

Reflexes and Brain

DANIL HAMMOUDI.MD



The Nervous System is the body's information gatherer, storage center and control system.

Its overall function is to collect information about the external conditions in relation to the body's internal state, to analyze this information, and to initiate appropriate responses to satisfy certain needs (Maintain Homeostasis).

The most powerful of these needs is survival.

The Nervous System has **FOUR FUNCTIONS** that enable the body to respond quickly. The Nervous System:

A. **Gathers information** both from the outside world and from inside the body. **SENSORY FUNCTION**

B. **Transmits the information** to the processing area of the brain and spinal cord.

C. **Processes the information** to determine the best response. **INTEGRATIVE FUNCTION**

D. **Sends information to muscles, glands, and organs (effectors) so they can respond correctly.** Muscular contraction or glandular secretions. **MOTOR FUNCTION**

**A REFLEX is the simplest
response to a STIMULUS.**

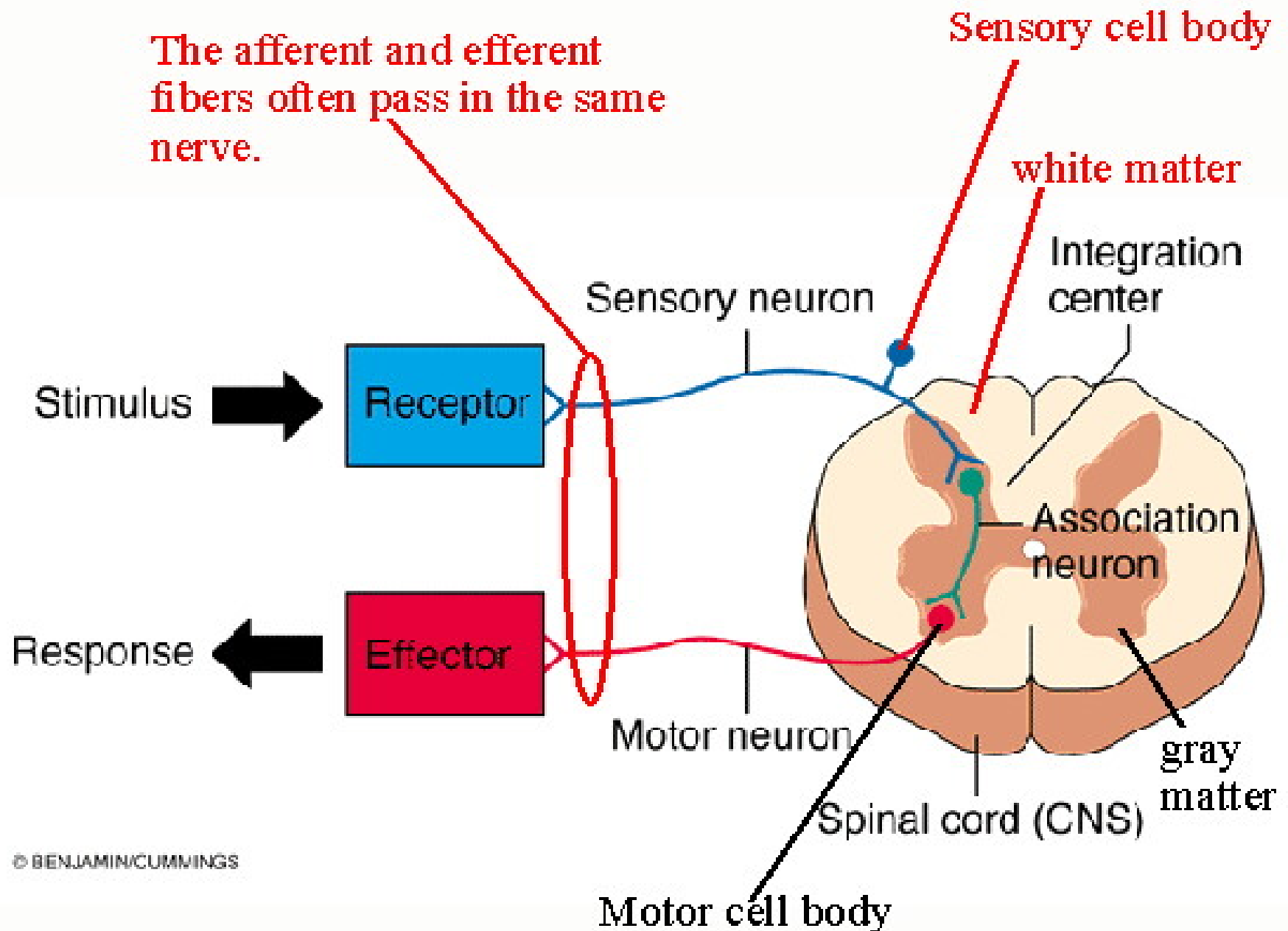
Sneezing and Blinking are two examples of Reflexes.

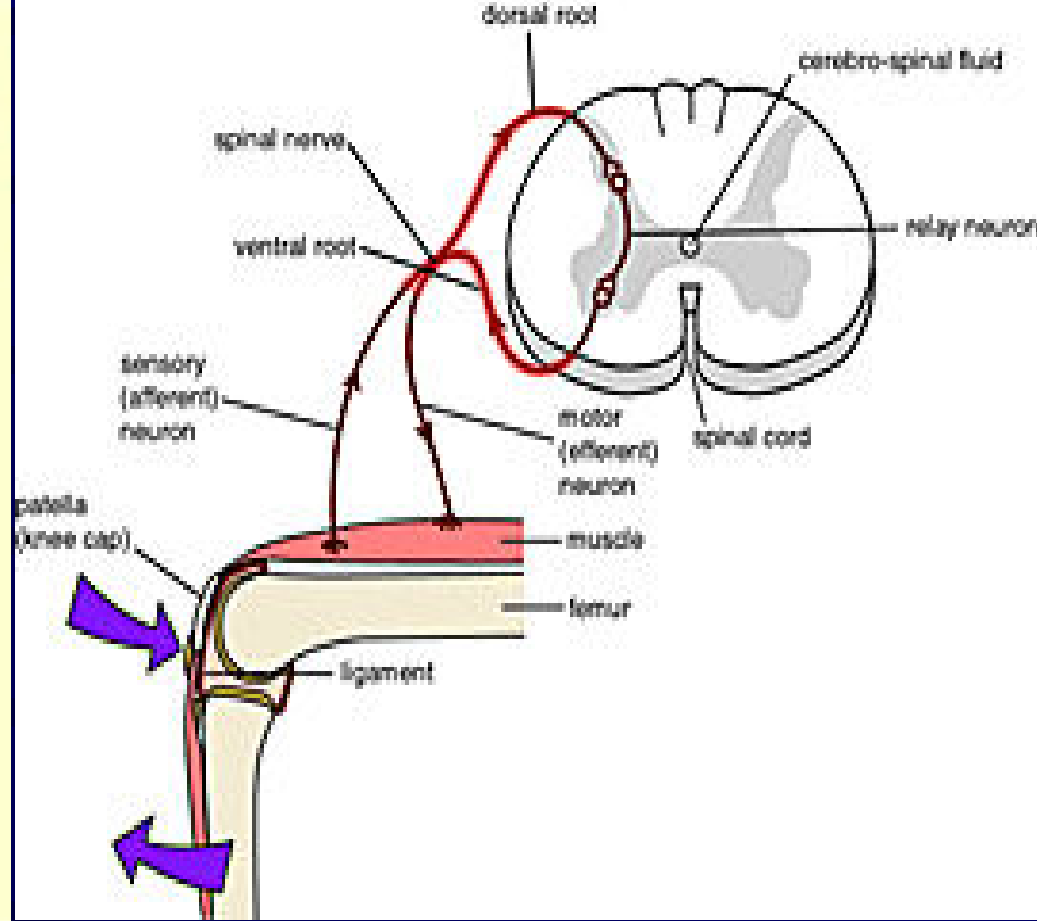
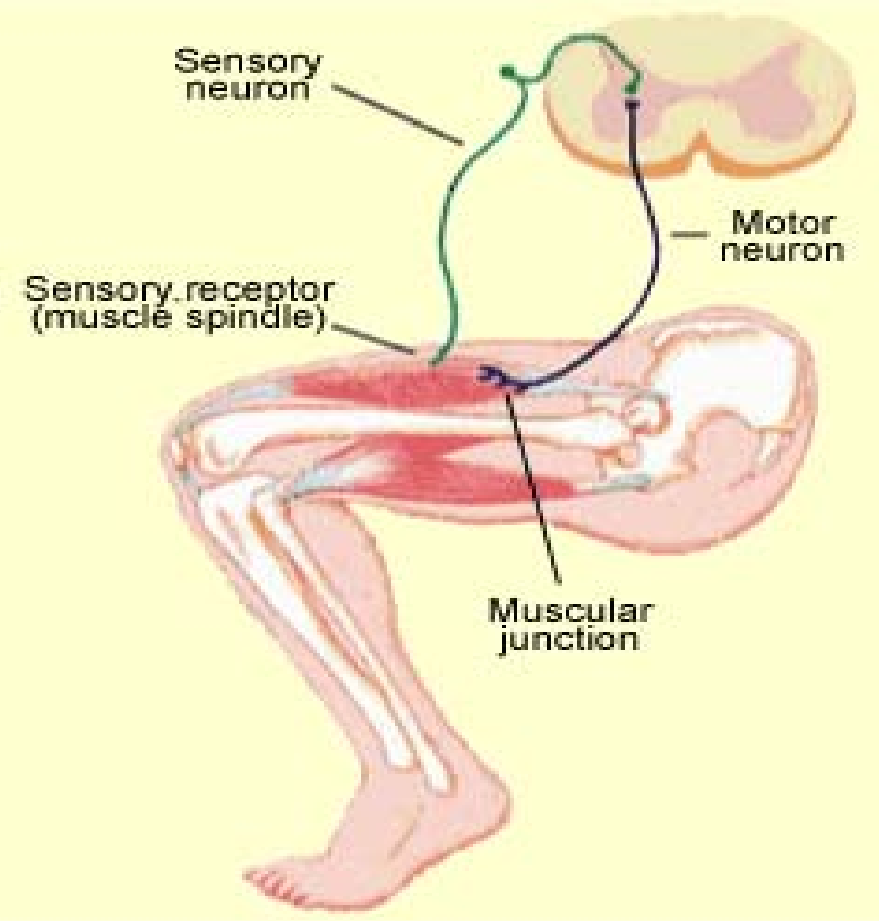
1. . A Reflex produces a rapid **MOTOR RESPONSE** to a **STIMULUS** because the Sensory Neuron Synapses **DIRECTLY** with a **MOTOR NEURON** in the Spinal Cord.
2. **REFLEXES** are very fast, and **Most Reflexes Never Reach the Brain.**
3. Blinking to protect your eyes from danger is a reflex.
4. 31 **PAIRS** of spinal nerves originate in the spinal cord and branch out to both sides of the body. Carrying messages to and from the spinal cord.
5. Sensory Neurons carry impulses from **RECEPTORS** to the spinal cord.
6. Motor Neurons carry impulses from the spinal cord to the **EFFECTORS.**
7. Within the spinal cord, motor and sensory neurons are connected by **INTERNEURONS.**

Effectors:

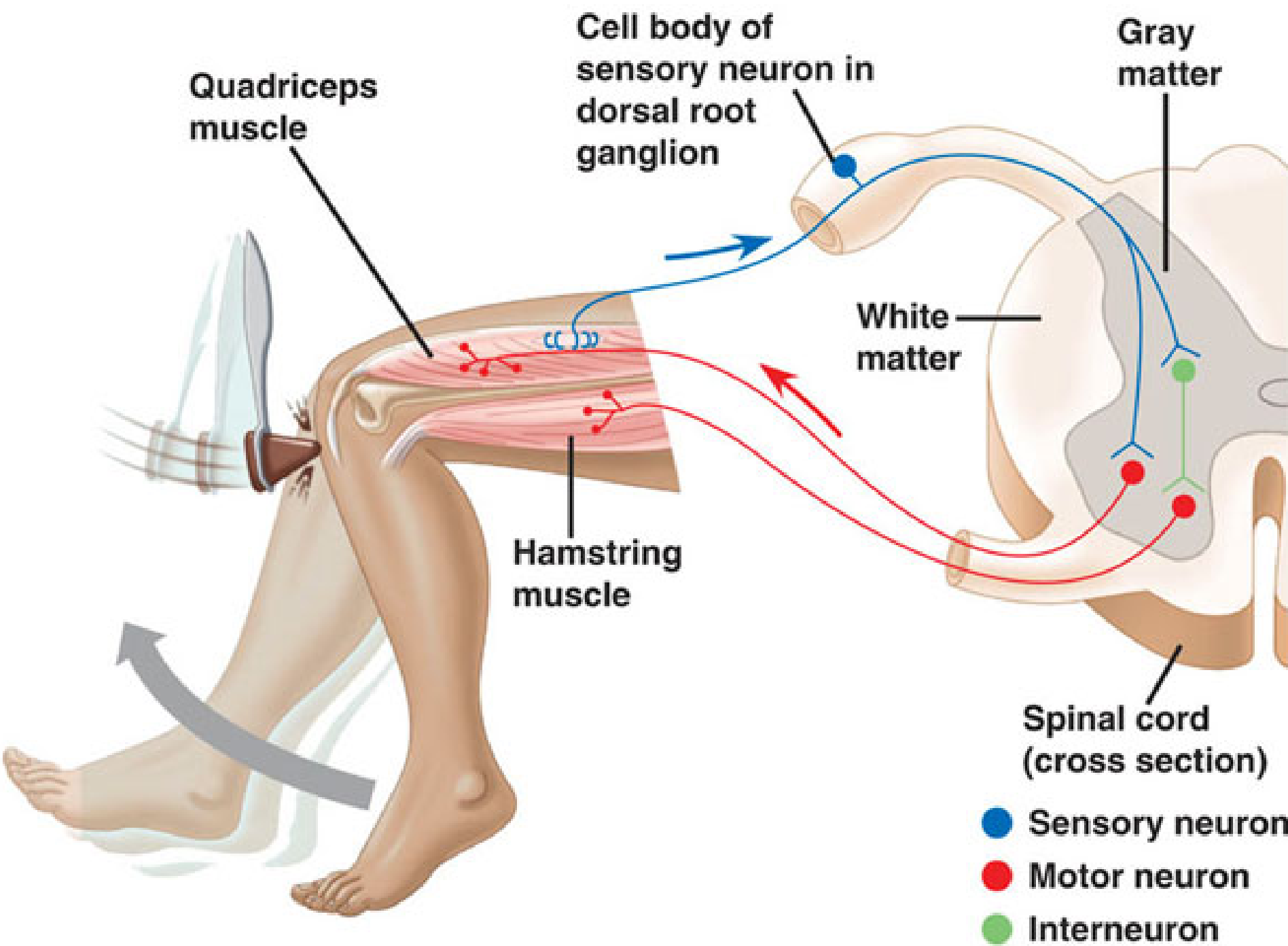
- Skeletal muscles ==→ somatic reflex
- Gland , smooth muscle, cardiac muscles==→ autonomic reflex

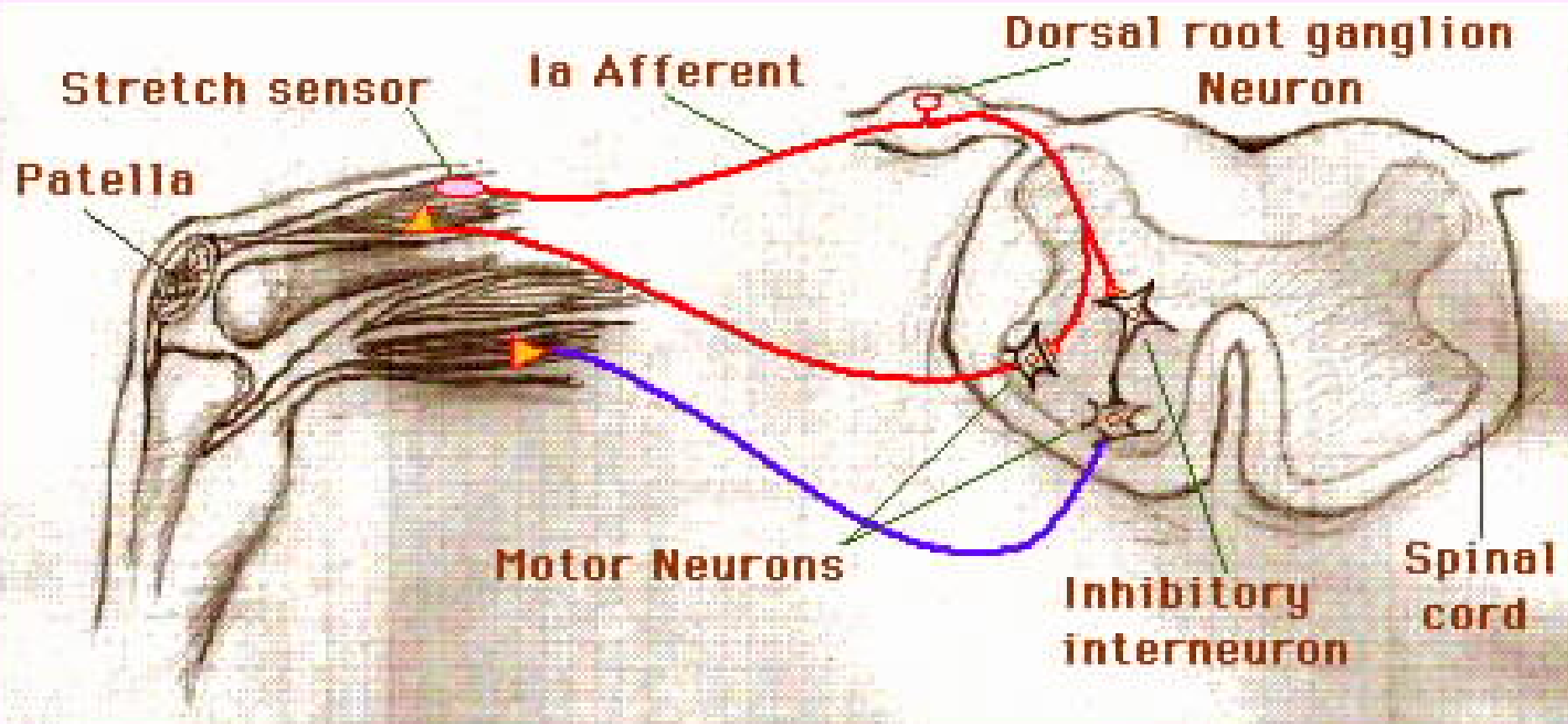
A Reflex Arc Shows How Neuron Types Work Together.

