspinal tract)

Fibers act in the spinal cord to block transmission of pain signals to the brain

This is pain associated with tissue damage, severe pain

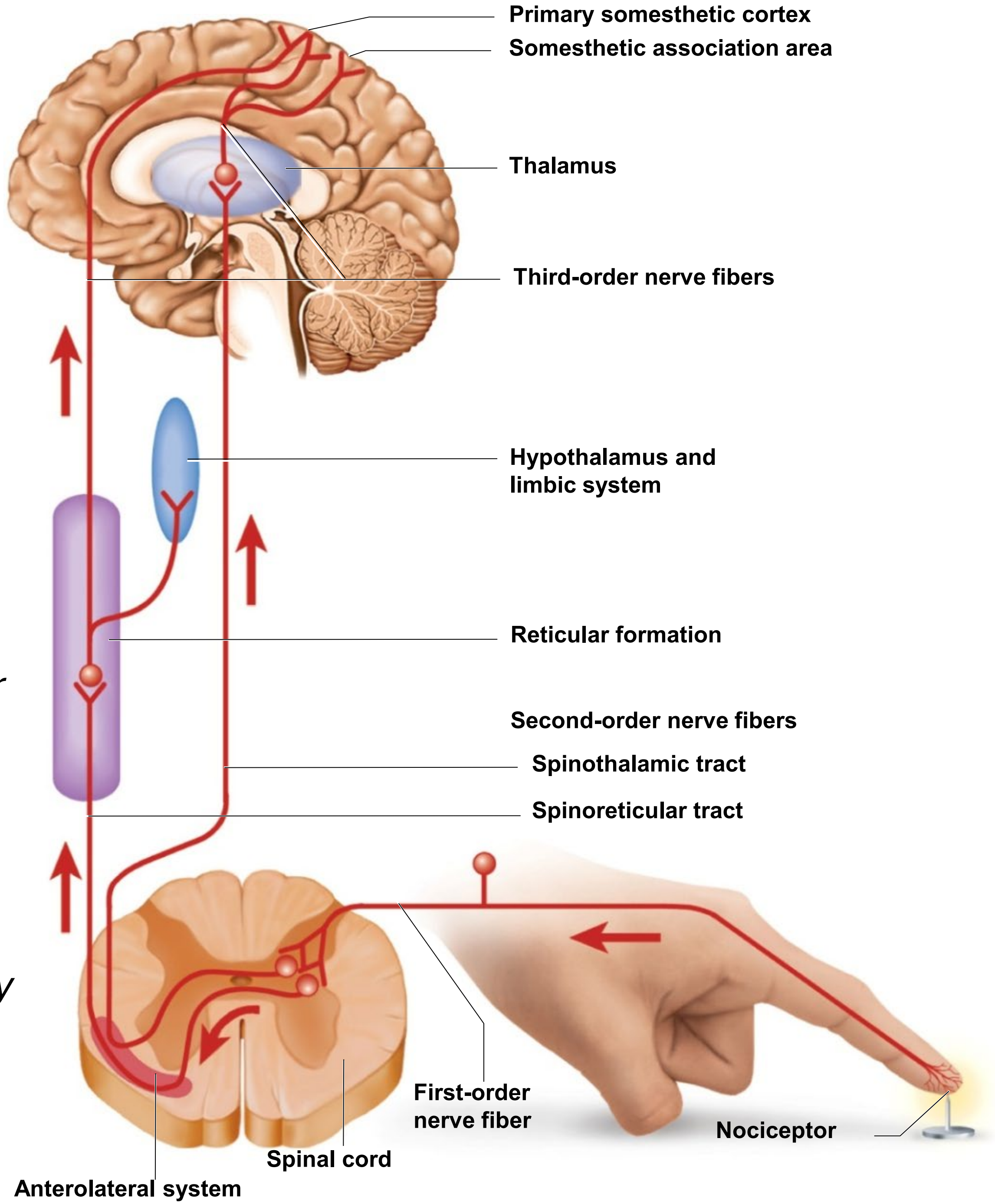
Ascending Pain Pathway

Two second-order nerve fibers
> spinothalamic tract
> spinoreticular tract

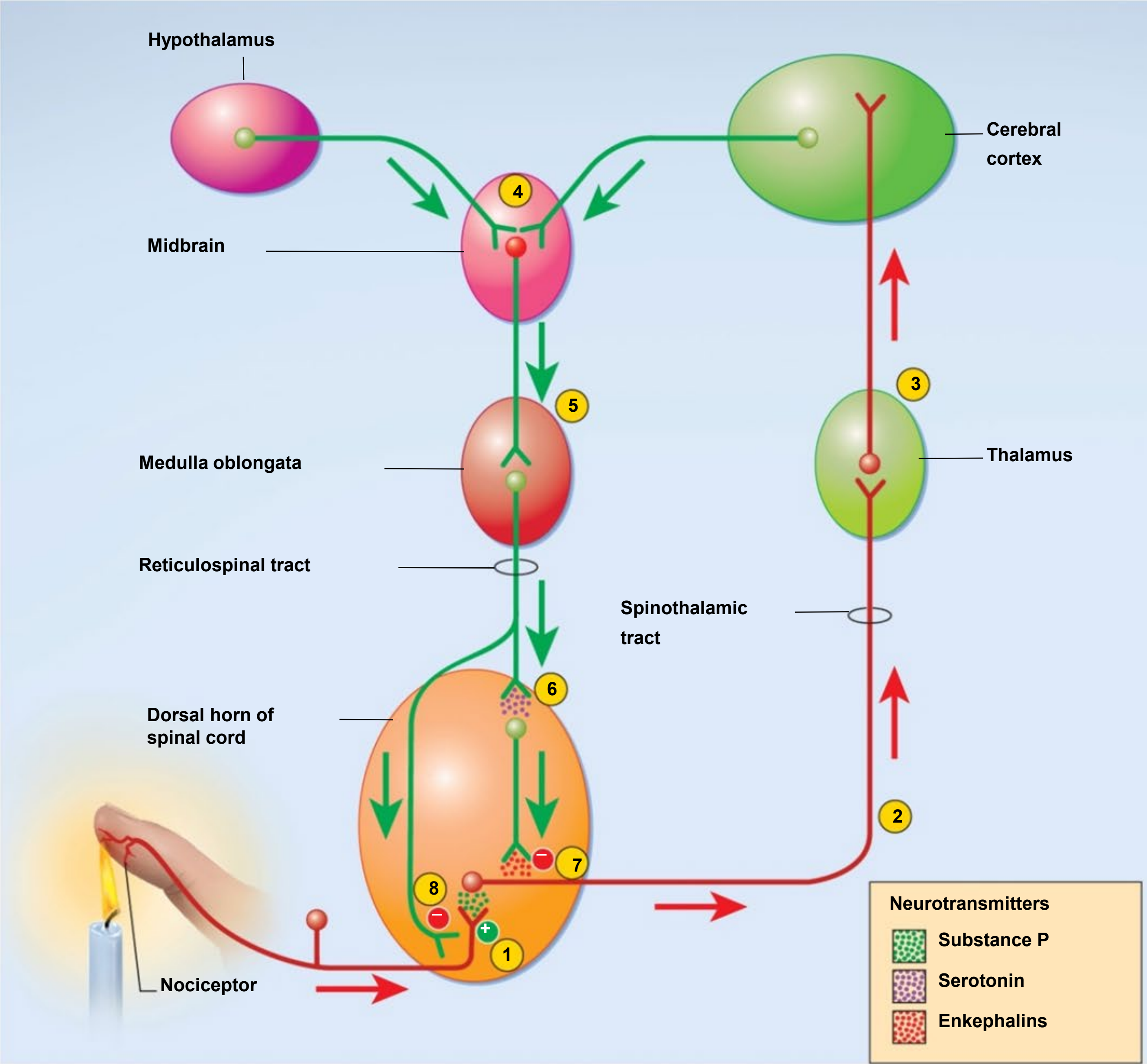
Spinoreticular tract to reticular and hypothalamus/limbic system then continues to primary someshetic cortex

See next slide to see how reticular formation and hypothalamus block pain pathway.

Hypothalamus regulates the homeostasis response to pain. The limbic system subconsciously remembers events as pleasant or unpleasant.



Spinal Gating of Pain Signals



1. Nociceptor releases substance P onto spinal interneuron.
2. Second-order neuron transmits signal up spinothalamic tract to thalamus.
3. Third-order neuron relays signal to somesthetic cortex.
4. Input from hypothalamus and cerebral cortex converges on central gray matter of midbrain.
5. Midbrain relays signal to reticular formation of medulla oblongata.
6. Some descending analgesic fibers from medulla secrete serotonin onto inhibitory spinal interneurons.
7. Spinal interneurons secrete enkephalins, blocking pain transmission by means of postsynaptic inhibition of second-order pain neuron.
8. Other descending analgesic fibers synapse on first-order pain fiber, blocking pain transmission by means of presynaptic inhibition.

More Reticular Formation Functions

Somatic motor control

Nuclei in reticular formation adjust muscle tension to maintain tone, balance, and posture // especially during body movements

Relays signals from eyes and ears to the cerebellum // integrates visual, auditory, balance and motion stimuli into motor coordination

Gaze center – allow eyes to track and fixate on objects

Central pattern generators – (examples) neural pools that produce rhythmic signals to the muscles of breathing and swallowing

Cardiovascular control **//** includes cardiac and vasomotor centers of medulla oblongata

The Diencephalon

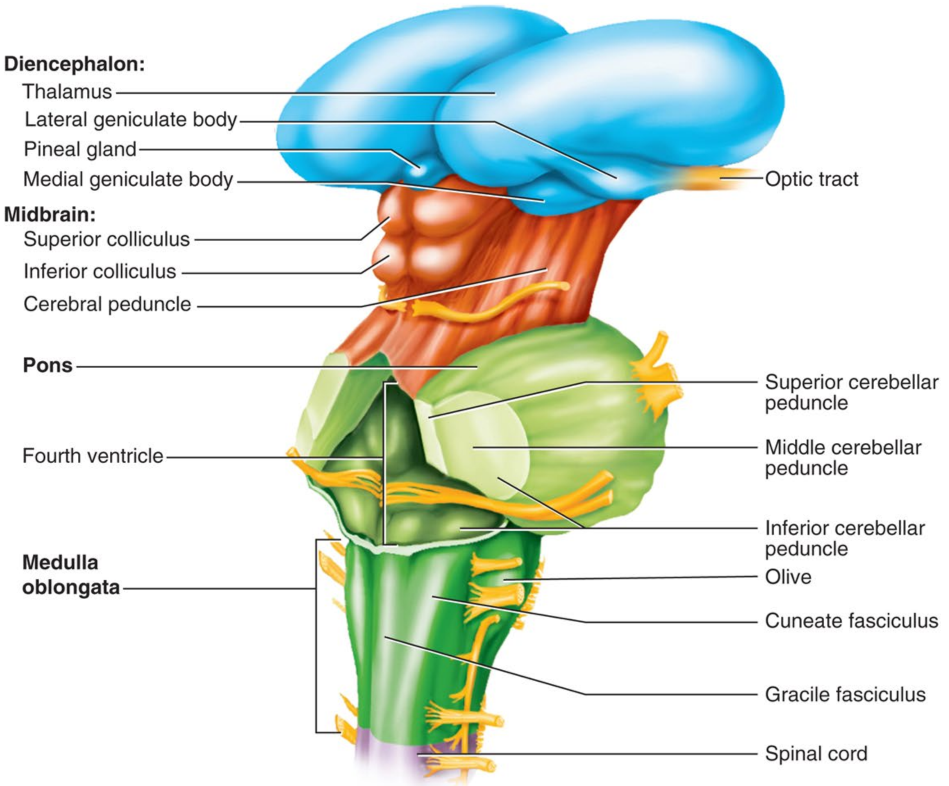
Perched at the superior end of the the brainstem beneath the cerebral hemispheres

Three main parts: thalamus, epithalamus, and hypothalamus

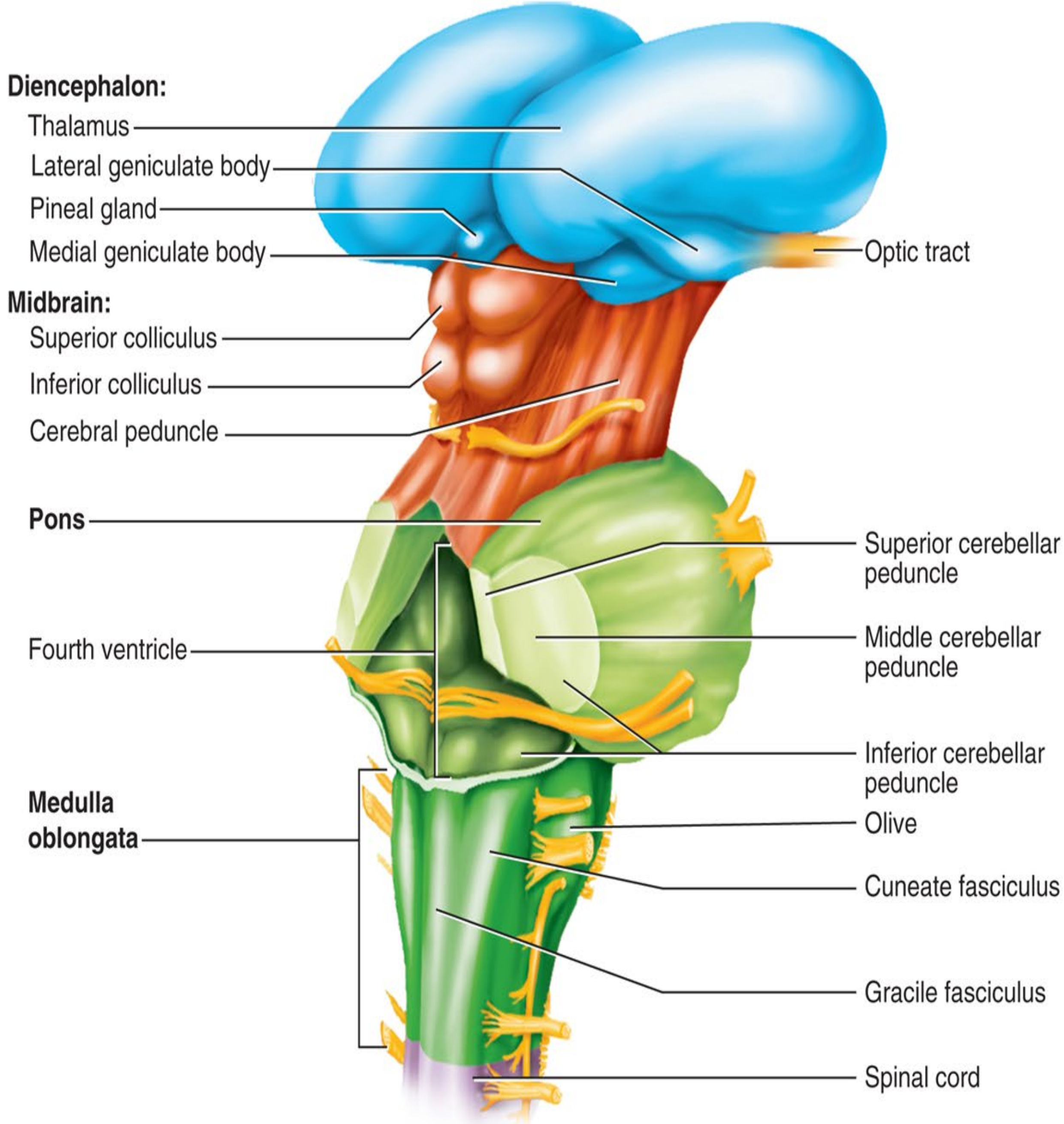
Thalamus (constitutes about four-fifths of the diencephalon) // consists of two lobes joined medially by a narrow intermediate mass

Thalamus composed of at least 23 nuclei

All sensory stimulus (except olfaction) must pass through thalamus to enter cerebrum



(b) Dorsolateral view

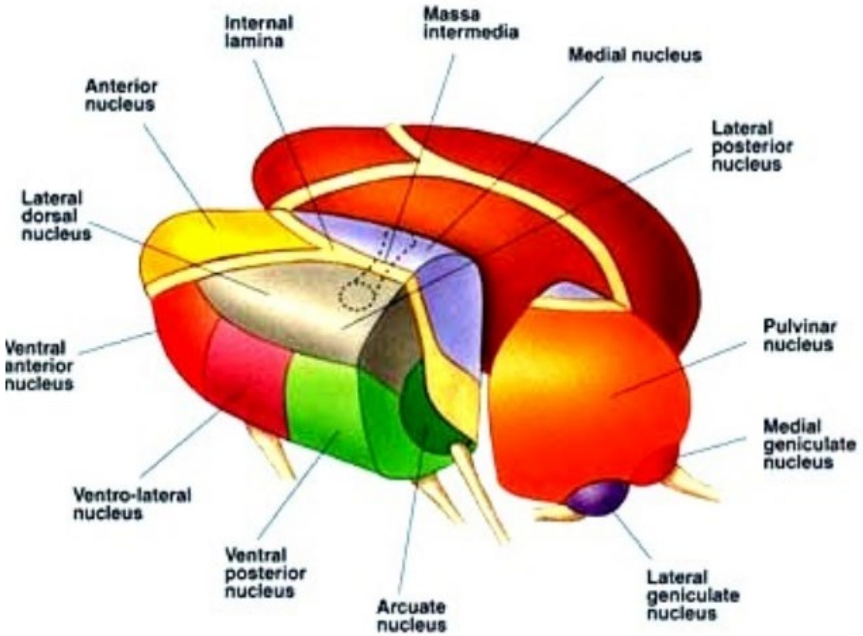



(b) Dorsolateral view

The Diencephalon

The diencephalon has three major sub-divisions

- thalamus
- hypothalamus
- epithalamus



The two lobes of the thalamus form the lateral walls of the third ventricle

Thalamus is the most rostral part of the brainstem

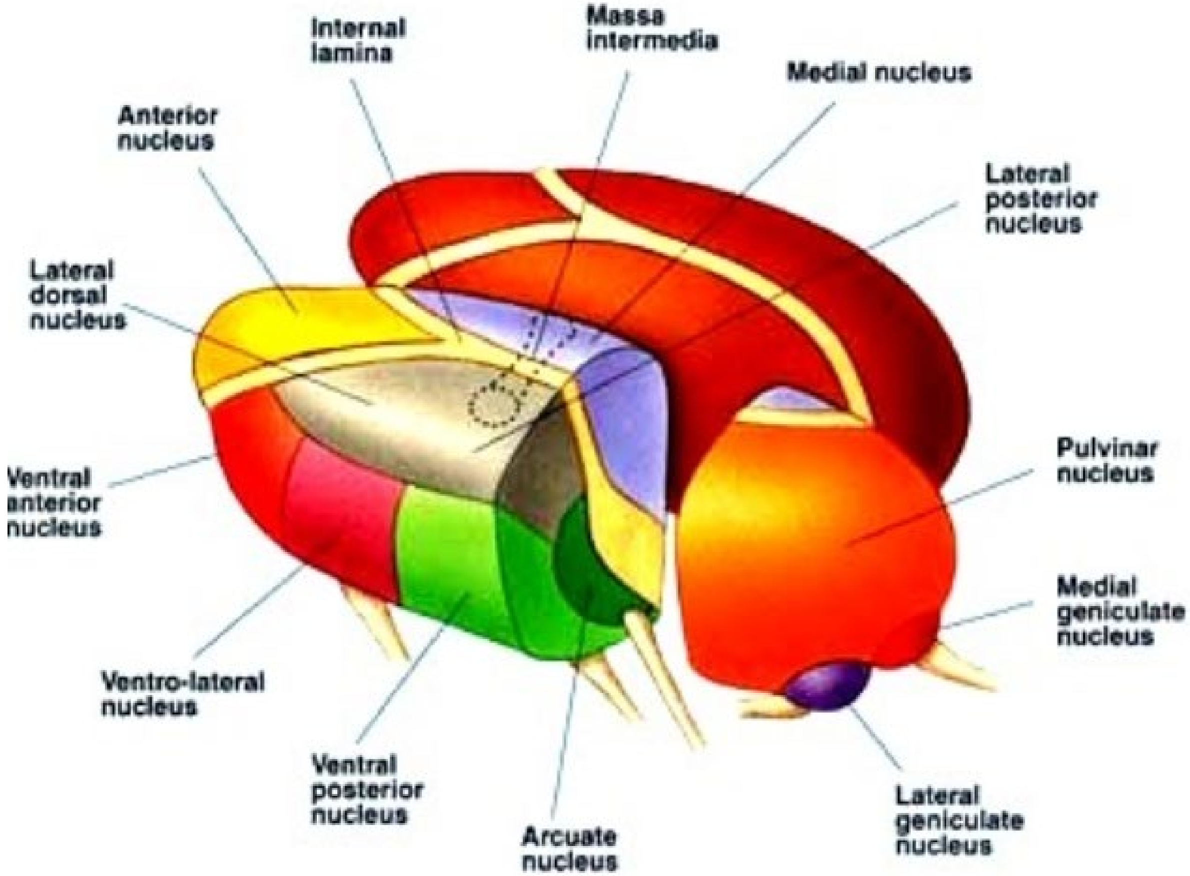
Nicknamed the gateway to the cerebrum

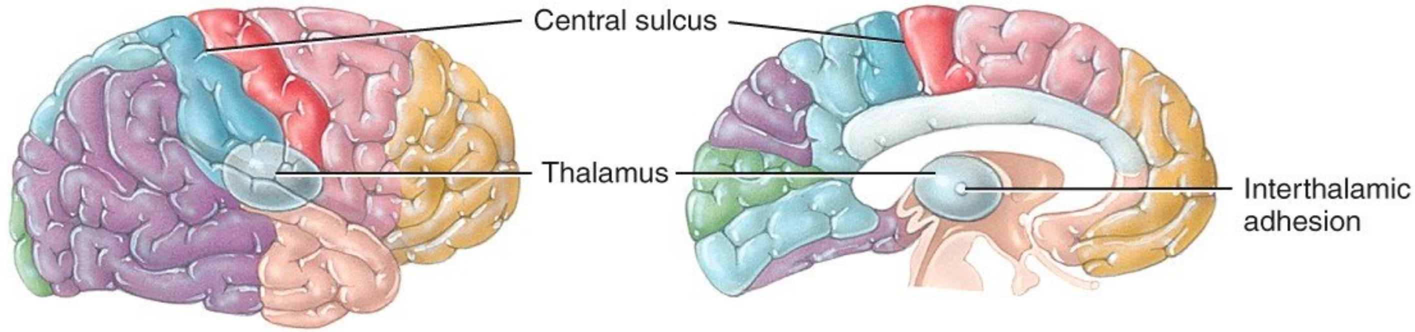
Functions like Grand Central Station // sending incoming signals to different areas within the cerebrum

All somatosensory tracts except one pass through the thalamus on their way into the cerebrum.

What sense does not pass through the thalamus?

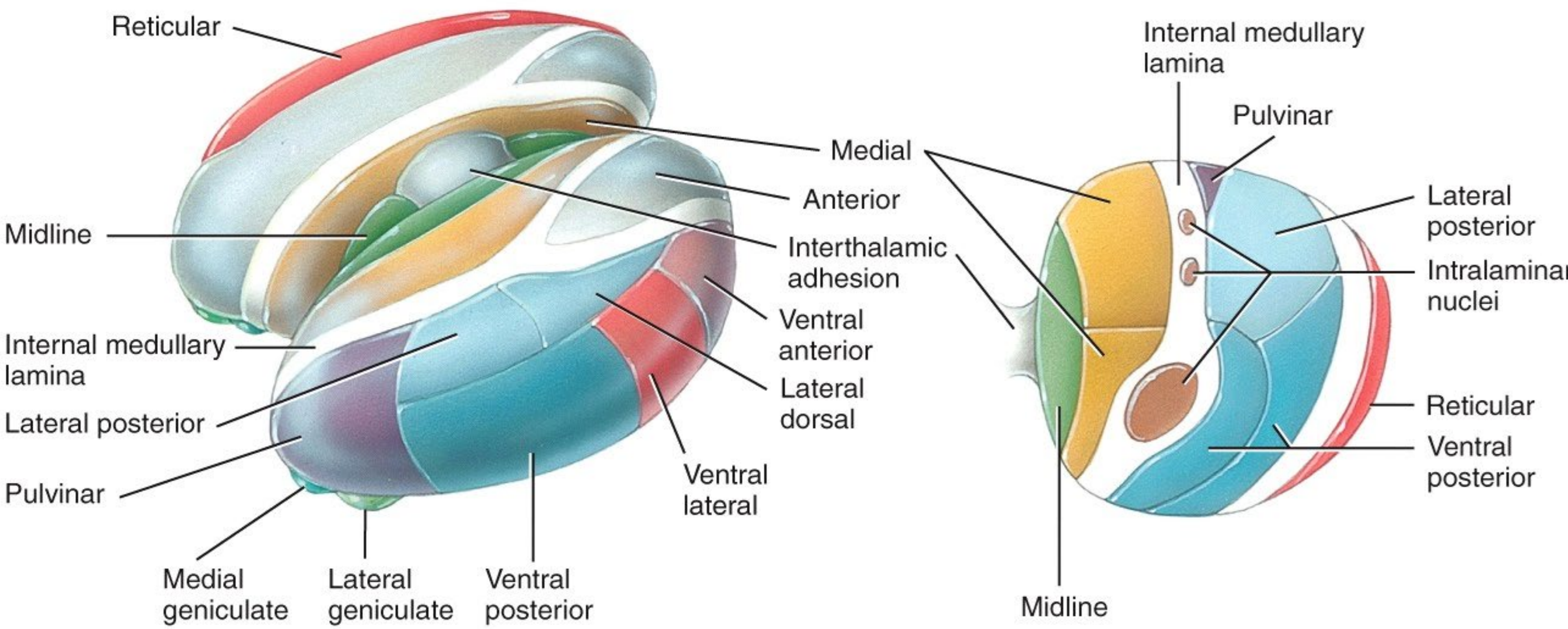
The Diencephalon





(a) Lateral view of right cerebral hemisphere

(b) Medial view of left cerebral hemisphere



(c) Superolateral view of thalamus showing locations of thalamic nuclei (reticular nucleus is shown on the left side only; all other nuclei are shown on the right side)

(d) Transverse section of right side of thalamus showing locations of thalamic nuclei

More About The Thalamus

Somatosensory ascending signal synapse in thalamus.

The signal is split as it ascends through thalamus and sends the same signal to the cerebrum (conscious) and to the limbic system (sub-conscious)

The pathway into cerebrum is further divided into the primary somatosensory area (conscious sensations) and into the somatosensory association area

The somatosensory association area forms memories of somatosensory signals

Example - You know by touch the difference between a dime and a quarter.

The Thalamus Role in Motor Control

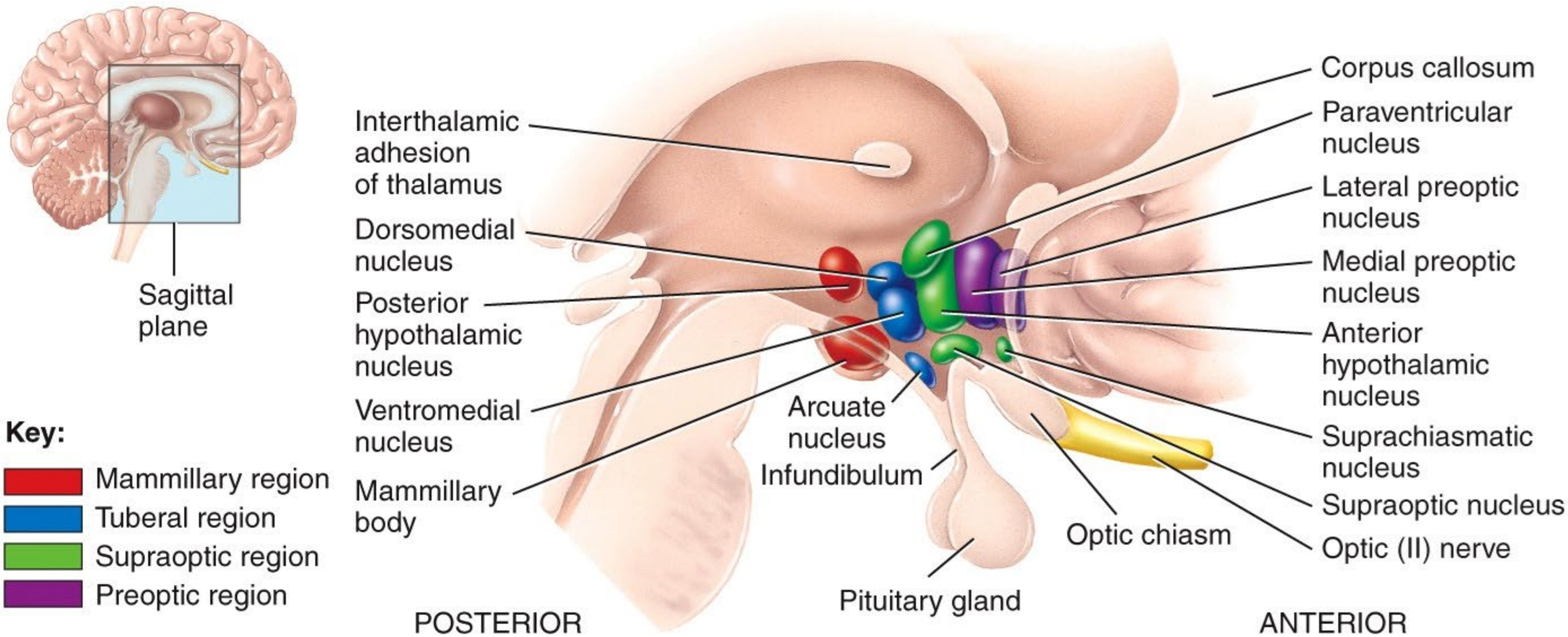
- Thalamus has a key role in motor control. Motor control is how we
- regulate skeletal muscle contractions. /// motor control requires
- complex pathways between the cerebrum's motor association area,
- basal ganglia, (and other subthalamic nuclei), thalamus, and
- cerebrum's motor strip

- thalamus provides pathways for feedback loops between the cerebral
- cortex, basal nuclei, and thalamus (note: called the cortico-basal
- nuclei-thalamo-cortico-loop) /// thalamus blocks motor action
- potentials from reaching the motor strip /// this prevents unwanted
- skeletal muscle contractions

- basal ganglia must inhibit the thalamus in order to allow action
- potential to reach primary motor cortex (precentral gyrus) // this is
- origin of upper motor neurons // track that sends action potentials to
- lower motor neurons and then onto skeletal muscles.

