NERVOUS SYTEM WEEK 3

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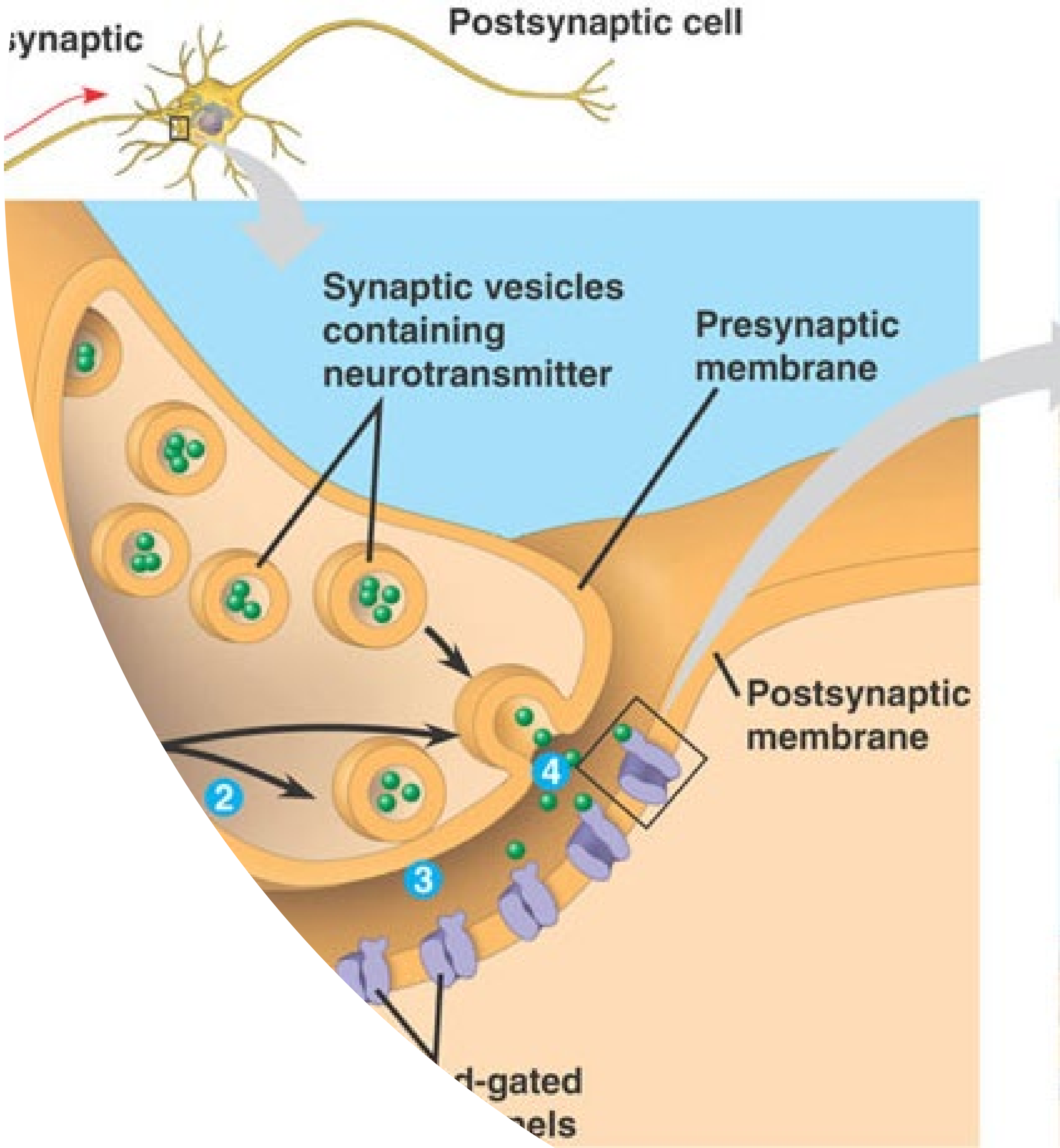
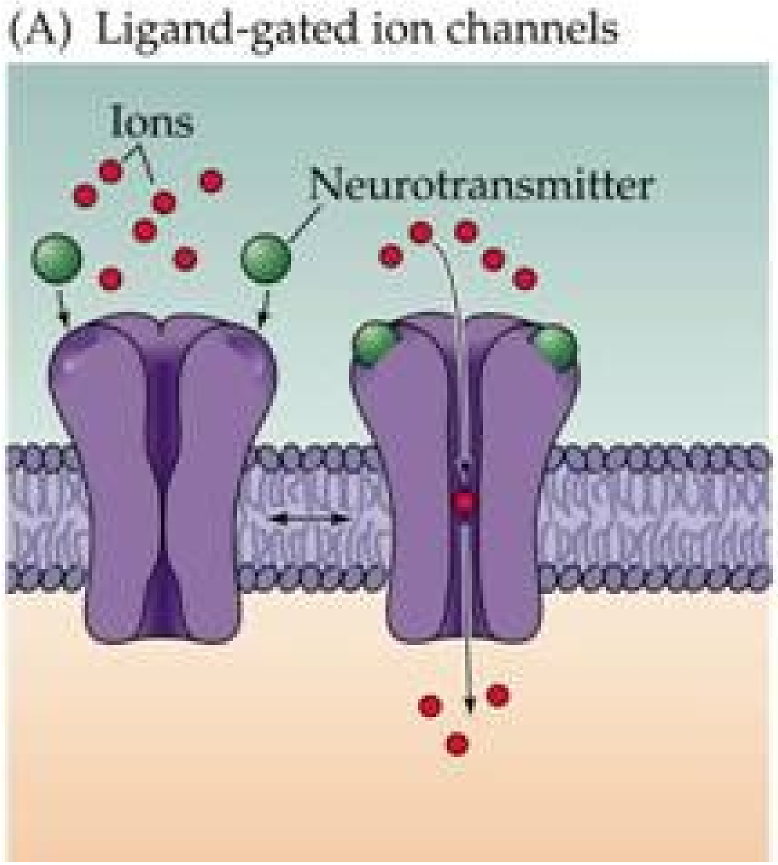
Receptors for neurotransmitters