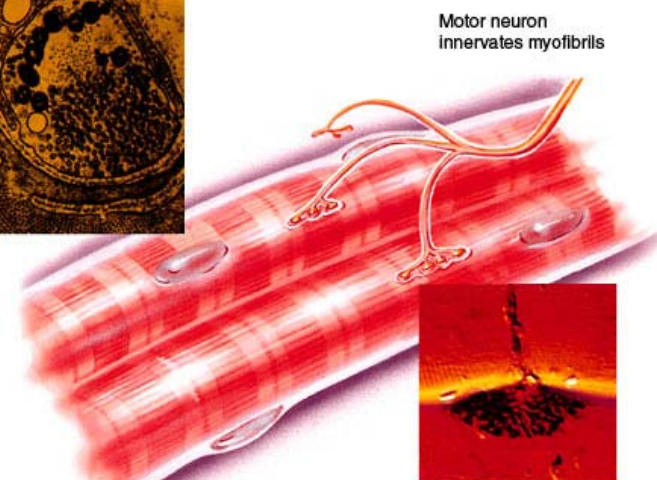
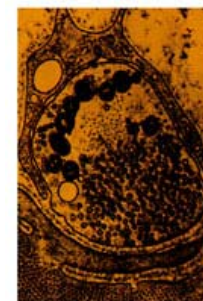
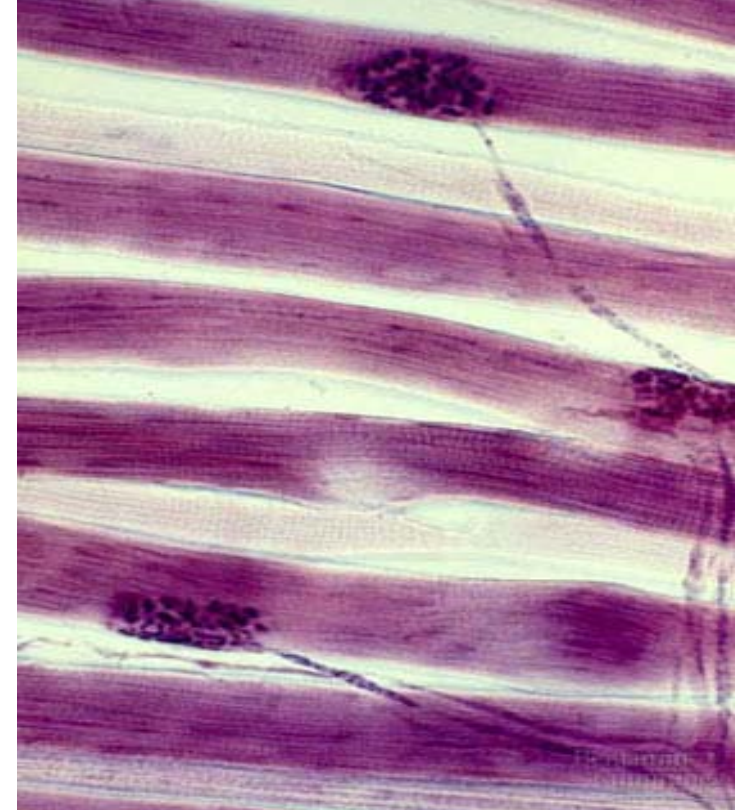
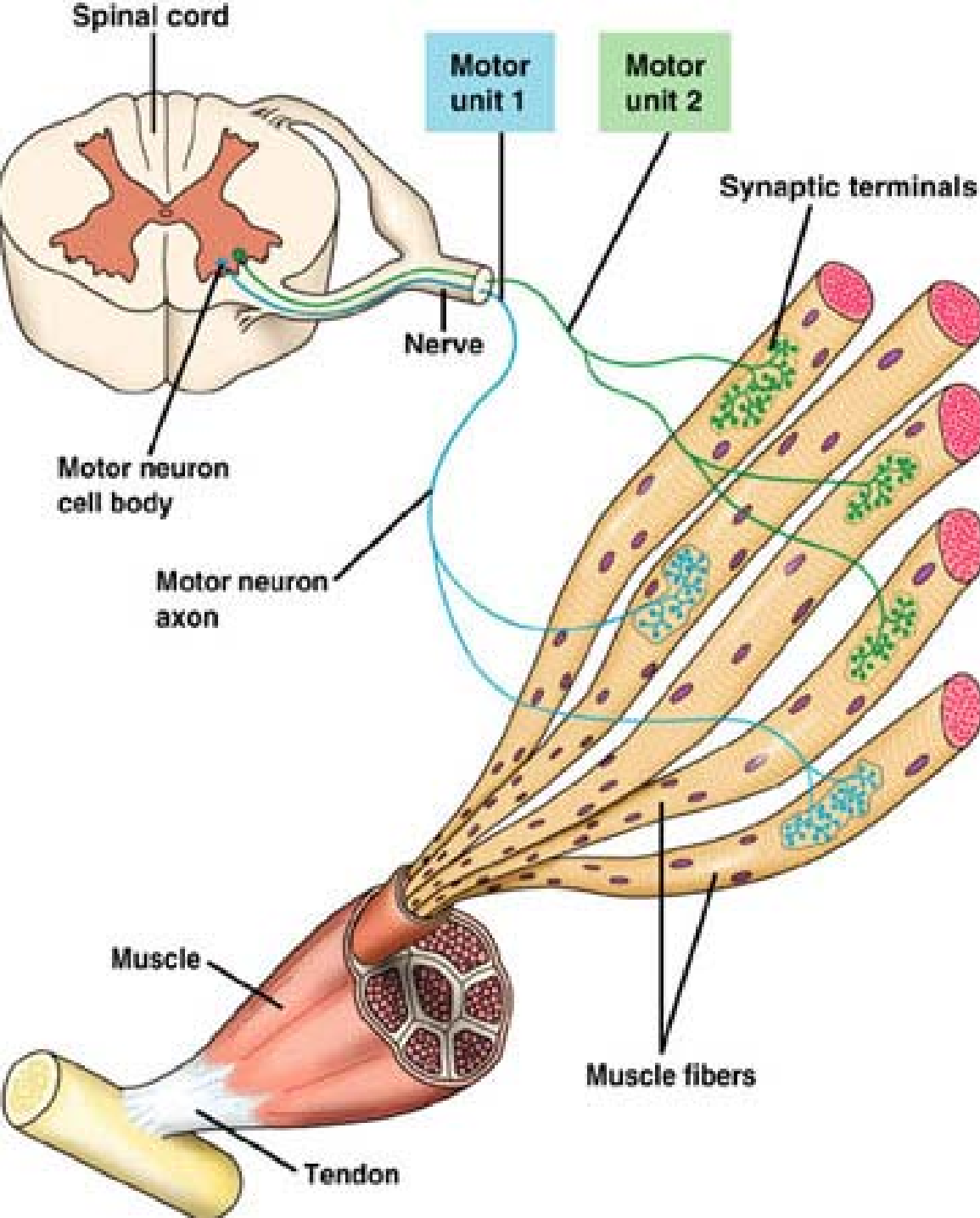




A reflex arc is the neural pathway that mediates a reflex action.







Left inset from Vu/T. Reese and Don W. Fawcett/ Visuals Unlimited; (right inset) courtesy of Lennart Nilsson.

Guess these pathways do not pass through the brain, but synapse in the spinal cord.

This characteristic allows reflex actions to occur relatively quickly by avoiding the delay of routing signals through the brain, although the brain will receive sensory input while the reflex action occurs.

When a reflex arc consists of only two neurons (one sensory neuron and one motor neuron), it is defined as **monosynaptic**.

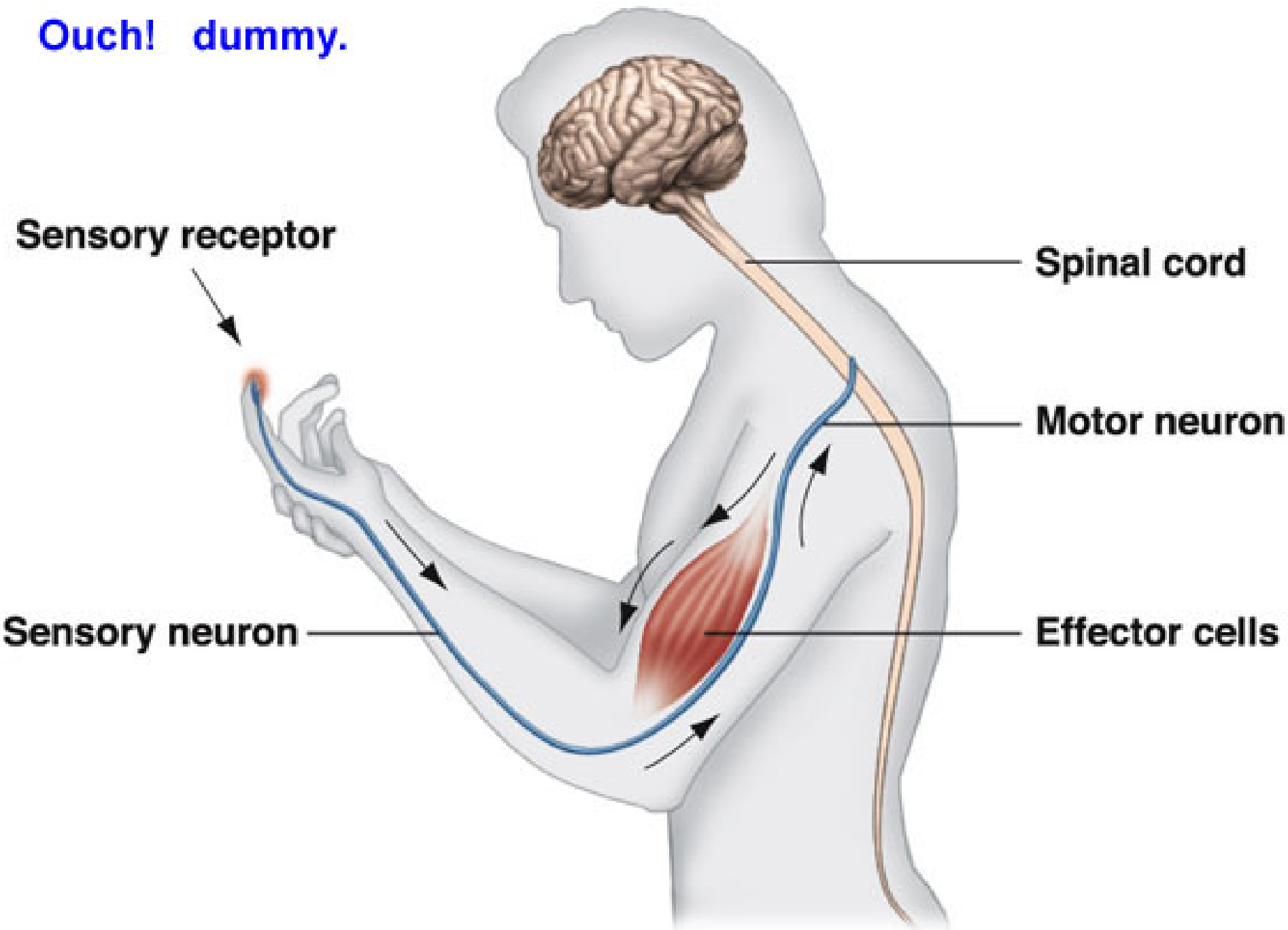
Monosynaptic refers to the presence of a single chemical synapse.

In the case of peripheral muscle reflexes (patellar reflex, achilles reflex), brief stimulation to the muscle spindle results in contraction of the agonist or effector muscle.

in **polysynaptic** reflex pathways, one or more interneurons connect afferent (sensory) and efferent (motor) signals.

All but the most simple reflexes are polysynaptic, allowing processing or inhibition of polysynaptic reflexes within the spinal cord

Ouch! dummy.



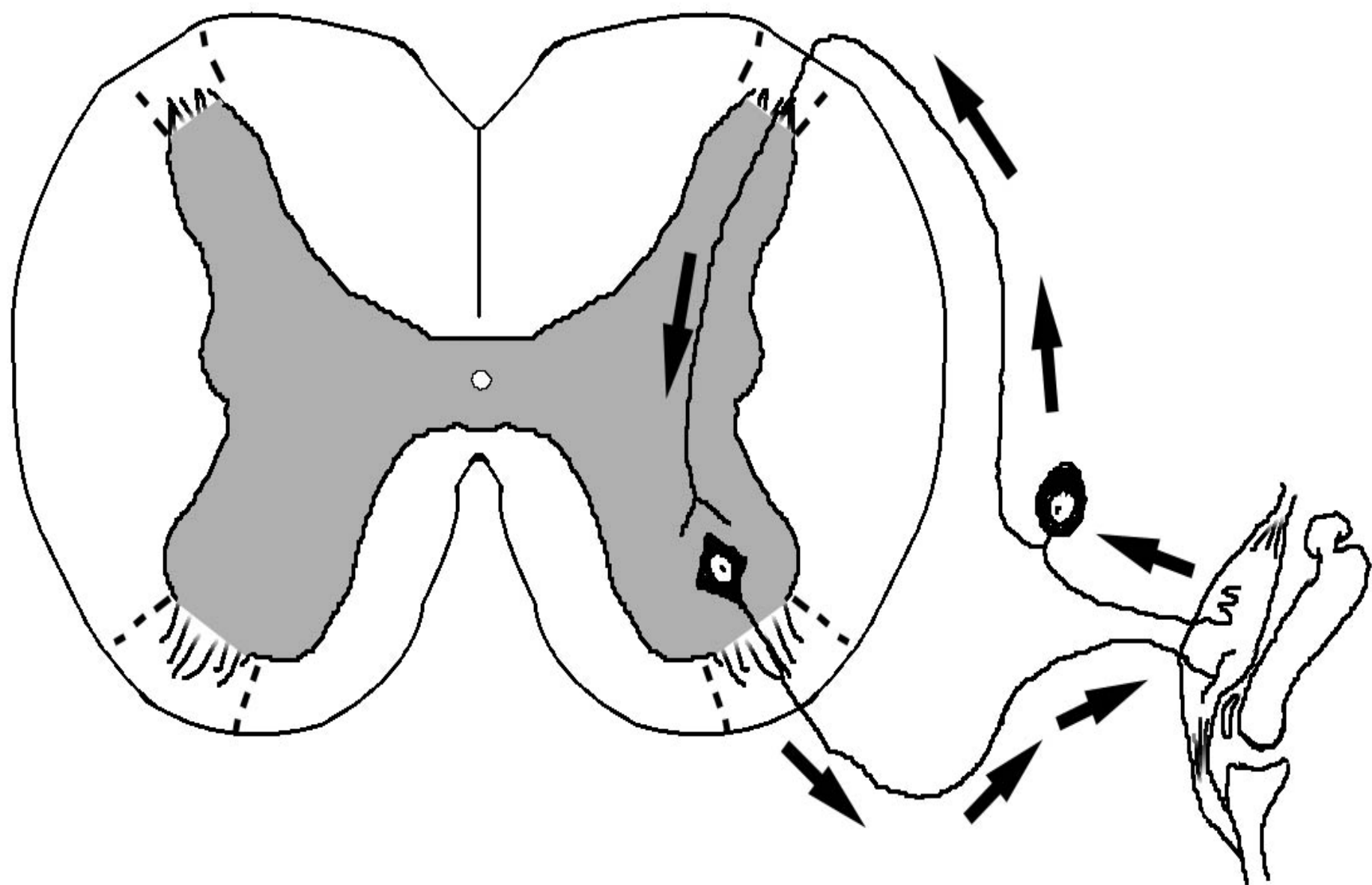
The Patellar Reflex

when the patellar tendon is tapped just below the knee, the patellar reflex is initiated and the lower leg kicks forward (via contraction of the quadriceps).

The tap initiates an action potential in a specialised structure known as a muscle spindle located within the quadriceps.

This action potential travels to the spinal cord, via a sensory axon which chemically communicates (see synapse) with a motor nerve.

The result of this motor nerve activity is contraction of the quadriceps muscle, leading to extension of the lower leg at the knee.