- **We will study motor control as a function of the cerebrum.**

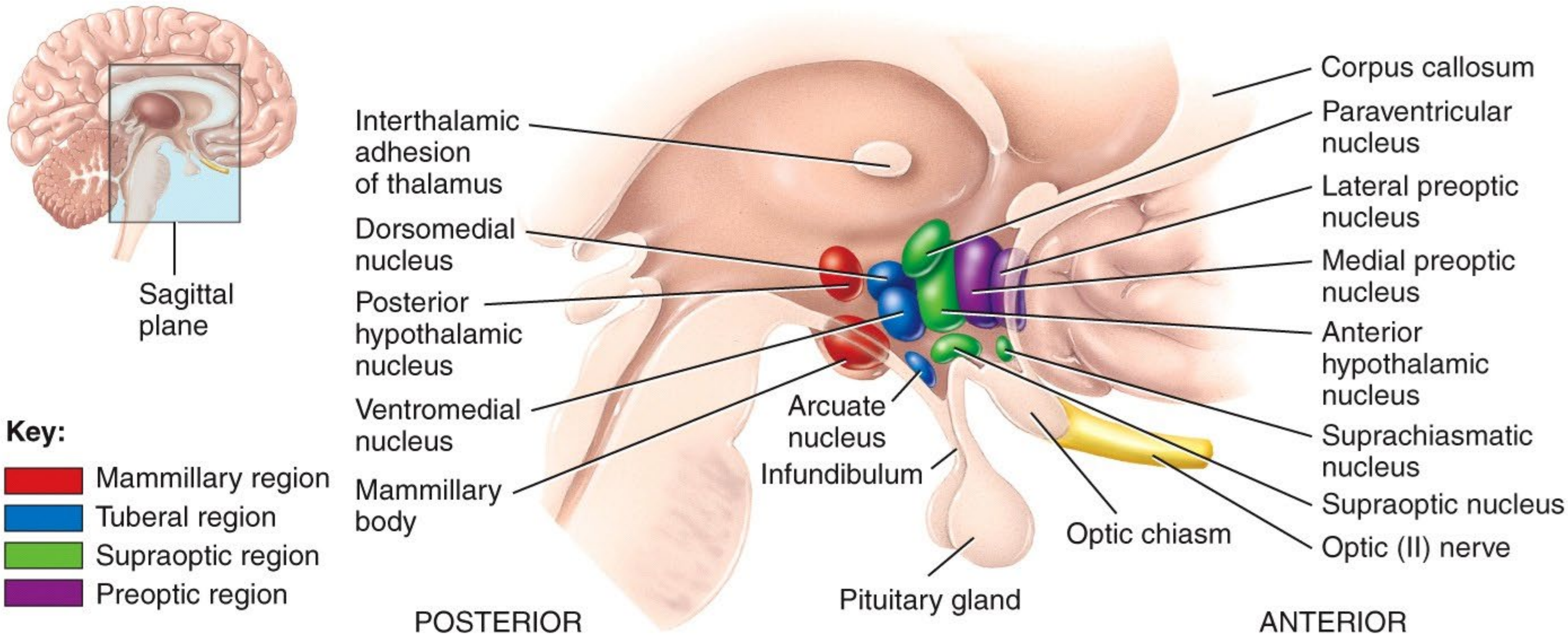
Hypothalamus



Sagittal section of brain showing hypothalamic nuclei

Funnel shaped / below thalamus / between mamillary body and optic chiasma

Hypothalamus



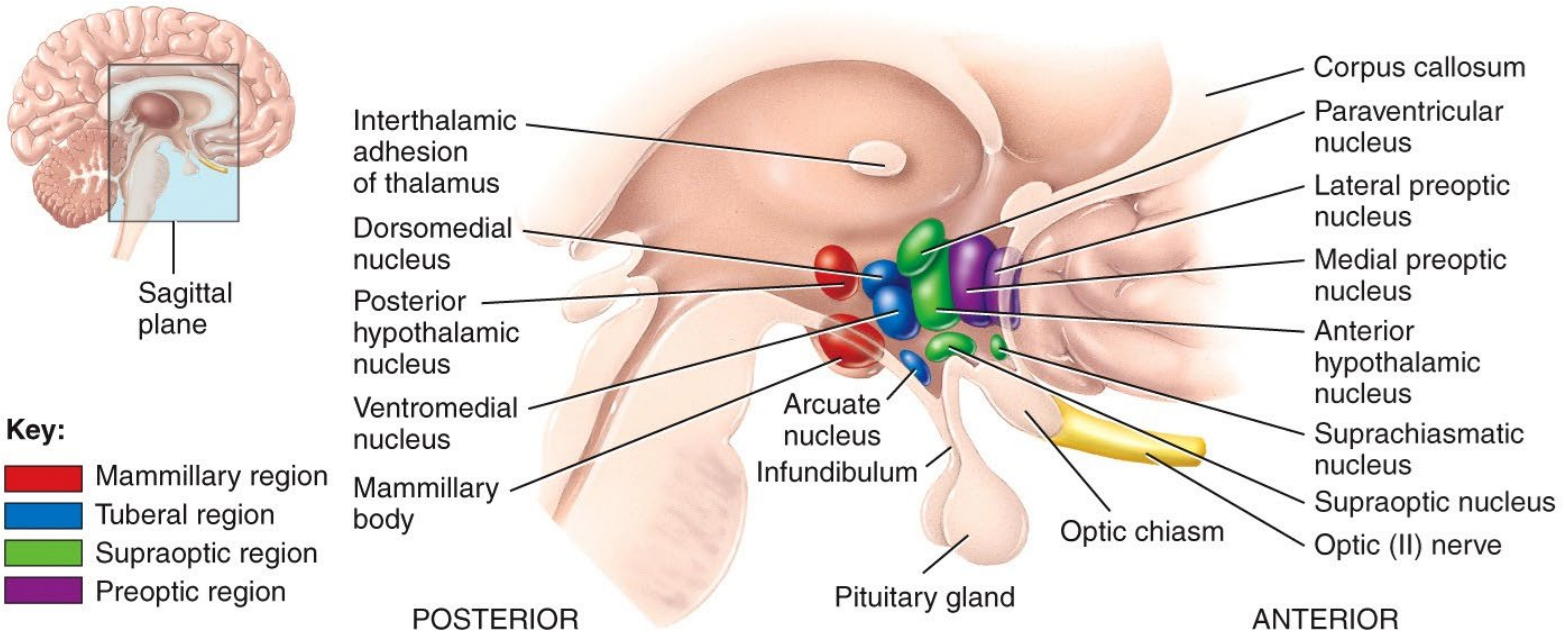
Sagittal section of brain showing hypothalamic nuclei

Forms part of the walls and floor of the third ventricle

Tissue boundary // anteriorly to optic chiasm // posteriorly to the paired mammillary bodies

Each mammillary body contains three or four mammillary nuclei // relay signals from the limbic system to the thalamus

Hypothalamus



Sagittal section of brain showing hypothalamic nuclei

Infundibulum – a stalk that attaches the pituitary gland to the hypothalamus

Each nuclei is a control center

Hypothalamus is the boss of the autonomic nervous system & endocrine system // *plays essential roll in homeostasis /// regulates all body systems*

Hypothalamic Nuclei Functions

Regulates hormone secretions

- controls anterior pituitary // secrete molecules which release hormones from anterior pituitary
- anterior pituitary hormones regulates growth, metabolism, reproduction,and stress responses

Regulates autonomic nervous system

- major integrating center for the autonomic nervous system
- nerve tracks between hypothalamus and medulla oblongata
- influences heart rate, blood pressure, gastrointestinal secretions and motility, and others

Thermoregulation

- hypothalamic thermostat monitors body temperature
- activates heat-loss center when temp is too high
- activates heat-promoting center when temp is too low

Hypothalamic Nuclei Functions

Food and water intake

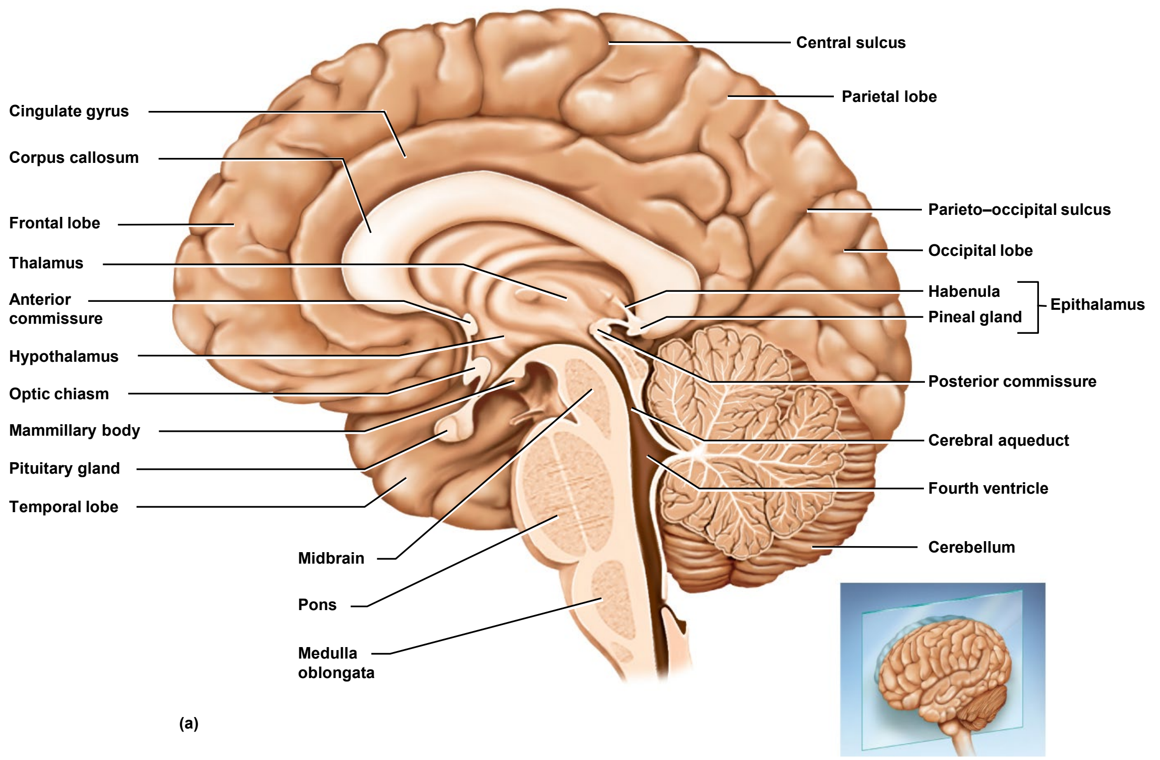
•hunger and satiety centers // produce sensations of hunger and satiety
•monitor blood glucose and amino acid levels
•thirst center monitors osmolarity of the blood

Rhythm of sleep and waking // controls 24 hour circadian rhythm of activity

Memory // mammillary nuclei receive signals from hippocampus (Declaritive Memory = knowing what) /// amygdala (Procedural memory = knowing how)

Emotional behavior // anger, aggression, fear, pleasure, and contentment // many tracts between hypothalamus and limbic system

Epithalamus



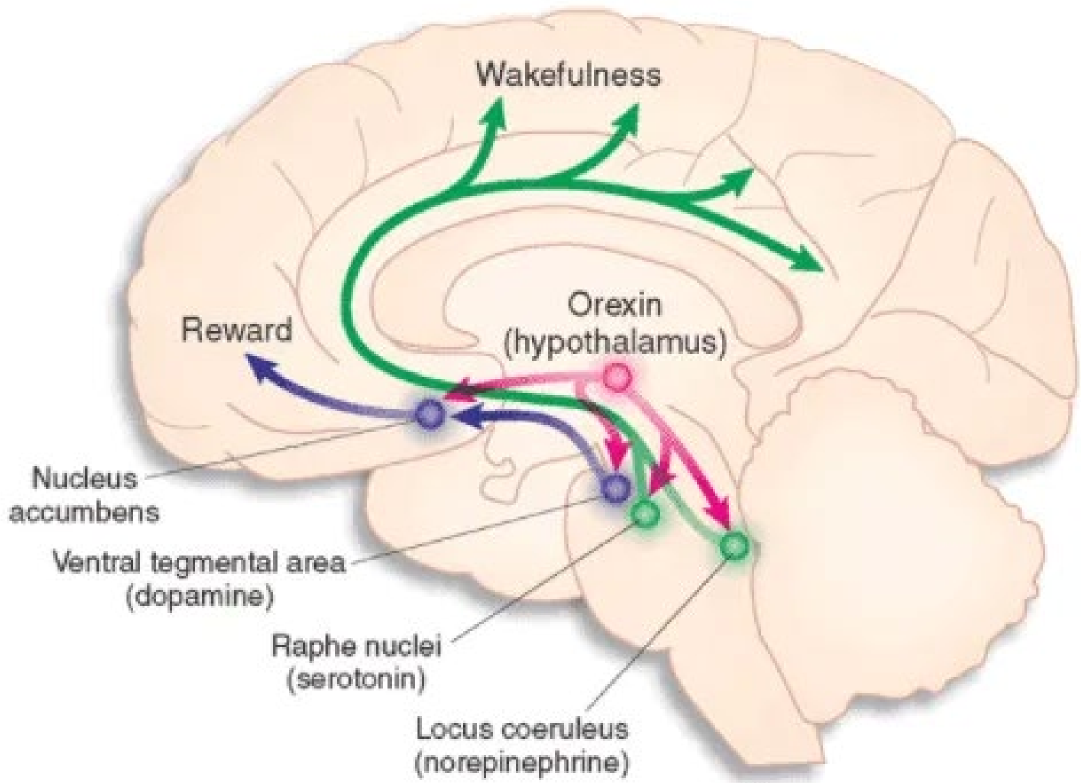
(a)

epithalamus – thin roof over the third ventricle // very small mass of tissue composed of

pineal gland – endocrine gland // produces melatonin

habenula – relay tract from the limbic system to the midbrain

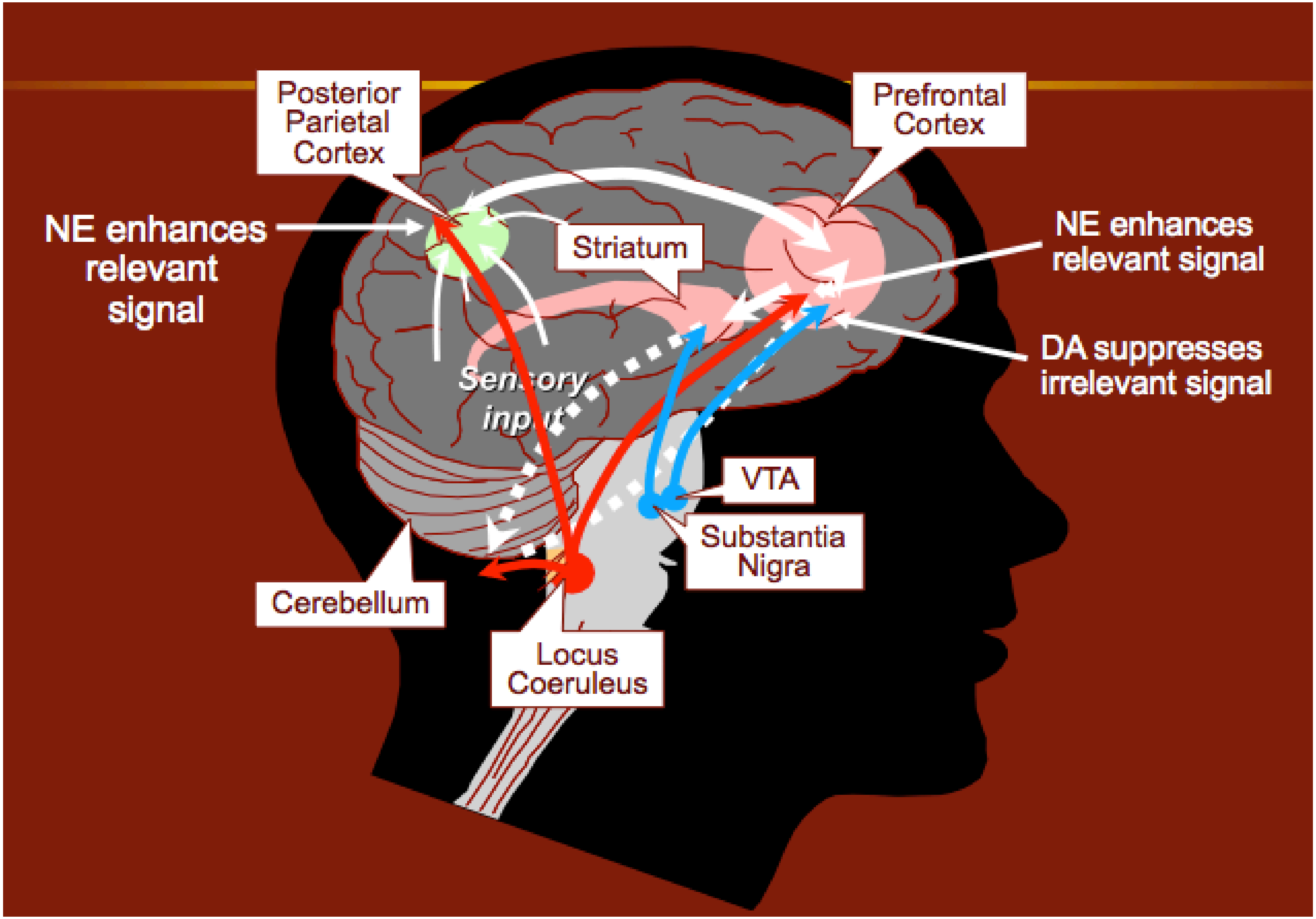
Locus Coeruleus

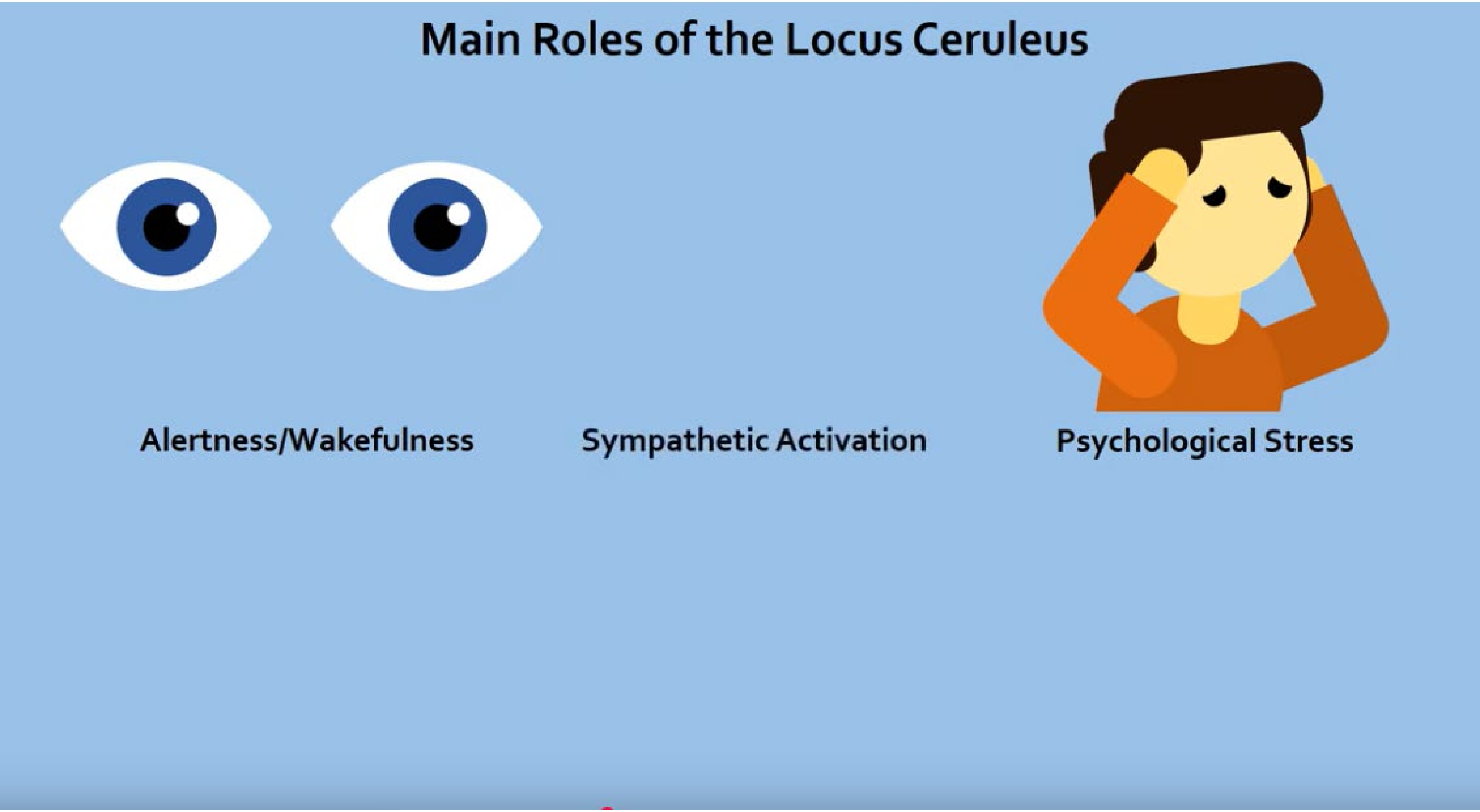


The locus coeruleus (LC) is a brain region primarily responsible for producing norepinephrine, a CNS neurotransmitter that plays a crucial role in regulating arousal, attention, and stress responses.

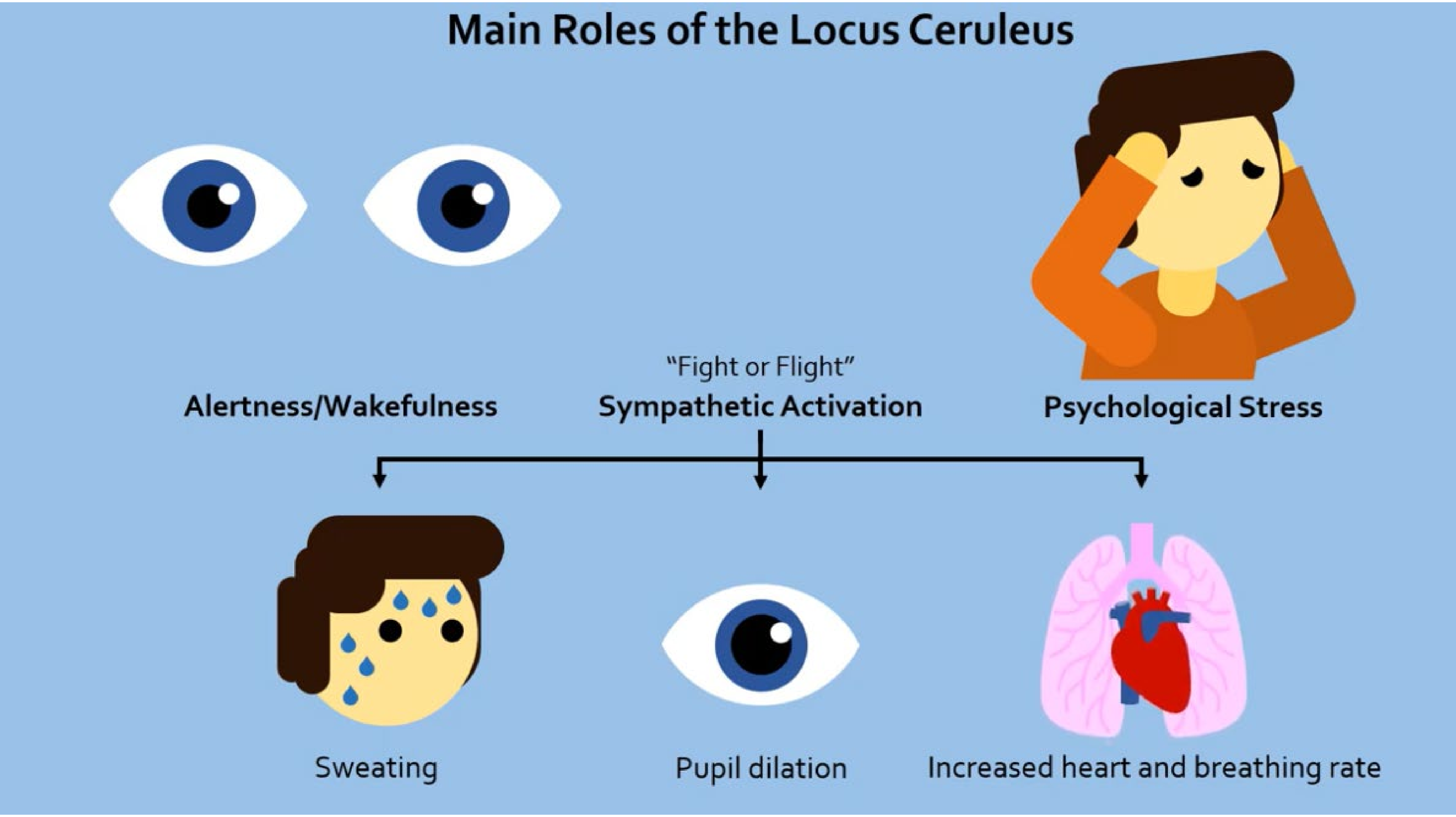
It's also involved in sleep-wake cycles, cognition, and mood. Dysregulation of the LC-norepinephrine system is implicated in various disorders, including sleep and arousal disorders, attention deficit hyperactivity disorder, and post-traumatic stress disorder.