- Neurotransmitters released from presynaptic sites bind with receptors on the postsynaptic membrane.
- Postsynaptic receptors are special signal recognition proteins.
- Their binding with a neurotransmitter changes the permeability to selected ions through their ion channels.
- This enables ions to distribute across the neuronal membrane according to their electrochemical gradient.

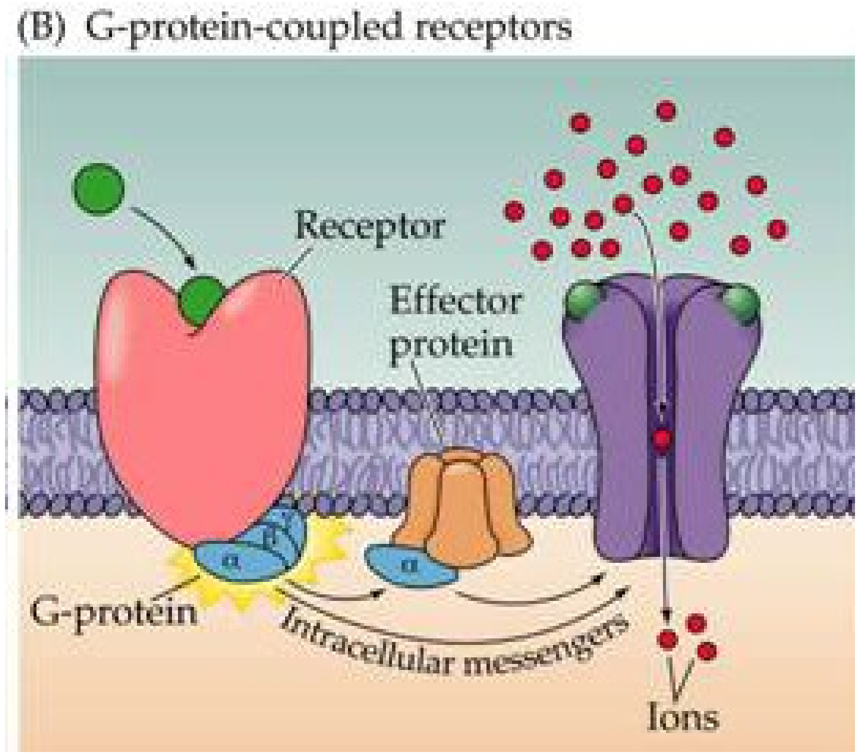


Ionotropic receptor



- The ion channels are gated either **directly** or **indirectly**.
- In **directly gated ion channels**, the binding site for the neurotransmitter is part of the ion channel.
- NT binding results in a conformational change that leads to opening of the ion channel.
- A receptor with directly gated ion channels is referred to as an **ionotropic receptor**.
- This quick synaptic response occurs in just a few milliseconds.
- Neurotransmitters that bind to ionotropic receptors include ACh, glutamate, glycine, and GABA.

Metabotropic receptor



- **Indirectly gated channels**, in contrast, are separated from the binding site of the neurotransmitter.
- Such receptors are called **metabotropic receptors**.
- Binding of neurotransmitters to metabotropic receptors activates a guanosine 5'-triphosphate (GTP)-binding protein (G-protein).
- G-protein, in turn, activates a second messenger system that either (i) opens the ion channel by directly acting on it or (ii) activates an enzyme that opens the channel by phosphorylating the channel protein.