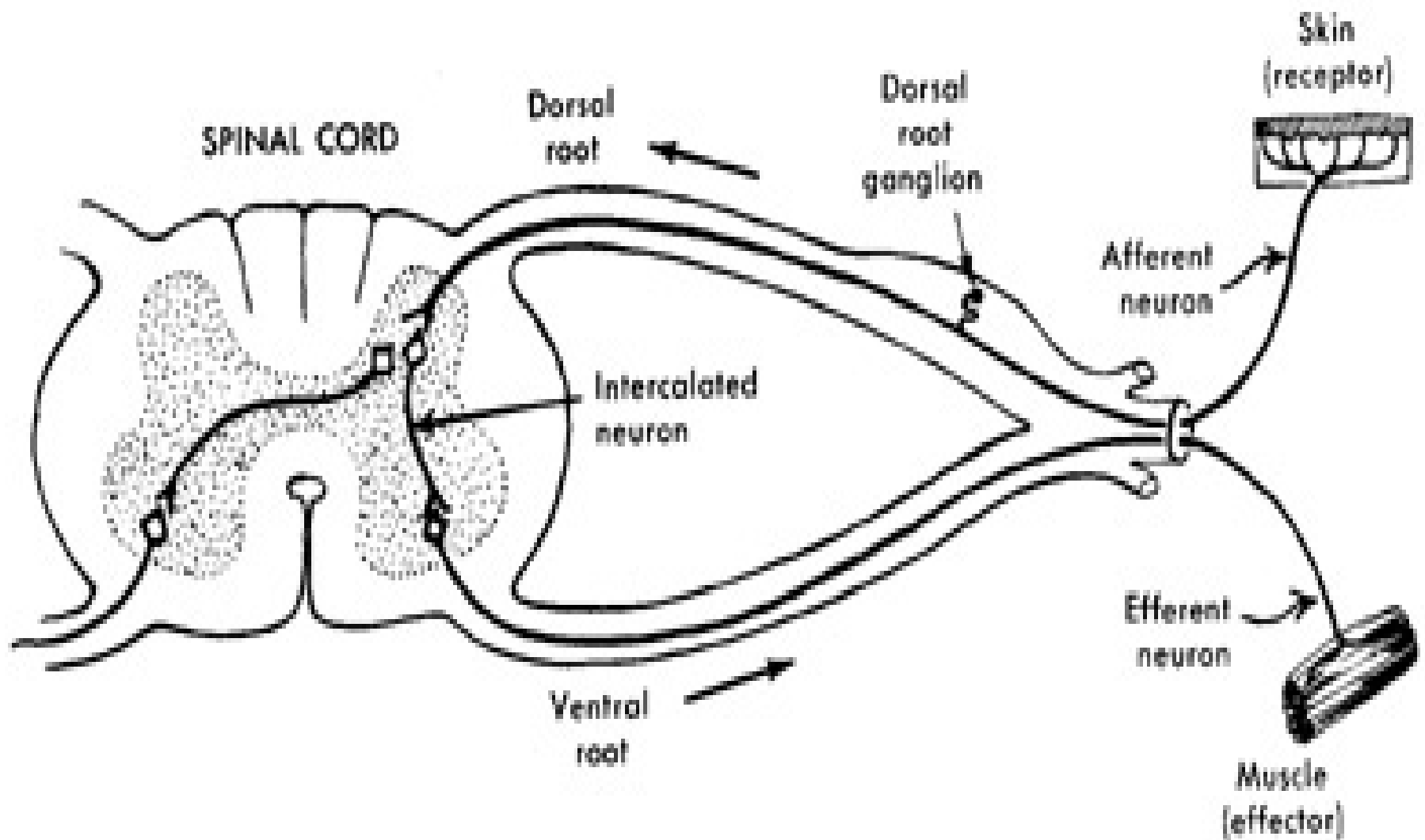
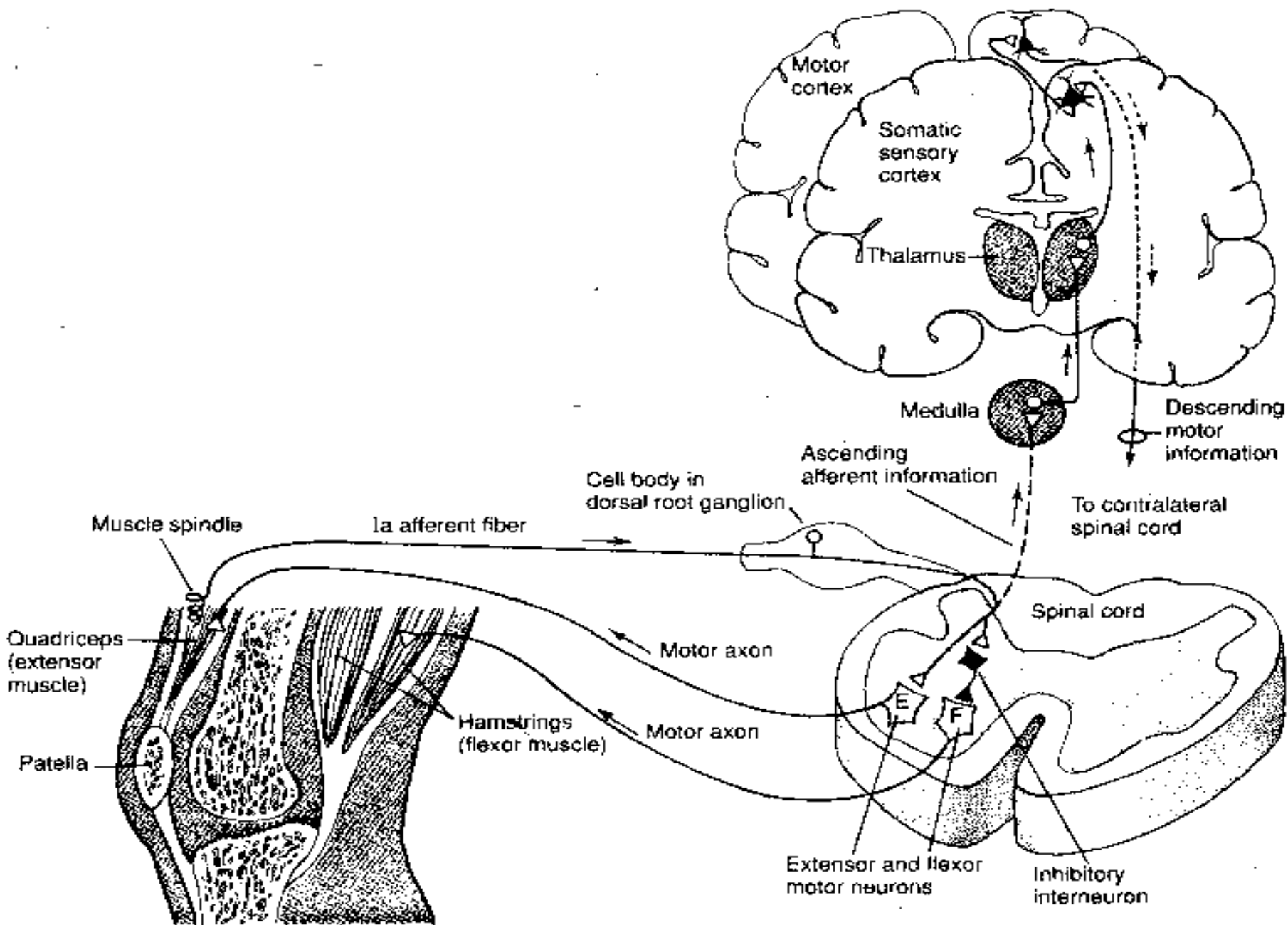


Fig. 19-3 Reflex arc. Message travels into spinal cord and out again without reaching brain.



The **crossed extensor reflex** is a withdrawal reflex. When the reflex occurs the flexors in the withdrawing limb contract and the extensors relax, while in the other limb the opposite occurs.

An example of this is when a person steps on a nail, the leg that is stepping on the nail pulls away, while the other leg takes the weight of the whole body.

Another example of a crossed extensor reflex is when someone violently grabs your arm, the arm that is grabbed retracts towards the body while the other arm moves towards the attacker for protection.

Withdrawal reflex

The **nociceptive withdrawal reflex** (NWR) is a spinal reflex intended to protect the body from damaging stimuli.

The classic example is when you touch something hot and withdraw your body part from the hot object.

The heat stimulates temperature and pain receptors in the skin, triggering a sensory impulse that travels to the central nervous system.

The sensory neuron then synapses with interneurons that connect to motor neurons.

Some of these send motor impulses to the flexors to allow withdrawal; some motor neurons send inhibitory impulses to the extensors so flexion is not inhibited - this is referred to as reciprocal innervation.

While all of this occurs, other interneurons relay the sensory information up to the brain so that the person becomes aware of the pain and what happened.

A **nociceptor** is a sensory receptor that sends signals that cause the perception of pain in response to potentially damaging stimulus. Nociceptors are the nerve endings responsible for nociception, one of the two types of persistent pain (the other, neuropathic pain, occurs when nerves in the central or peripheral nervous system are damaged). When they are activated, nociceptors can trigger a reflex.

In medicine, the pupillary reflex or pupillary light reflex is the reduction of pupil size in response to light.

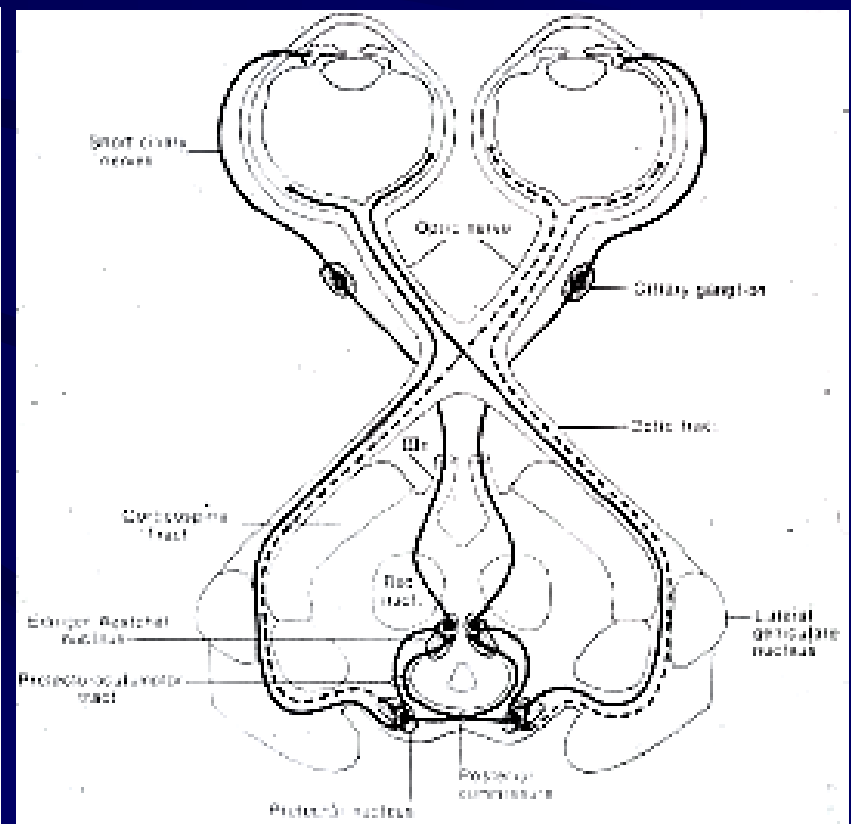
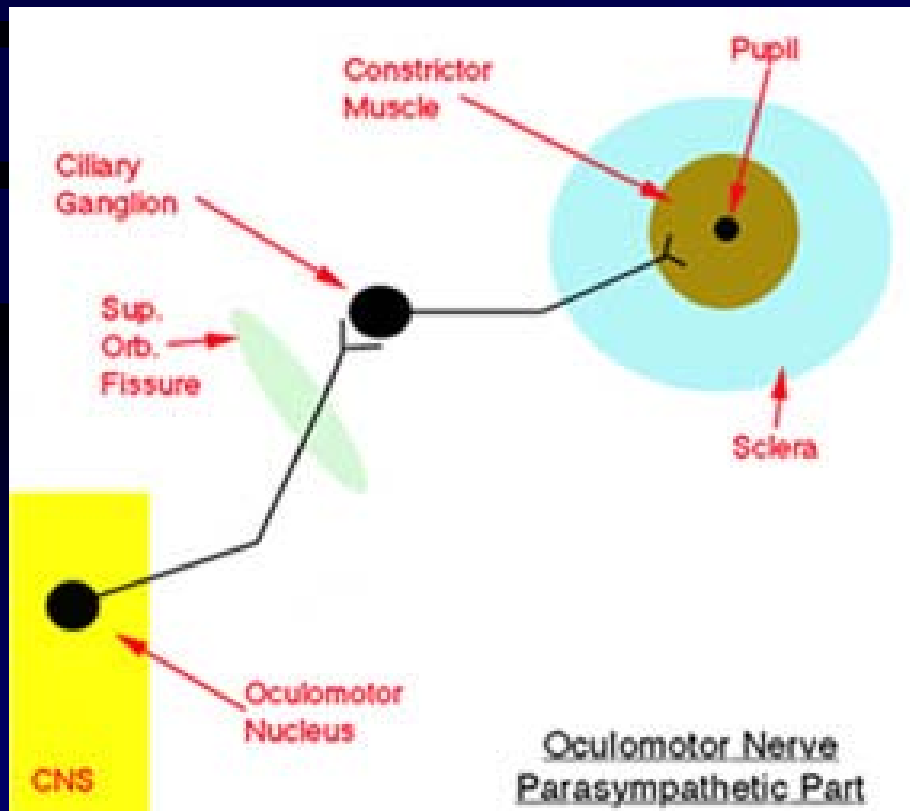
It is a normal response and dependent on the function of the optic nerves and oculomotor nerves.

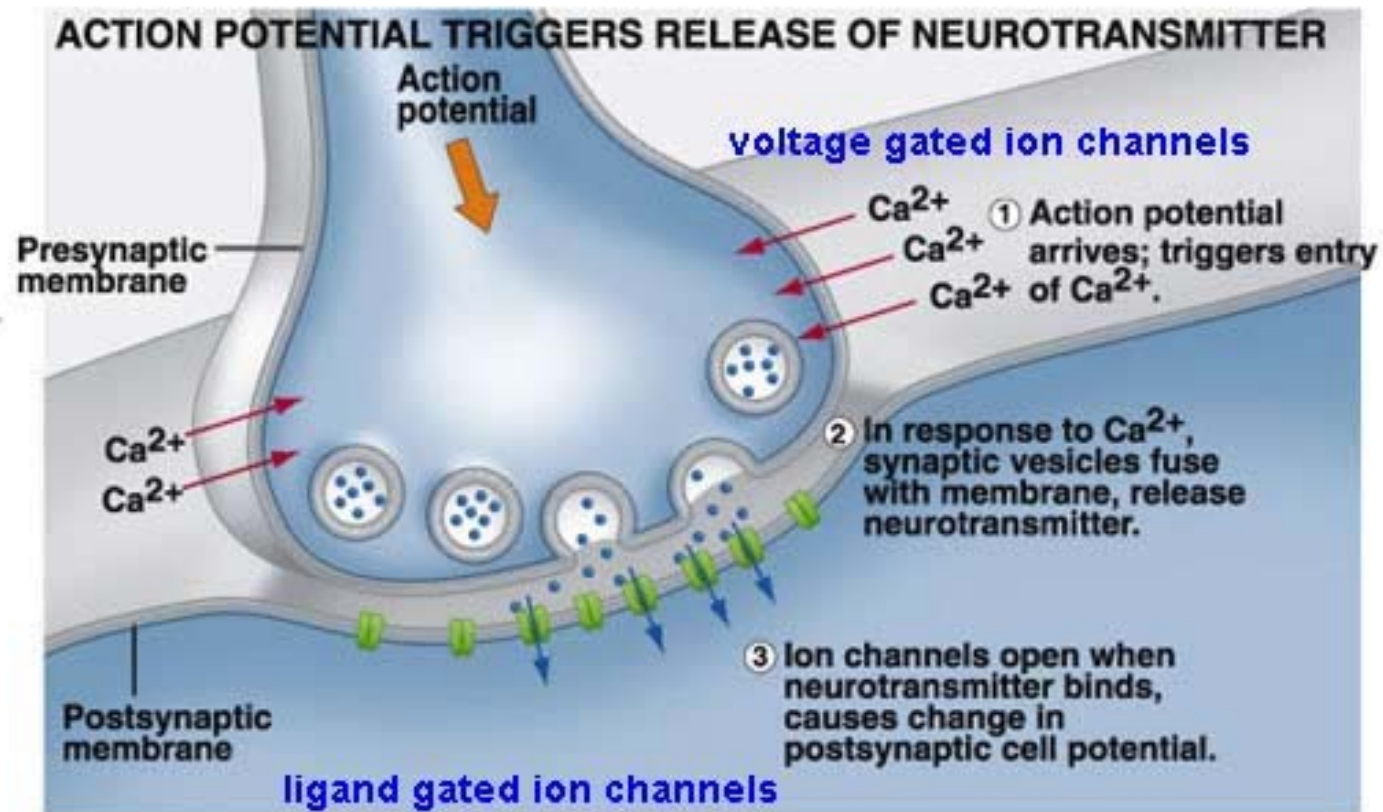
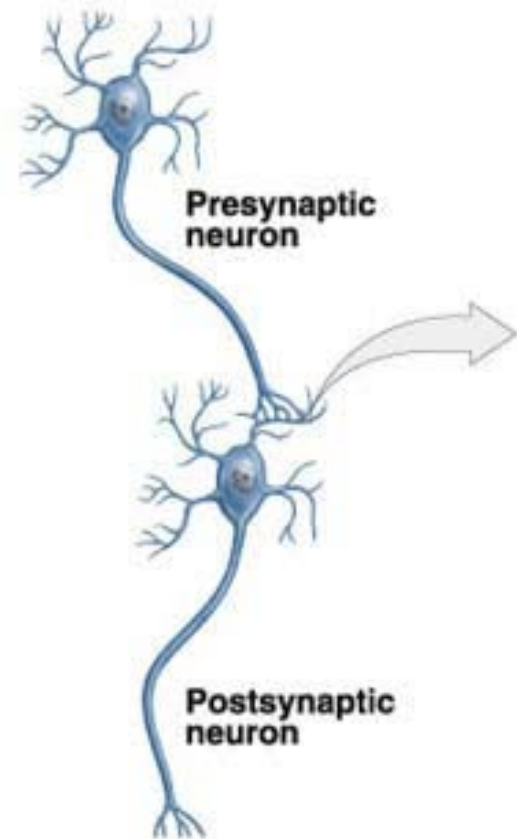
Pupillary constriction is sometimes used as a synonym for *pupillary reflex* but something more general.