Locus Coeruleus

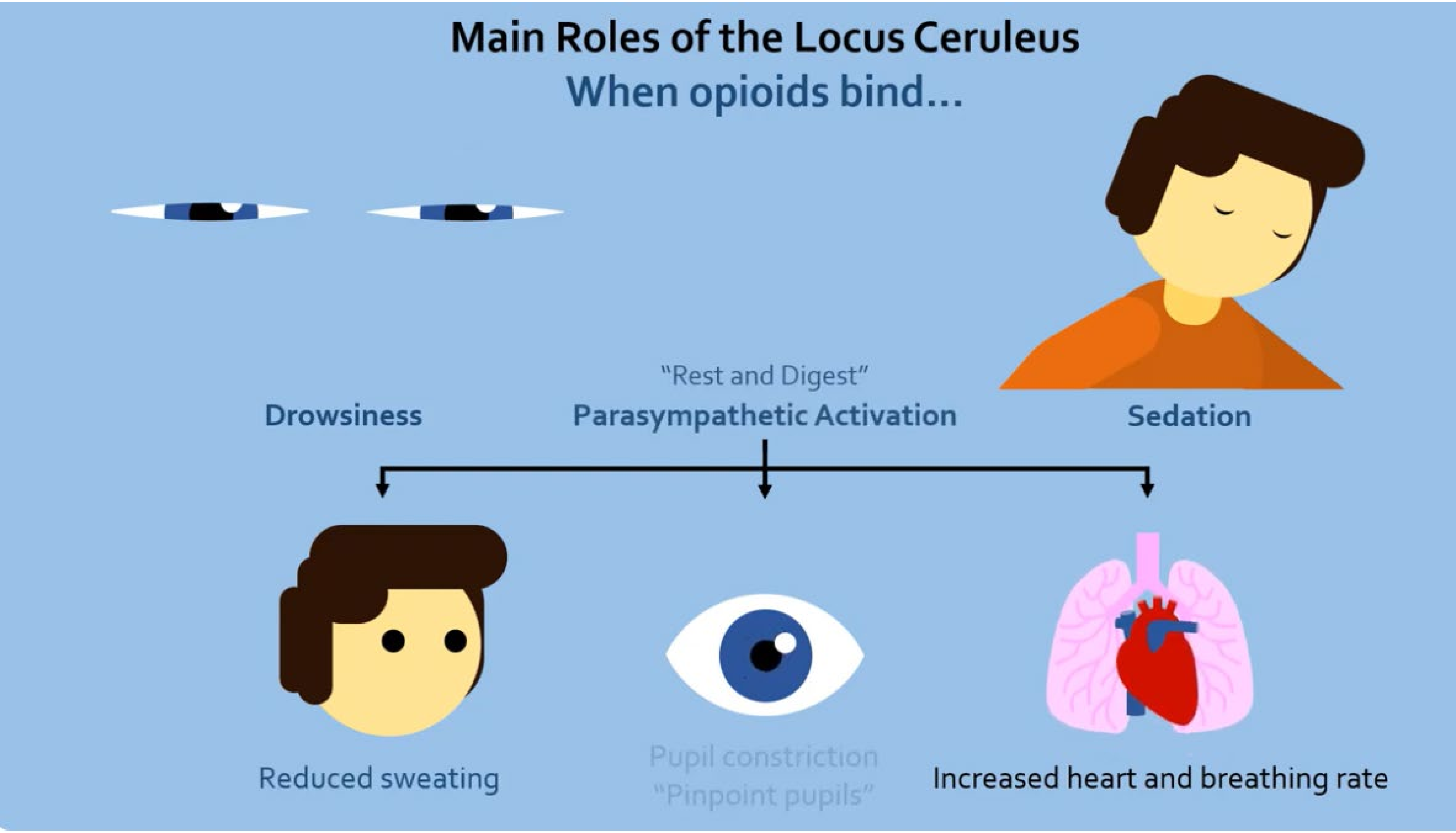


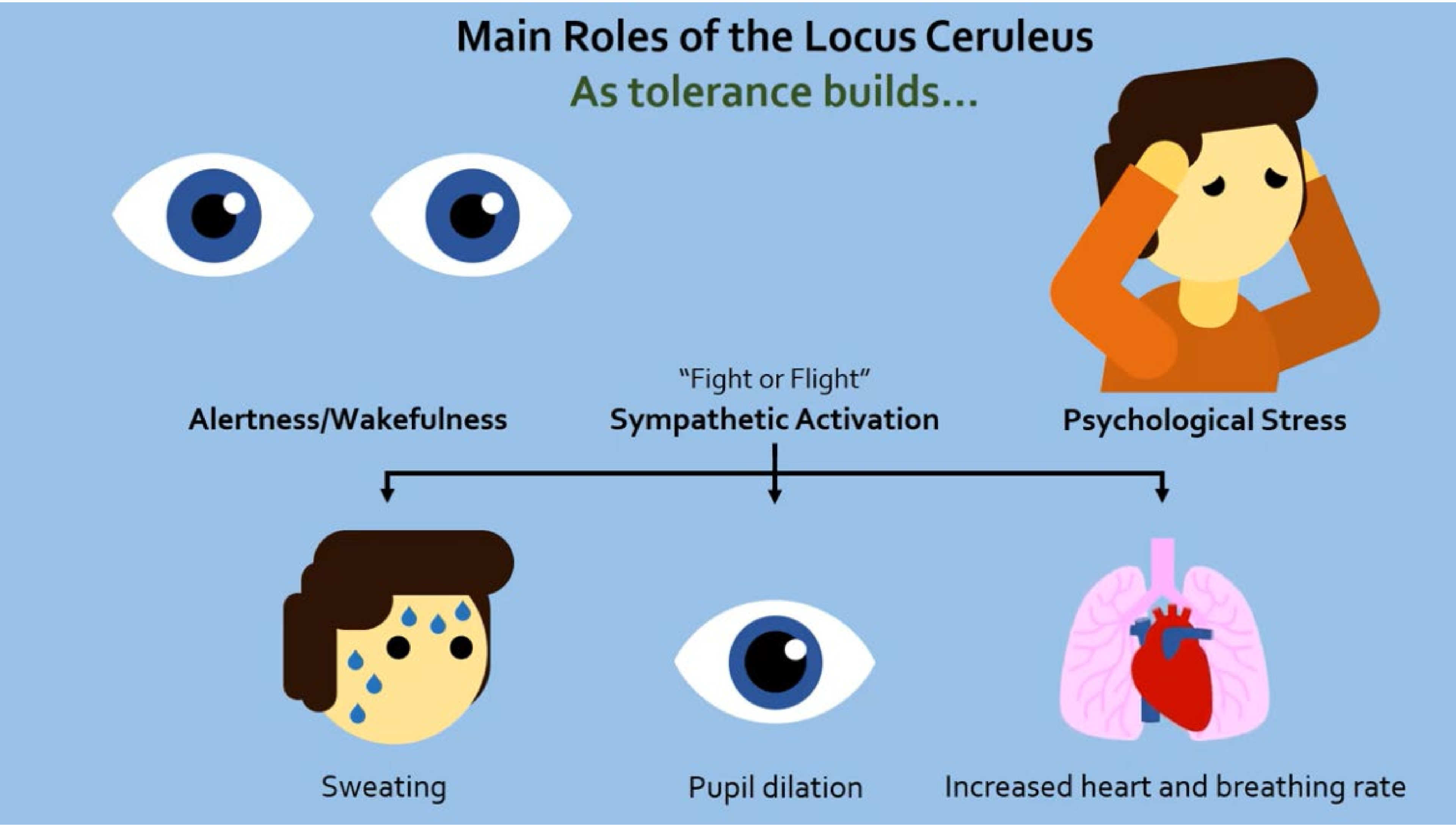


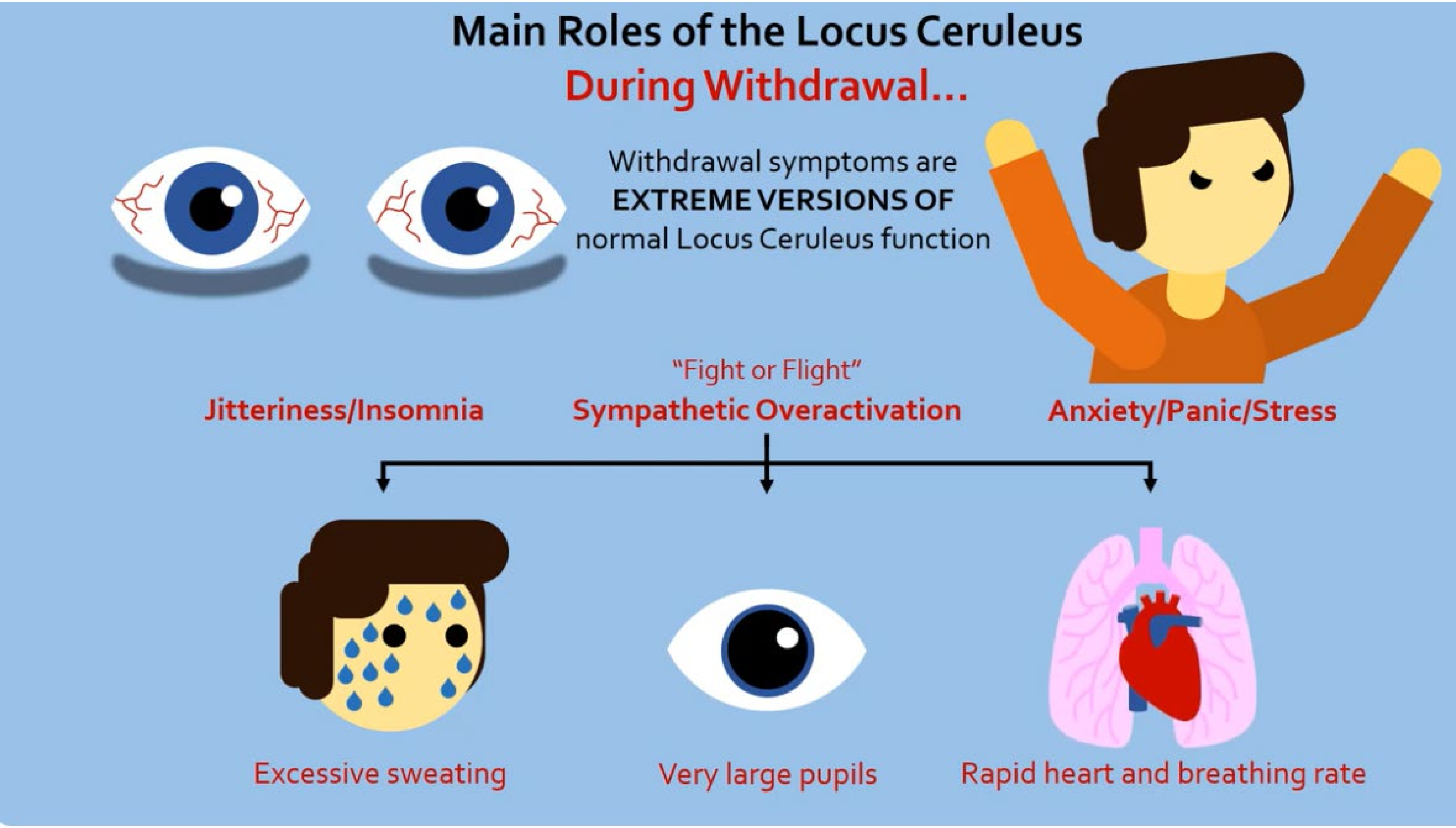
These events increase when locus ceruleus becomes secretes more noradrenalin.



Hypothalamus is the boss of the endocrine and autonomic nervous systems. These systems are responsible for the sympathetic response.

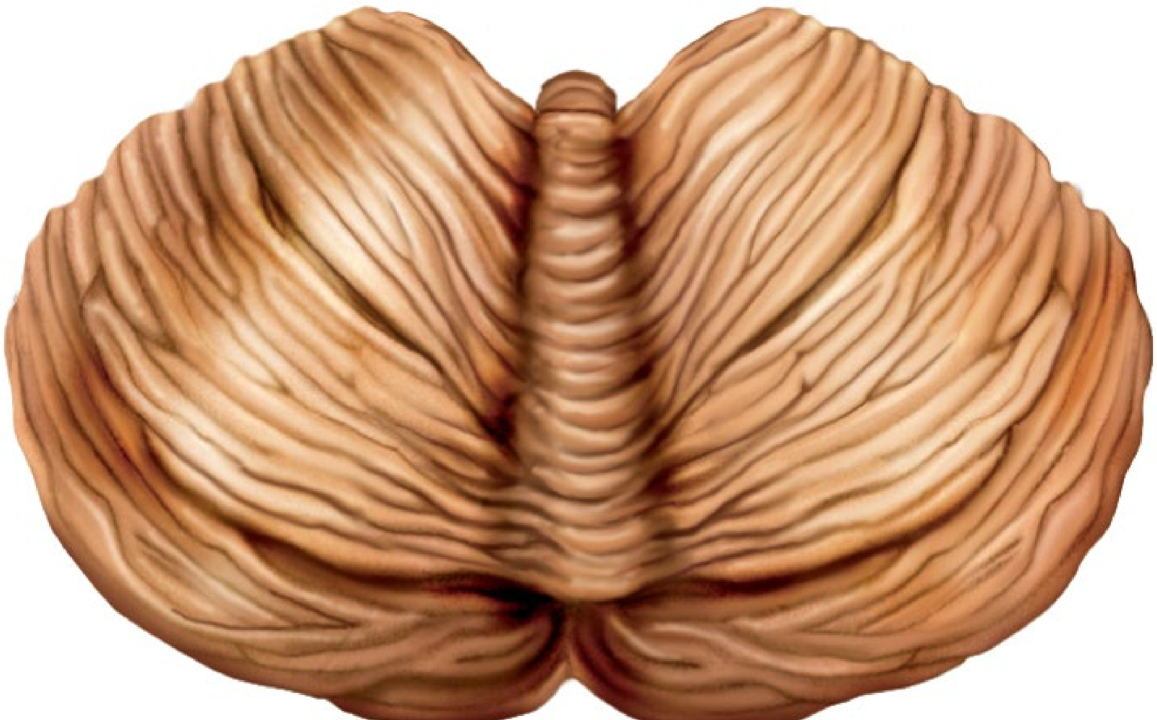

Main Roles of the Locus Ceruleus
When opioids bind…
"Rest and Digest"
Drowsiness
Parasympathetic Activation
Sedation
Reduced sweating
Pupil constriction
"Pinpoint pupils"
Increased heart and breathing rate


Main Roles of the Locus Ceruleus
As tolerance builds…
Alertness/Wakefulness
"Fight or Flight"
Sympathetic Activation
Psychological Stress
Sweating
Pupil dilation
Increased heart and breathing rate

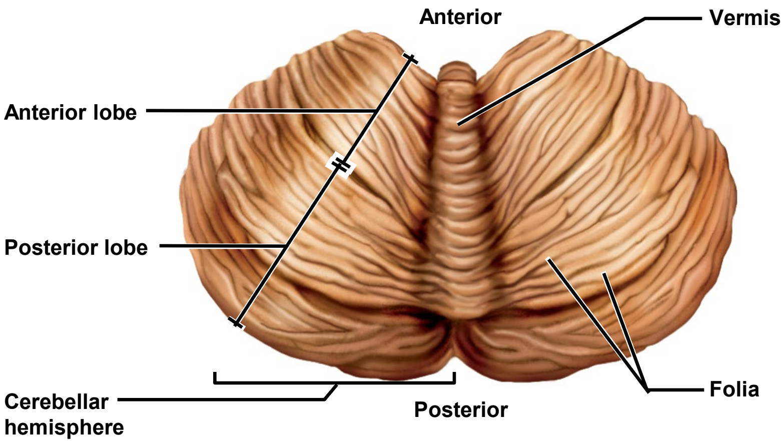


Main Roles of the Locus Ceruleus
During Withdrawal…
Withdrawal symptoms are
EXTREME VERSIONS OF
normal Locus Ceruleus function
"Fight or Flight"
Jitteriness/Insomnia
Sympathetic Overactivation
Anxiety/Panic/Stress
Excessive sweating
Very large pupils
Rapid heart and breathing rate

The Cerebellum



Cerebellum



(b) Superior view

consists of right and left cerebellar hemispheres connected by **vermis**

cortex of gray matter with folds (**folia**) and four deep nuclei in each hemisphere

granule cells and **Purkinje cells** synapse on deep nuclei

white matter branching pattern is called **arbor vitae**

The <u>second largest part of the brain as a whole</u>

Only 10% total mass of brain

But contains 50% or more of all brain neurons

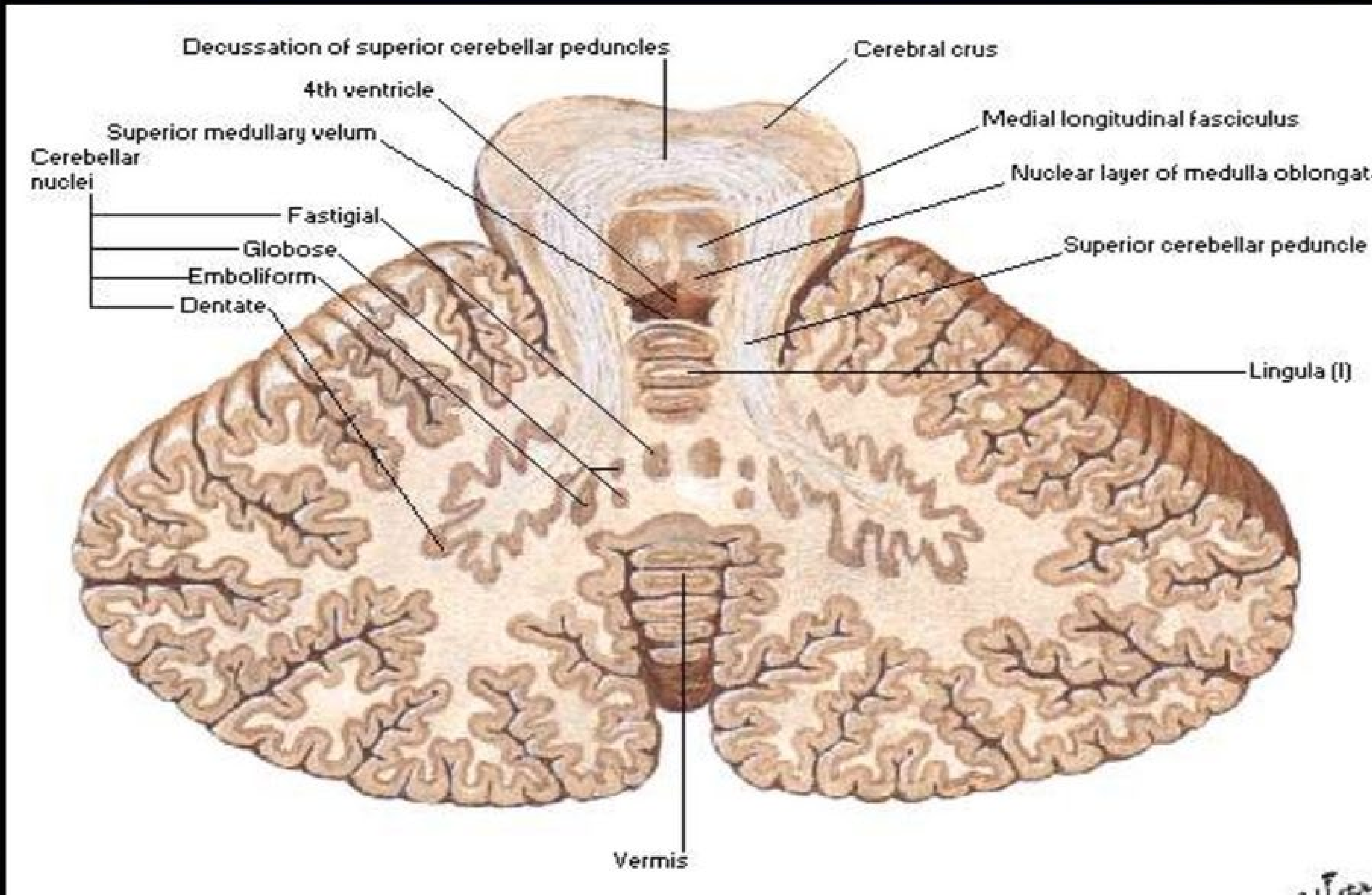
Only 60% surface area of the cerebrum

Cerebellum has 100 billion neurons

Cerebellum's soma have more synapses than soma of the cerebrum

100,000 synapses per soma compared to 10,000 for another cortical soma

Internal structure of cerebellum (grey and white matter)



Cerebellum's Functions

In the 1950s we had limited understanding of the cerebellum's functions.

In the 1970s learned the cerebellum coordinated skeletal muscle performance

Today we understand the full range of cerebellum's functions:

Generally speaking, the cerebellum "compares all sorts of stimuli"

Receives and integrates sensory signals then sends efferent signals to other areas of the brain…..

Cerebellum's Functions

Comparing textures of two objects without looking at them

Spatial perception

Comprehension of different views of 3D objects belonging to the same object

Skeletal muscle “motor control” // monitor skeletal muscle's contraction (the “intent) VS actual skeletal muscle contraction (performance) /// Motor control compares intent to performance and make necessary adjustments (see slides for cerebrum functions)

Cognition (information processing) /// note: children with attention-deficit disorder have unusually small cerebellum

Cerebellum's Functions

Timekeeping center // Judge lapse time between two stimuli

Predicting movement of objects

Helps predict how much the eyes must move to compensate for head movements and remain fixed on an object

Coordinates fixed eye vision as head/body moves

Allows predator to catch prey or baseball player to catch a ball

Hearing // distinguish between different pitches // distinguish between similar sounding words (rapid vs rabbit)

Role in formation/storage of procedural memory.

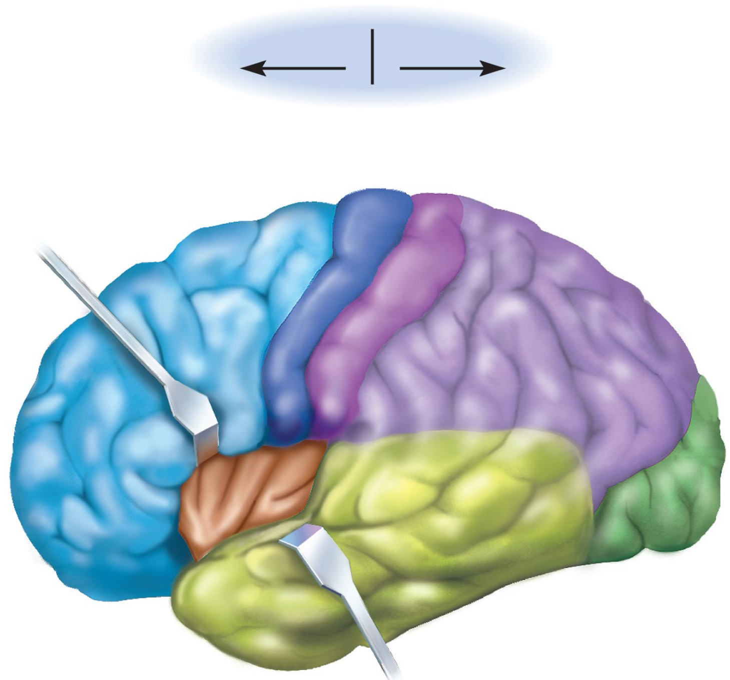
Cerebellum's Functions

- Language output // Relate word “apple” to verb “eat”
- Planning and scheduling tasks
- Lesions in cerebellum may result in emotional overreactions and trouble with impulse control

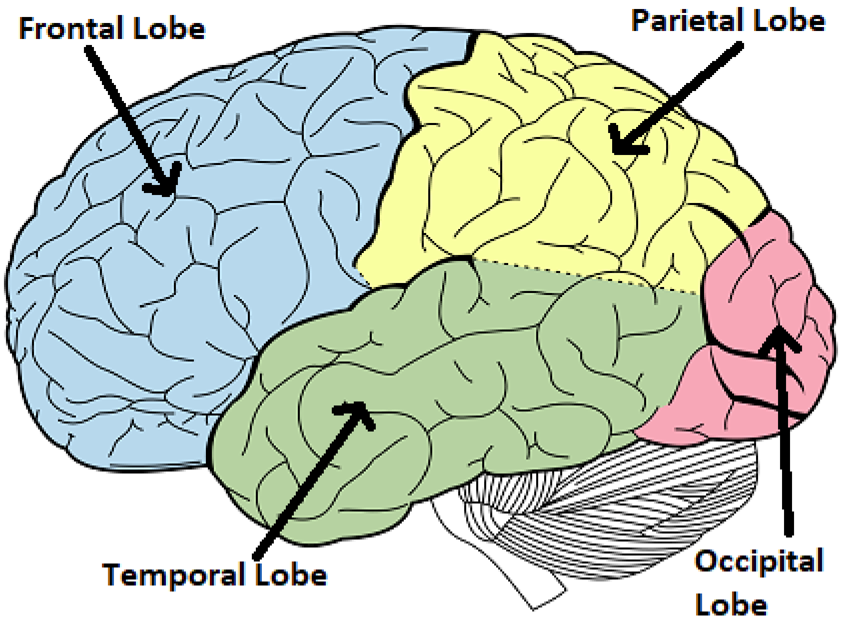
**Peduncles – tracts that connect cerebellum to brainstem at the pons /// **(inferior peduncles, middle peduncles, superior peduncle)

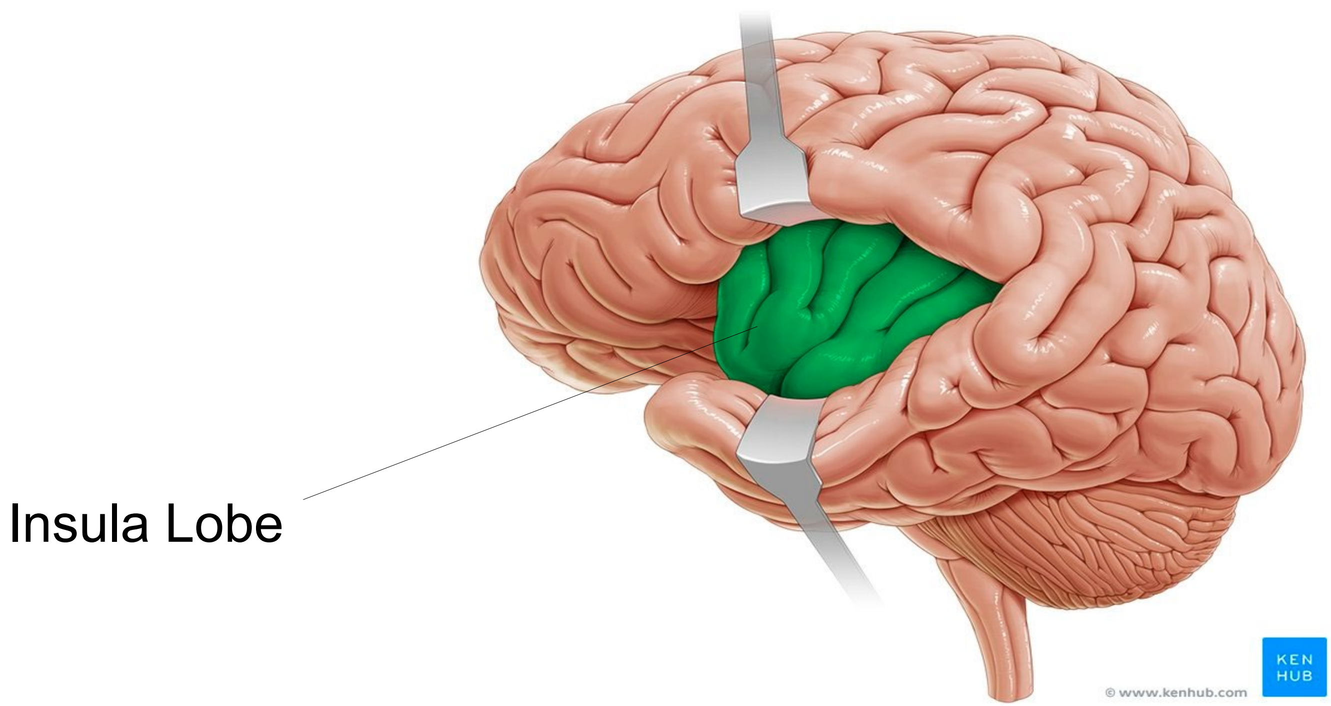
Peduncles play important role in **Motor Control** // how skeletal muscles compare the intent to actual muscle contraction // cerebellum uses this information to make “corrections” so muscle contraction matches the intended muscle contraction /// more to come with cerebrum slides

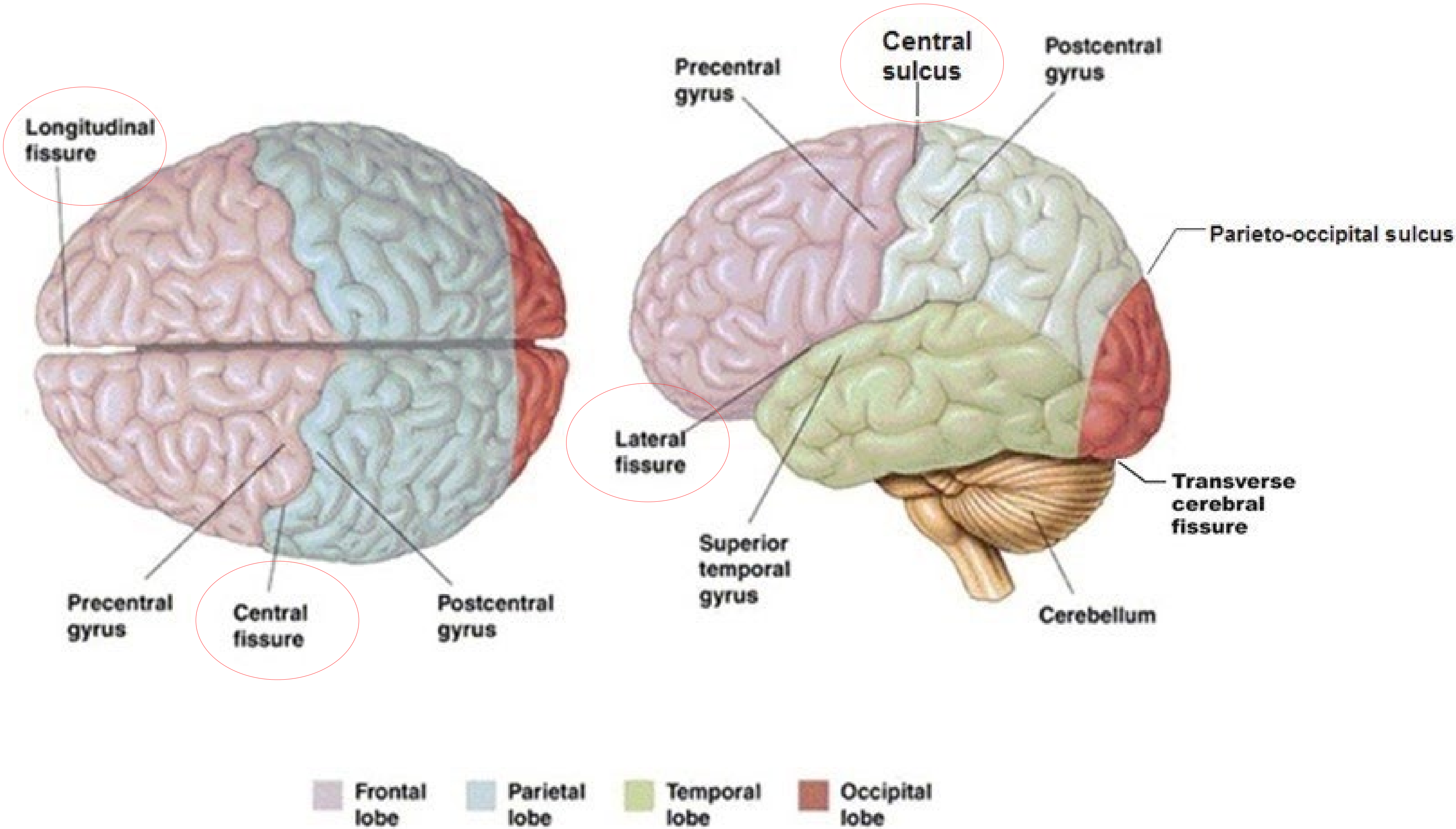
The Cerebrum's Functions



Five Lobes of the Cerebrum






Longitudinal fissure
Precentral gyrus
Central fissure
Postcentral gyrus
Precentral gyrus
Central sulcus
Postcentral gyrus
Parieto-occipital sulcus
Lateral fissure
Transverse cerebral fissure
Superior temporal gyrus
Cerebellum
Frontal lobe
Parietal lobe
Temporal lobe
Occipital lobe

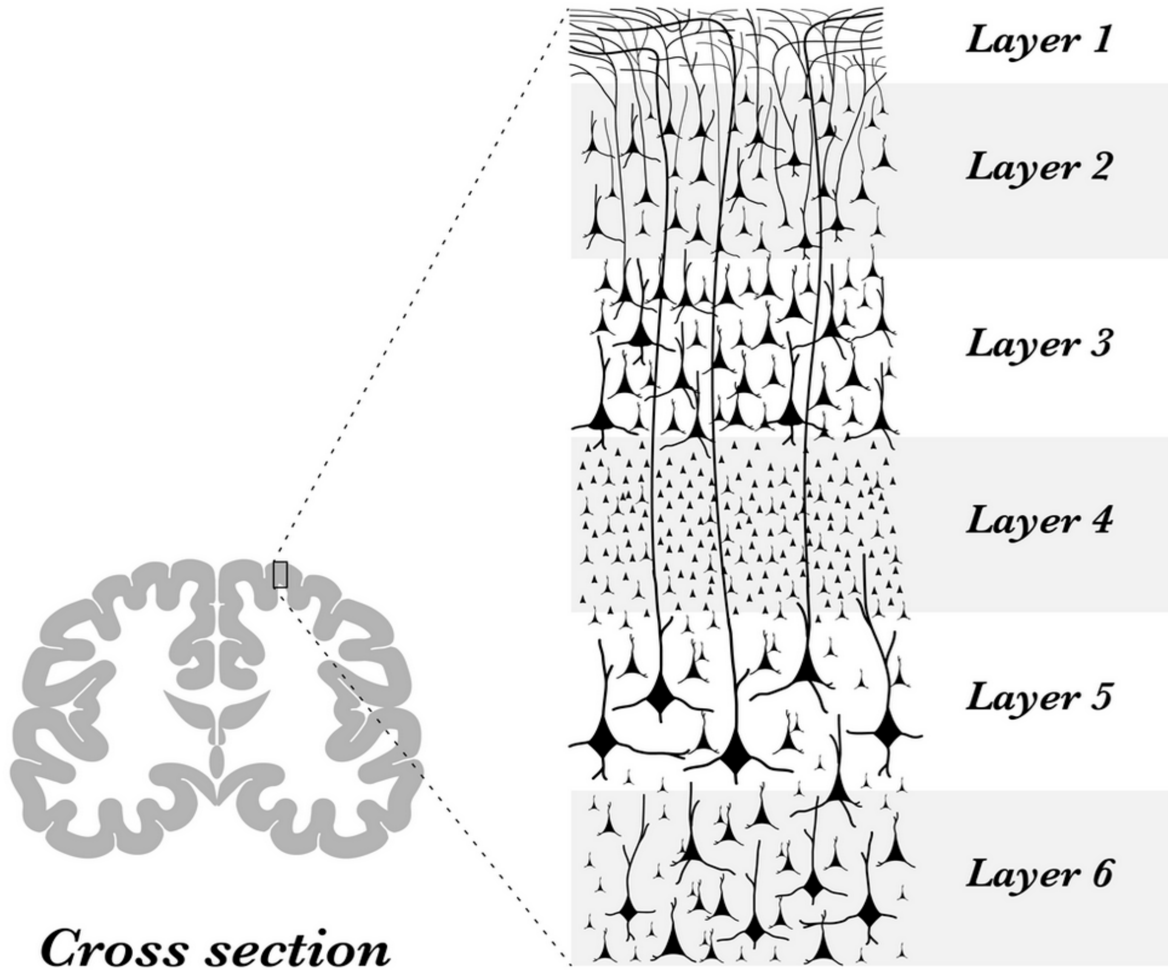
Neocortex of Cerebrum

The function of the neocortex became apparent in the 1970s.