Receptors for neurotransmitters

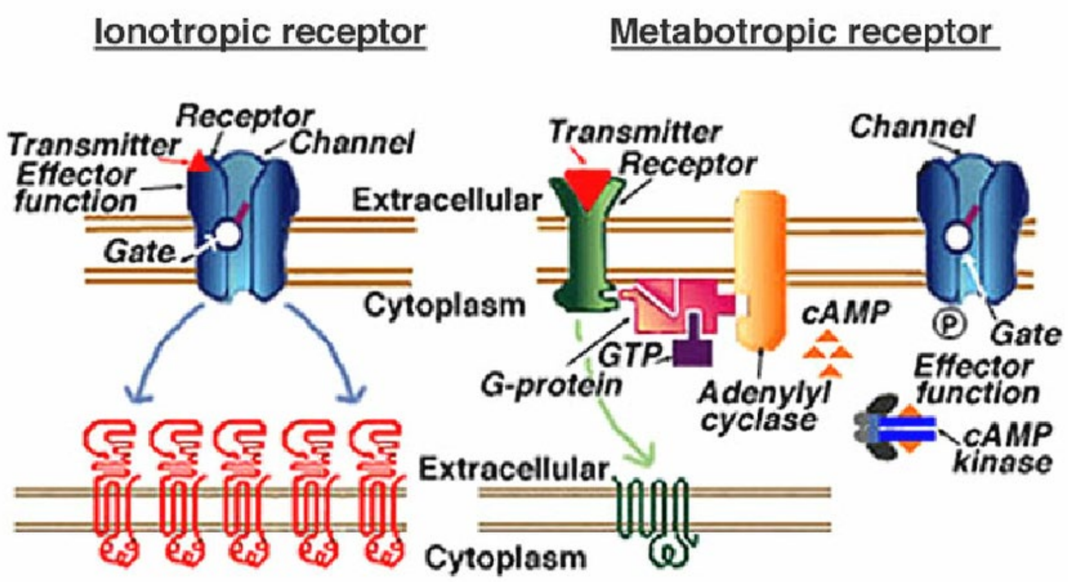
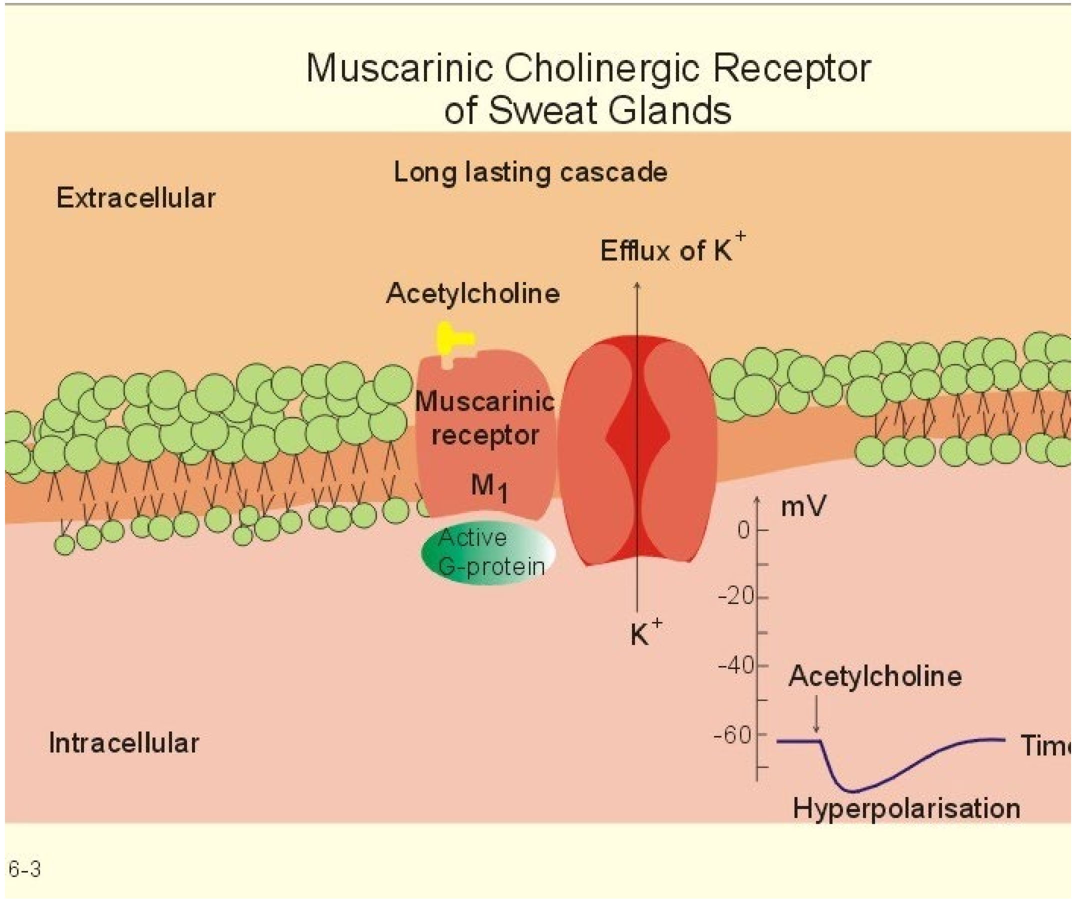


Fig. 5a. Ionotropic receptors and their associated ion channels form one complex (top). Each iGluR is formed from the co-assembly of multiple (4-5) subunits (From Kandel et al., 1991).

Fig. 5b. Metabotropic receptors are coupled to their associated ion channels by a second messenger cascade (top). Each mGluR is composed of one polypeptide, which is coupled to a G-protein (from Kandel et al., 1991).