Pupillary constriction may be induced pharmacologically by parasympathomimetics and is also seen in accommodation (when the eyes focus on something close).

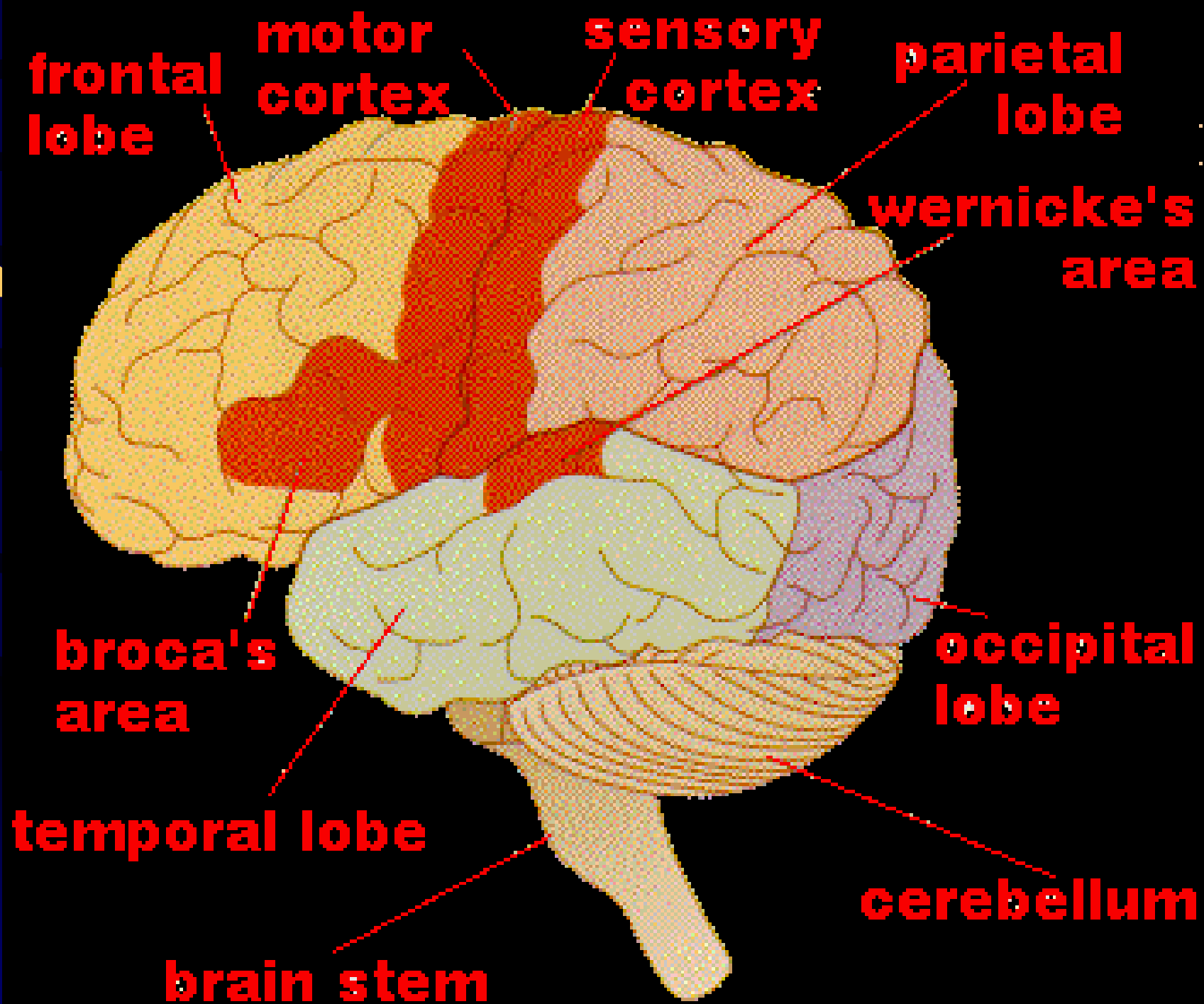
- **Direct pupillary reflex:** whether each pupil constricts with light shone into the *that eye*
- **Consensual pupillary reflex:** whether each pupil constricts with light shone into *the other eye*

The reflex pathway consists of retinal ganglion cells, which convey information from the photoreceptors to the optic nerve which connects to the pretectal nucleus of the high midbrain. It bypasses the lateral geniculate nucleus and the primary visual cortex. From the pretectal nucleus neurons send axons to neurons of the Edinger-Westphal nucleus whose axons run along both the left and right oculomotor nerves. Oculomotor nerve axons synapse on ciliary ganglion neurons whose axons innervate the constrictor muscle of the iris.





The brain



Brain

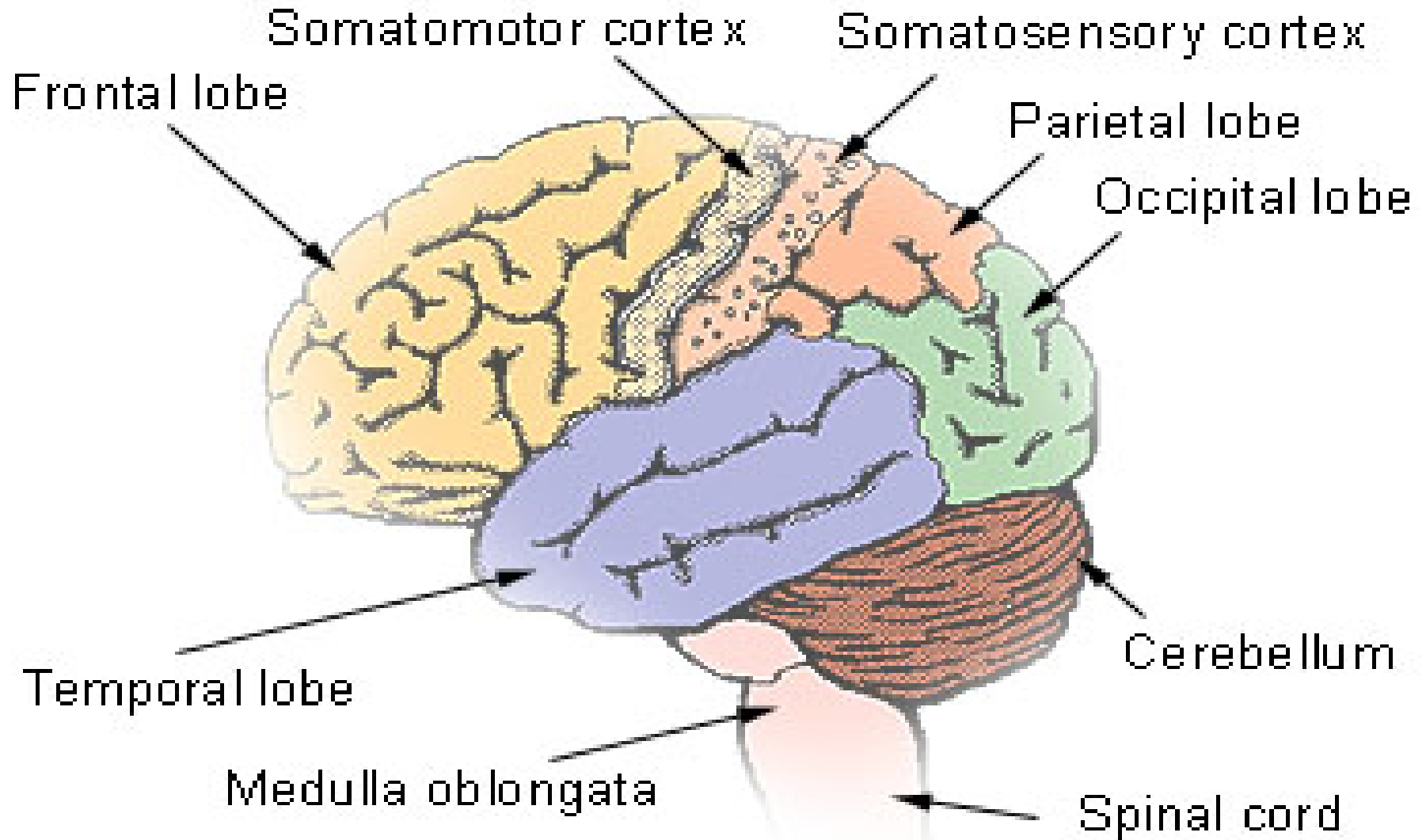
- Cerebrum
- Diencephalon
- Brain stem
- Cerebellum

The standard areas of cortex (isocortex) is characterized as having six distinct layers. From outside inward:

1. Molecular layer
2. External granular layer
3. External pyramidal layer
4. Internal granular layer
5. Internal pyramidal layer
6. Multiform layer.

- The molecular layer I contains few scattered neurons and consists mainly of extensions of apical dendrites and horizontally oriented axons, and some Cajal-Retzius and spiny stellate neurons can be found.
- The external granular layer II contains small pyramidal neurons and numerous stellate neurons.
- The external pyramidal layer III contains predominantly small and medium sized pyramidal neurons, as well as non-pyramidal neurons with vertically-oriented intracortical axons. Layers I through III are the main target of interhemispheric corticocortical afferents, and layer III is the principal source of corticocortical efferents.
- The internal granular layer IV contains different types of stellate and pyramidal neurons, and is the main target of thalamocortical afferents as well as intra-hemispheric corticocortical afferents.
- The internal pyramidal layer V contains large pyramidal neurons (as the Betz cells in the primary motor cortex), as well as interneurons, and it is the principal source of efferent for all the motor-related subcortical structures.
- The multiform layer VI contains few large pyramidal neurons and many small spindle-like pyramidal and multiform neurons. The layer VI sends efferent fibers to the thalamus establishing a very precise reciprocal interconnection between the cortex and the thalamus