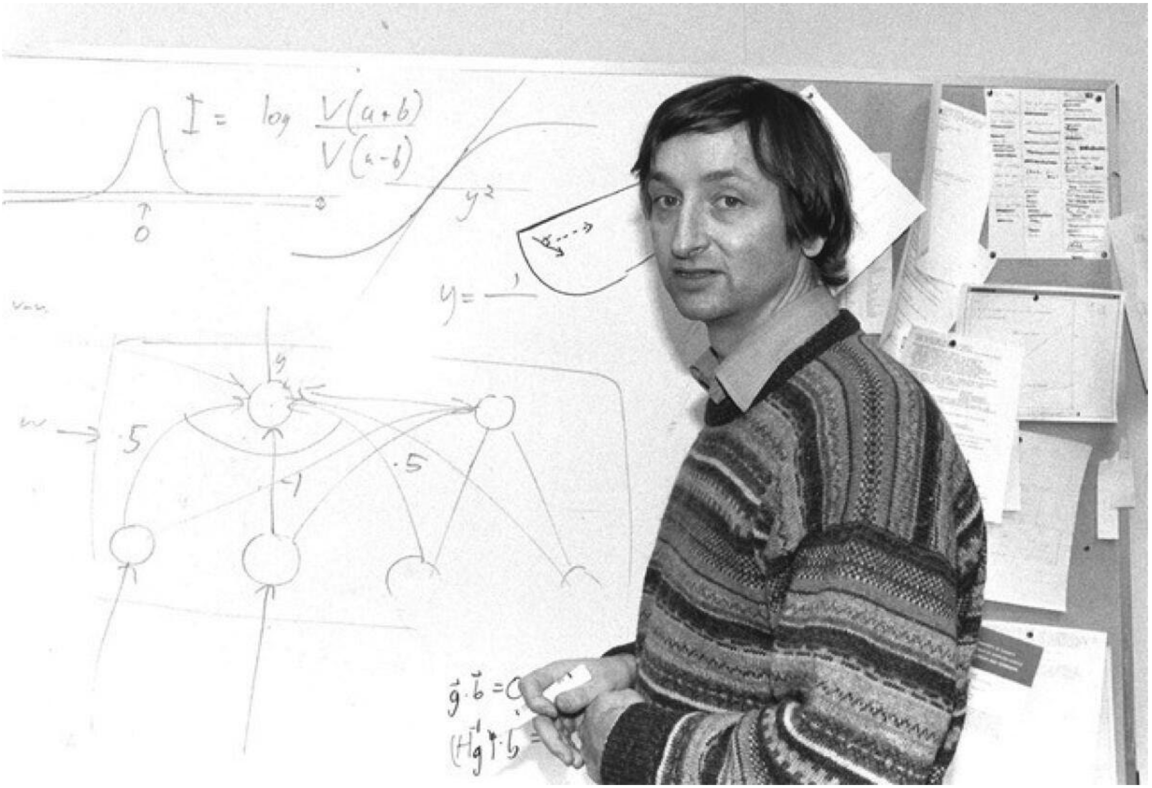
It seemed that the individual neuron from different layers were able to share signals and “learn” from the other neuron’s experience.

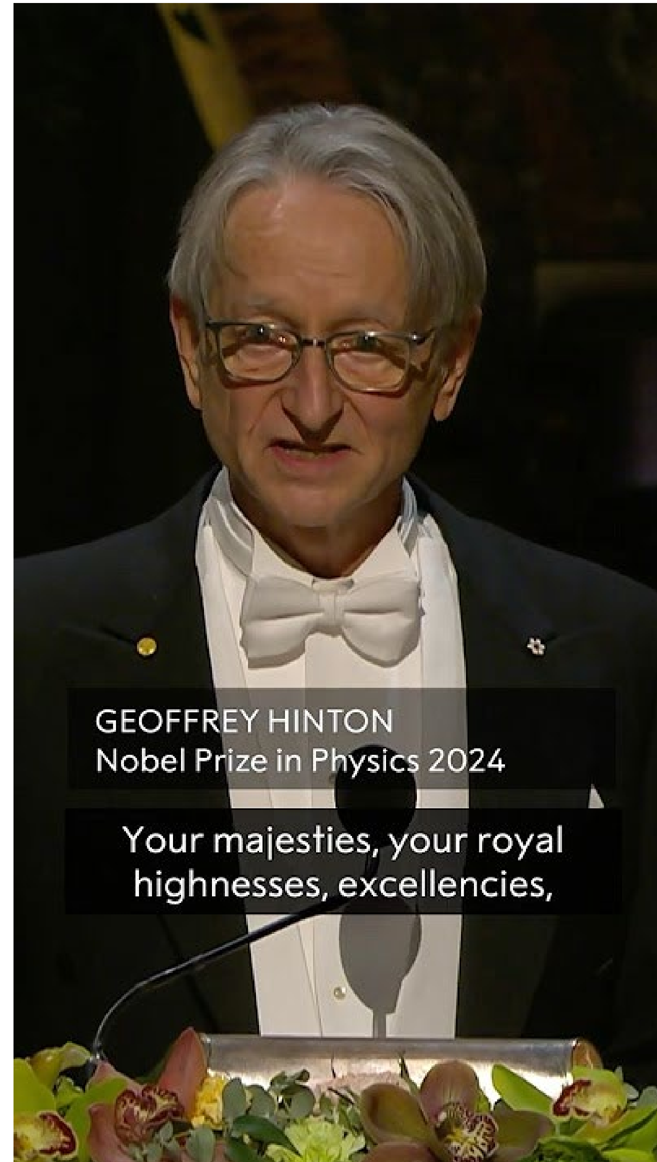
A physiology student, Geoffrey Hinton, became curious about the neocortex and started to design a computer program to mimic the neocortex.

Geoffrey Hinton is now considered the “grandfather of AI”. He retired recently as the director of Google’s AI department.



The first 4 mm below The pia mater




GEOFFREY HINTON
Nobel Prize in Physics 2024
Your majesties, your royal highnesses, excellencies,

Structure of the Six Layers Of the Neocortex

Layer I (Molecular Layer):

- Contains a sparse distribution of neurons and glial cells.
- Receives inputs from other cortical areas and subcortical structures.

Layer II (External Granular Layer):

- Densely packed with small pyramidal neurons.
- Involved in intracortical connections and sensory processing.

Layer III (External Pyramidal Layer):

- Contains larger pyramidal neurons that project to other cortical areas.
- Plays a role in corticocortical communication.

Layer IV (Internal Granular Layer): Primarily composed of stellate cells and Receives sensory inputs from the thalamus.

Layer V (Internal Pyramidal Layer):

- Contains large pyramidal neurons that send outputs to subcortical structures.
- Involved in motor control and other long-range projections.

Layer VI (Polymorphic Layer):

- Contains a mix of neurons, including pyramidal cells, stellate cells, and spindle neurons.
- Sends feedback projections to other cortical areas and the thalamus.

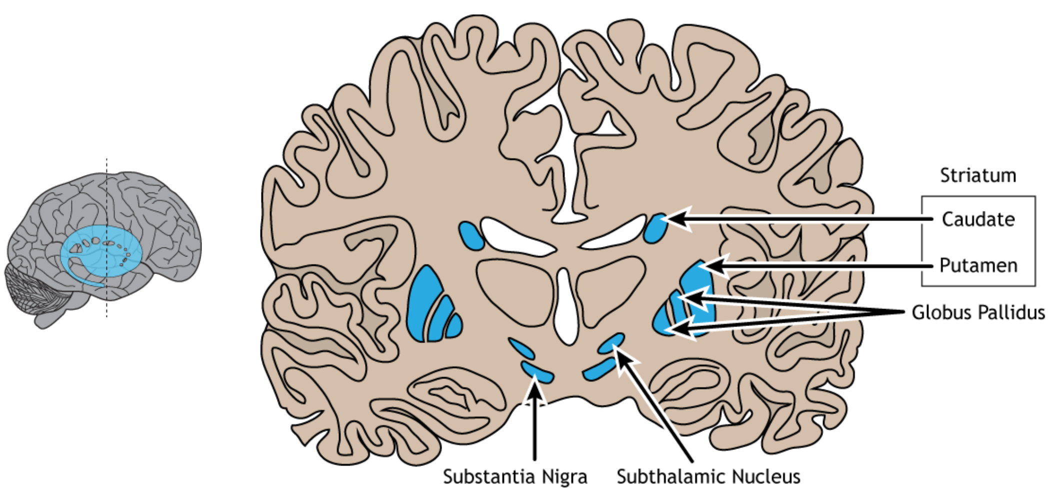
These layers are present throughout most of the neocortex, but their specific composition and function may vary slightly depending on the cortical region. For example, the frontal lobe has a prominent layer III, while the temporal lobe has a more developed layer IV.

Subcortical Nuclei

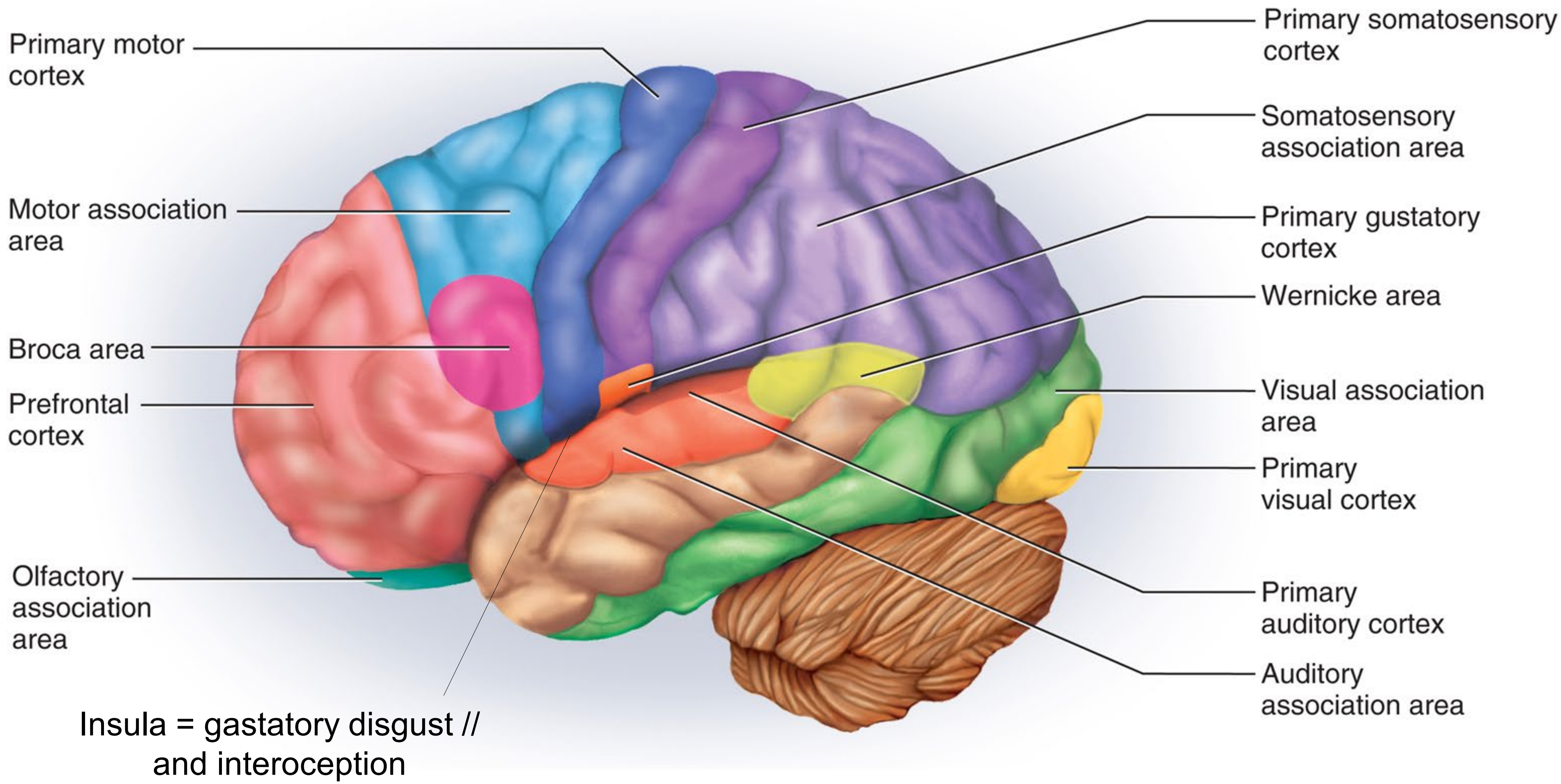
Within the cerebrum but positioned below the cerebral cortex are sub-cortical nuclei.

These structures form the limbic system, basal ganglia, and other important sub cortical structures.

These sub-cortical nuclei form a constellation of nuclei around the thalamus.



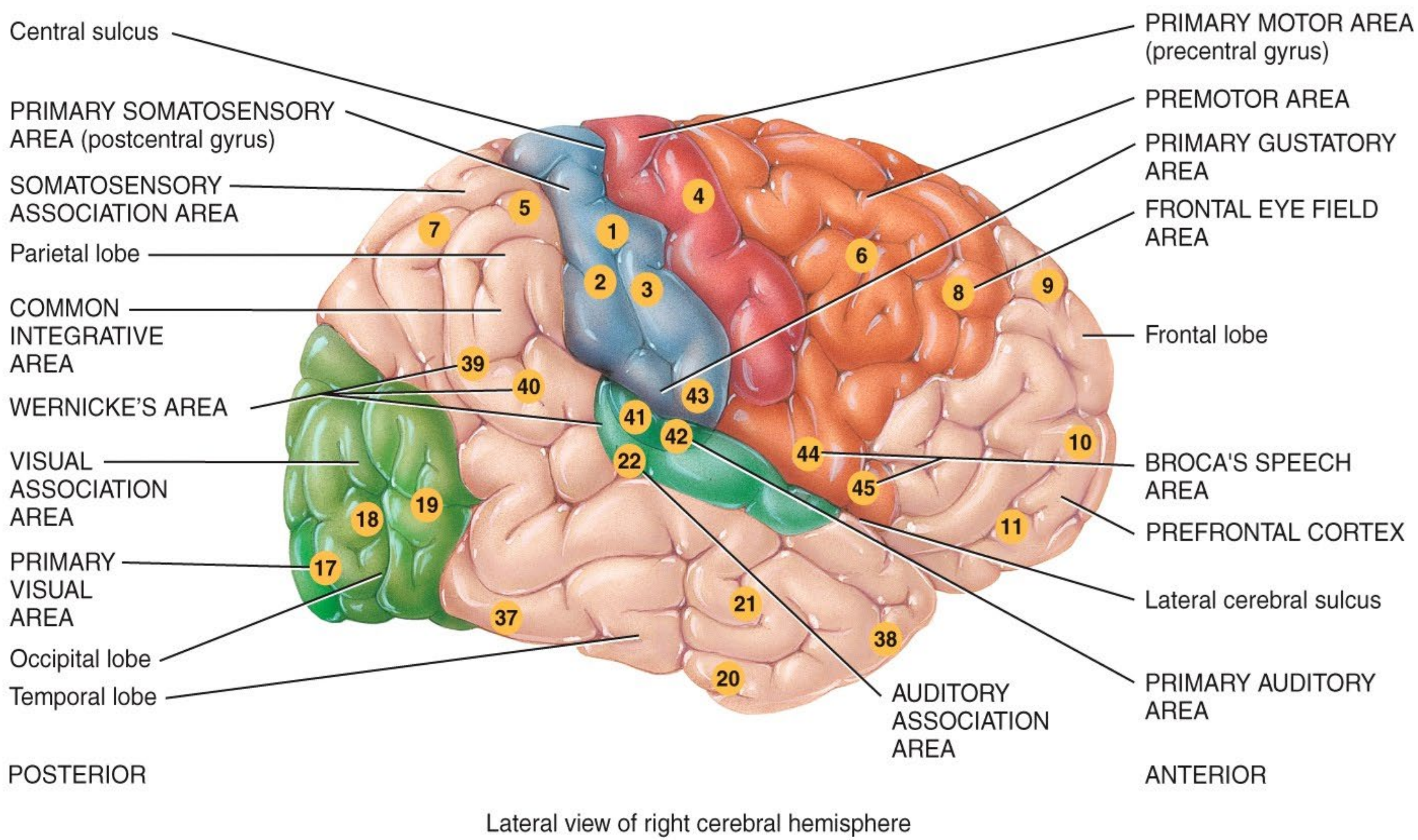
Cerebrum's Regional Functions



Insula = gastatory disgust // and interoception

> What is the significance between the primary area and their association areas?

Brain Function



Lateral view of right cerebral hemisphere

Note: Functions organized as primary and association areas.

Somatotopy
Precentral VS Postcentral Gyrus

precentral gyrus = “motor strip” // corticospinal tract = upper motor neuron

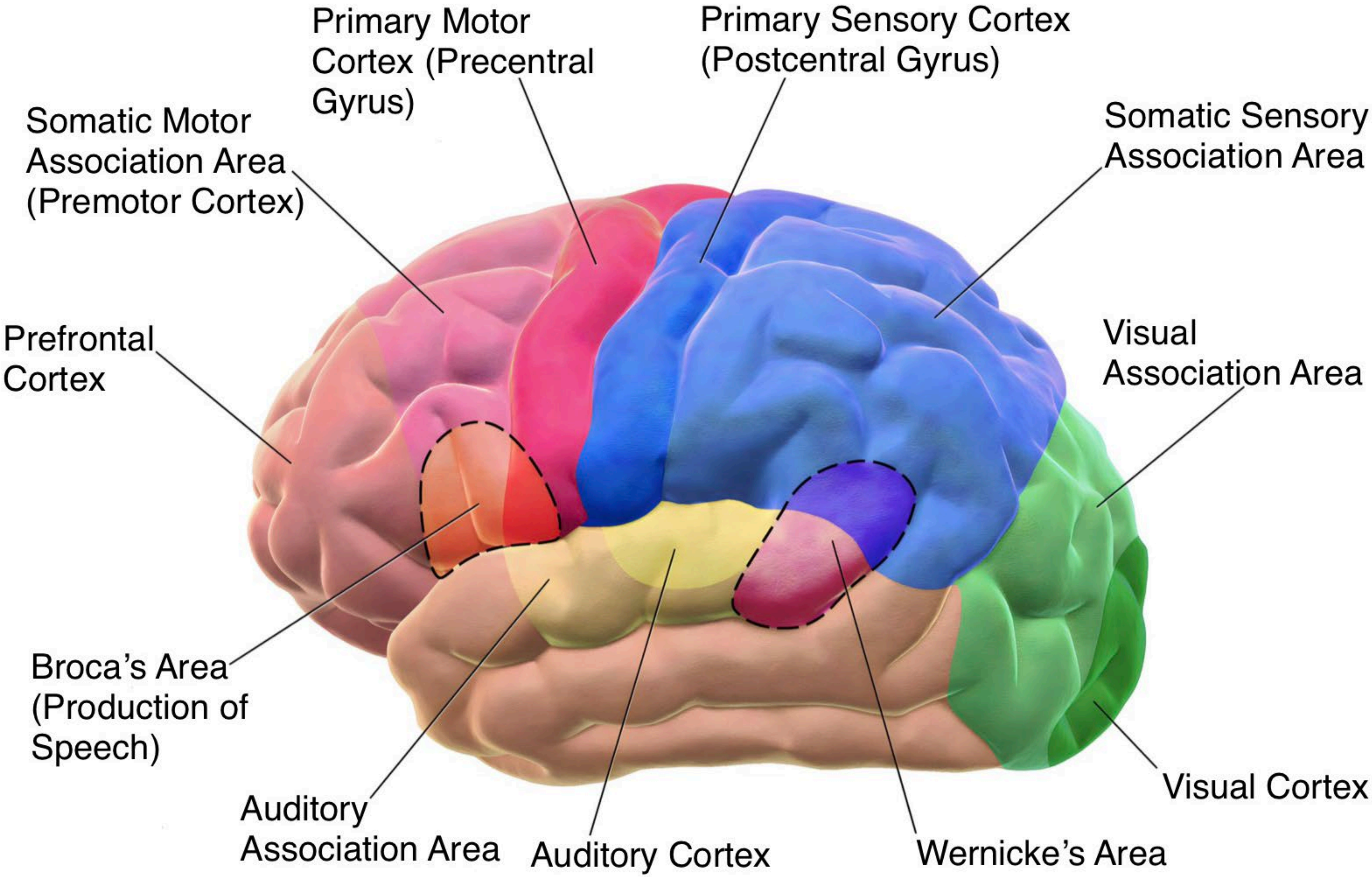
postcentral gyrus = “somatosensory strip” // receives spinalcortico tract

somatotopy – point-for-point correspondence between an area of the body and an area on either the primary motor or sensory gyrus

motor and sensory neurons for toe are deep in the longitudinal fissure of the medial side of the gyrus

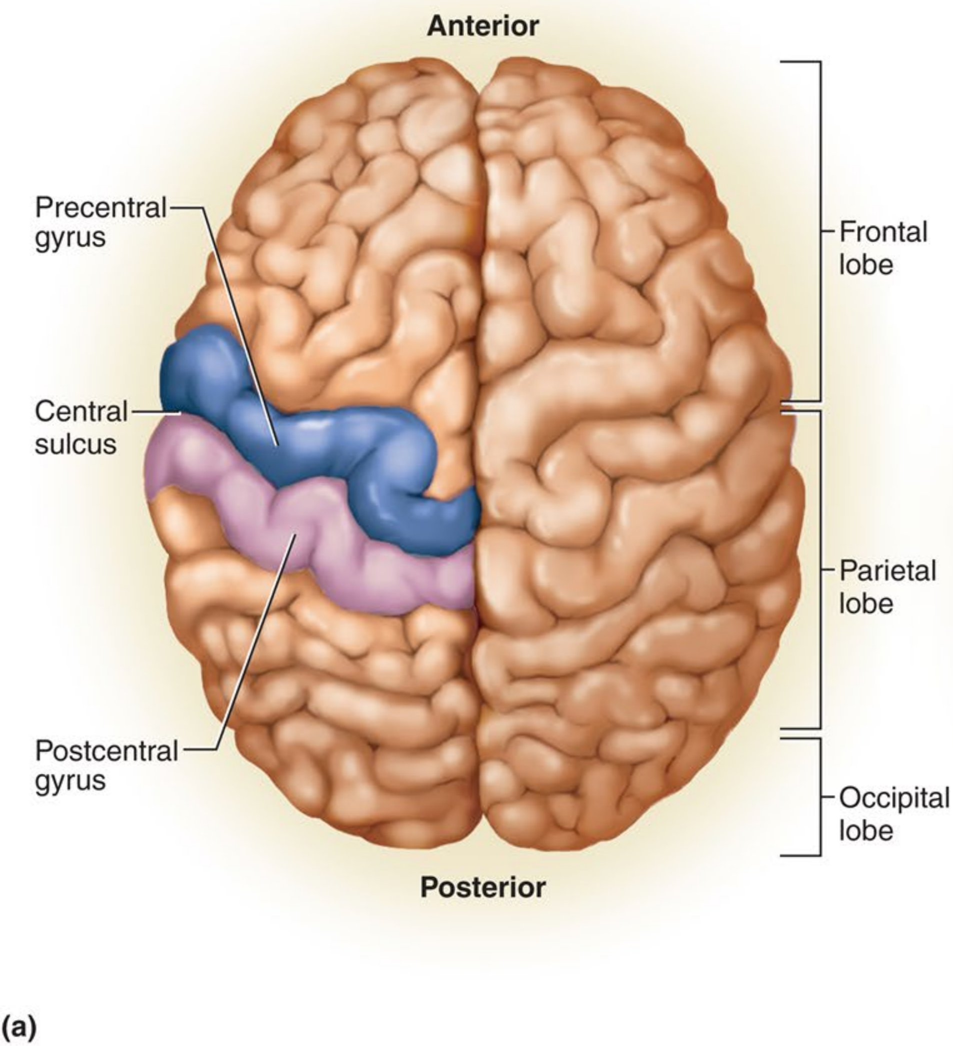
the summit of the gyrus controls the trunk, shoulder, and arm /// the inferolateral region controls the facial muscles

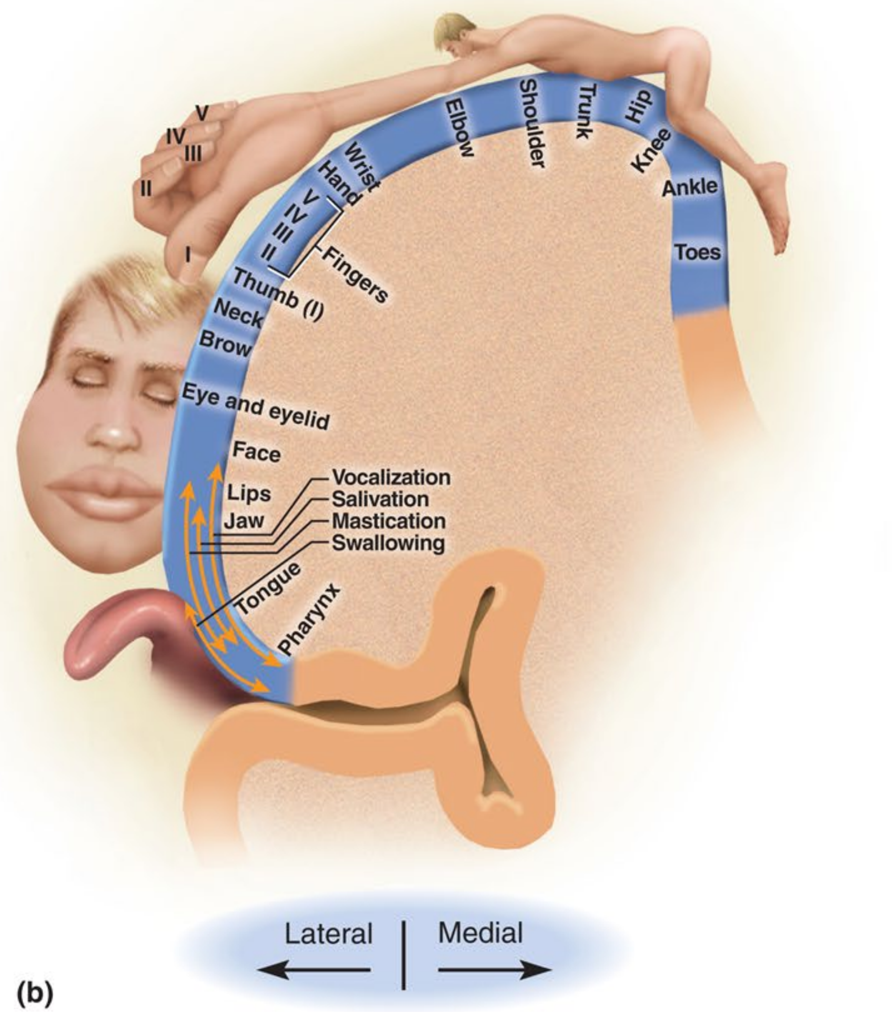
motor homunculus is a distorted projection of the body image onto the motor or sensory gyri to show proportional mapping of muscle/sensory functions to body region

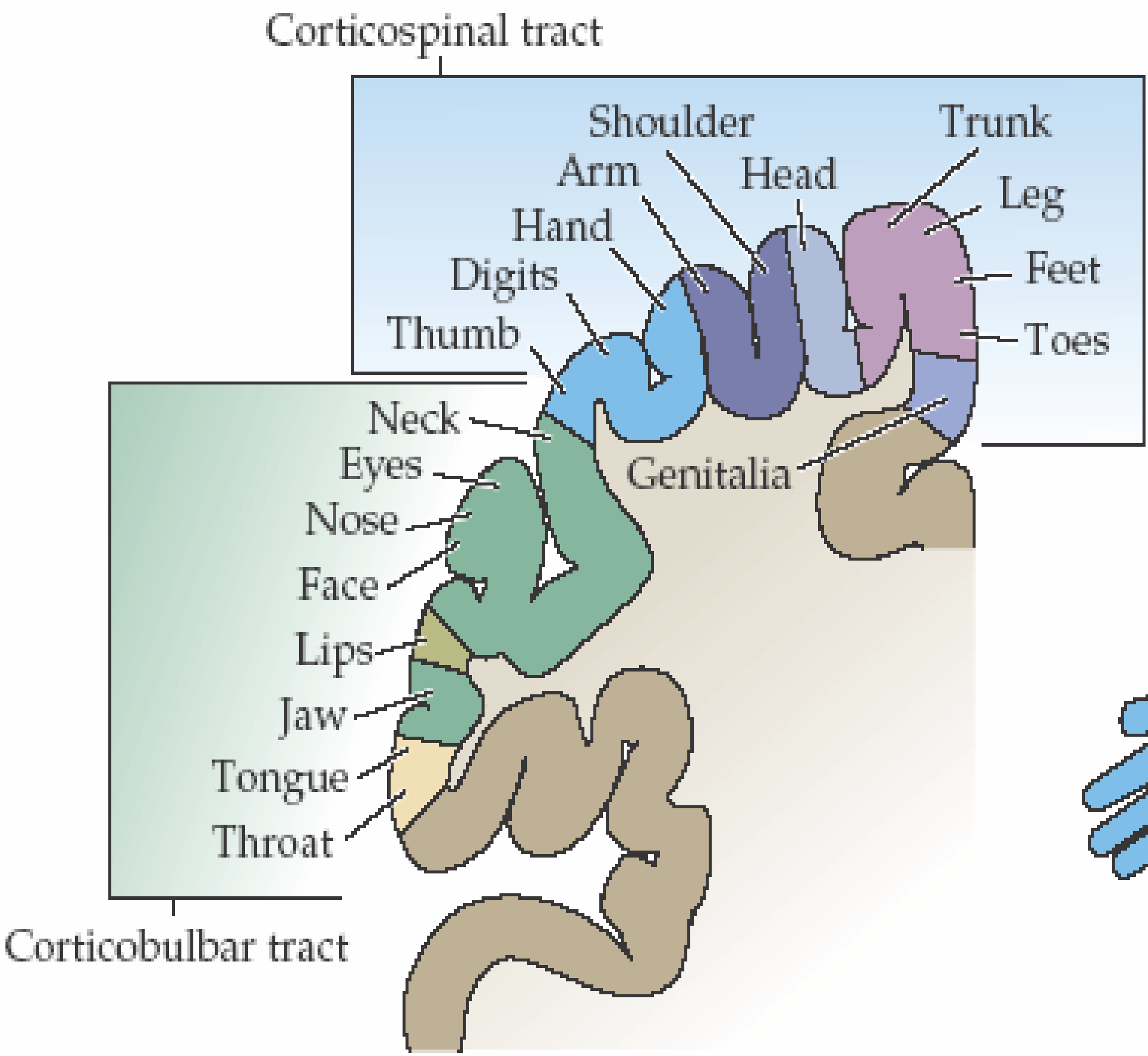


Each hemisphere's surface area is about the size of a 13-inch pizza!