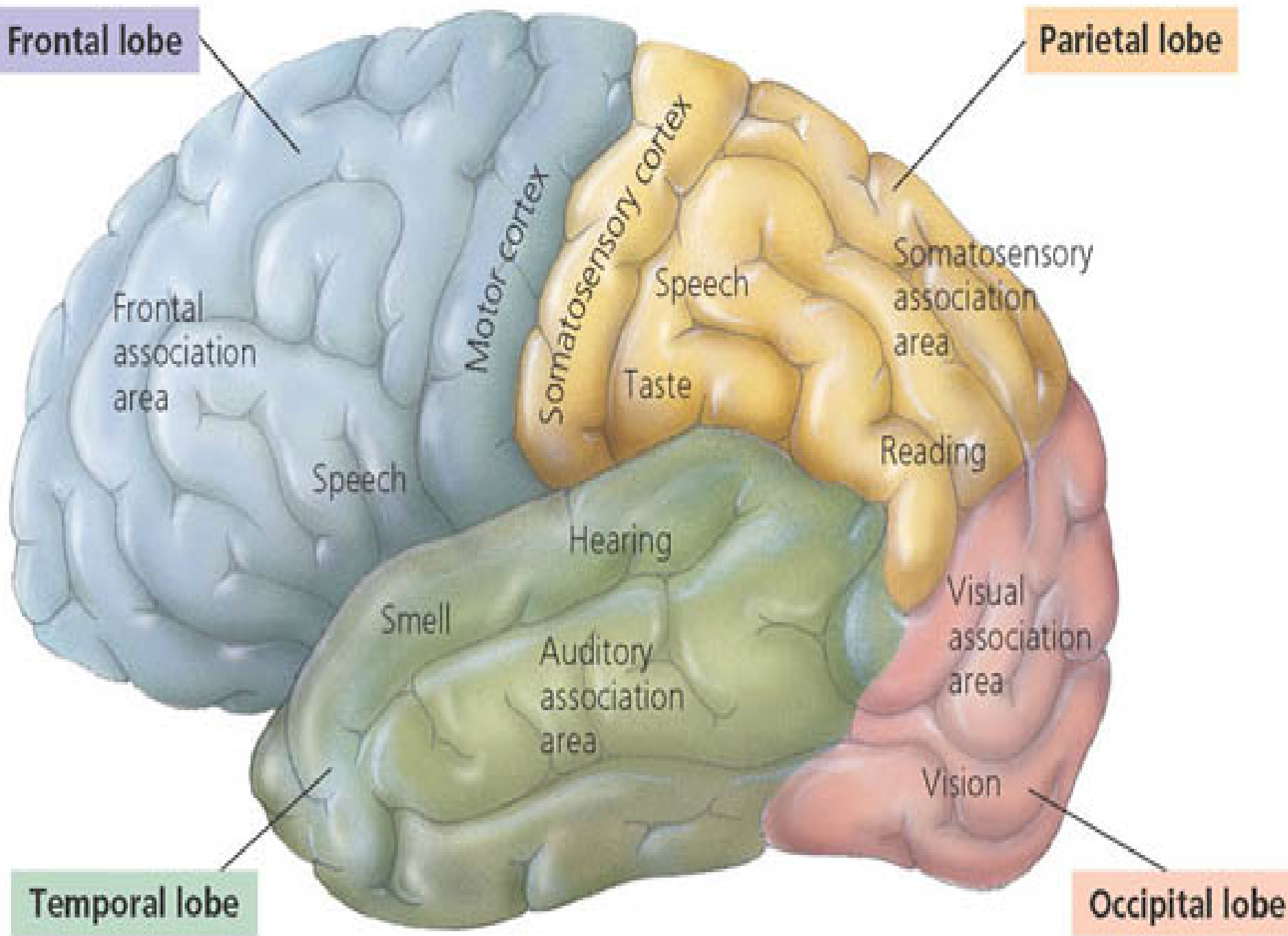
Cerebrum



Lobes of the cerebrum

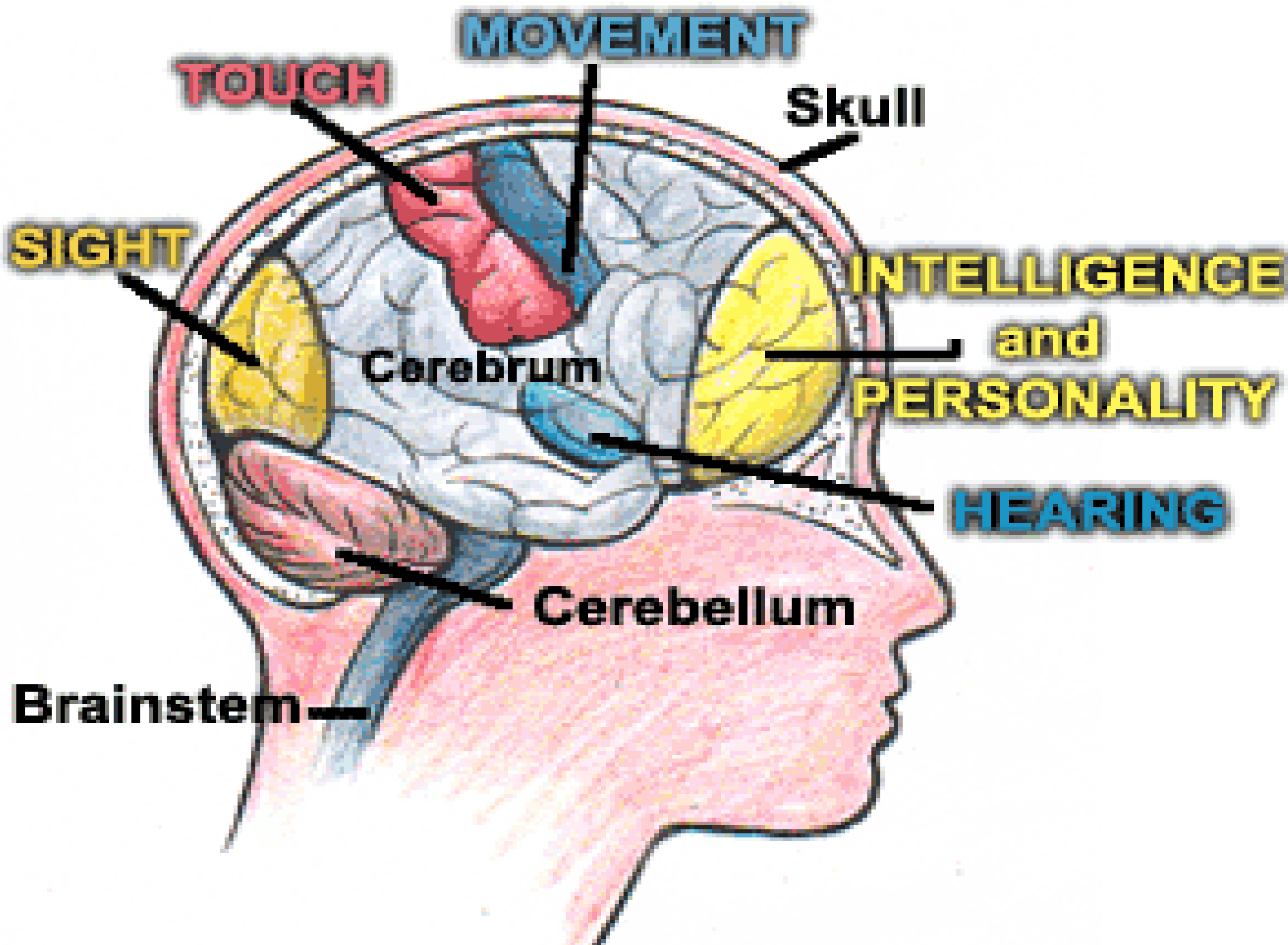
Frontal lobe

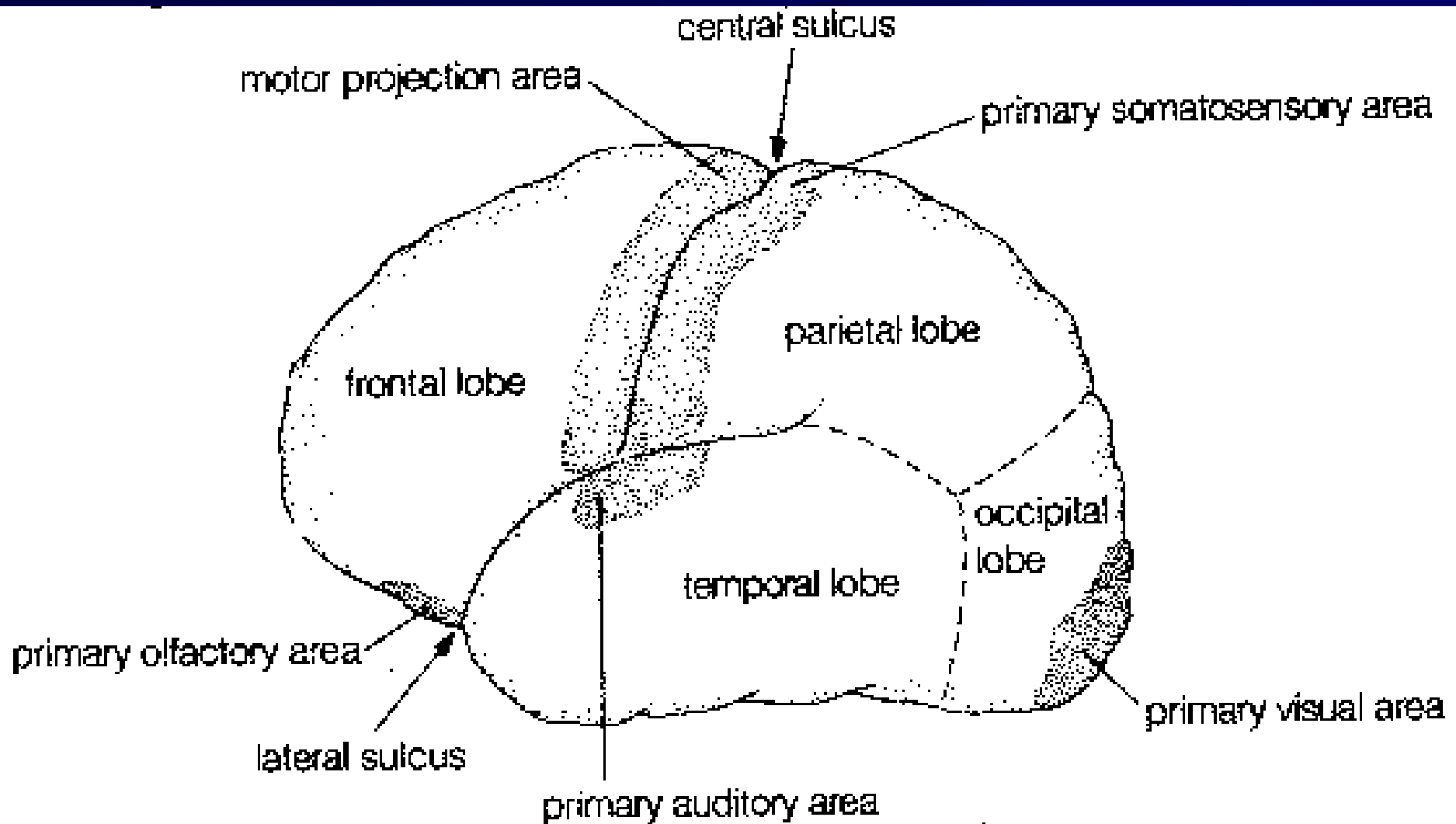
Parietal lobe



Temporal lobe

Occipital lobe





cortex may be classified on the basis of gross topographical conventions into the following:

- Temporal Cortex
- Parietal Cortex
- Frontal Cortex
- Occipital Cortex
- Limbic Cortex
- Insular Cortex

Association areas comprise three major groups:

- 1.Parietal, temporal, and occipital lobes - all located in the posterior part of the brain - are involved in producing our perceptions resulting from what our eyes see, ears hear, and other sensory organs inform us about the position of different parts of our body and relate them to the position of other objects in the environment
- 2.Frontal lobe - called *prefrontal association complex* and involved in planning actions and movement, as well as abstract thought
- 3.Limbic association area - involved in emotion and memory.

In humans, the association areas of the left hemisphere, especially the parietal-temporal-occipital complex, are responsible for our understanding and use of language.

The cerebral cortex sends connections (efferents) and receives connections (afferents) from many subcortical structures like the thalamus and basal ganglia. Most of the sensory stimulation arrives to the cerebral cortex indirectly through different thalamic nuclei. This is the case of touch, vision and sound but not of olfactory stimulation, that arrives directly to the olfactory cortex. The largest part of the connections arriving to the cerebral cortex do not come from subcortical structures however. The main source of cortical stimulation is the cerebral cortex itself: up to 75% of the total connections. Areas that receive that particular information are called sensory areas. Parts of the cortex that receive sensory inputs from the thalamus are called primary sensory areas.

The senses of vision, audition and touch are served by the primary visual cortex, primary auditory cortex and primary somatosensory cortex. In general, the two hemispheres receive the information from the opposite sides of the body. For example the right primary somatosensory cortex receives information from the left limbs and the right visual cortex receives information from the left visual field. Other areas receive impulses from the primary sensory areas and integrate the information coming in from different types of receptors (i.e., modalities). These are often called association areas and make up a great deal of the cortex in all primates, humans included. Thus, the cortex is commonly described as comprised of the primary sensory areas, the motor areas and the association areas.

The motor areas are located in both hemispheres of the cortex. They are shaped like a pair of headphones stretching from ear to ear. The motor areas are very closely related to the control of voluntary movements, especially fine fragmented movements performed by the hand. The right half of the motor area controls the left side of your body and vice versa.

Two areas of the cortex are commonly referred to as motor:

- *Primary motor cortex*, which **executes** voluntary movements
- *Supplementary motor areas* and *premotor cortex*, which **select** voluntary movements.

In addition, motor functions have been described for:

- *Posterior Parietal Cortex*, which guides voluntary movements in space
- *Dorsolateral Prefrontal Cortex*, which decides which voluntary movements to make according to higher-order instructions, rules, and self-generated thoughts.

cerebrum

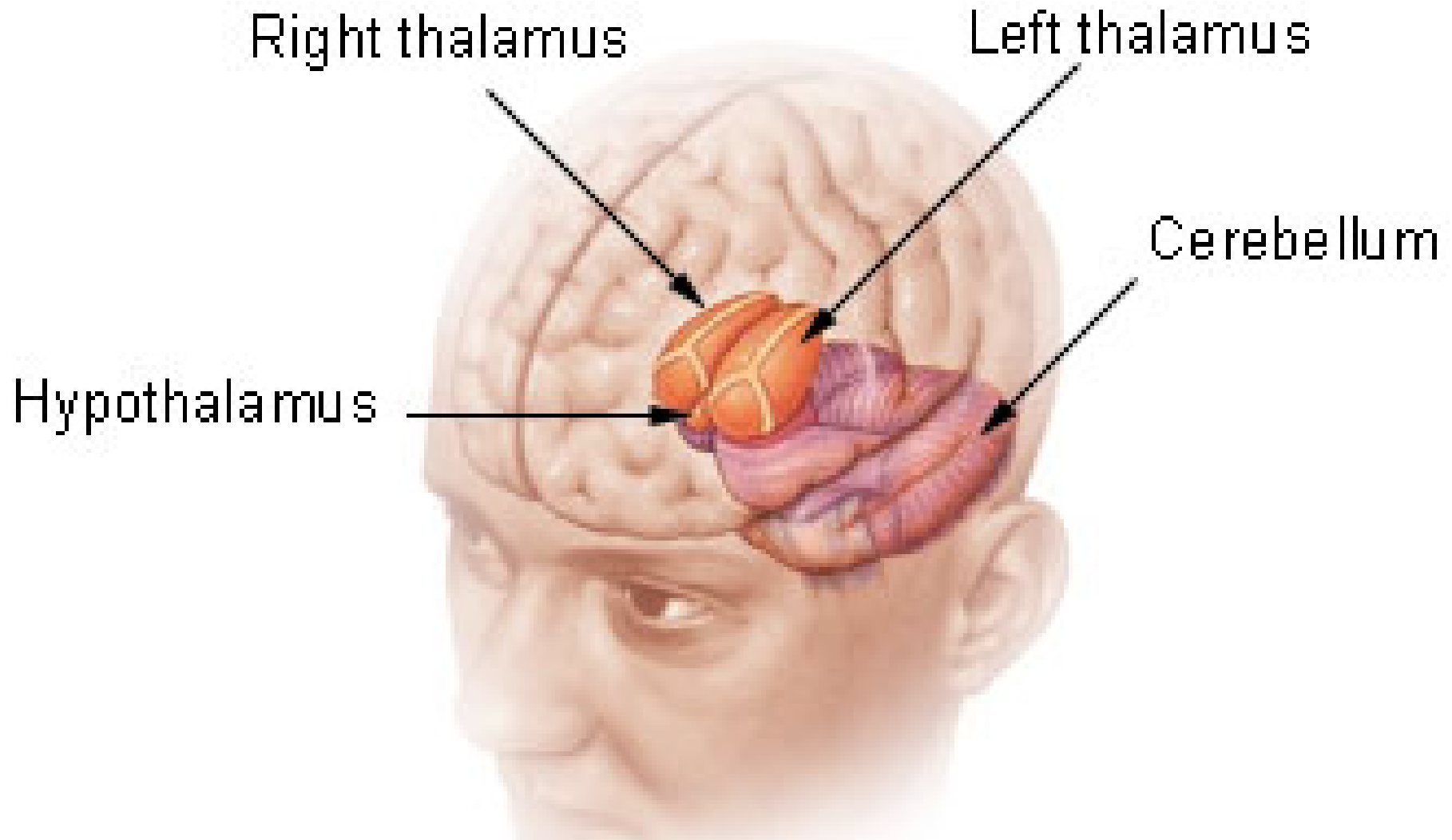
- The largest and most obvious portion of the brain is the cerebrum, which is divided by a deep longitudinal fissure into two cerebral hemispheres.
- The two hemispheres are two separate entities but are connected by an arching band of white fibers, called the **corpus callosum** that provides a communication pathway between the two halves.
- The cerebrum is located in the **anterior portion of the forebrain**. It is divided into two hemispheres that are connected by the corpus callosum.

- Each cerebral hemisphere is divided into five lobes,
- four of which have the same name as the bone over them:
 - the frontal lobe,
 - the parietal lobe,
 - the occipital lobe,
 - the temporal lobe.
- A fifth lobe, the insula or Island of Reil, lies deep within the lateral sulcus.

Cerebrum Function:

- Determines Intelligence
- Personality
- Interpretation of Sensory Impulses
- Motor Function
- Planning and Organization
- Touch Sensation

Diencephalon



The diencephalons is centrally located and is nearly surrounded by the cerebral hemispheres

Diencephalon

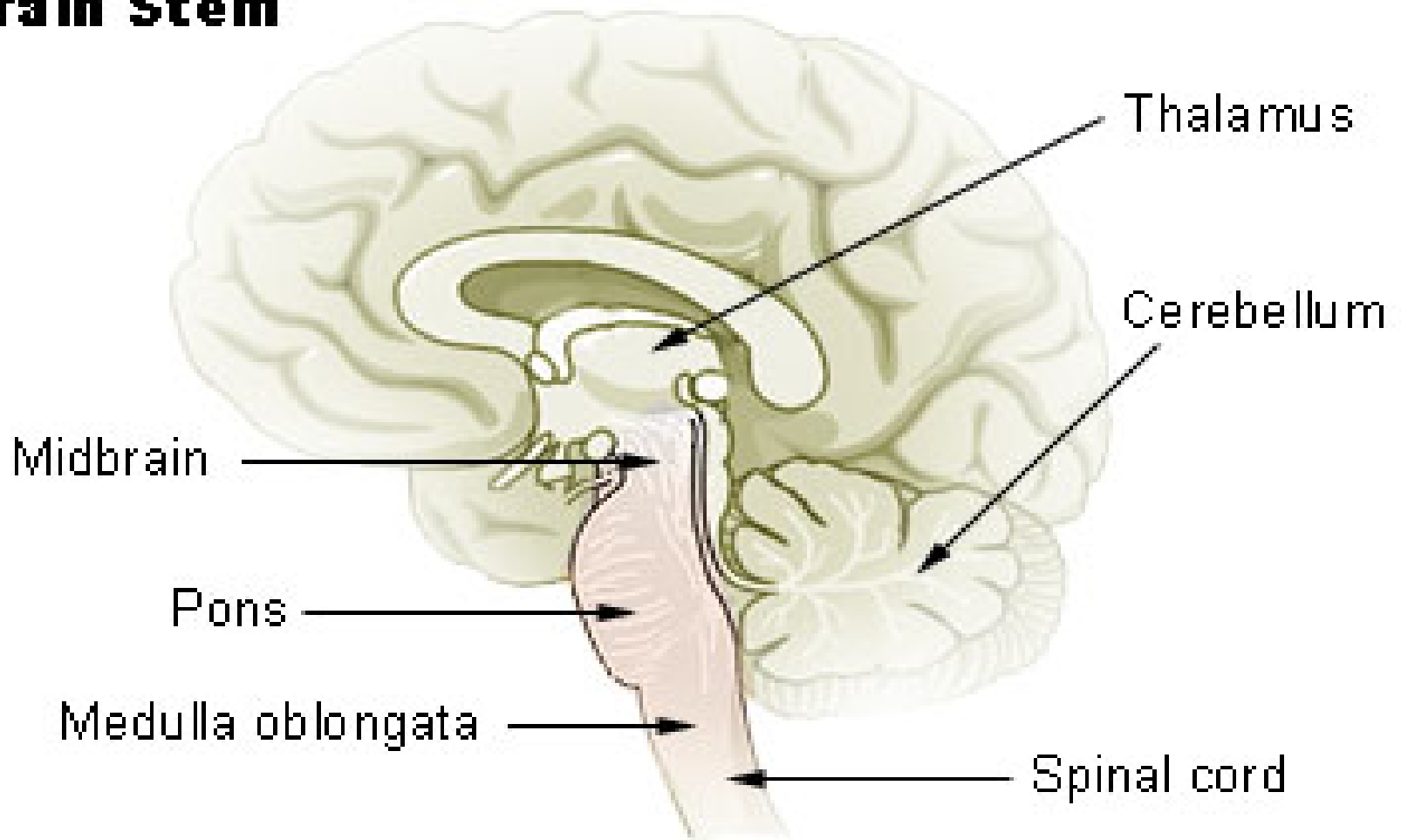
- It includes **the thalamus, hypothalamus, and epithalamus.**
- The thalamus, about 80 percent of the diencephalons, consists of two oval masses of gray matter that serve as relay stations for sensory impulses, except for the sense of smell, going to the cerebral cortex.
- The hypothalamus is a small region below the thalamus, which plays a key role in maintaining homeostasis because it regulates many visceral activities.
- The epithalamus is the most dorsal portion of the diencephalons. This small gland is involved with the onset of puberty and rhythmic cycles in the body. It is like a biological clock.

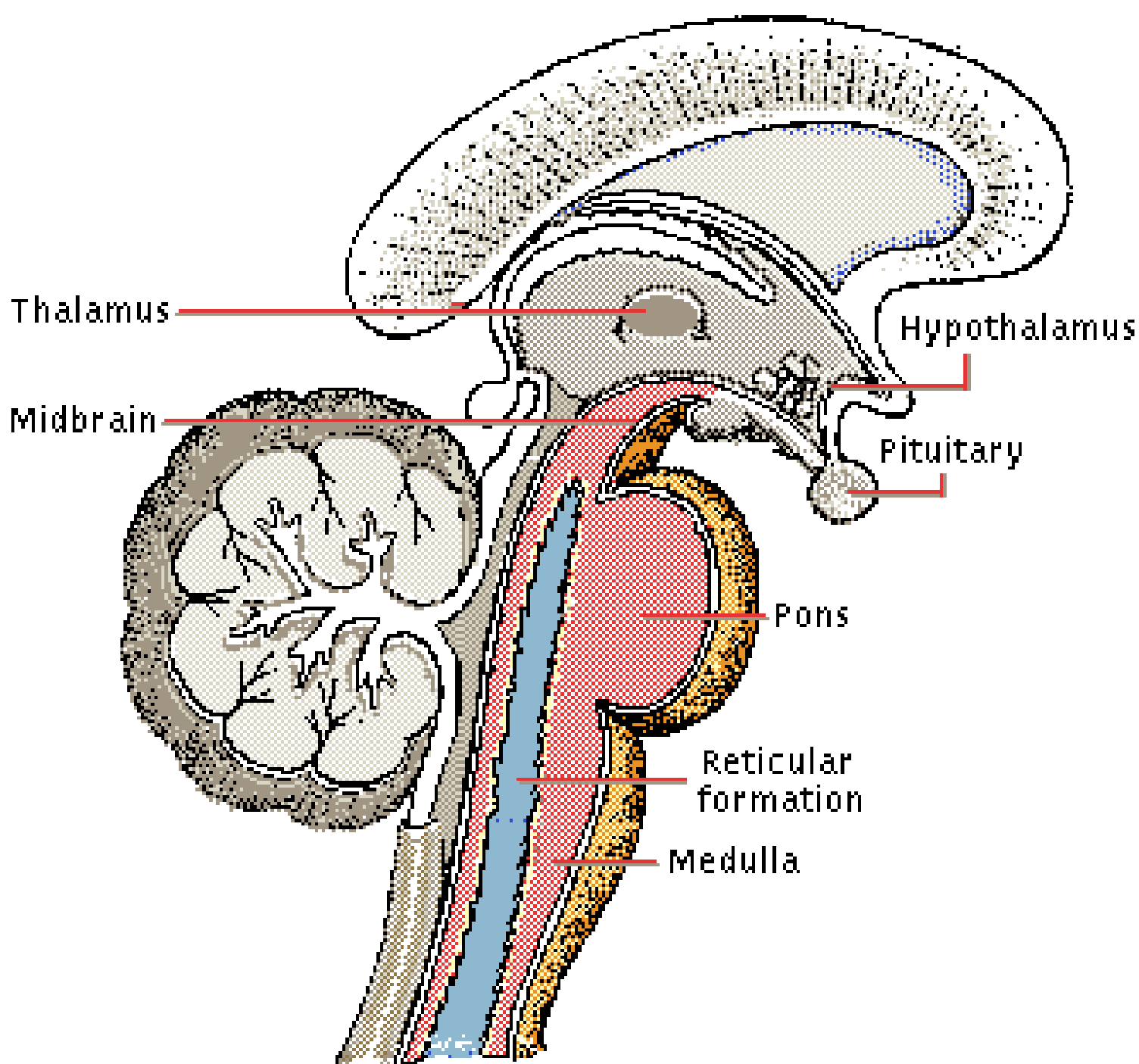
The Epithalamus comprises

- the trigonum habenulæ,
- the pineal body,
- and the posterior commissure.

Brain Stem

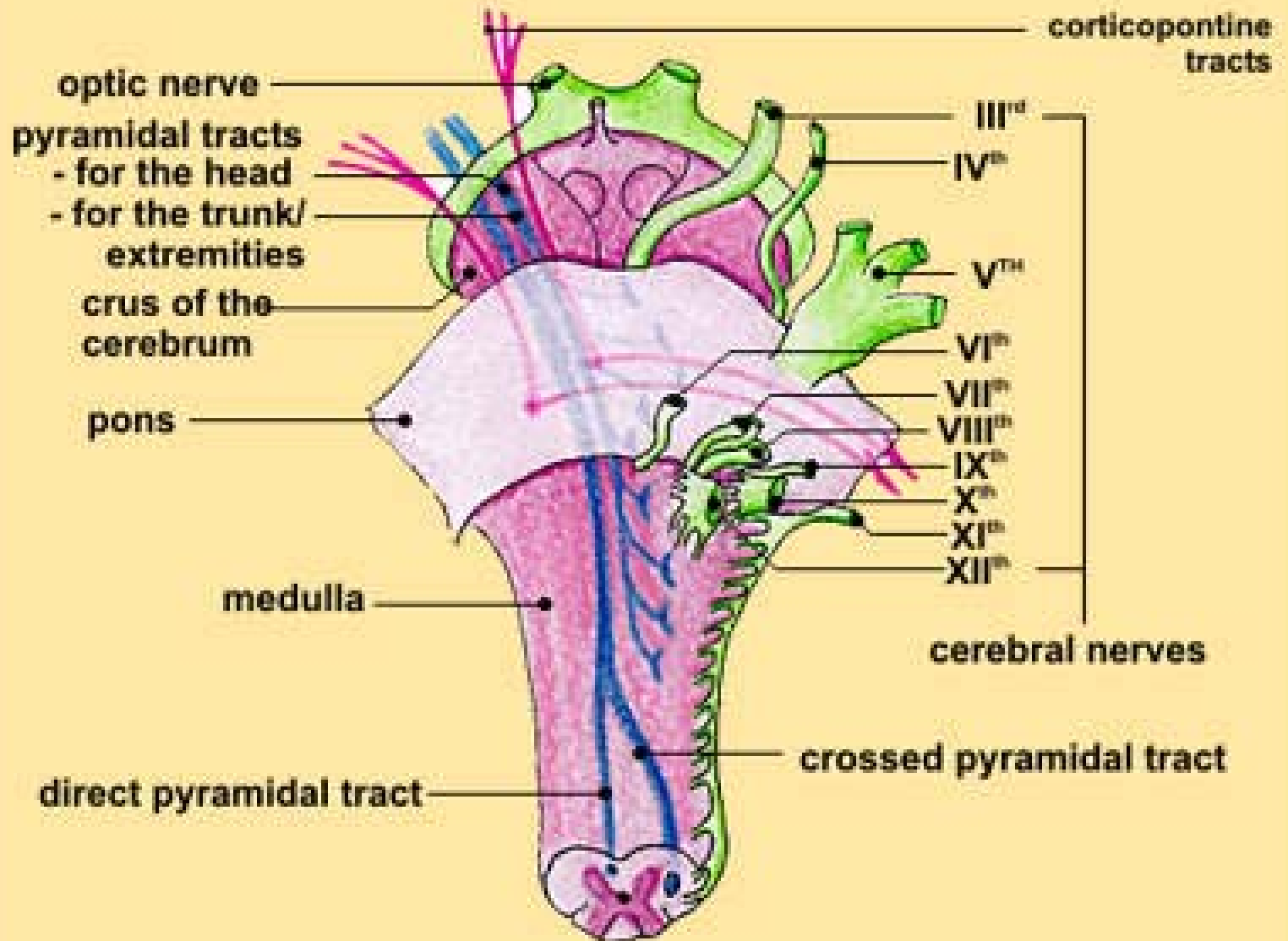
Brain Stem

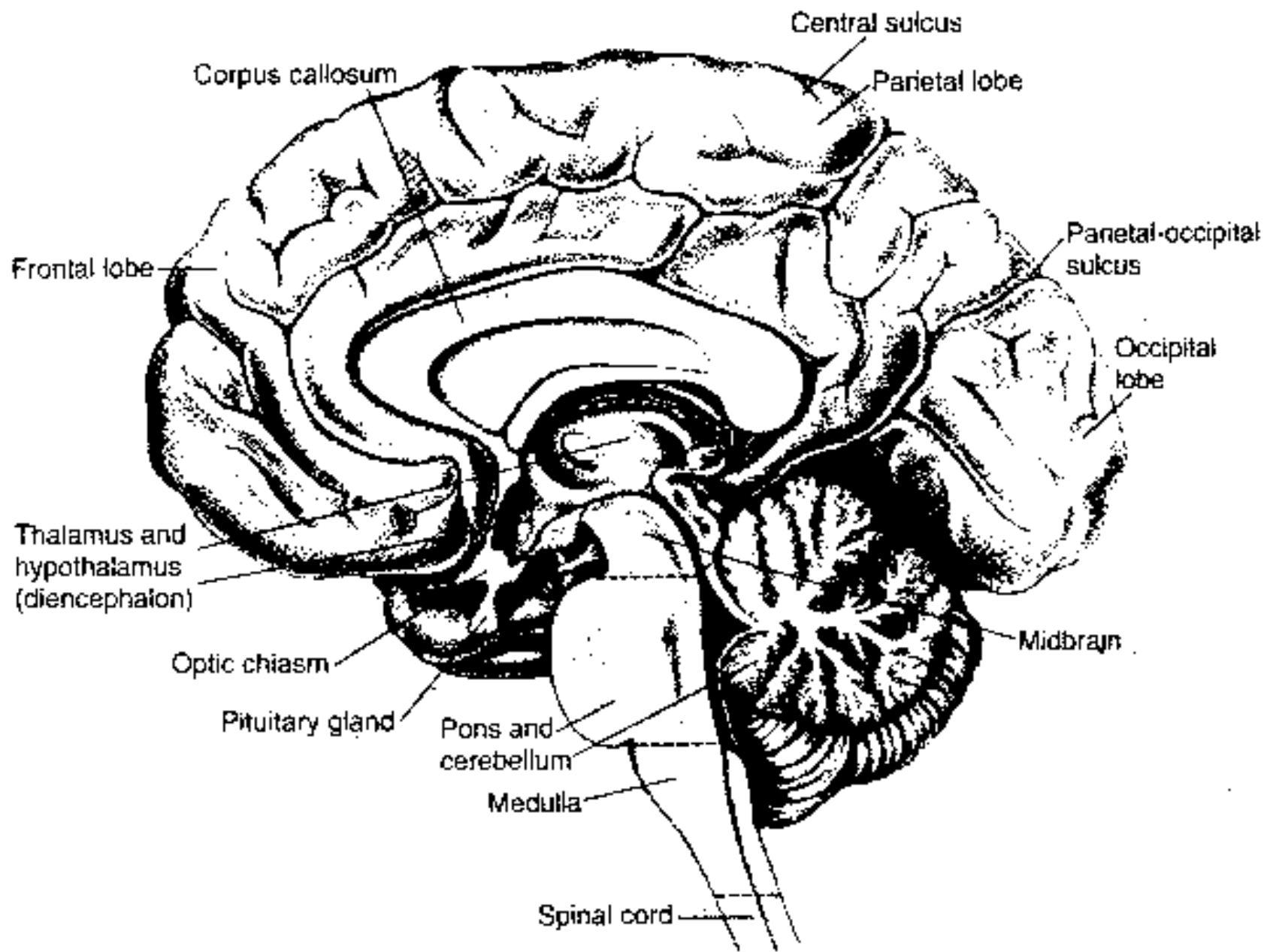




The brain stem has three main parts: the medulla, pons, and midbrain. A canal runs longitudinally through these structures carrying cerebrospinal fluid.

The Brain Stem





The brain stem is the region between the diencephalons and the spinal cord.

It consists of three parts:

- midbrain,
- pons,
- and medulla oblongata.
- The midbrain is the most superior portion of the brain stem.
- The pons is the bulging middle portion of the brain stem.

This region primarily consists of nerve fibers that form conduction tracts between the higher brain centers and spinal cord.

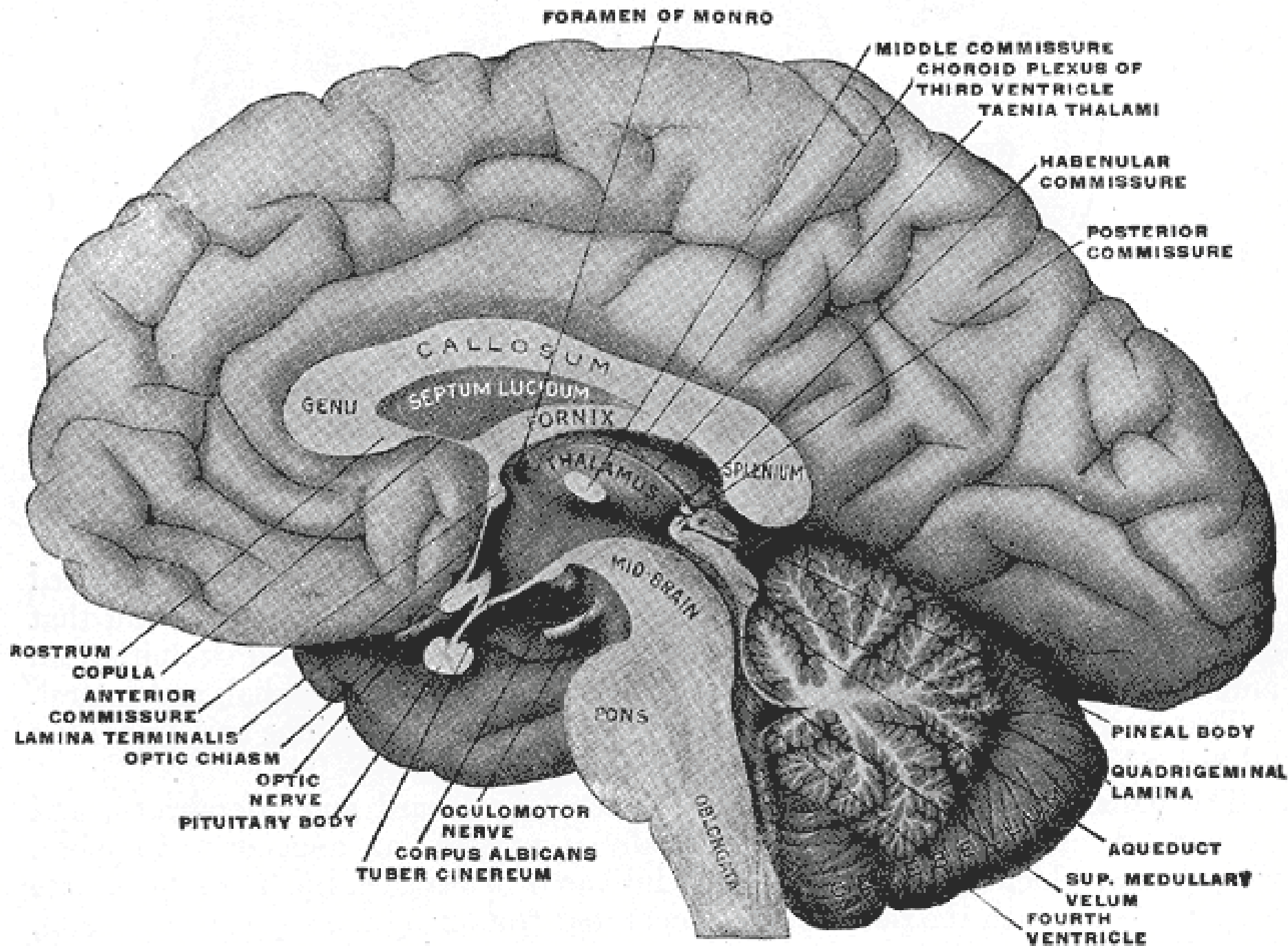
- The medulla oblongata, or simply medulla, extends inferiorly from the pons.
- It is continuous with the spinal cord at the foramen magnum.
- All the ascending (sensory) and descending (motor) nerve fibers connecting the brain and spinal cord pass through the medulla.