The Homunculus







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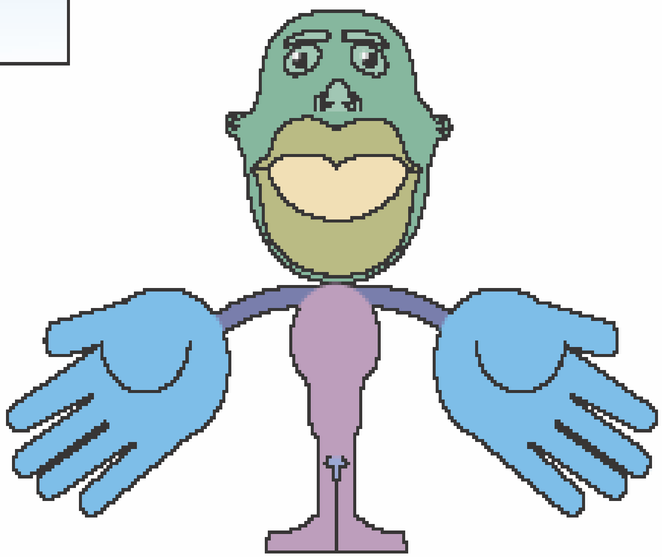
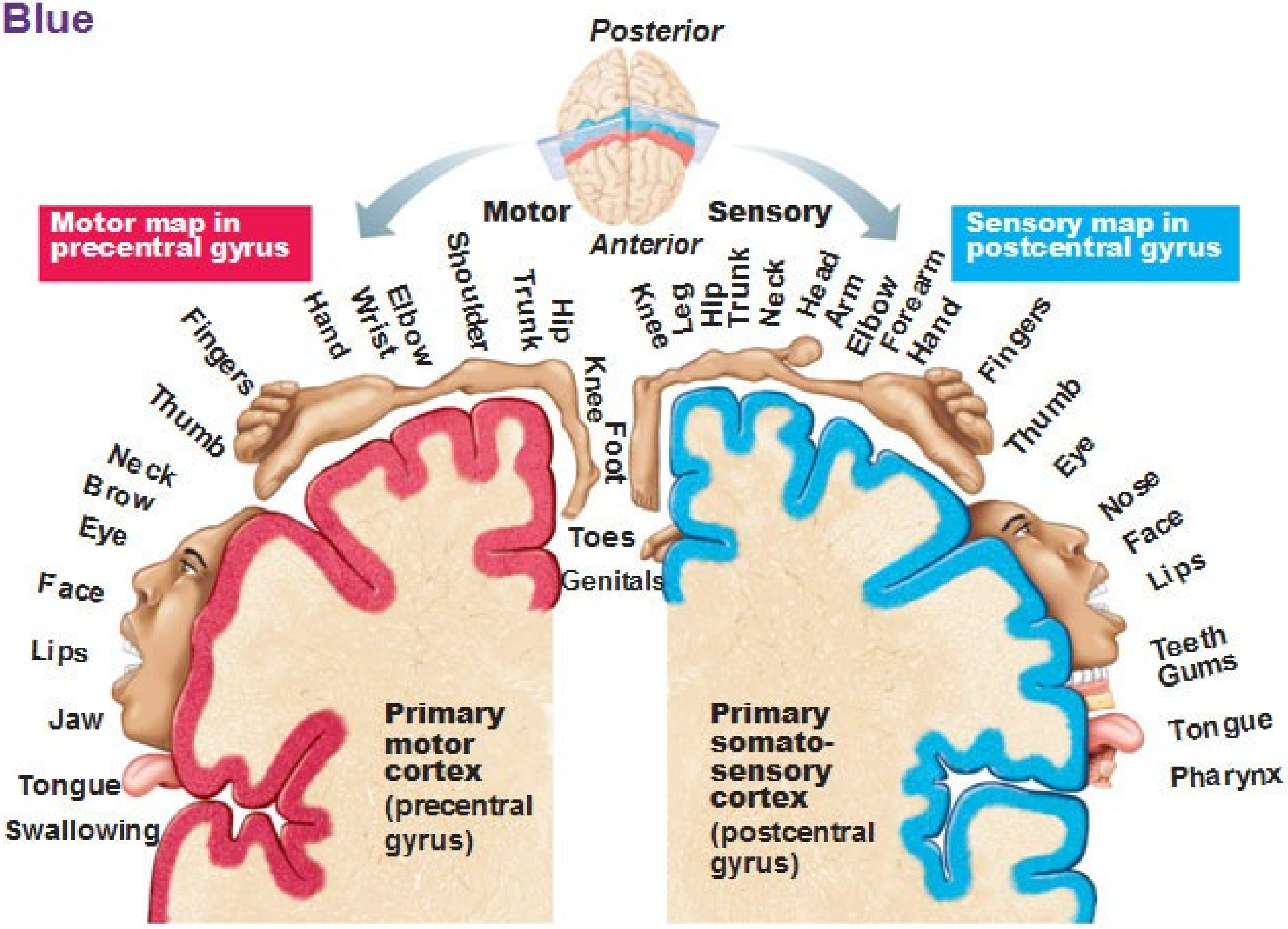


The Homunculus

Homunculus of Primary Somatosensory Cortex in Blue

Note that each hemisphere receives info from the opposite side of the body

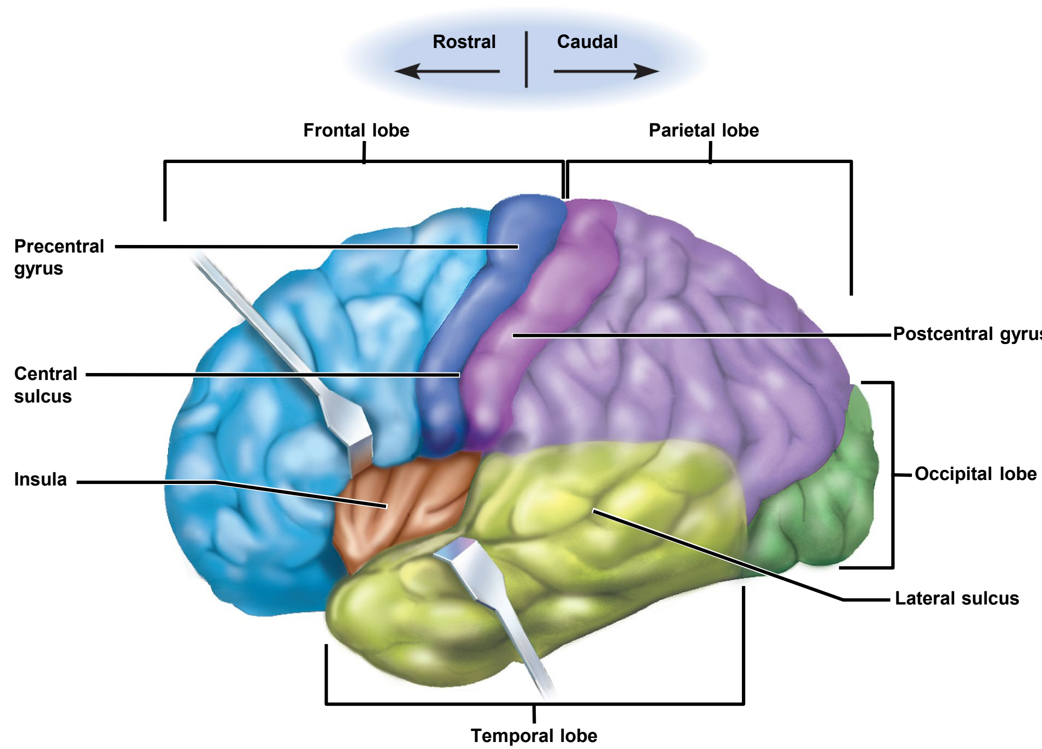


Cerebrum's Functions Are Isolated in Lobes of the Cerebrum

Frontal lobe (precentral gyrus, motor association area, prefrontal cortex, medial orbital frontal cortex, anterior cingulate gyrus)

Precentral gyrus = motor control

Motor association area = compile motor "applications" which maybe executed by prefrontal cortex



Note: each hemisphere's surface area is about the size of a 13 inch pizza!

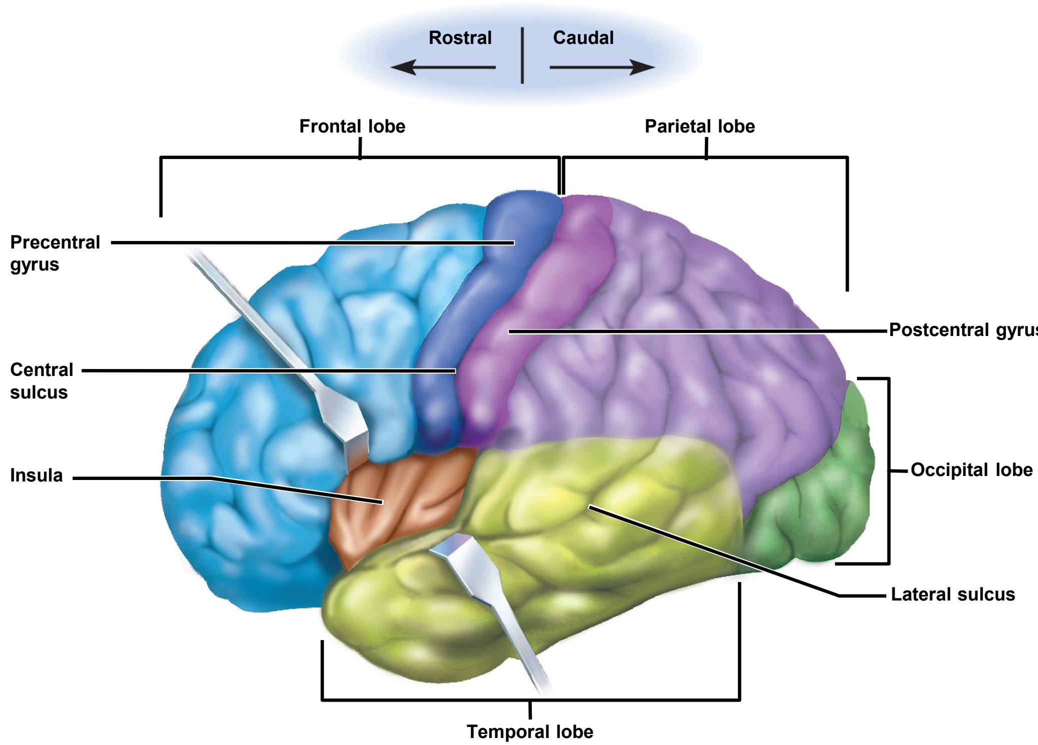
- Anterior cingulate gyrus = site of empathy / bidirectional connections with prefrontal cortex – check to see if you caused the pain in other person // conflict resolution.

Cerebrum's Functions Are Isolated in Lobes of the Cerebrum

Prefrontal cortex = Executive functions, cognition, impulse control, planning, foresight, social judgment, decision making, delay gratification

It is the Captain that steers the ship.

It makes you do the harder thing when it is the right thing to do!



Note: each hemisphere's surface area is about the size of a 13 inch pizza!

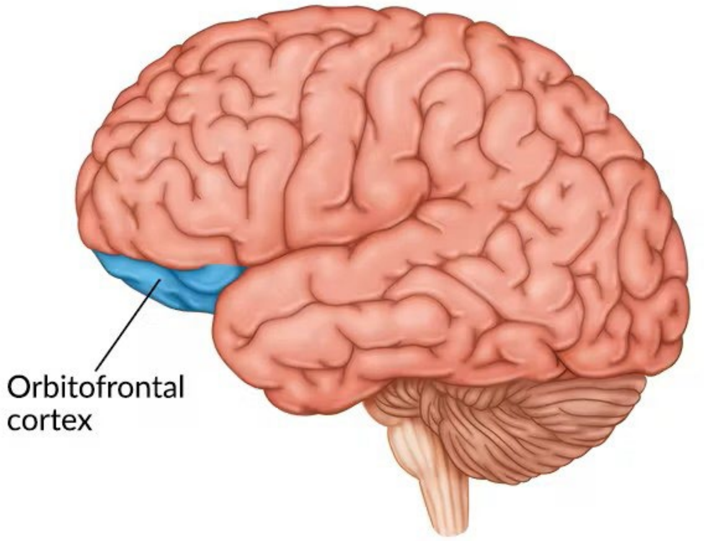
- Anterior cingulate gyrus = site of empathy / bidirectional connections with prefrontal cortex – check to see if you caused the pain in other person // conflict resolution.

Medial Orbital Frontal Cortex

Medial Orbital Frontal Cortex // right above your nose and between your eyes.

Region of the prefrontal cortex in the frontal lobe involved in the cognitive process of decision-making.

Involved in risk reward analysis. // ventral-medial prefrontal cortex vs dorsal-lateral prefrontal cortex



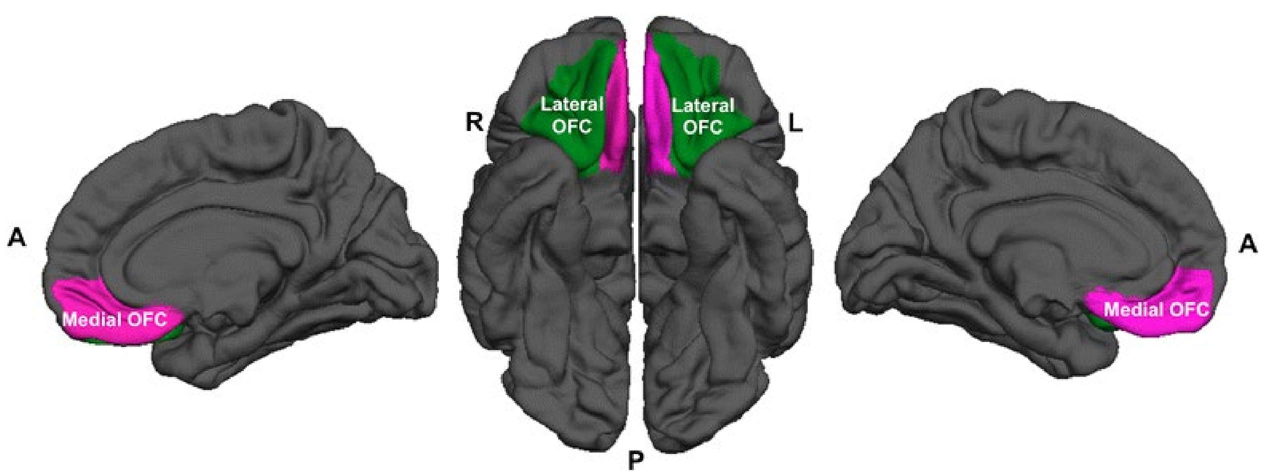
What is the function of the medial orbital frontal lobe?

Medial orbital frontal cortex is the "great decider". It is a small area in the frontal lobe directly above the eye's orbits.

MOFC is divided into the ventral lateral prefrontal cortex and the dorsal medial prefrontal cortex.

Ventral lateral has direct pathway from amygdala (emotional input). Dorsal medial decisions are made without emotional input.

This tissue functions to make decisions. In our conscious state, we make an endless stream of decision as we move through time.



The more decisions you make early in the day means that you are more likely to make a bad decision later in the day!

What is the function of the medial orbital frontal cortex?

If the frontal lobe is the site of our working memory, then the medial orbital frontal cortex provides the raw data for our working memory.

The medial orbital frontal lobe works in a two-step process:

> first, it makes the decision based on a reward-punishment analysis

> it then sends decision to the pre-frontal lobe to be executed

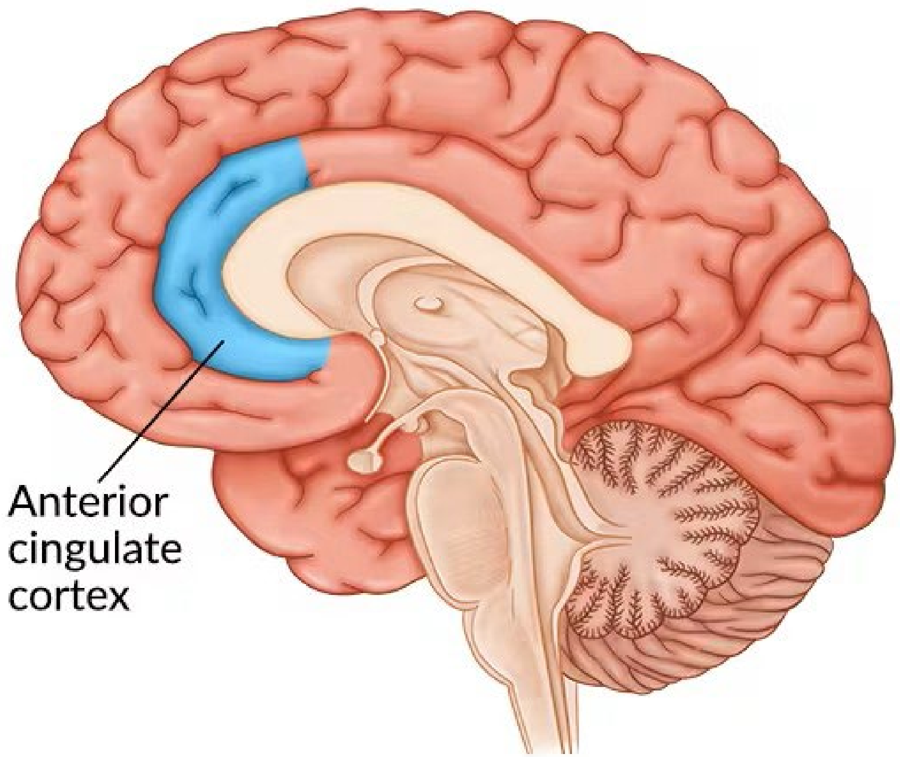
The medial orbital frontal lobe remembers the decision made and after the execution of the behavior will revisits the decision to see if the reward-punishment analysis was correct

> **This is how we learn to make better decisions!**

If you are tired, hungry, and/or stressed, then the VLPFC dominates with great influence from the amygdala (more emotional*). Now the fast brain dominates but it is less accurate and more likely to make bad decisions.*

The more decisions you make early in the day makes it more likely that you will make a bad decision later in the day. We call this decision fatigue.

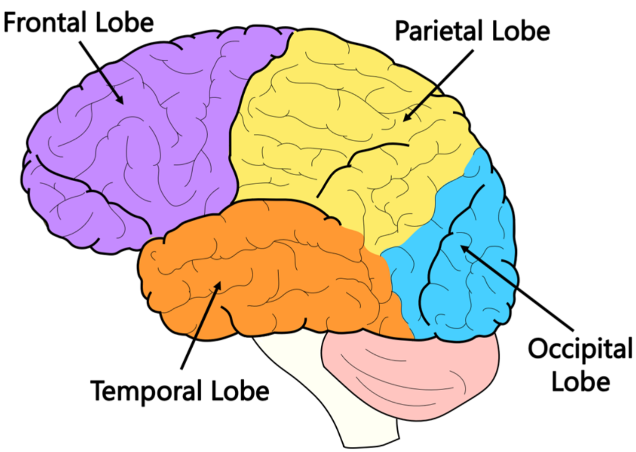
Cerebrum’s Anterior Cingulate Gyrus



Anterior cingulate gyrus = site of empathy / bidirectional connections with prefrontal cortex

Check to see if you caused the pain in another person // “don’t want to be voted of the island” /// Also the site of conflict resolution.

Cerebrum's Functions Are Isolated in Cerebrum's Lobes



parietal lobe

receives and integrates general sensory information // e.g. taste and some visual processing

occipital lobe

primary visual center of brain

temporal lobe

areas for hearing, smell, learning, memory, and some aspects of vision and emotion // hippocampus dependent memory

insula (hidden by other regions)

understanding spoken language, taste // gustatory disgust // in humans also moral disgust as in "I am sick to my stomach" and interoception = sensory information from visceral receptors

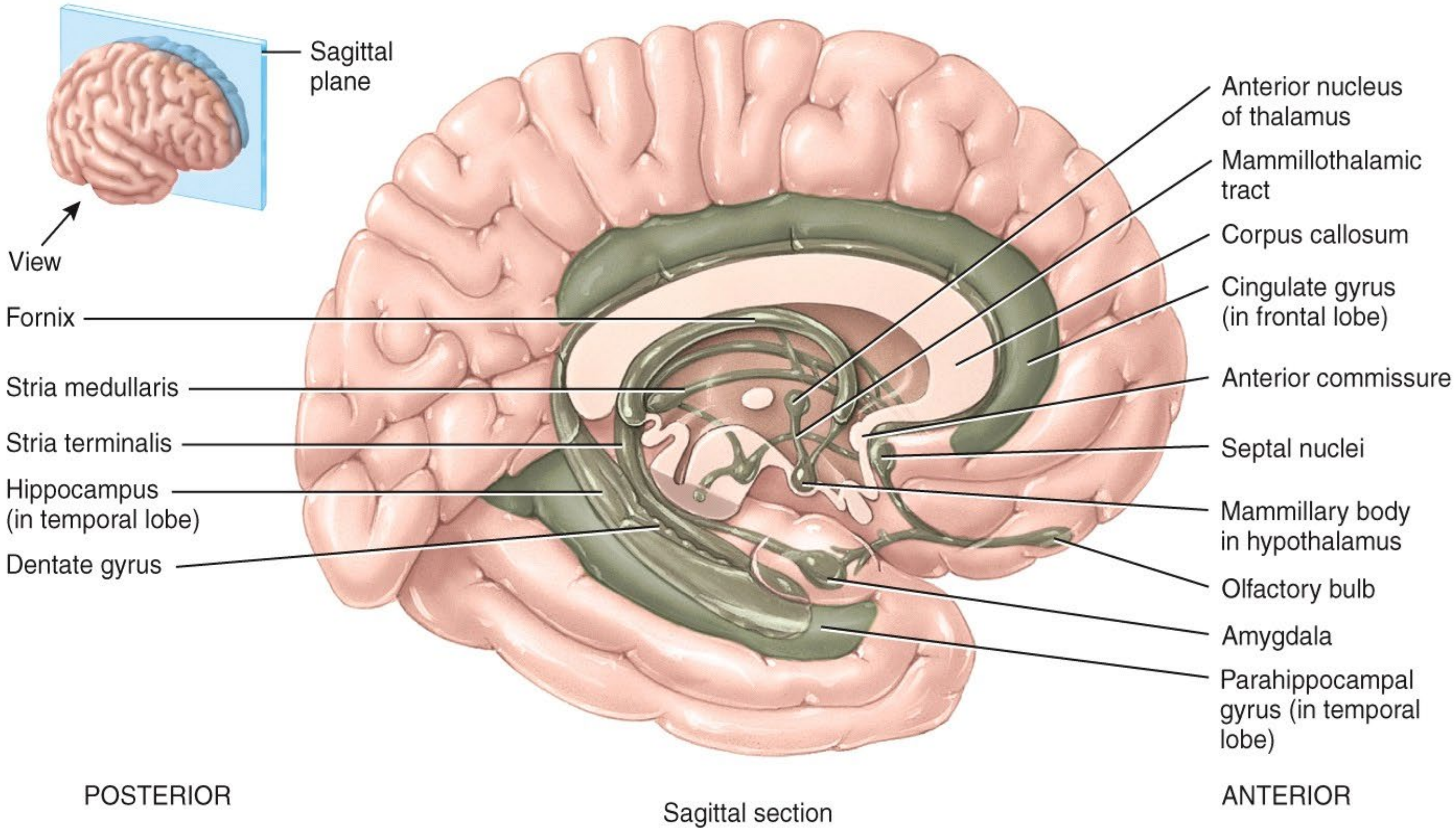
Interoception is loosely defined as the perception of internal signals from the body.

While the five commonly recognized senses — sight, hearing, touch, taste, and smell (and proprioception) — help us understand the world around us, interoception processes information from the heart, gut, lungs, and more to allow internal organs to interact with the brain.

The Limbic System

(Emotional Brain / Survival Brain // Fast Brain)

(Nuclei buried deep inside the cerebrum)



All nuclei are connected by nerve fiber tracts. After action potential enters LS the action potential transits through all nuclei. // LS forms subconscious memories as either pleasant or unpleasant events. // Where are emotions and values are stored.

The Limbic System

Somatosensory information is “split” at the top of the brainstem: one path goes through the thalamus and into different cerebral lobes and the other path goes into the limbic system.

Conscious = cerebral cortex VS Subconscious = limbic lobe

New declarative memories are formed by first passing through the hippocampus then landing in the medial temporal lobe. These memories are referred to hippocampus dependent memories. The frontal lobe may use these memories to solve problems then return the memories to the medial temporal lobe. In the process, your memories “may be altered”!

Procedural memories are formed via amygdala, globus pallidus, and stored in cerebellum

Each nuclei of the limbic system becomes associated with a different “type of emotional memory”.

These memories of subconscious information then helps us to shape our judgments and behavior.

The subconscious brain helps us guide our conscious brain.

Key Components of the Limbic System

- **Amygdala**: Processes emotions, particularly fear, pleasure, and aggression.
- **Hippocampus**: Crucial for forming new long-term memories and spatial navigation.
- **Hypothalamus**: Regulates autonomic functions (hunger, thirst, sleep, body temperature) and hormone release.
- **Cingulate Gyrus**: Involved in processing emotions, regulating behavior, and autonomic functions.
- **Fornix**: A major fiber tract acting as the output path for the hippocampus.
- **Septal Nuclei (Septal Area):** Involved in pleasure, reward, and reinforcement.
- **Parahippocampal Gyrus**: Surrounds the hippocampus and plays a role in memory.

Key Components of the Limbic System

- **Thalamus**: Specifically the anterior and mediodorsal nuclei, which act as relay stations.

- **Mammillary Bodies**: Part of the hypothalamus involved in memory recollection.

- **Olfactory Bulbs**: Involved in processing odors and connecting them to emotion and memory.

- **Limbic Cortex**: Includes the orbitofrontal cortex and insula, involved in motivation.

These structures are often interconnected via pathways like the Papez circuit, allowing them to function as a cohesive system for emotional and behavioral regulation.

What is the relationship between the frontal lobe and the limbic system?

The frontal lobe is our conscious brain. Cognition, our "working thoughts" occur here.

The limbic system is our subconscious brain, the location of judgment values and remembrances of emotional events that are stored as pleasant or unpleasant events.

These two areas are richly interconnected with nerve tracts. Therefore, the limbic system may influence frontal lobe function.

The three brain formations (brain stem / limbic system / cerebral cortex) are all interconnected and may each influence the other formations.

Motivational system (e.g. reward pathway that shapes our behavior //
also involved in addictions)

Nucleus accubens is part of the LS and is
nicknamed the pleasure center

What is the relationship between the frontal lobe and the limbic system?

The frontal lobe is our slow brain, and the limbic system is our fast brain.

Therefore, the limbic system can influence frontal lobe function. And the frontal lobe may influence the limbic system (e.g. cause psychosomatic disease).

Because the brainstem, limbic system, and cerebrum are all bidirectionally connected this is why holding a warm cup of coffee makes you feel better about your Mother.

If under stress then the frontal lobe's efficiency is degraded (i.e. panic state) and now the limbic system dominates (i.e. anxiety leads to fear leads to aggression /// trigger pathway to the fright, flight or fight reaction)

The limbic system matures faster than the prefrontal cortex. The frontal cortex does not mature until the age of 25 yrs.

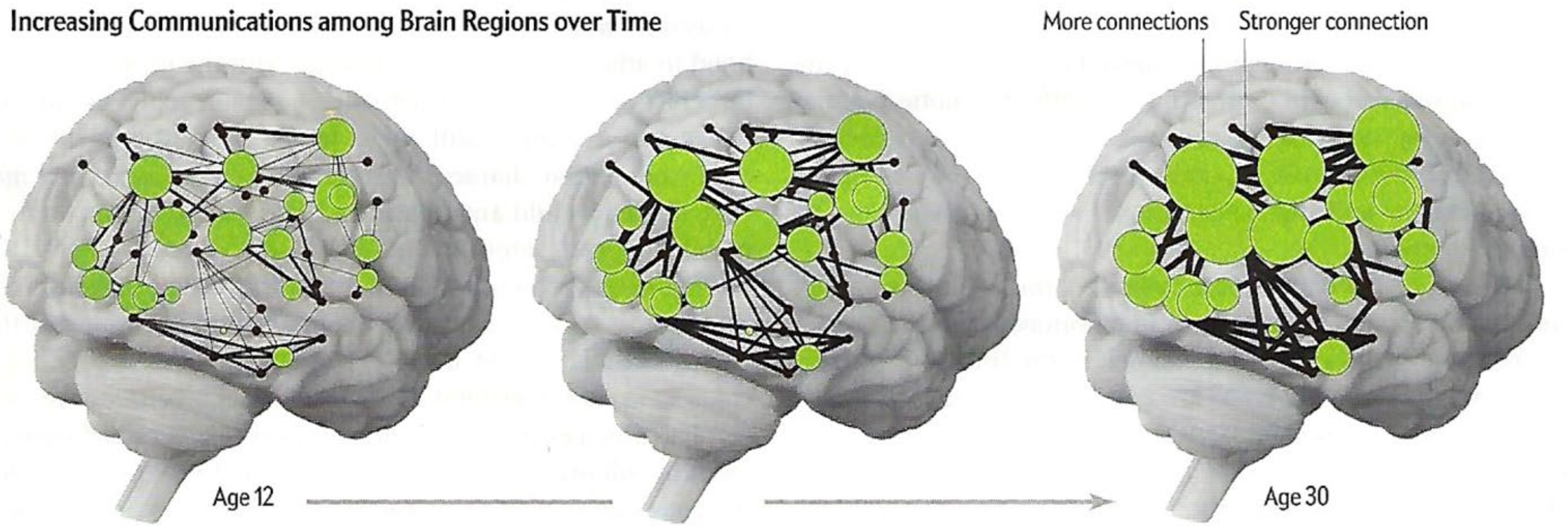
Juvenile behavior is dictated by the limbic system.

A NEW VIEW

Greater Networking Brings Maturity

The most significant change taking place in an adolescent brain is not the growth of brain regions but the increase in communications among groups of neurons. When an analytical technique called graph theory is applied to data from MRI scans, it shows that from ages 12 to 30, connections between certain brain regions or neuron groups become stronger (*black lines that get thicker*). The analysis also shows that certain regions and groups become more widely connected (*green circles that get larger*). These changes ultimately help the brain to specialize in everything from complex thinking to being socially adept.