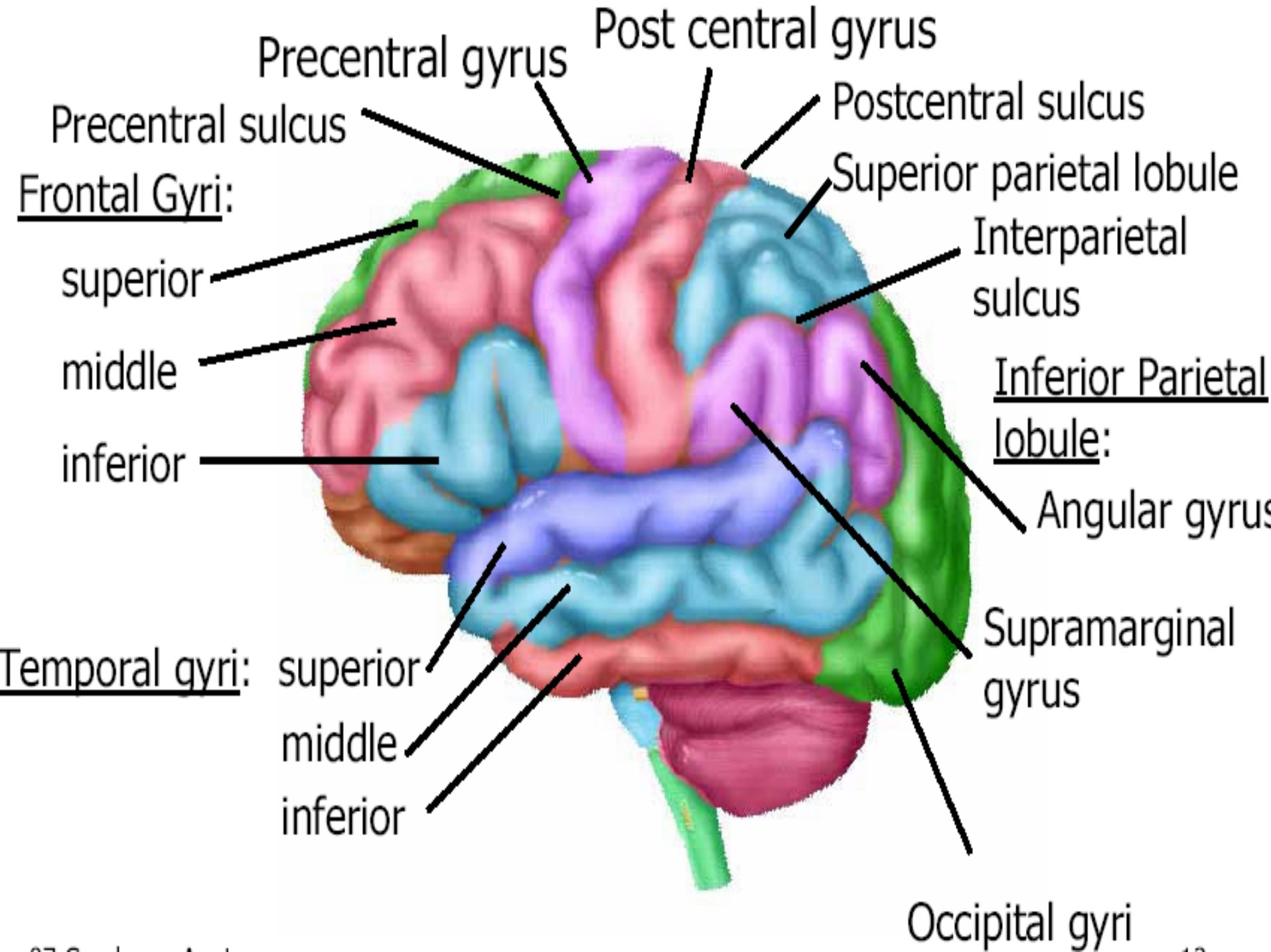
Cerebellum

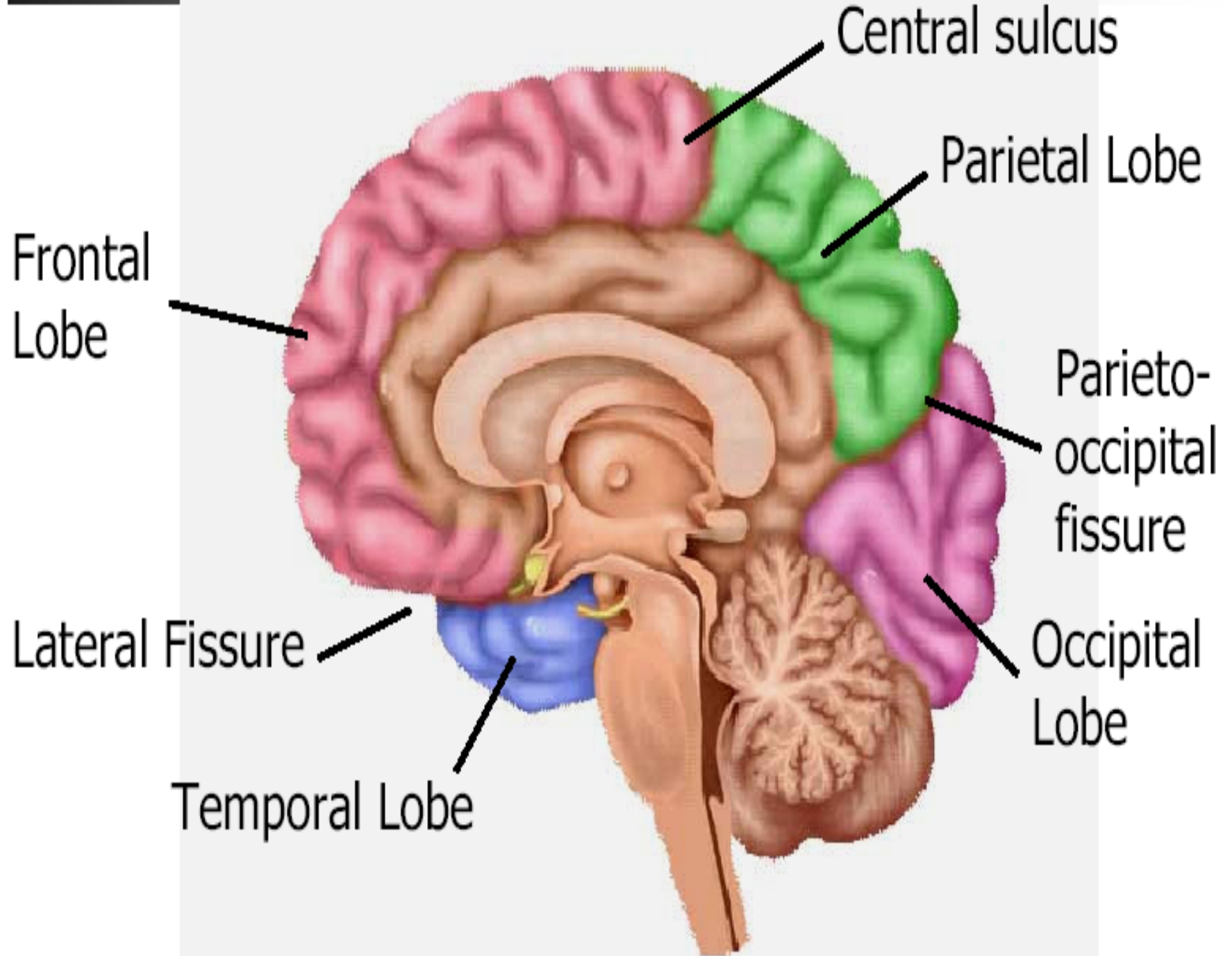
- The cerebellum, the second largest portion of the brain, is located below the occipital lobes of the cerebrum.
- Three paired bundles of myelinated nerve fibers, called cerebellar peduncles, form communication pathways between the cerebellum and other parts of the central nervous system.

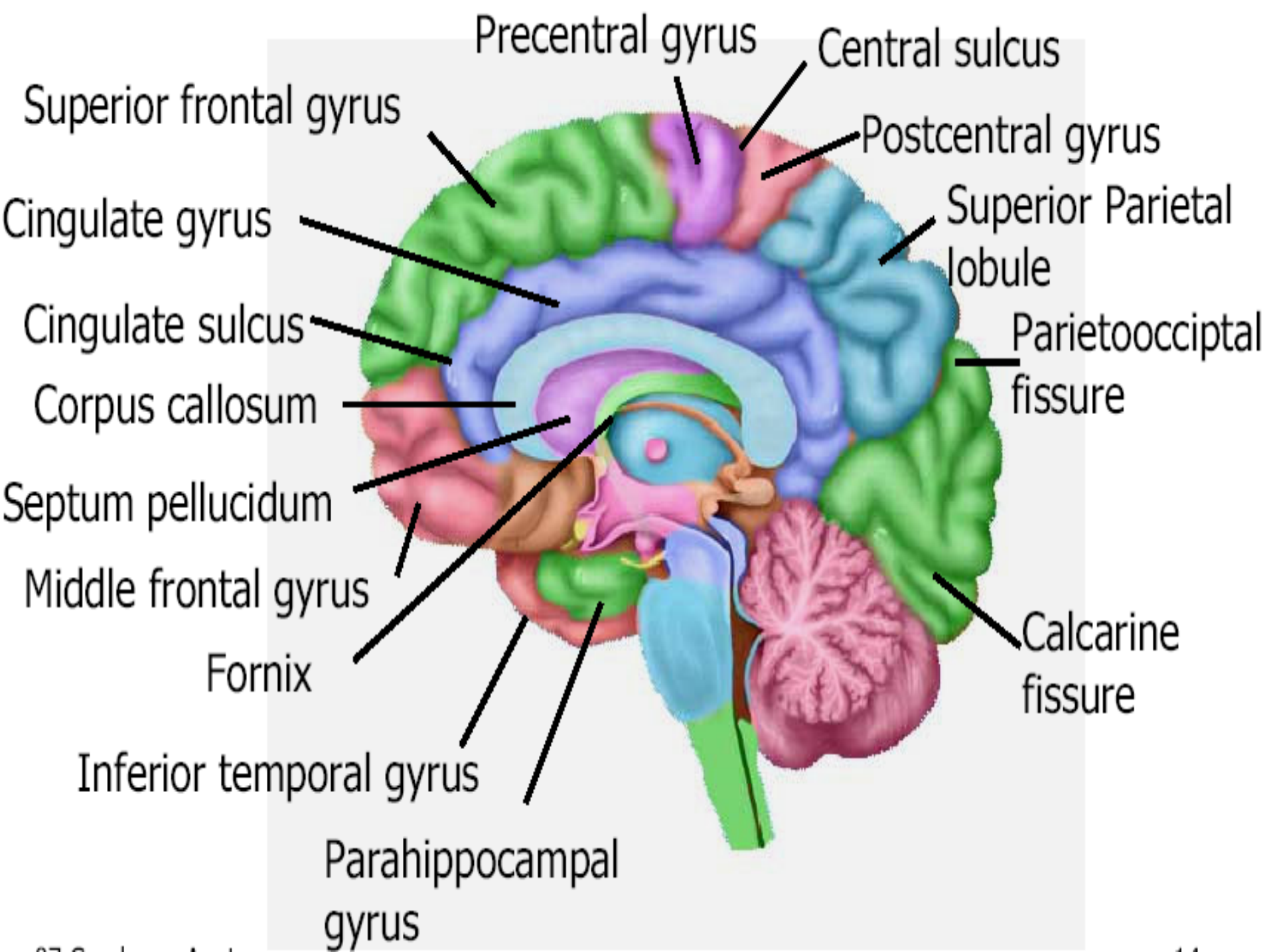
Ventricles and Cerebrospinal Fluid

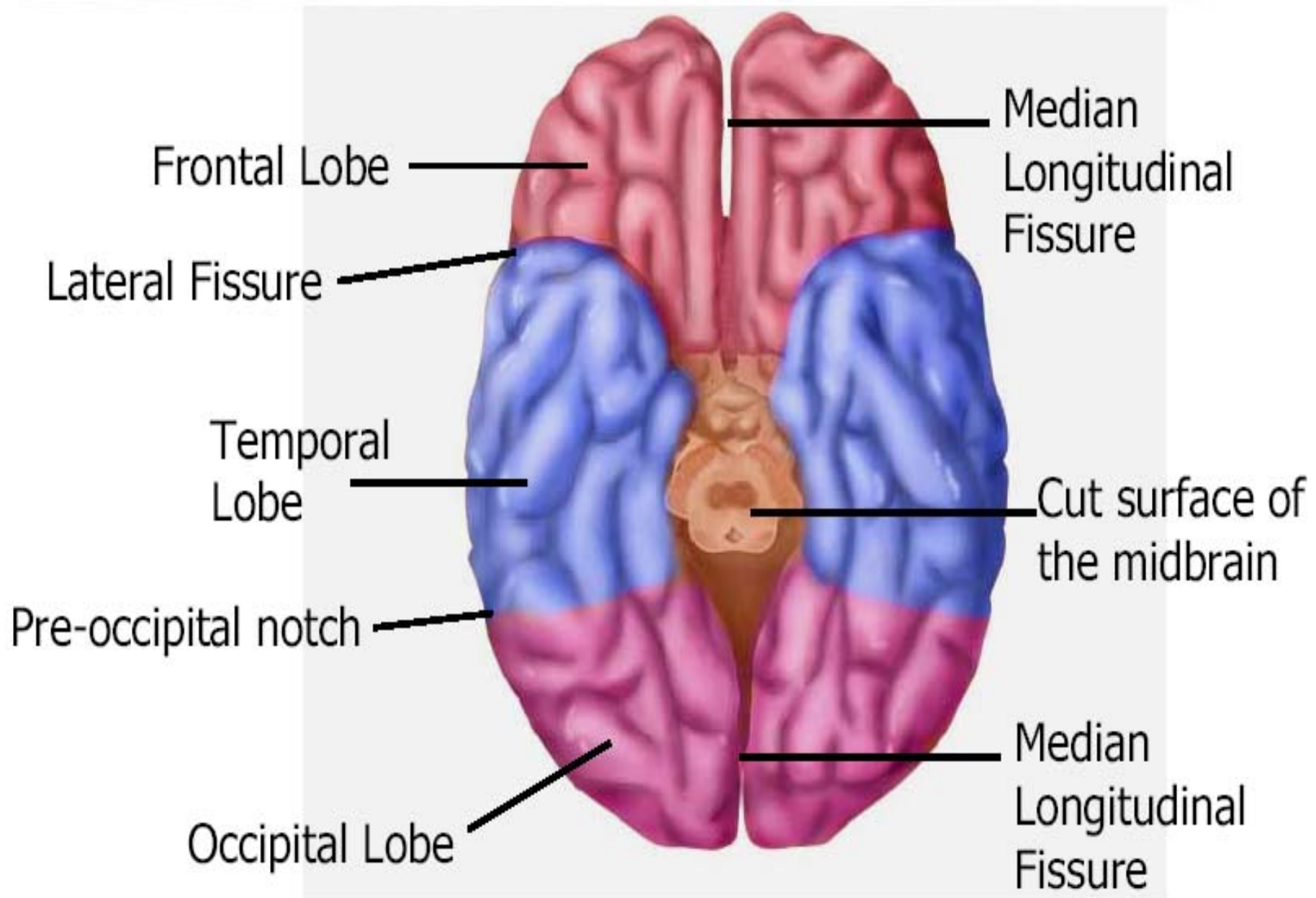
- Ventricles and Cerebrospinal Fluid
A series of interconnected, fluid-filled cavities are found within the brain.
- These cavities are the ventricles of the brain, and the fluid is cerebrospinal fluid (CSF).



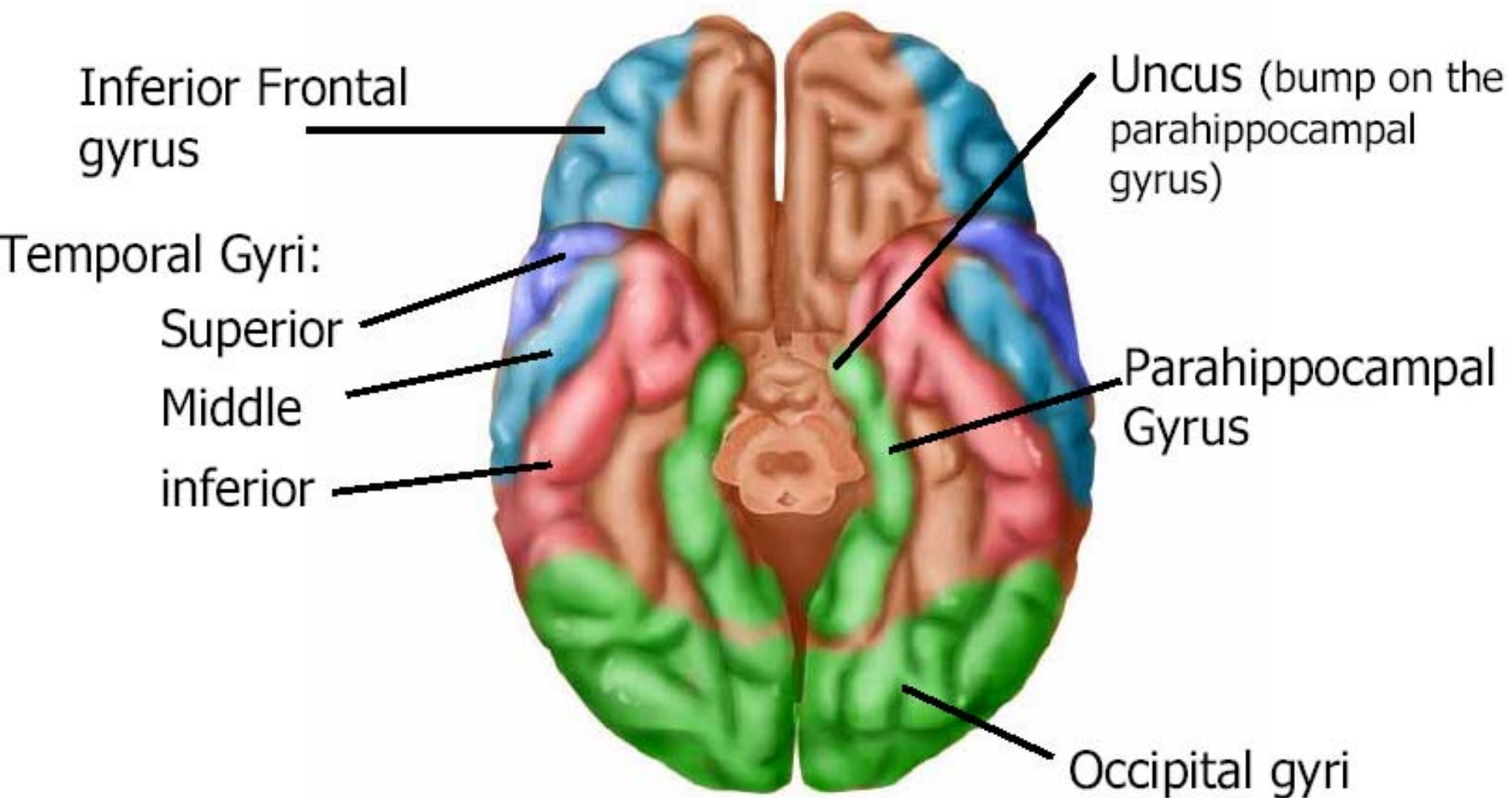








Inferior surface of the cerebrum –
brainstem and cerebellum removed



The Brainstem “the lower brain”

- *Consists of a stalk with caplike swellings at the anterior end of the spinal cord*
- Three parts:
 - *Medulla oblongata* – contains centers that controls several visceral functions
 - Ex. ~ (functions) breathing, heart & blood activity, etc.
 - *Pons* – participates in certain automatic, homeostatic functions
 - Ex. ~ regulating breathing centers in medulla
 - *Midbrain* – develops into *sensory integrating* and *relay centers* that send sensory information to the *cerebrum*
 - Contains centers for the receipt and integration of sensory information
 - Contain neuron cell bodies that send axons to many areas of the cerebral cortex and cerebellum → releases neurotransmitters
 - Prominent centers: inferior & superior colliculi
[part of auditory and visual systems]

The Brainstem [continued]

- Functions in: homeostasis, coordination of movement, and conduction of information to higher brain centers
 - Ex. ~ norepinephrine, dopamine, serotonin, & acetylcholine
 - Causes changes in attention, alertness, appetite and motivation
 - Most axons carrying info about movement cross from one side of the CNS to the other in the medulla
 - Therefore – the right side of brain controls much of the movement of the left side of the body, and vice versa
- All axons carrying *sensory* information to the higher brain regions must pass through the *brainstem*
- *Reticular Formation* = a diffuse network of neurons
 - Contains over 90 separate clusters of cell bodies; passes through the core of the brainstem
 - *Reticular Activating System* (RAS) – regulates sleep & arousal

The Cerebellum

- Developed from Metencephalon
- Coordination & error checking skills
 - For motor, perceptual, and cognitive functions
 - cognitive – includes an integrated sensory awareness of the surroundings
- Learning and Remembering skills
 - Ex. ~ riding a bicycle
- Receives Sensory Information
 - Position of joints and the length of the muscles
 - Auditory and visual systems
- Given Input on Motor Commands
 - Integrates this sensory & motor information while coordinating movements & balance
- Major Ex. ~ hand-eye coordination
 - If cerebellum is damaged – eyes can only *follow* a moving object, but they won't *stop* at the same place as the object

Depending on the area and side of the cerebrum affected by the stroke, any, or all, of the following body functions may be impaired:

- movement and sensation
- speech and language
- eating and swallowing
- vision
- cognitive (thinking, reasoning, judgment and memory) ability
- perception and orientation to surroundings
- self-care ability
- bowel and bladder control
- emotional control
- sexual ability

Effects of a right hemisphere stroke:

The effects of a right hemisphere stroke may include the following:

- left-sided weakness (left hemiparesis) or paralysis (left hemiplegia) and sensory impairment
- denial of paralysis or impairment and reduced insight into the problems created by the stroke (this concept is called "left neglect")
- visual problems, including an inability to see the left visual field of each eye (homonymous hemianopsia)
- spatial problems with depth perception or directions such as up/down and front/back
- inability to localize or recognize body parts
- inability to understand maps and find objects such as clothing or toiletry items
- memory problems
- behavioral changes such as lack of concern about situations, impulsivity, inappropriateness, and depression

Effects of a left hemisphere stroke:

The effects of a left hemisphere stroke may include the following:

- right-sided weakness (right hemiparesis) or paralysis (right hemiplegia) and sensory impairment
- problems with speech and understanding language (aphasia)
- visual problems, including the inability to see the right visual field of each eye (homonymous hemianopsia)
- impaired ability to do math or to organize, reason, and analyze items
- behavioral changes such as depression, cautiousness, and hesitancy
- impaired ability to read, write, and learn new information
- memory problems

What effects can be seen with a stroke in the brain stem?

The brain stem is located at the very base of the brain right above the spinal cord. Many of the body's vital "life-support" functions such as heartbeat, blood pressure, and breathing are controlled by the brain stem. It also helps to control the main nerves involved with eye movement, hearing, speech, chewing, and swallowing. Some common effects of a stroke in the brain stem include problems with the following:

- breathing and heart functions
- body temperature control
- balance and coordination
- weakness or paralysis in all four limbs
- chewing, swallowing, and speaking
- vision
- coma

Unfortunately, death is common with brain stem strokes.

The Diencephalon

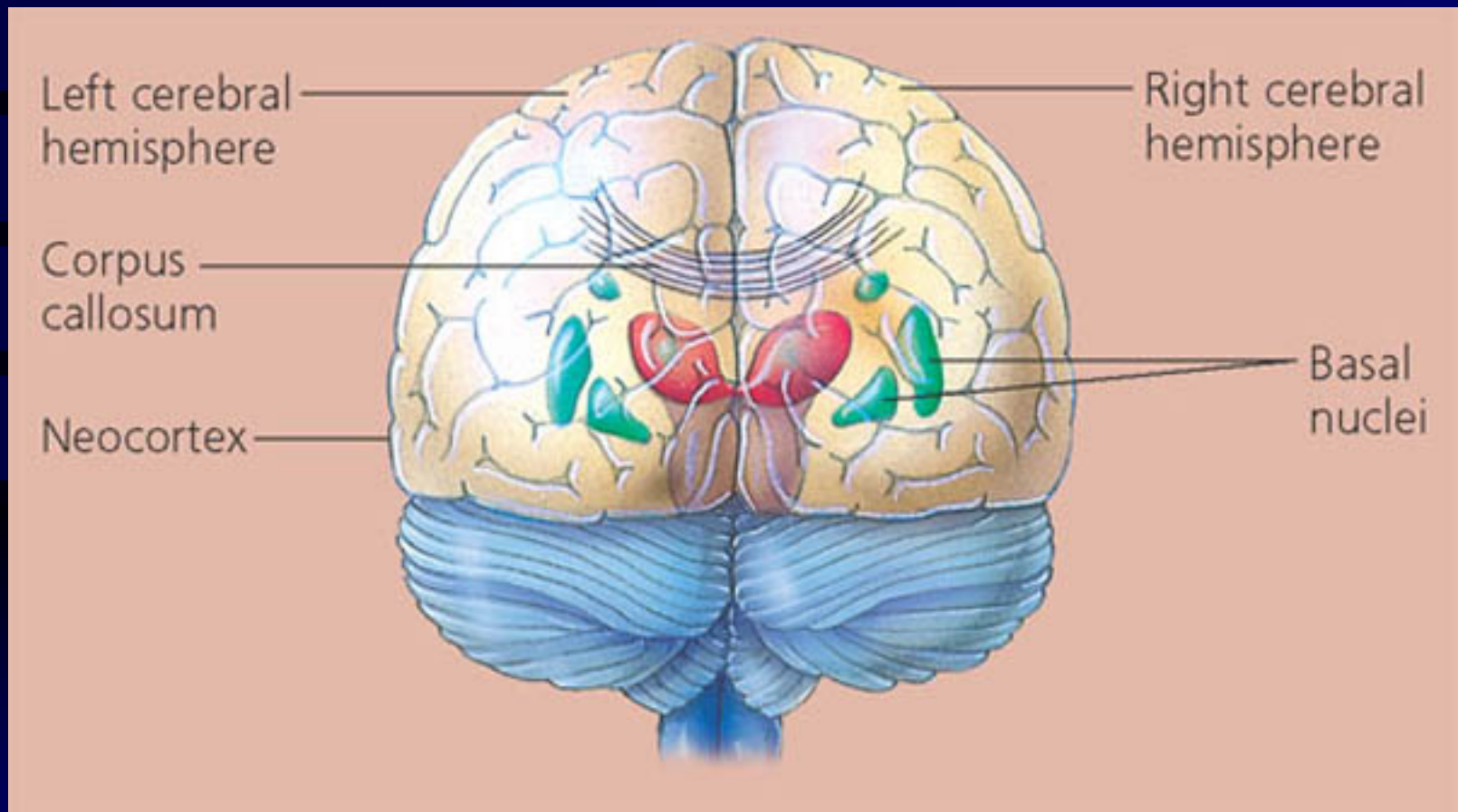
Embryonic version → 3 adult brain regions:

- **Epithalamus** = pineal gland & *choroid plexus*
 - Choroid plexus: capillaries that produce *cerebrospinal fluid* from blood
- **Thalamus** = main input center for *sensory info* going to the cerebrum & main output center for *motor info* leaving the cerebrum
- **Hypothalamus** = contains many other basic survival mechanisms
 - Mechanisms – body's thermostat, regulates hunger, thirst, sexual & mating behaviors, the fight-or-flight response, and pleasure
 - source of two sets of hormones:
 - *posterior pituitary* hormones & *releasing* hormones that act on the anterior pituitary
- **Biological clock** = involved in maintaining circadian rhythms
[animals]
 - Include: hormone release, hunger, & heightened sensitivity to external stimuli
- **Suprachiasmatic Nuclei (SCN)** = biological clock; pair of hypothalamic structures
 - Ex. ~ visual info about light intensity transmitted to SCN synchronizes the mammalian clock with the natural cycles of day length & darkness

The Cerebrum

- Forebrain → Telencephalon → *cerebrum* and *cerebral cortex*
 - extends over/around much of human brain
 - Outgrowth of forebrain – evolved so to support olfactory reception as well as *auditory & visual* processing
- Cerebral Hemispheres = left & right hemisphere; consists of an outer covering of *gray matter*, the *cerebral cortex*, internal *white matter*, and *basal nuclei*
 - **Basal nuclei** = groups of neurons located deep within the white matter
 - Important centers – planning and learning movement sequences
 - **Cerebral Cortex** = sensory information analyzed, motor commands issued, and language is generated
 - Mammals possess a region in it known as the *neocortex*
 - **Neocortex** = forms outermost part of the mammalian cerebrum; consists of 6 parallel layers of neurons running tangential to the brain surface
 - **Corpus callosum** = thick band of axons that enable communication between right & left cerebral cortices
 - » Damage to one area of the cerebrum early in development frequent causes redirection of its normal functions to other areas;
Ex. ~ an entire infant's cerebral hemisphere is removed as a treatment for severe epilepsy

The Cerebrum



Information Processing

cerebral cortex

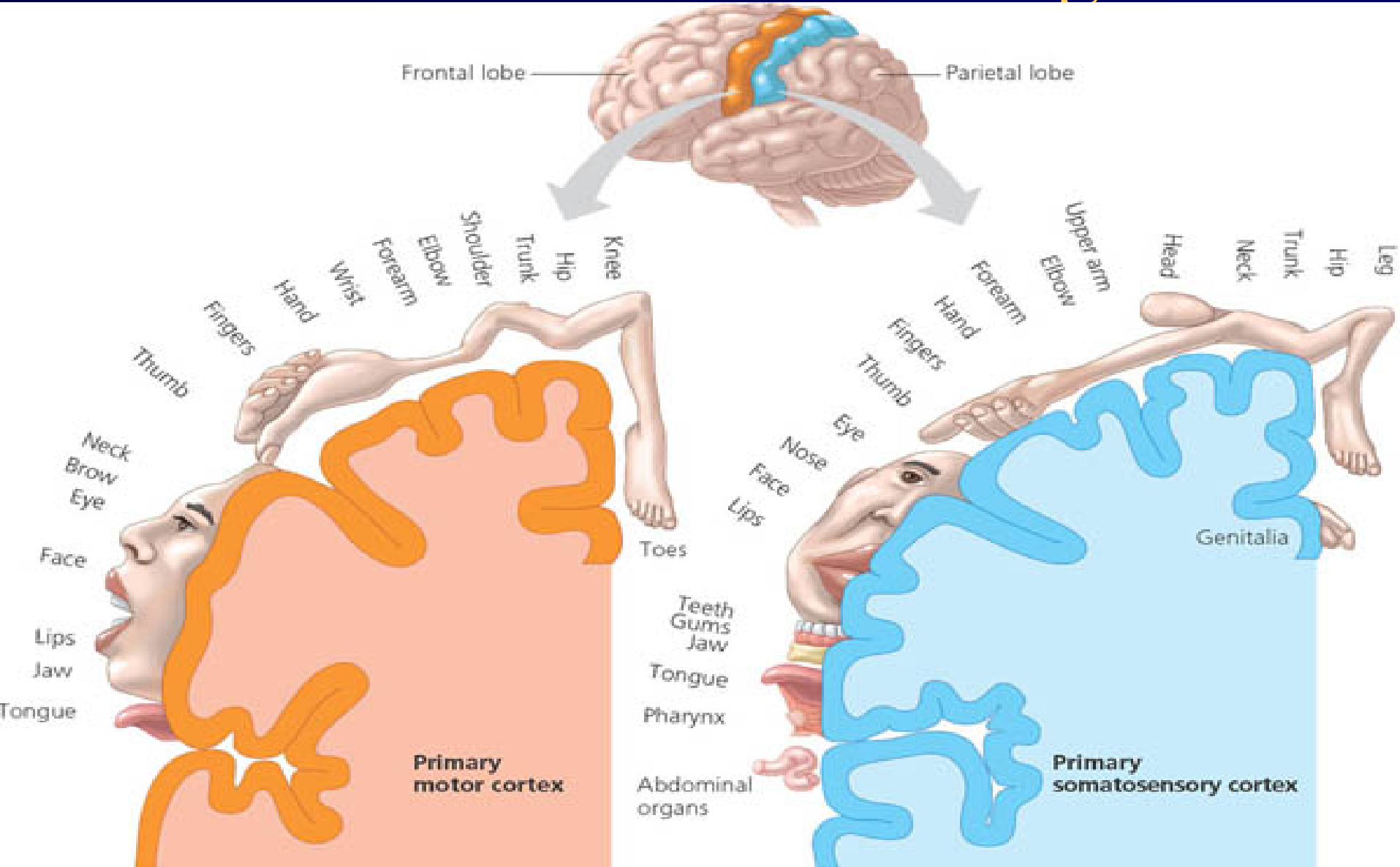
- Most sensory info coming into the cortex – directed via the thalamus to primary sensory areas within the lobes:
 - visual information → occipital lobe
 - auditory input → temporal lobe
 - Olfactory info → “primitive” regions → frontal lobe
 - somatosensory info → parietal lobe
 - touch, pain, pressure, position of muscles & limbs, temperature
 - Taste (separate sensory region, same lobe)
- Two primary parts:
 - Somatosensory and Motor cortex
 - Both of their neurons are distributed according to the part of the body that generates the sensory input or receives the motor commands

Information Processing

cerebral cortex

- **Primary Somatosensory Cortex** – send info to nearby association areas that can process particular features in the sensory input
 - Ex.~ *Primary visual cortex* – some neurons are sensitive to bars of light that have a certain width & orientation
- **Primary Motor Cortex** – helps issue commands that consist of action potentials produced by neurons [located: rear of frontal lobe, adjacent to the primary somatosensory cortex]
 - Action potentials travel along axons to brainstem & spinal cord → excite motor neurons → excite skeletal muscle cells

Information Processing



Voluntary Movement and Cognitive Functions

- *Lateralization* = segregation of functions in the left and right cortex hemispheres of the brain
 - Left hemisphere – language, math, logical operations, & serial processing of info sequences
 - Specializes in focused perception
 - for the detailed, speed-optimized activities & the processing of fine visual and auditory details
 - Right hemisphere – pattern recognition, face recognition, spatial relations nonverbal thinking, emotional processing in general; the simultaneous processing of many kinds of info
 - Specializes in perceiving the relationship between images and the whole context in while they occur
 - Emphasis on *understanding* and generating *stress & intonation patterns* of *speech* that convey *emotional* content

Voluntary Movement and Cognitive Functions

Language and speech

- *Broca's area* – located at left frontal lobe and is part of the primary motor cortex that controls muscles in the face
- *Wernicke's area* – posterior portion of the temporal lobe that controls comprehension and generation of speech
- Frontal & temporal areas become active when meaning must be attached to words (ex. ~ a person generates verbs to go with nouns)
 - Damage in this spot abolishes the ability to comprehend speech, but left speech generation intact

Emotions

- Result of a complex interplay of many regions of the brain
- **Limbic system** = a ring of structures around the brainstem composed of three main parts and some inner portions of the thalamus and hypothalamus
 - Includes three parts – amygdala, hippocampus, and olfactory bulb
 - Attaches “feelings” to basic, survival-related functions controlled by brainstem
 - Interacts with sensory areas of the neocortex & other higher brain centers
 - Mediates primary emotions → becomes manifested in behaviors like laughing & crying

Voluntary Movement and Cognitive Functions

- Memory and Learning
 - *Short-term memory* – the ability to hold information, anticipations, or goals for a time and then release them if they become irrelevant
 - *Long-term memory* – the ability to hold, associate, and recall information over one's life
 - Motor skills – learned by repetition
 - Transfer from short-term → long-term: enhanced by rehearsal (“practice makes perfect!”), positive or negative emotional state (amygdala), and the association of new data with data previously learned & stored in long-term memory
 - *Neurons make new connections* (help with memorization of facts/places)
 - *Long-term potentiation* (LTP) – involves an increase in the strength of synaptic transmission that occurs when presynaptic neurons produce a brief, high-frequency series of action potentials
- Consciousness [both broad & subjective]
 - fMRI – brain-imaging technique; allows for the human brain activity (in its different states of consciousness) to be observed
 - Postulations: “is an emergent property of the brain” & “scanning mechanism – repetitively sweeps across the brain, integrating widespread activity into a unified, conscious moment”

Physiology

- Nervous system conveys high-speed *electrical signals* along neurons → such rapid messages control the movement of body parts in response to sudden environmental changes
 - Ex.1 ~ jerking hand away from a hot pan
 - Ex.2 ~ pupils dilating as you enter a dark room
- Overlaps with endocrine regulation
 - **Neurosecretory cells** = release hormones into blood (contained in the *hypothalamus* part of the brain); produce *neurohormones*

Control Pathways & Feedback Loops

- *Receptor (sensor)* – detects a stimulus and sends information to *control center*
 - **Control center** = compares the incoming info to a *set point* (“desired” value) and sends out a signal that directs an *effector* to respond
 - Ex. ~ a change in blood calcium level
- *Positive Feedback* – reinforces the stimulus and leads to an even greater response
 - Ex. ~ neurohormone pathway that regulates the release of milk by a nursing mother; suckling *stimulates sensory nerve cells* in the nipples, which send *nervous signals* that eventually reach the *control center* (hypothalamus)
- *Negative Feedback* – the effector response reduces the initial stimulus → response ceases
 - Prevents overreaction by the system and wild fluctuations in the variable being regulated

- Baby's Brain

- <http://www.pbs.org/wnet/brain/episode1/video.html>

Spinal Cord

- The spinal cord extends from the foramen magnum at the base of the skull to the level of the first lumbar vertebra.
- The cord is continuous with the medulla oblongata at the foramen magnum.
- Like the brain, the spinal cord is surrounded by bone, meninges, and cerebrospinal fluid.
- The spinal cord is divided into 31 segments with each segment giving rise to a pair of spinal nerves. At the distal end of the cord, many spinal nerves extend beyond the conus medullaris to form a collection that resembles a horse's tail. This is the cauda equina. In cross section, the spinal cord appears oval in shape.
- The spinal cord has two main functions:
 - Serving as a conduction pathway for impulses going to and from the brain. Sensory impulses travel to the brain on ascending tracts in the cord. Motor impulses travel on descending tracts.
 - Serving as a reflex center. The reflex arc is the functional unit of the nervous system. Reflexes are responses to stimuli that do not require conscious thought and consequently, they occur more quickly than reactions that require thought processes. For example, with the withdrawal reflex, the reflex action withdraws the affected part before you are aware of the pain. Many reflexes are mediated in the spinal cord without going to the higher brain centers.