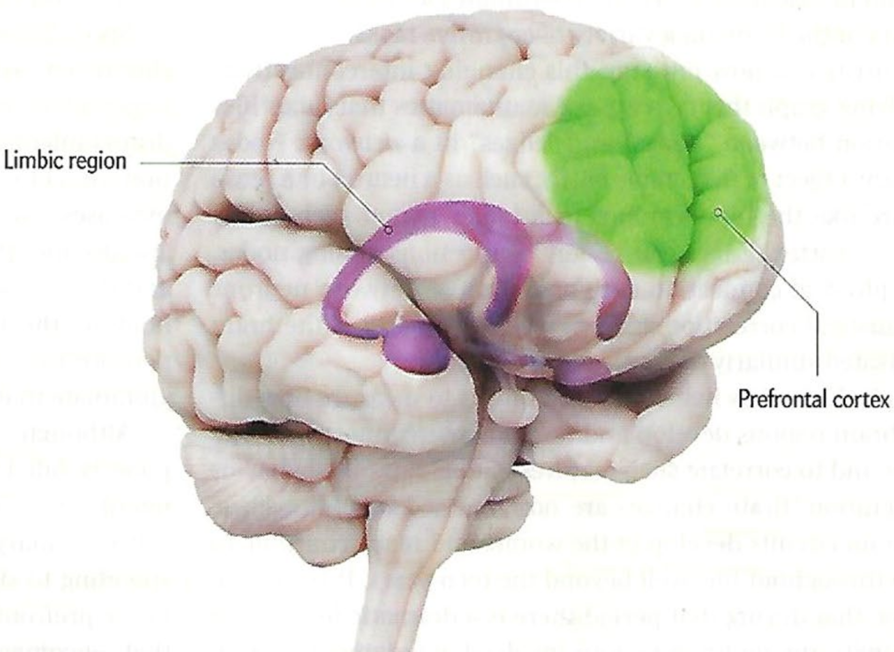
Increasing Communications among Brain Regions over Time

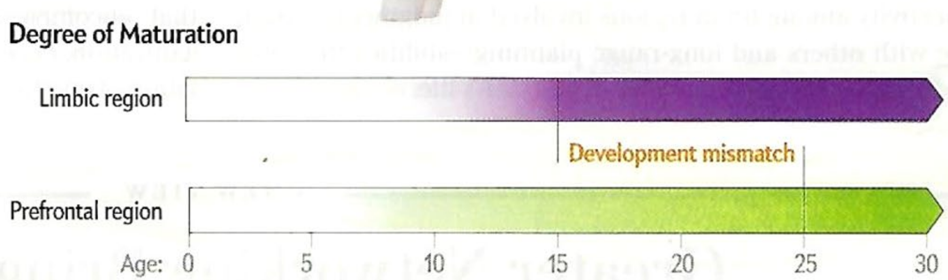


Fast brain is the survival brain, the limbic system. The slow brain is the prefrontal cortex. These two regions are "hardwired" together. If you are stressed, hungry, and/or tired then the fast brain shuts down the slow brain. This is when you make poor decisions.

Emotion vs. Control

Teenagers are more likely than children or adults to engage in risky behavior, in part because of a mismatch between two major brain regions. Development of the hormone-fueled limbic system (*purple*), which drives emotions, intensifies as puberty begins (typically between ages 10 to 12), and the system matures over the next several years. But the prefrontal cortex (*green*), which keeps a lid on impulsive actions, does not approach full development until a decade later, leaving an imbalance during the interim years. Puberty is starting earlier, too, boosting hormones when the prefrontal cortex is even less mature.

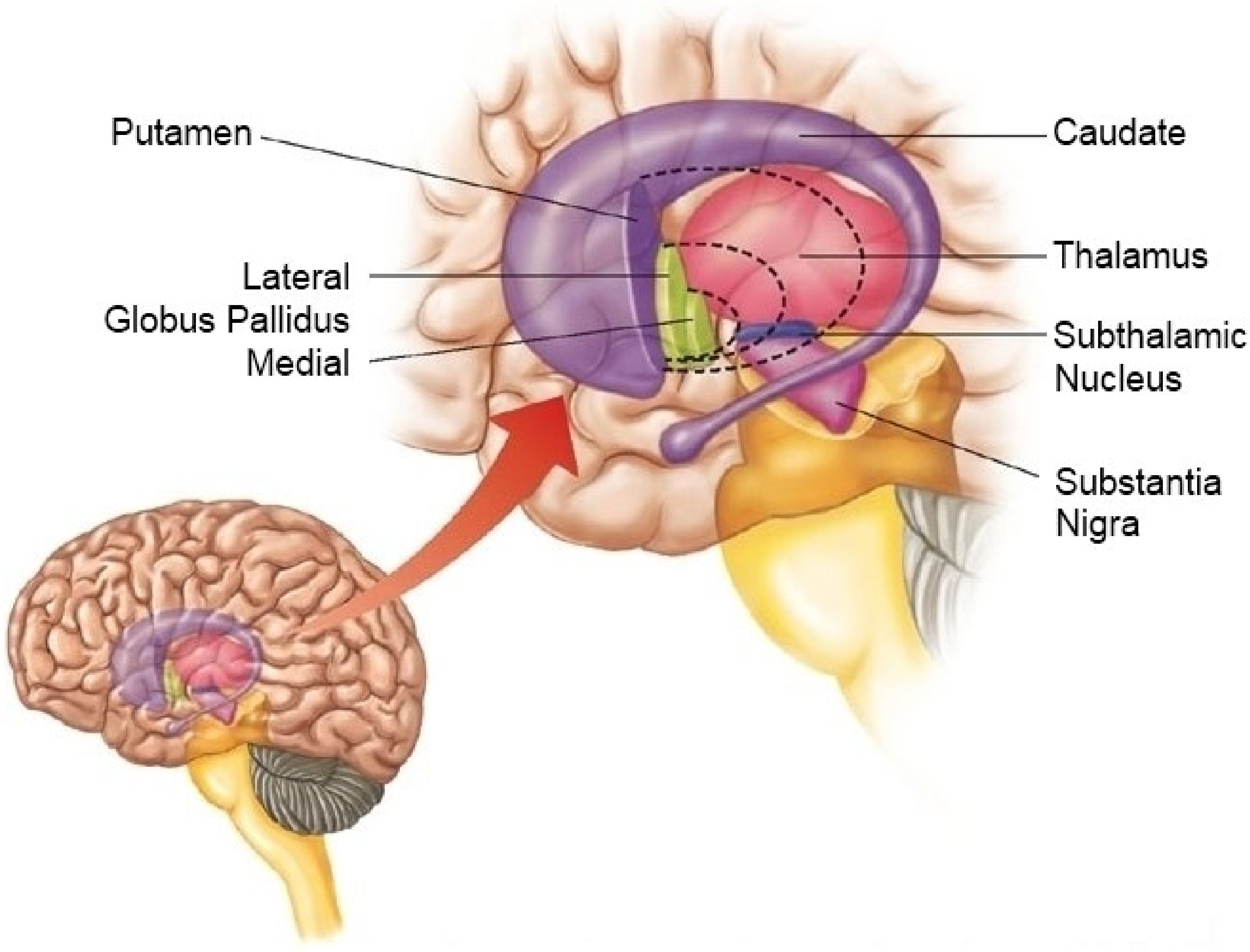




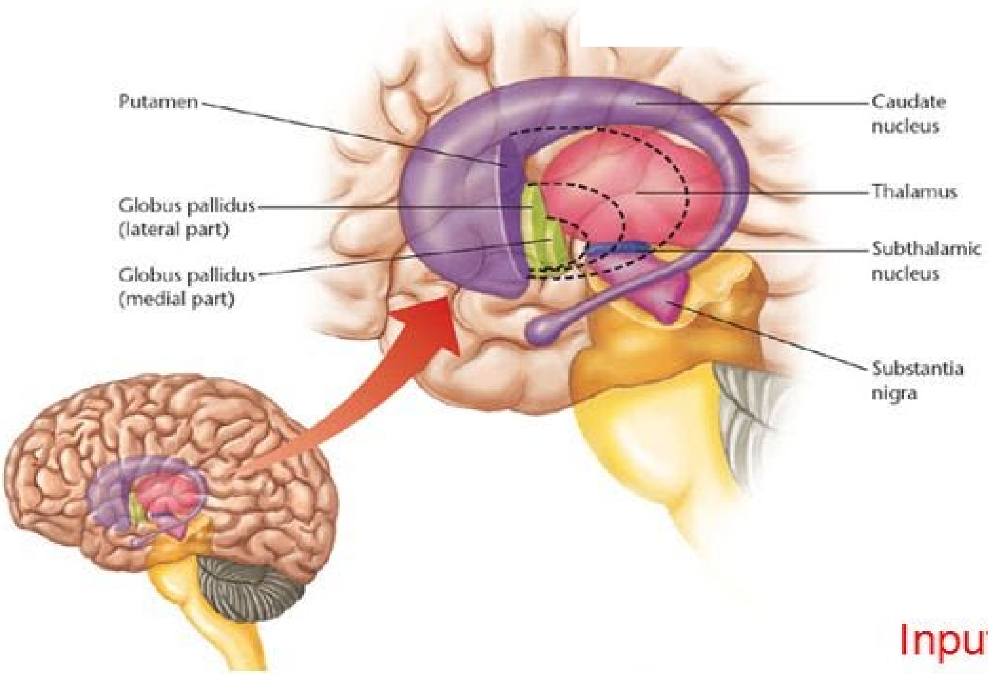
This illustrates the problem with the half-baked teenage brain.

Should our criminal system treat teenagers as adults?

Basal Ganglia



Basal Ganglia



Part of the motor system:
control of voluntary movement

- Caudate Nucleus
- Putamen
- Globus Pallidus

} Dorsal **Striatum**

DS = direct and indirect pathways / muscle regulation

Input to caudate and putamen from
- Cerebral cortex
- Substantia Nigra (Dopamine)

Nickname = Action Selection

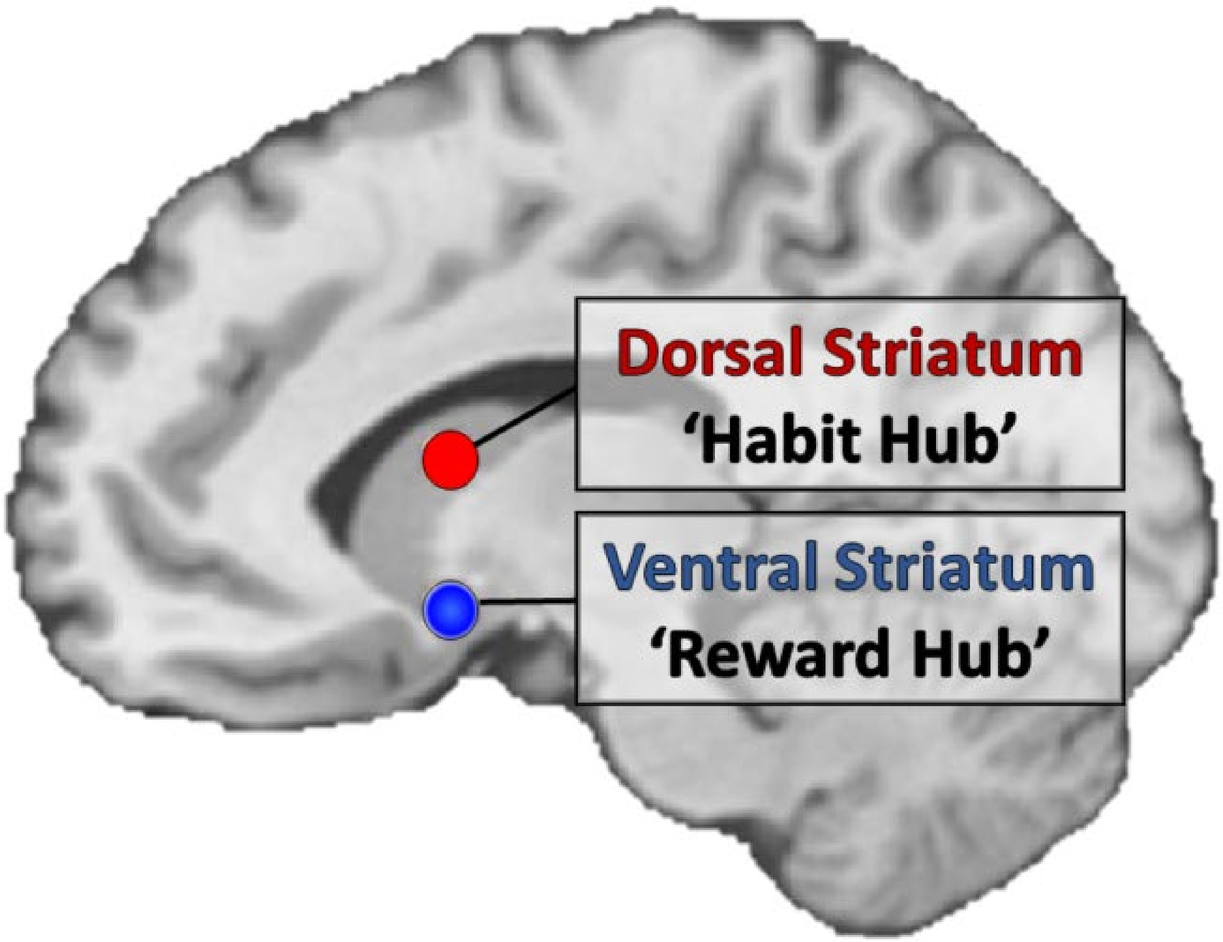
Output through the globus pallidus to
- Thalamus to the motor cortex
- Brain stem

Ventral striatum

nucleus accumbens

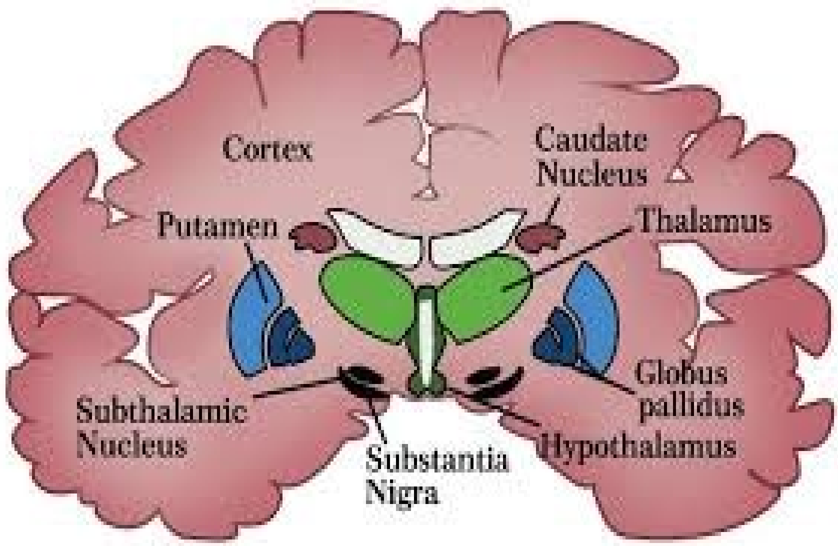
reward + motivation + focus

Ventral striatum = go or reward hub
Dorsal striatum = habit hub



In substance use disorder (addiction) the brain is rewired so signals are routed not through the reward hub (go hub) but through the habit hub. Dopamine is the neurotransmitter for pathway to the reward hub and glutamate is the neurotransmitter for the pathway to the habit hub. Repeated use of drug activates gutametergic pathways which trigger habitual behavior. The first neurotransmitter of addiction is dopamine and the second neurotransmitter of addiction is glutamate.

Basal Ganglia



Basal ganglia is also able to remember and execute routine implicit memory independent from the prefrontal cortex.

This allows the cerebrum to work on one task while the basal ganglia executes another action.

Example: Globus pallidus // Have you ever experienced yourself "subconsciously" driving your car as your thoughts focused on another task? This is the basal ganglia driving the car as your prefrontal cortex is working to makes other decisions.

Also plays role in addiction when user learns to associate drug with dopamine release.

Basal Ganglia Role in Motor Control

The basal ganglia (nuclie in CNS) are a group of subcortical nuclei positioned around the thalamus

Before the motor strip can send an action potential down the upper motor neuron (UMN), the motor association cortex must first direct its commands through the basal ganglia.

Think of the basal ganglia as a "skeletal muscle consultant" that prevents unwanted muscle contractions while coordinating and smoothing out wanted skeletal muscle contractions.

Basal ganglia is the "action selection center".

BG is responsible for coordinating a voluntary skeletal muscle contraction (BG excitatory) while also preventing unwanted contraction (BN inhibitory). The BG also plays a role in visual perception and other functions. These are the direct (Go) and indirect (No Go) pathways.

Basal Ganglia Role in Motor Control

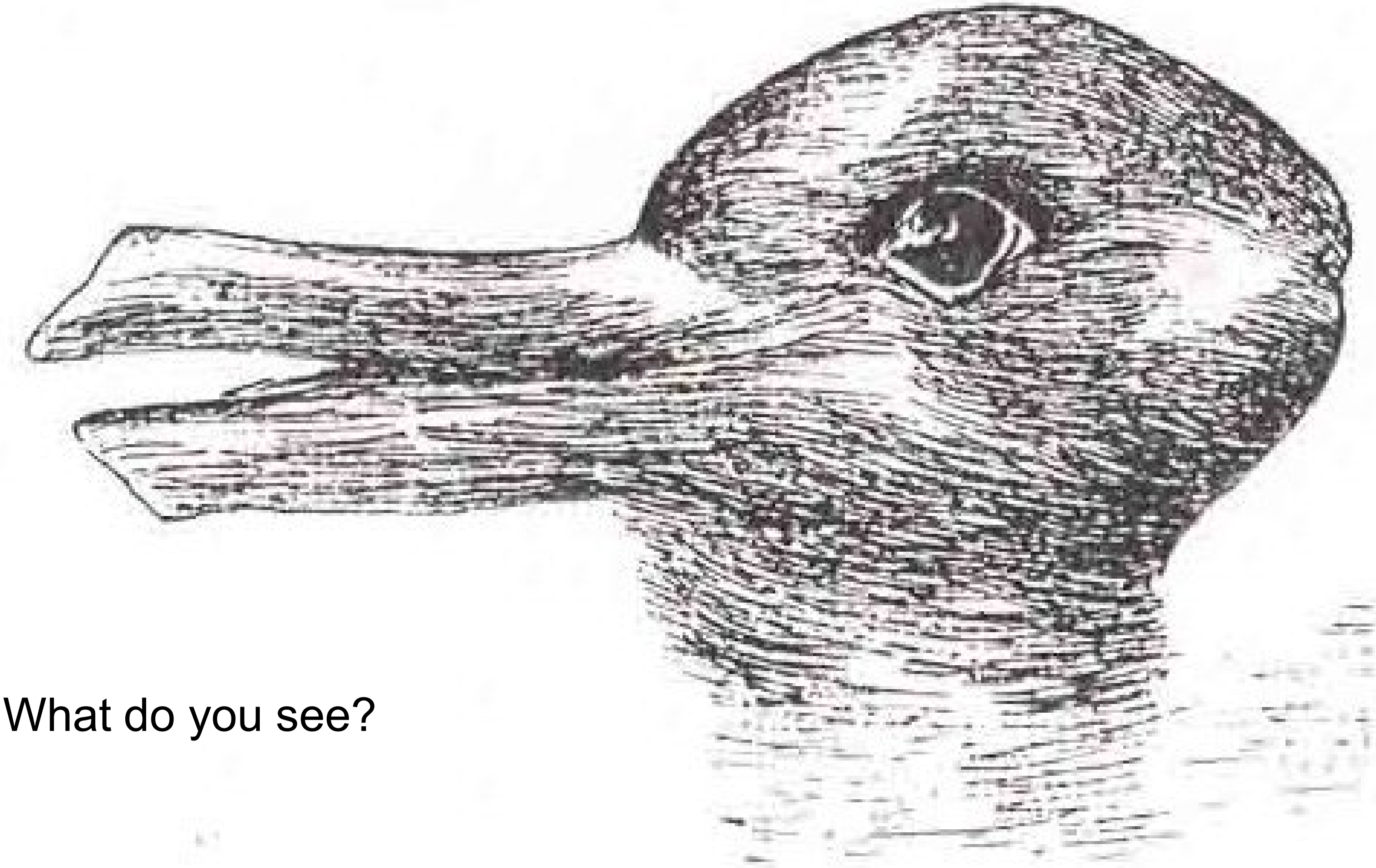
Think about the rhythmic muscle contraction and relaxation that occurs when you walk. You must initiate and stop contractions, but you must also inhibit other skeletal muscle's unwanted contractions

Motor association area sends action potentials (AP) into two nuclei of the basal nuclei called the striatum (caudate and putamen nuclei) // efferent AP either stimulatory or inhibitory sent to globus pallidus and eventually makes its way first to the thalamus then to the motor strip //   AP at motor strip may now move down UMN to the 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 Role in Perception

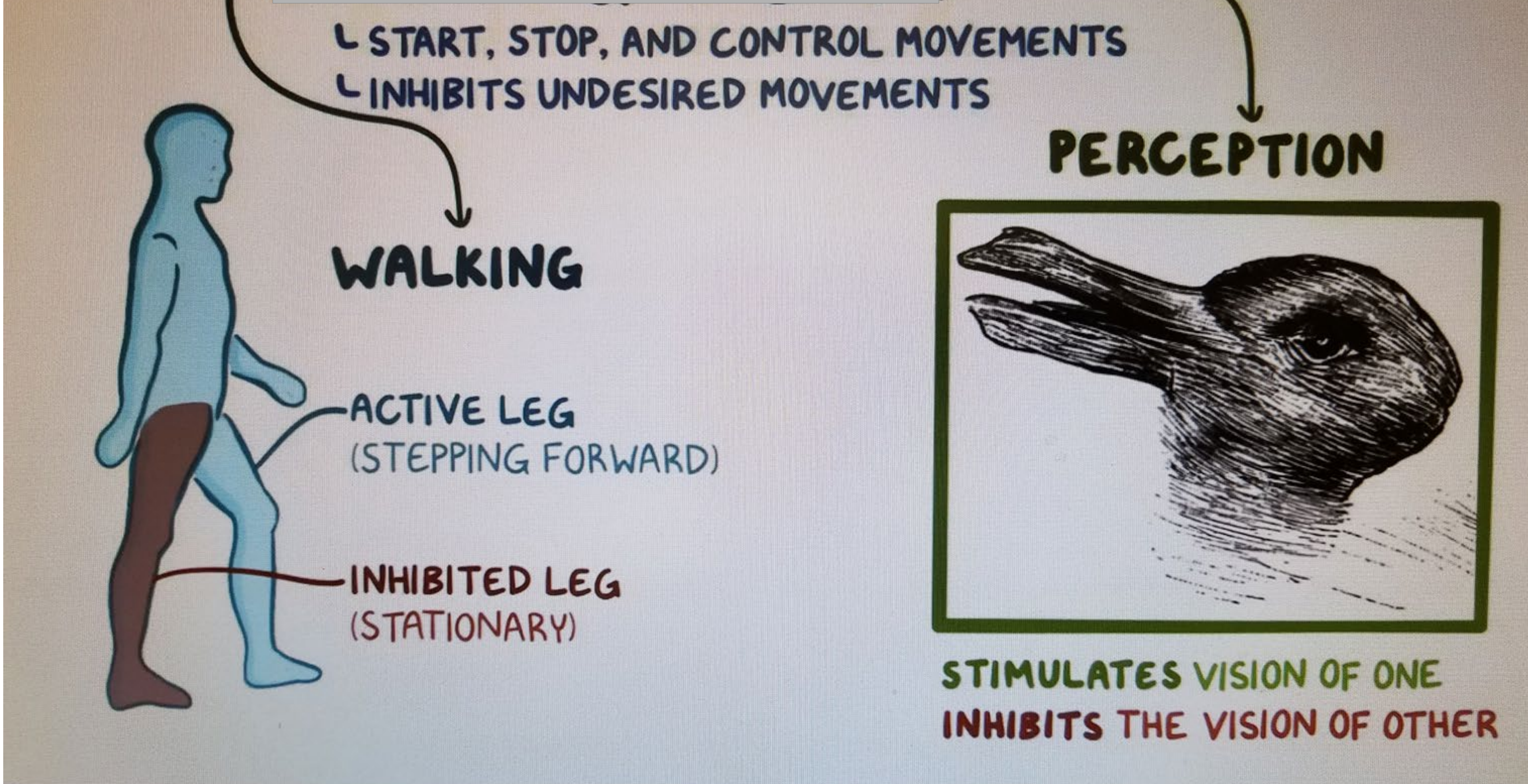
(Action Selection)



What do you see?

BN only allows you to see one image at a time.

Basal Nuclei



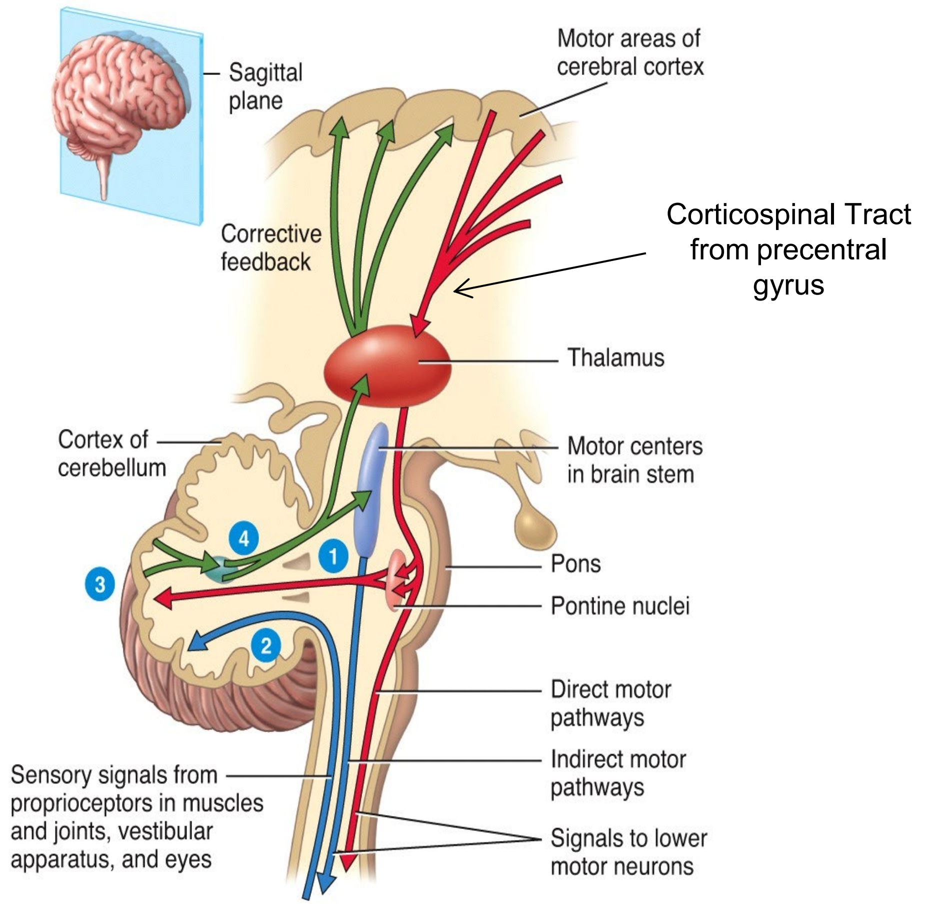
Motor Control and the Peduncles

There are three peduncles that enter and exit the cerebellum at the level of the pons.

Superior peduncle is branch of cortiocspinal tract that enters the cerebellum // tells cerebellum about the intent to contract skeletal muscle (#1)

Inferior peduncle carries sensory signals into cerebellum about skeletal muscle performance (#2)

Middle peduncle carries corrective signals out of the cerebellum to cerebrum motor areas and to indirect motor pathways (#3 & #4)



Sagittal section through brain and spinal cord

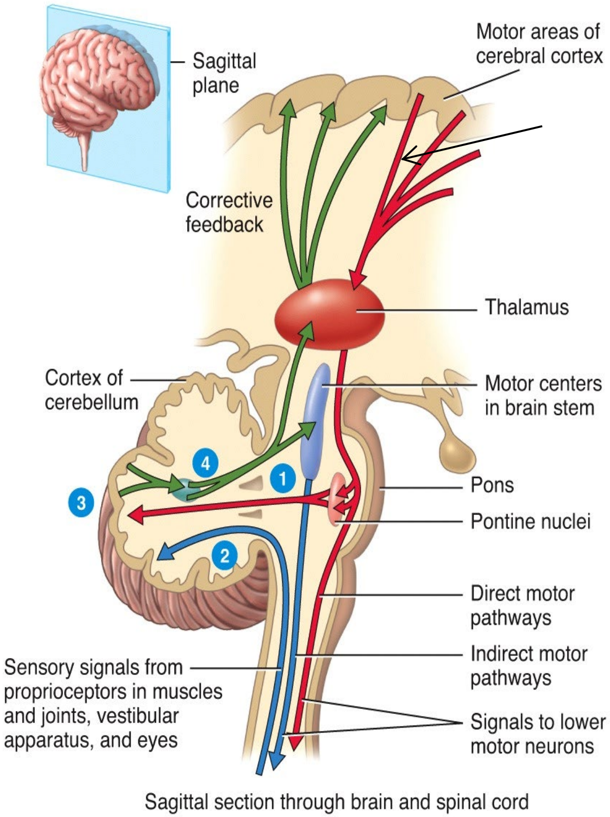
The cerebellum compares the intent to the performance so it can make corrections to skeletal muscle contractions.

More content about motor control to be covered later in discussion about cerebrum function.

The cerebral peduncles are nerve tracts that pass through the midbrain. These tracks carry action potentials between the brain, skeletal muscles, and the cerebellum.

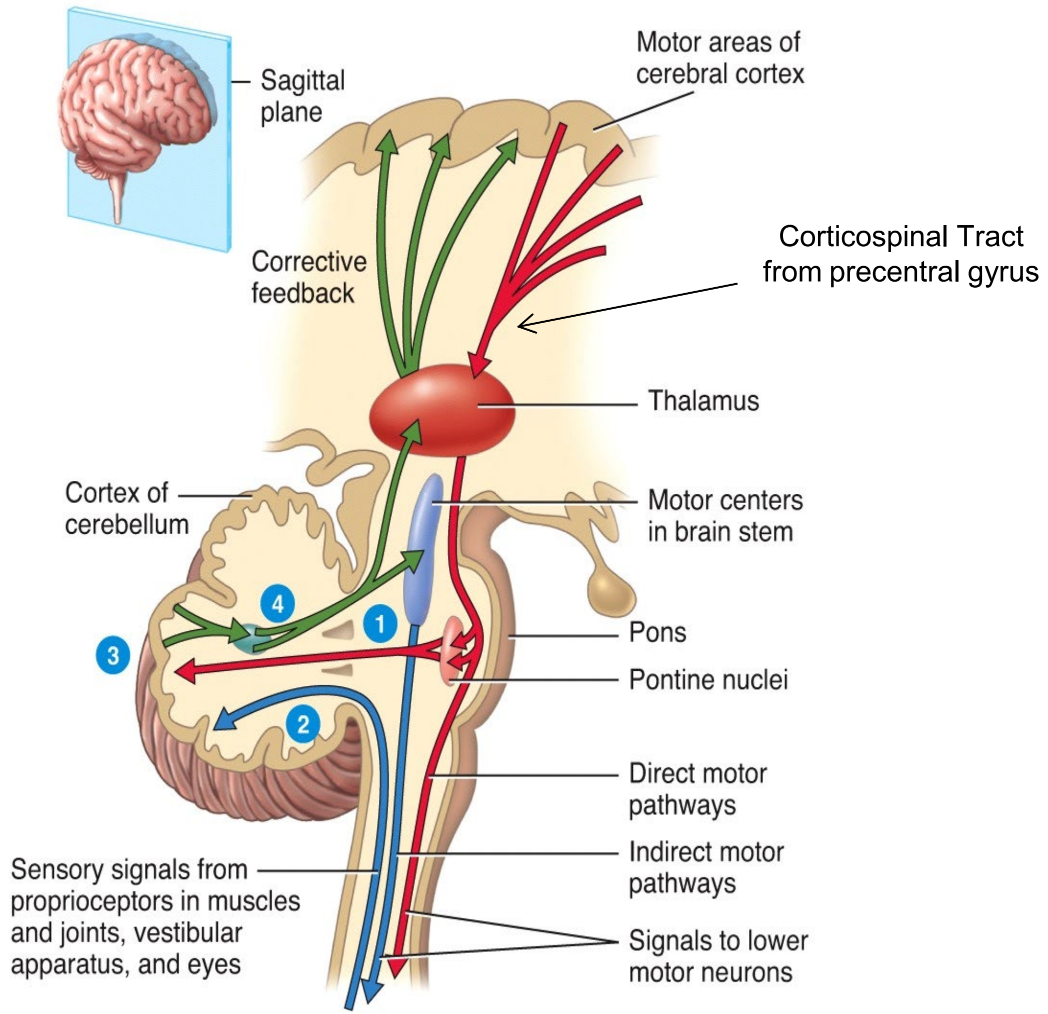
These nerve tracks are used to coordinate skeletal muscle contractions and allow the cerebellum to compare the “intent” of a skeletal muscle contraction to the actual “performance” of the skeletal muscle contraction.

Motor Control and the Peduncles



Corticospinal Tract from precentral gyrus

The Cerebral Peduncles and Motor Control

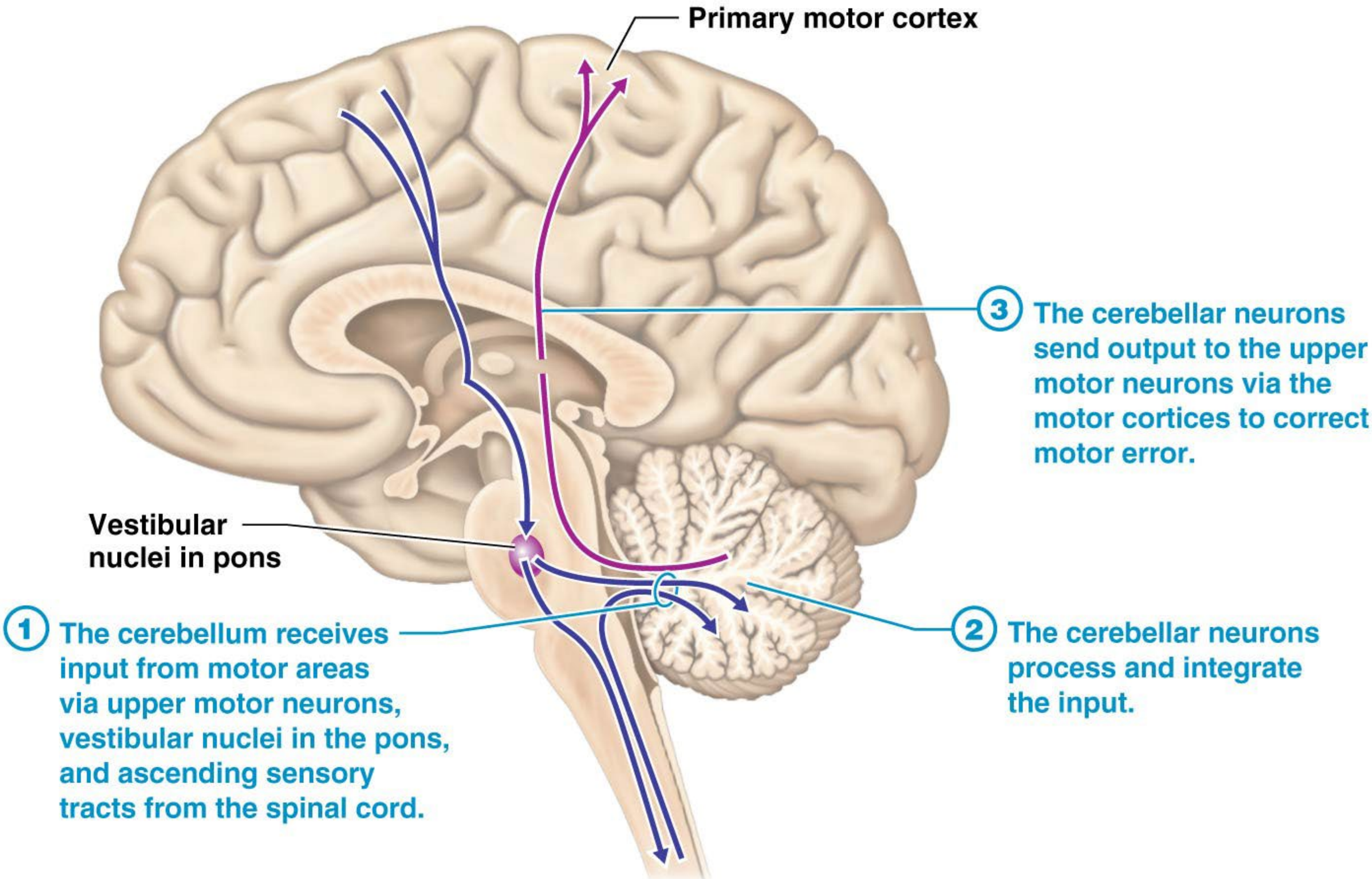


Sagittal section through brain and spinal cord

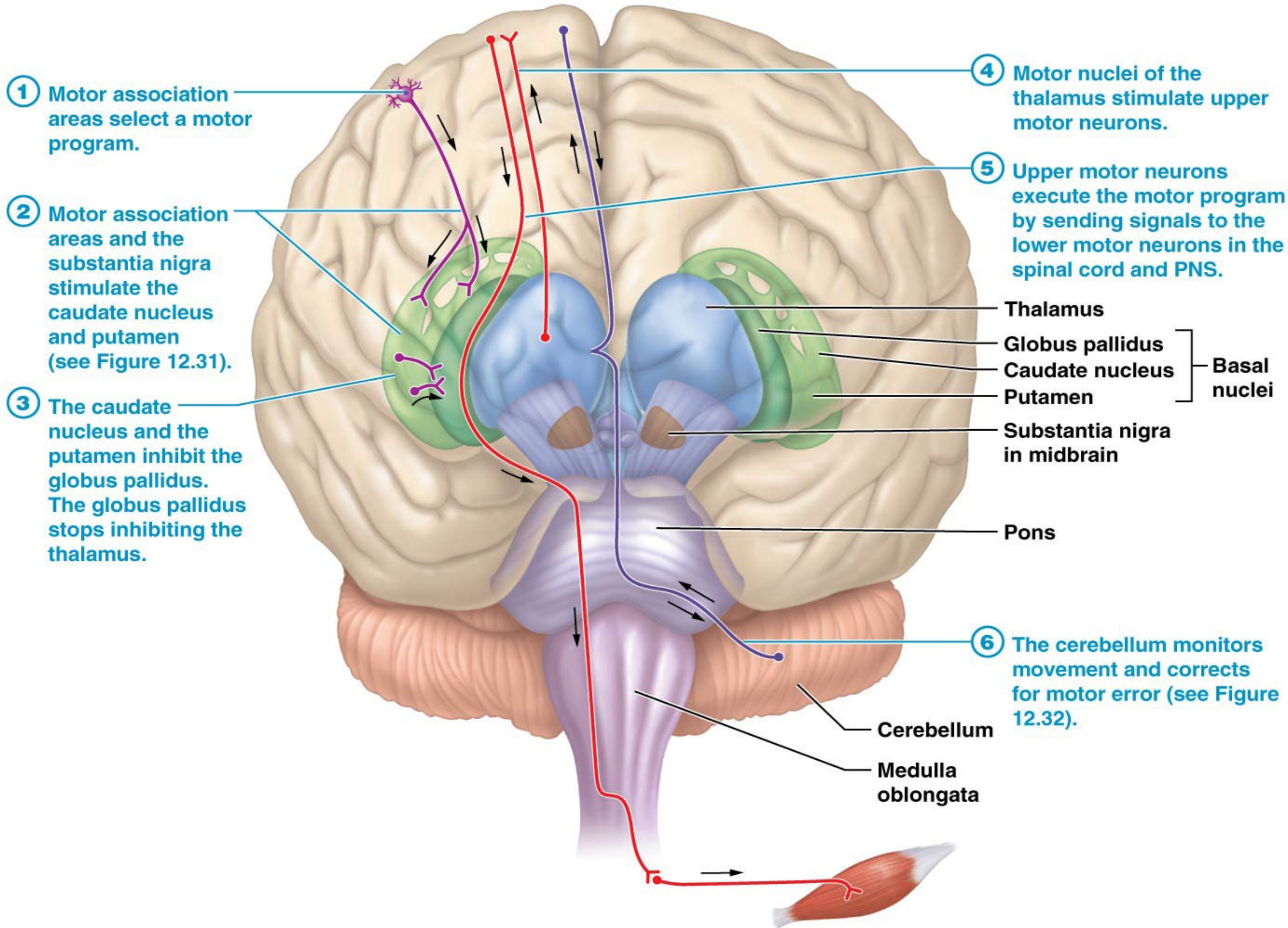
What is the difference between intent and performance?

Cerebellum function in voluntary movement.

The cerebellum compares the intent with performance.

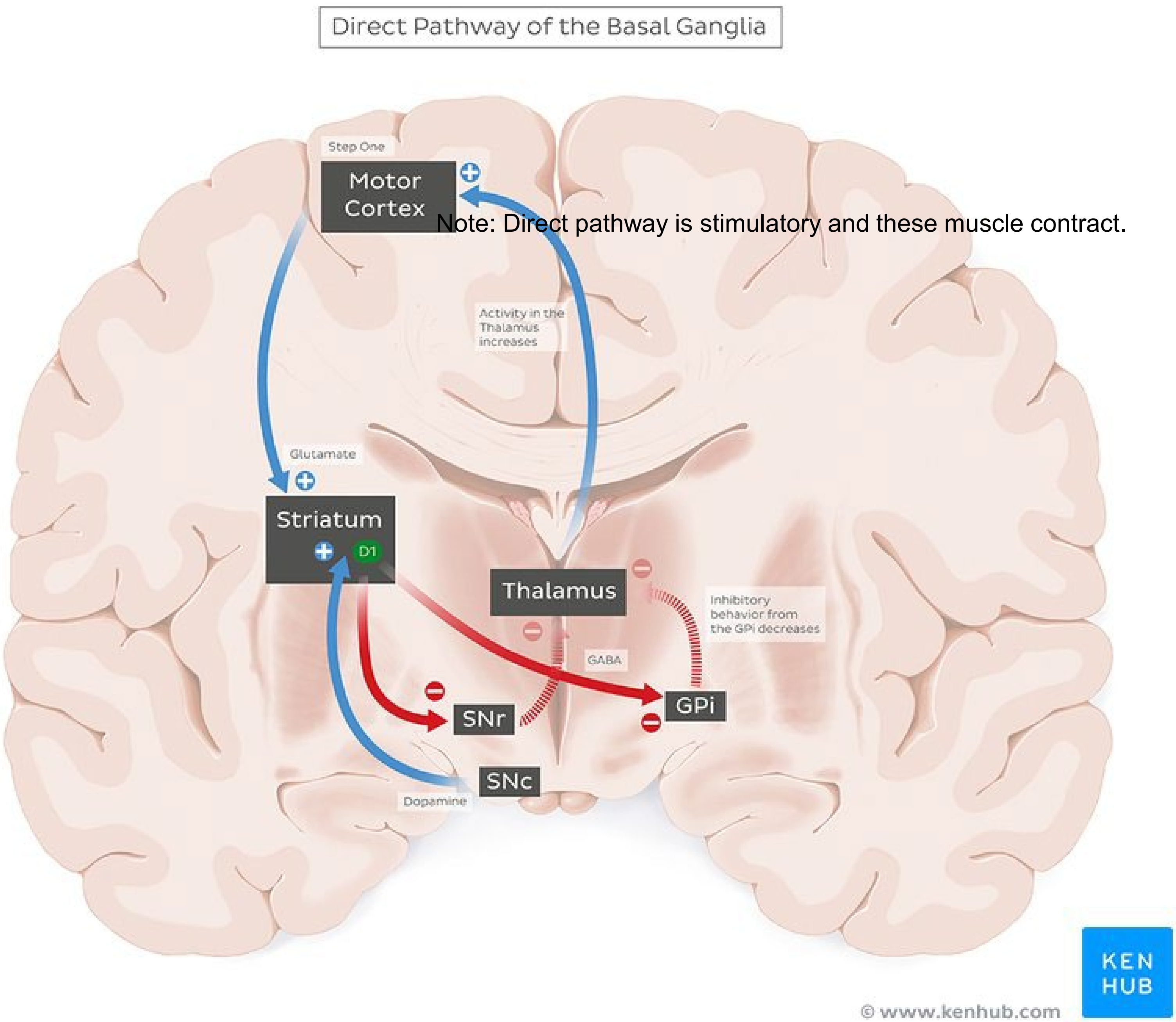


The Big Picture of CNS Control of Voluntary Movement.



Not Required Learning Objective

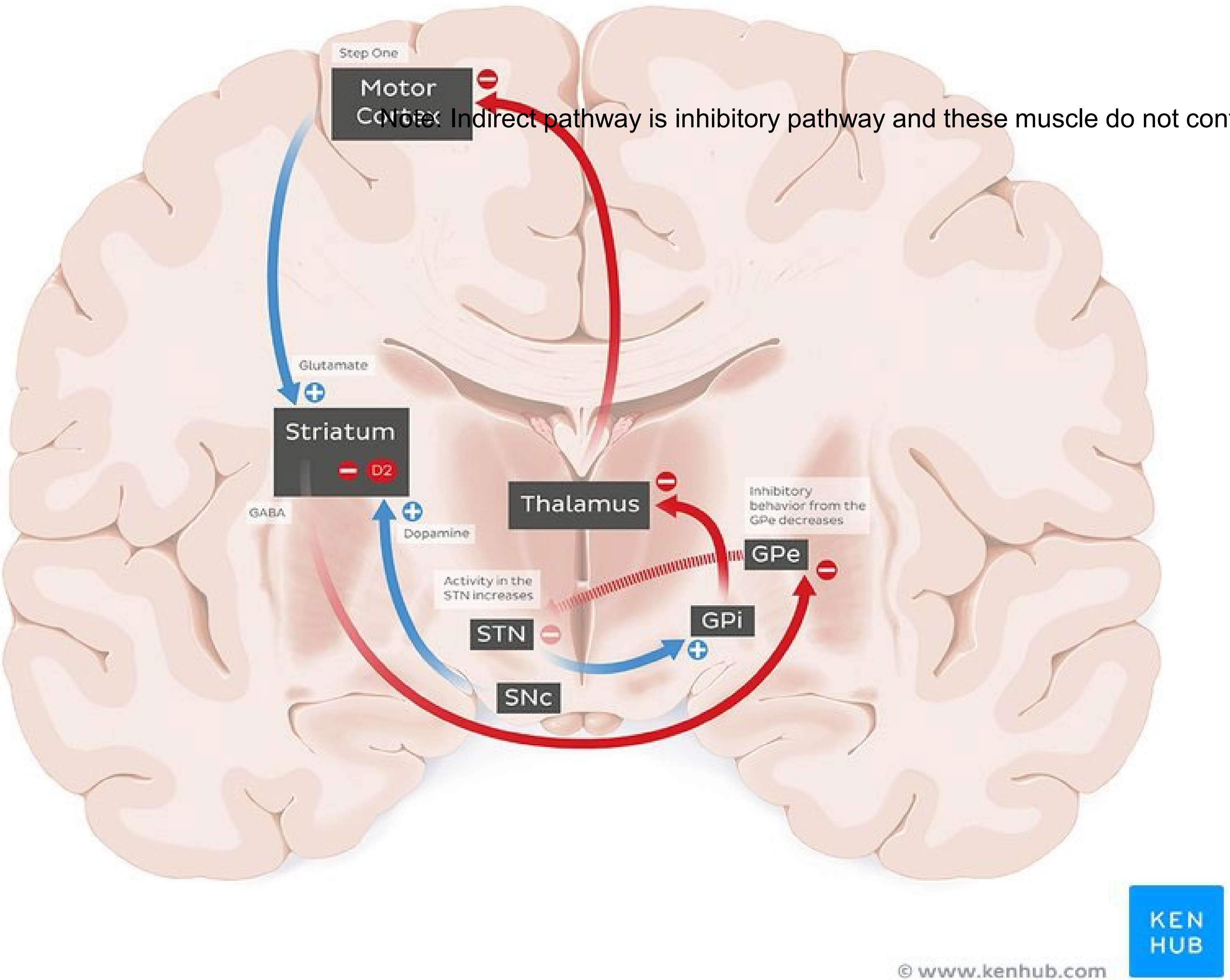
Note: Direct pathway is stimulatory and these muscle contract.



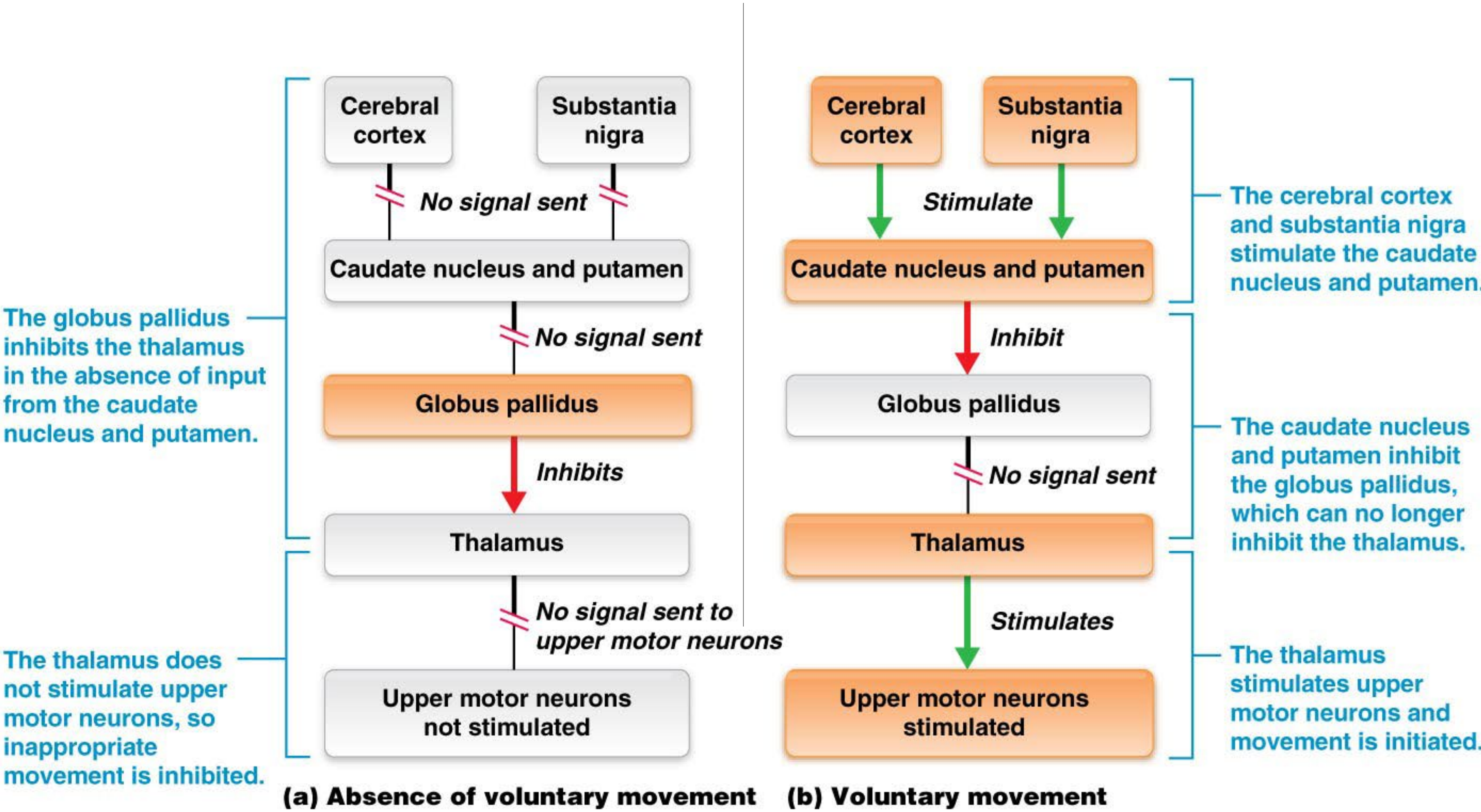
Not Required Learning Objective

Indirect Pathway of the Basal Ganglia

Note: Indirect pathway is inhibitory pathway and these muscle do not contract.



Role of the basal nuclei in voluntary movement.



Not Required Learning Objective

Language

Eight-five million years ago, early primates first started to develop language as “hand gestures”. This predates spoken language.

Some researchers believe laryngeal modification may have started in an ancestor like Australopithecus (appearing around 3.85 million years ago) or later within the genus Homo erectus (emerging about 2.4 million years ago).

The fox-pro-2 gene allowed the hyoid bone to be positioned lower in the pharynx. This then allowed early hominids and later homo sapiens (i.e. humans) to now make consonants and vowels.

Chimpanzees may hoot and make sound but can not form consonants and vowels because their hyoid bone is positioned higher in the pharynx).

What Are the Evolutionary Advantages for the Placement of the Larynx?

The position of the larynx determines if food maybe aspirated into the trachea and if the animal may vocalize vowels and consonants .

If the larynx is positioned high in the pharynx, then food may not enter the trachea. If the larynx is positioned low in the pharynx, then food may enter the trachea.

If the larynx is positioned high in the pharynx, then you cannot vocalize vowels and consonants. If the larynx is placed lower than you may vocalize vowels and consonants which means you may have language.

Because the chimpanzee larynx is positioned high in their pharynx, they can not pass food into their trachea. But they lack language because they can not form vowels and consonants.

Humans may form vowels and consonants but run the risk of choking to death if they aspirate food into the trachea.

Newborn babies have the larynx high in the pharynx so they may drink milk and breath at the same time. This occurs during breast feeding. When they start to vocalize, the hyoid bone drops and now it is possible to aspirate food into the trachea.

Language

FOXP2 and Laryngeal Development: FOXP2 is a transcription factor involved in regulating genes related to vocal tract configuration and features of the trachea and larynx, which are important for vocal production.

The descent of the larynx and the development of human speech likely resulted from multiple factors and genes, not just FOXP2.

In summary, while FOXP2 is a key gene involved in speech and language development and plays a role in larynx development, the exact timing of the larynx lowering in human evolution and its direct connection to specific FOXP2 changes are still under investigation due to the limitations of fossil evidence.

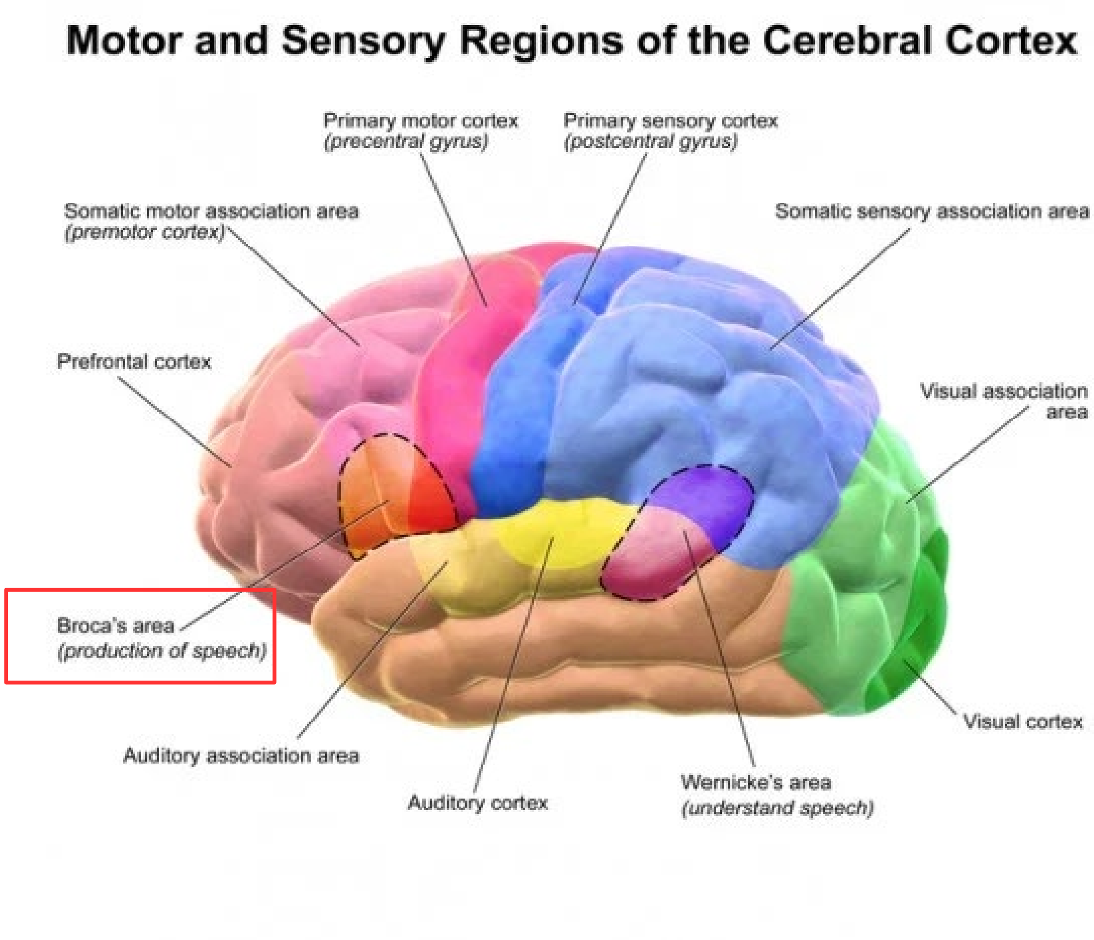
Human language likely began as a cognitive capacity around 135,000 years ago, with social use becoming widespread around 100,000 years ago. This timeline is based on genetic evidence of early human population splits and the emergence of symbolic behavior in the archaeological record, which is unique to language user

Brocca's Language Center

Brocca's Area is the expressive language center. It is where the grammar of our language is located

Located in the dominant hemisphere, on the left side of the frontal lobe with functional links to the motor strip skeletal muscles used in speech production and respiratory centers.

This is where word syntax and grammar is constructed



Wernicke's Language Center

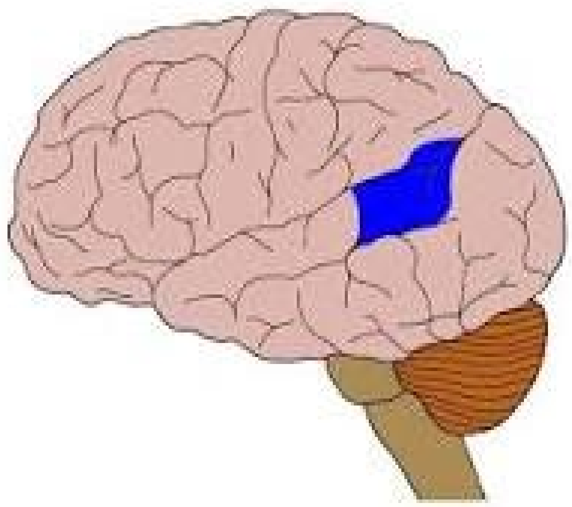
Wernicke Areas is in the left cerebral hemisphere.

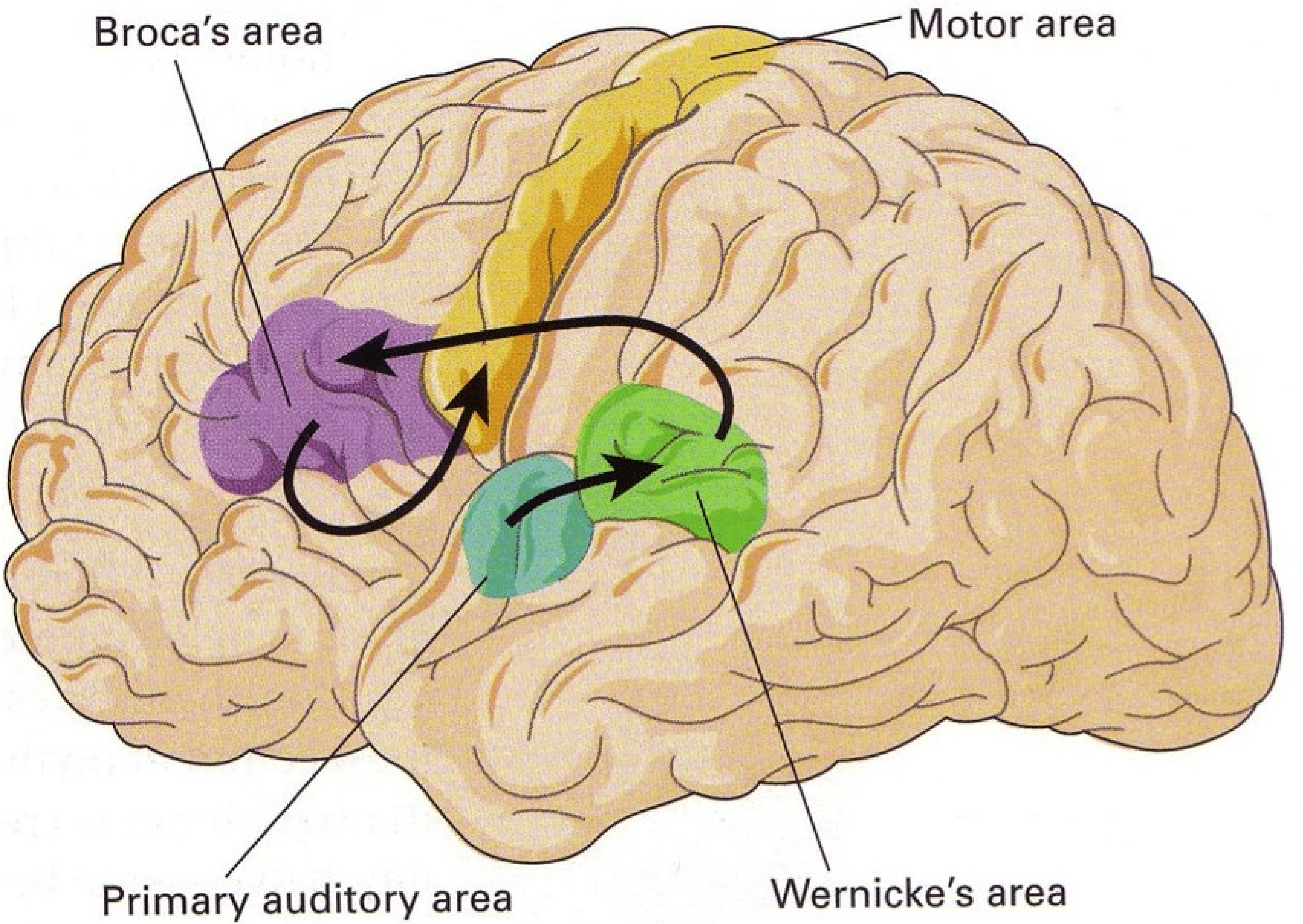
This area encircles the auditory cortex on the lateral sulcus (the part of the brain where the temporal lobe and parietal lobe meet).

This is the receptive language center.

Other areas receive sound or symbolic stimulus and must decide if it is language. If it is language, then the stimulus is passed to Wernicke Areas for interpretation

Note – language maybe written or spoken.

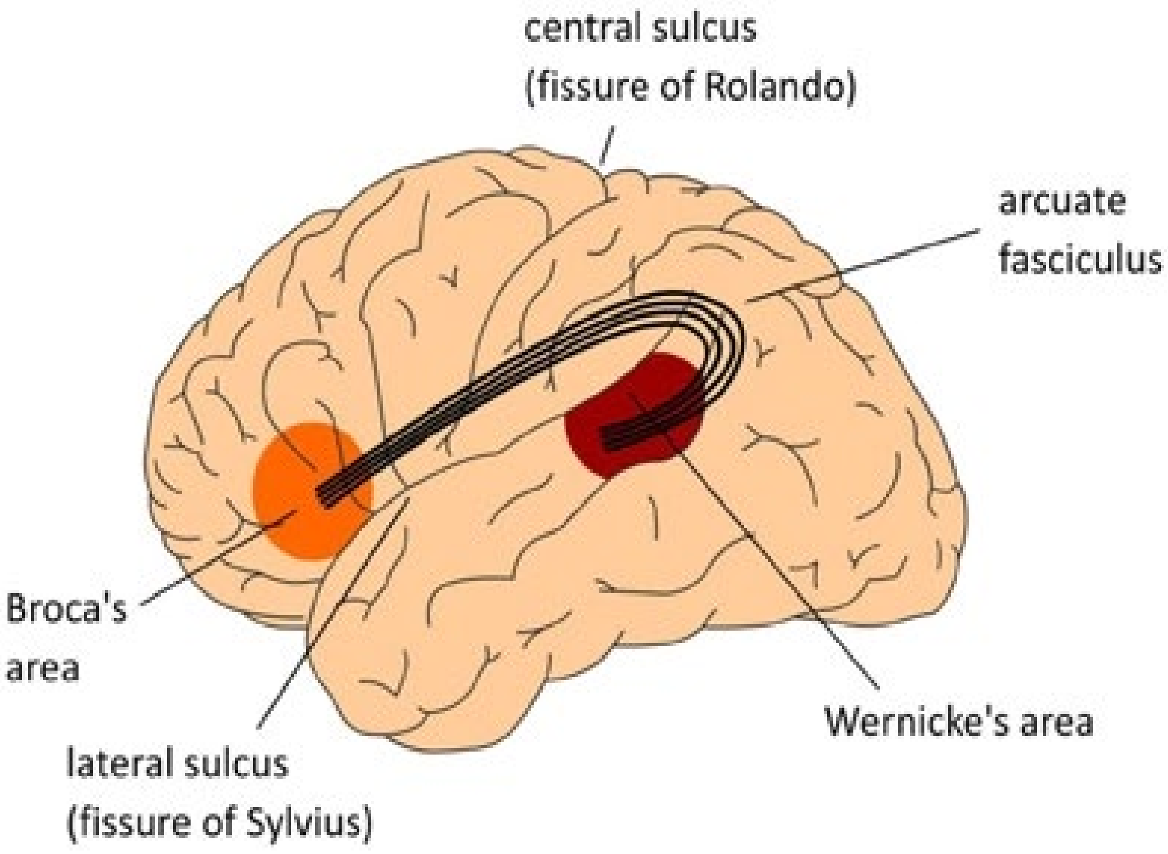




Broca's area
Motor area
Primary auditory area
Wernicke's area

Language

Wernicke and Brocca Areas are connected by a nerve tract, arculate fascicula.



Aphasia and Written Language

Aphasia usually occurs suddenly, often following a stroke or head injury, but it may also develop slowly, as the result of a brain tumor or a progressive neurological disease. **The disorder impairs the expression and understanding of language as well as reading and writing**.

Expressive aphasia (also known as Broca's aphasia) is a type of aphasia characterized by partial loss of the ability to produce language (spoken, manual, or written), although **comprehension generally remains intact**.

Most people with aphasia experience difficulty with writing. An acquired difficulty with writing is sometimes called dysgraphia or agraphia. Often, a person's writing resembles their verbal speech. Some people will find writing easier than speaking. People with aphasia might experience difficulty with writing that ranges from none at all to severe.

- **Little to no impairment:** Writing is intact with only minor errors. Someone might experience difficulty with word-finding in writing, similar to what they experience in speaking. This level of impairment is common in conduction aphasia and anomic aphasia.

- **Mild impairment:** Difficulty with word-finding and writing longer or more complex information. Spelling complex words is difficult.

- **Moderate impairment:** Able to write words and short phrases. Sentence structure and igrammar are not present. Spelling errors are common.

- **Severe impairment:** Writing is severely impaired, and the person might not be able to write at all. Common in global and Wernicke's aphasia.

What Are the Types of Aphasia?

Aphasia results from damage to the parts of the brain responsible for language and communication.

Expressive Aphasia

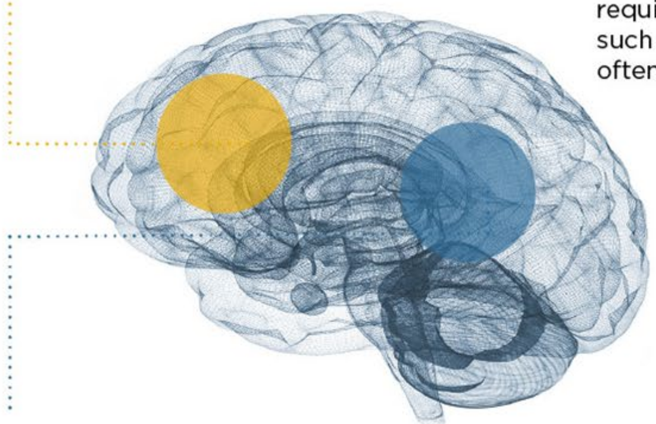
Sometimes called

Broca's or non-fluent aphasia

Region affected:

frontal lobe, which also controls motor movement

People with expressive aphasia might know what they want to say but even using single words requires great effort. Small words such as "the," "is," or "and" are often omitted.



Receptive Aphasia

Sometimes called

Wernicke's or fluent aphasia

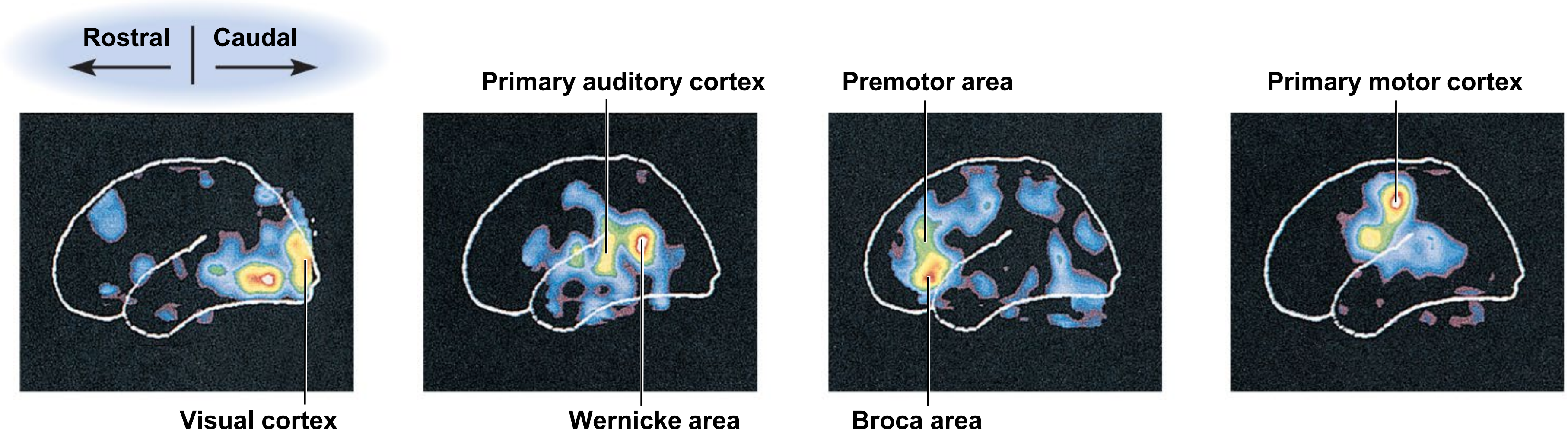
Region affected:

temporal lobes, which also store memories and help with hearing, visual recognition and language

People with receptive aphasia might struggle to speak in coherent sentences. It may be a challenge to understand what they are trying to say and they are often unaware of their spoken mistakes.

(Commonly called Word Salad)

PET Scans and a Language Task



1. The word car is seen in the visual cortex.
2. Wernicke area conceives of the verb drive to go with it.
3. Broca area compiles a motor program to speak the word drive.
4. The primary motor cortex executes the program and the word is spoken.

This shows how brain processes information from one area onto another area.

Is the claustrum the site of consciousness?

The claustrum is located between the insula and caudate/putamen. This area has the highest density of bidirectional fiber tracts in the brain.

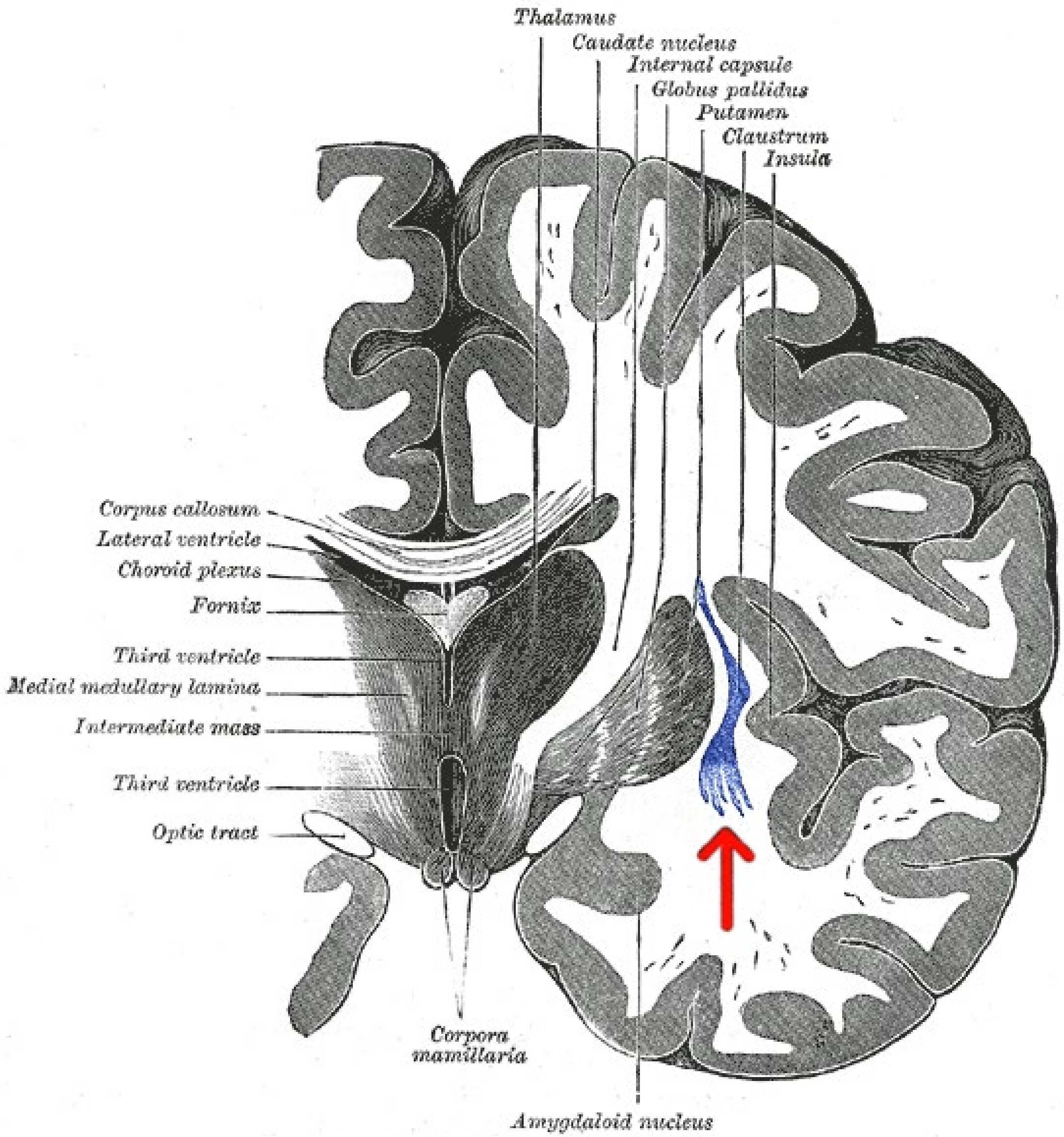
The claustrum receives major inputs from limbic, cortical, and subcortical structures and sends outputs to the entire cortical mantle, most notably regions of the frontal cortex that drive executive functions.

This network connectivity profile positions the claustrum as a limbic–sensory-motor interface, which suggests that a primary function of the claustrum is to *integrate limbic and sensory information to direct and sustain attention towards behaviorally relevant, salient stimuli during the awake state.*

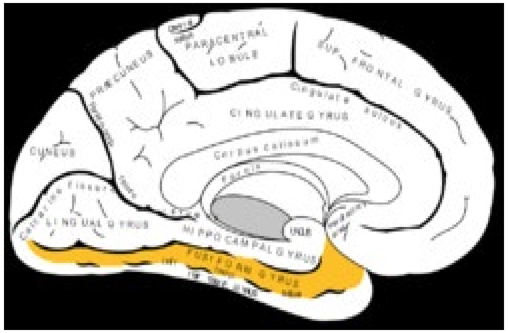
What is the function of the salience network of the brain?

The salience network is a collection of regions of the brain that select which stimuli are deserving of our attention. The network has key nodes in the insular cortex and is critical for detecting behaviorally relevant stimuli and for coordinating the brain's neural resources in response to these stimuli.

Is the claustrum the site of consciousness?



Fusiform Face Area

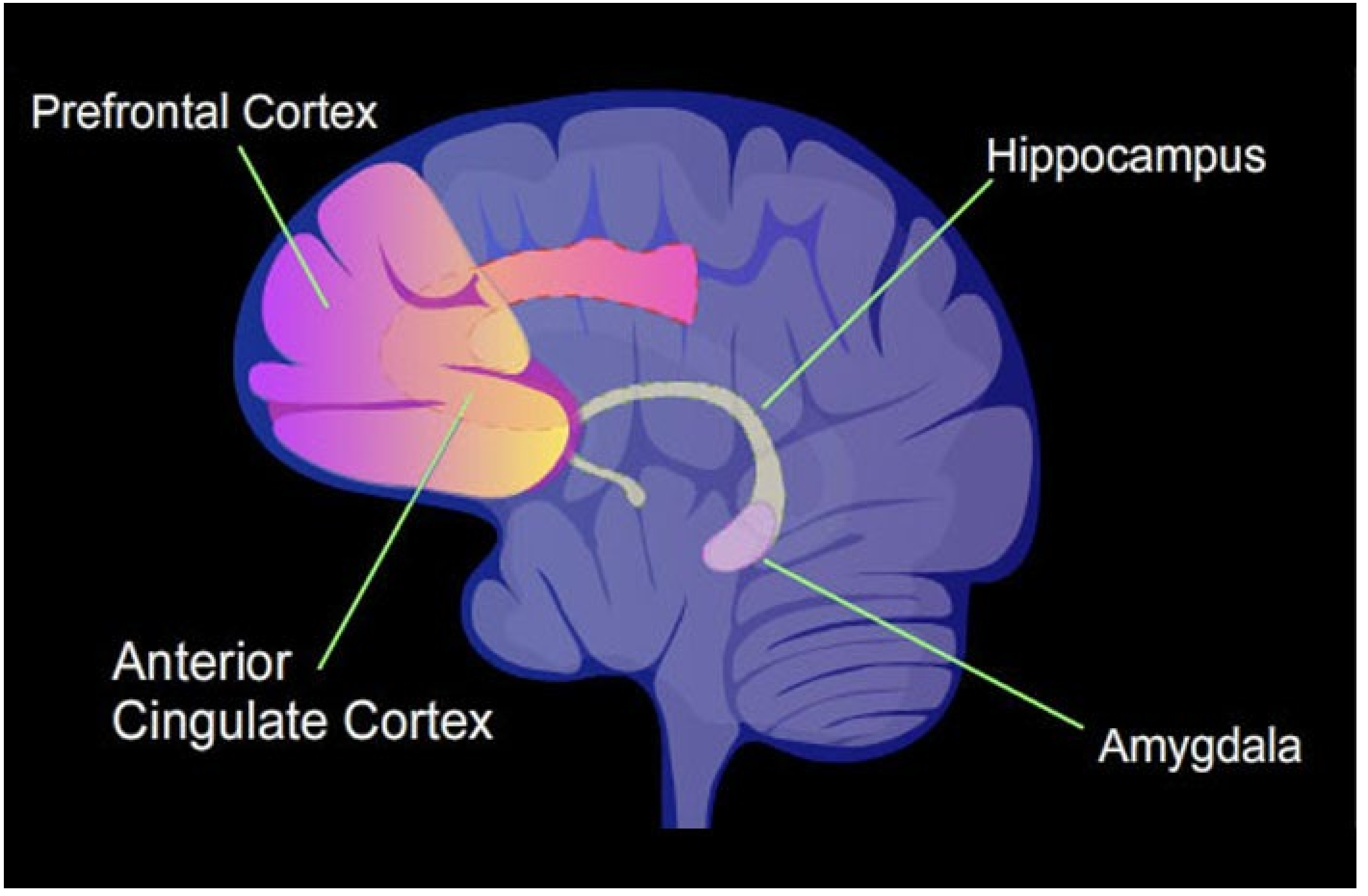


The fusiform face area (FFA, meaning spindle-shaped face area) is a part of the human visual system (while also activated in people blind from birth) that is specialized for facial recognition.

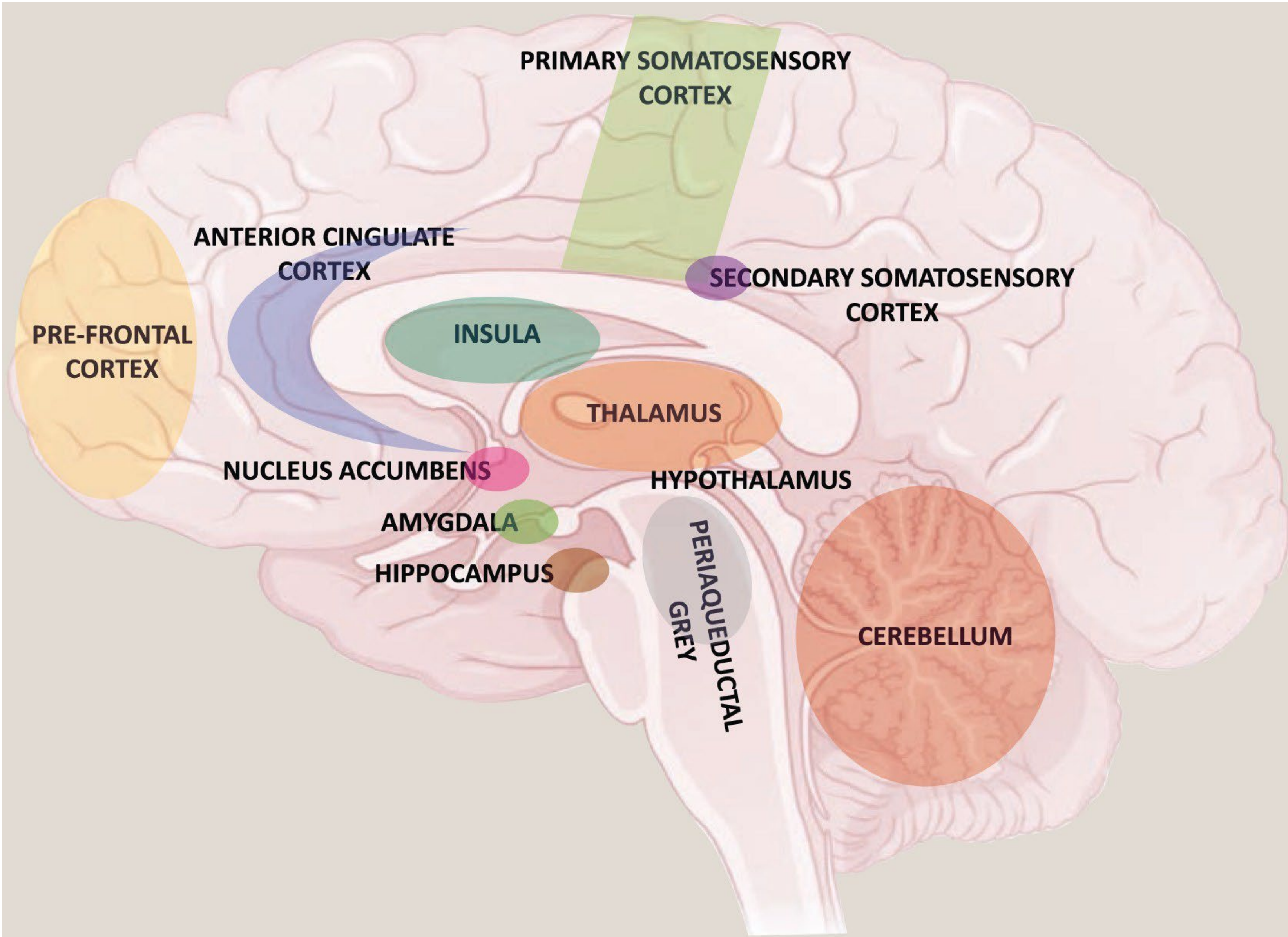
The fusiform gyrus, also known as the lateral occipitotemporal gyrus,[1][2] is part of the temporal lobe and occipital lobe in Brodmann area 37.[3] The fusiform gyrus is located between the lingual gyrus and parahippocampal gyrus above, and the inferior temporal gyrus below.[4] Though the functionality of the fusiform gyrus is not fully understood, it has been linked with various neural pathways related to recognition. Additionally, it has been linked to various neurological phenomena such as synesthesia, dyslexia, and prosopagnosia.

What can result from damage to the fusiform face area? Some evidence suggests that fusiform gyrus damage tends to bring about difficulties in face perception and recognition, whereas damage to other areas of the temporal lobes is associated with difficulties accessing memories of faces.

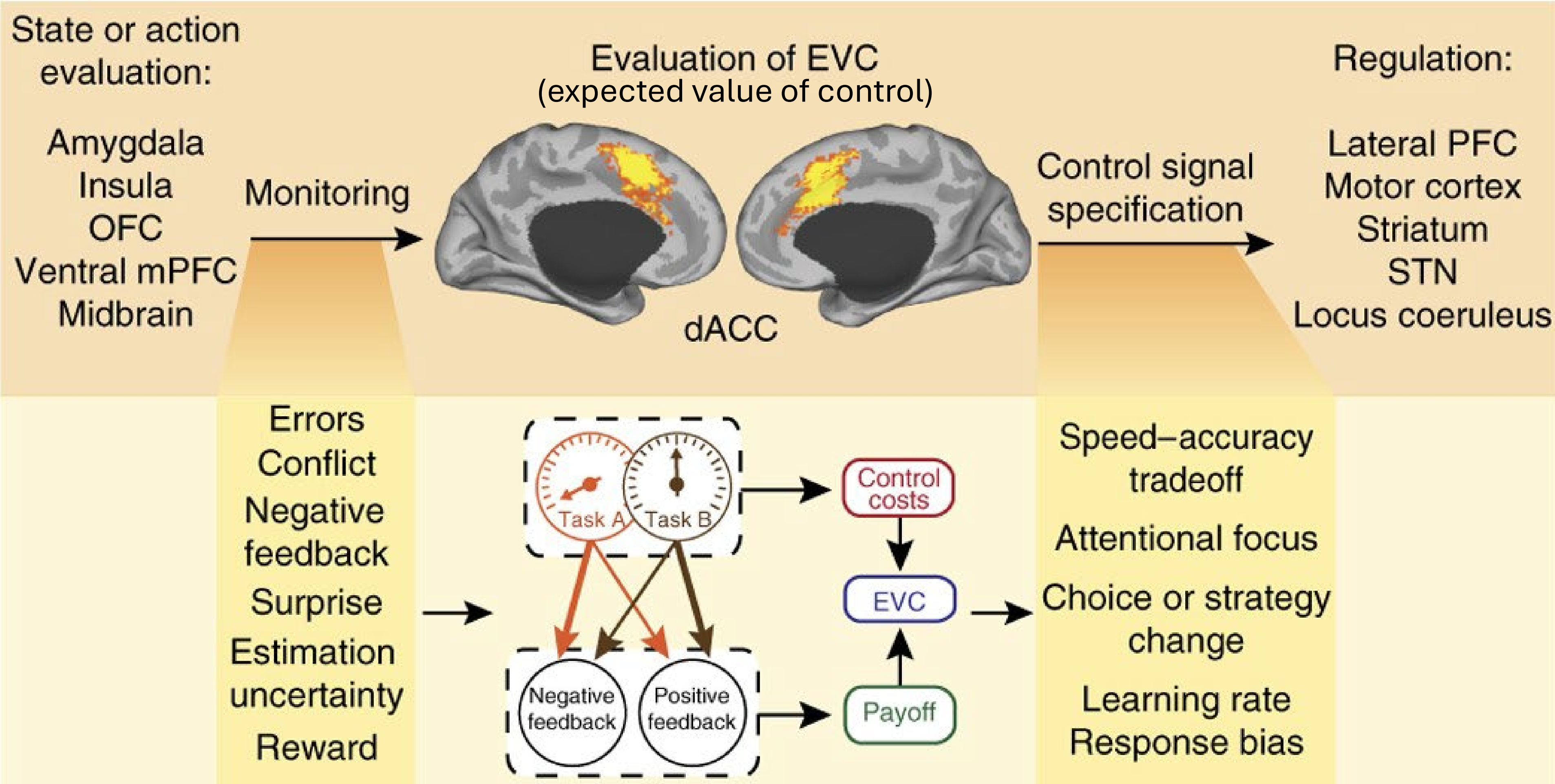
Anterior Cingulate Gyrus



Anterior Cingulate Gyrus



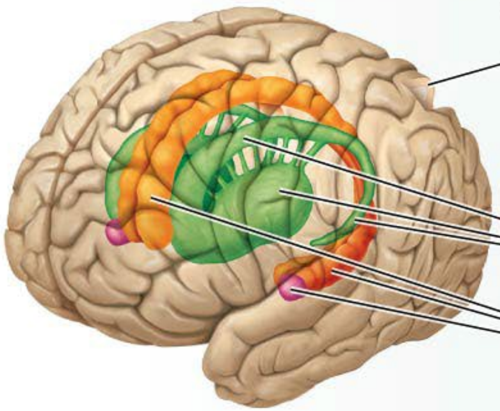
Anterior Cingulate Cortex



ACG main functions = error conflict resolution and empathy.

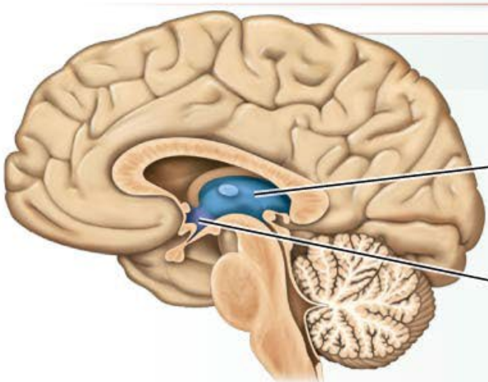
How are these two functions related?

A Summary for Major Brain Structure Functions.



Anterolateral view

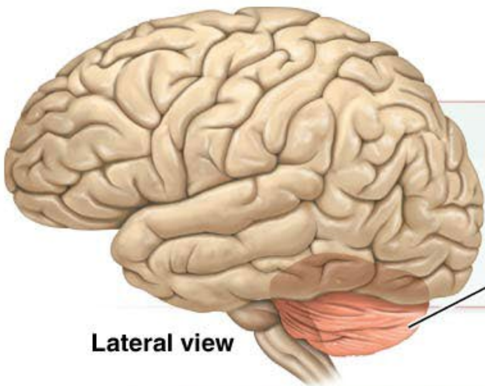
DIVISION	STRUCTURES	SUBSTRUCTURES	MAIN FUNCTIONS
Cerebrum	Cerebral cortex	Primary motor cortex	• Plans and executes movement
		Primary somatosensory cortices	• Receive and process different types of sensory input
		Multimodal association areas	• Integrate sensory and motor information from a variety of different primary cortices
	Basal nuclei	Caudate nuclei Putamen Globus pallidus	• Regulate movement
	Limbic system	Hippocampus	• Plays a role in memory and learning
		Amygdala	• Plays a role in behavioral expression and emotion



Midsagittal section

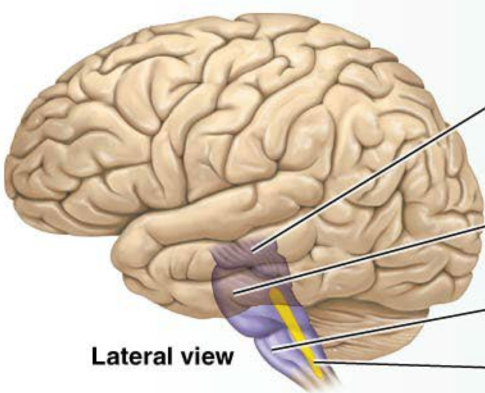
DIVISION	STRUCTURES	MAIN FUNCTIONS
Diencephalon	Thalamus	• Controls information entry into the cerebral cortex • Edits, sorts, and routes stimuli
	Hypothalamus	• Regulates the autonomic nervous system • Regulates the sleep/wake cycle • Regulates thirst and hunger • Regulates body temperature • Produces hormones • Controls secretion from the pituitary gland

A Summary for Major Brain Structures and Their Functions.



Lateral view

DIVISION	MAIN FUNCTION
Cerebellum	• Coordinates voluntary movement



Lateral view

DIVISION	STRUCTURES	MAIN FUNCTIONS
Brainstem	Midbrain	• Processes and routes visual and auditory stimuli to the thalamus • Carries motor fibers from the cerebral cortex • Monitors movement with the basal nuclei
	Pons	• Regulates breathing • Regulates reflexes • Regulates the sleep/wake cycle
	Medulla oblongata	• Contains tracts of white matter involved in movement and sensation • Regulates many homeostatic functions
	Reticular formation	• Involved in sleep and arousal • Involved in pain transmission • Plays a role in mood regulation • Involved in many homeostatic functions