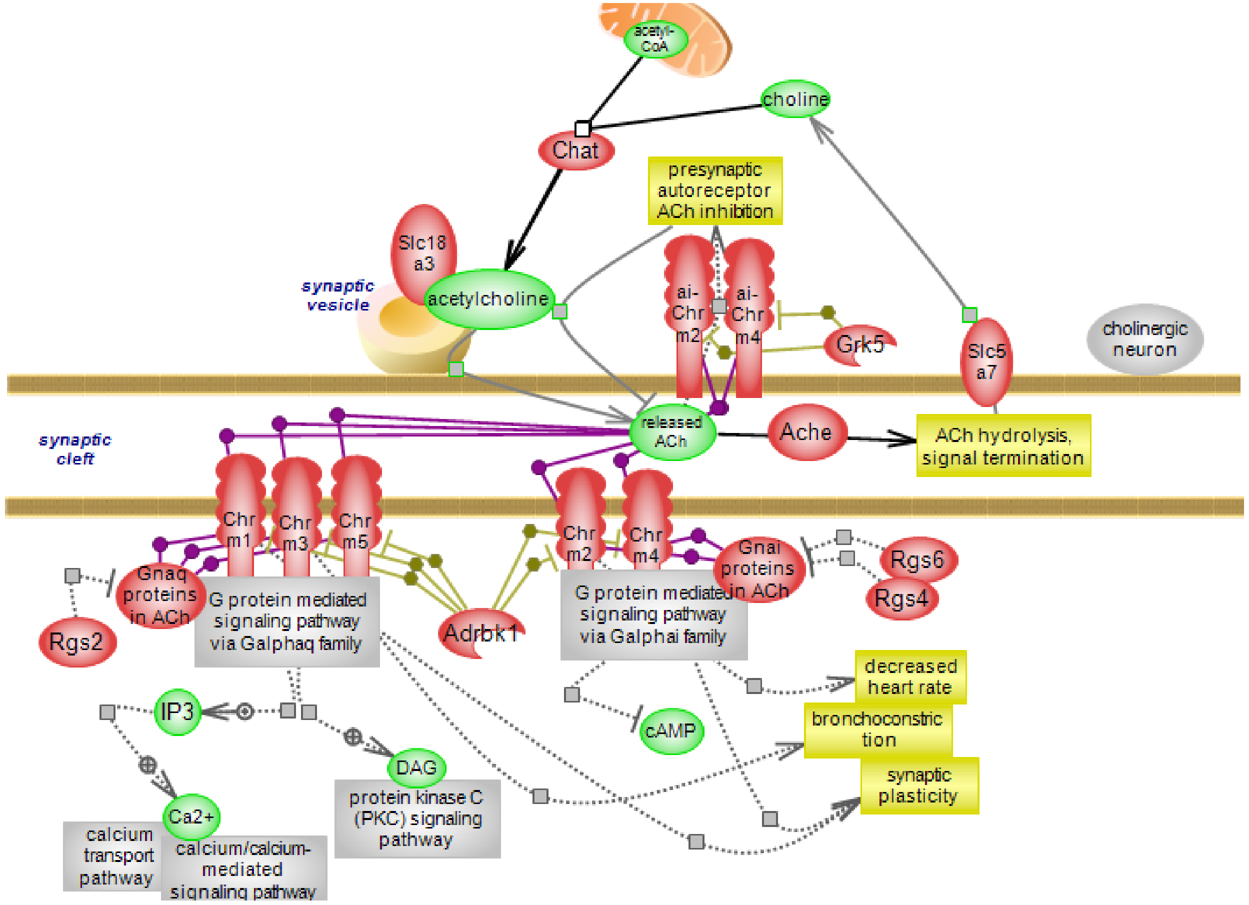
- Activation of metabotropic receptors leads to slow and long-lasting synaptic action.
- Neurotransmitters in the CNS and PNS, with the exception of nitric oxide, bind to several different receptor types.
- Each receptor type may have numbers of subtypes, which trigger different effects on binding with a given neurotransmitter

Cholinergic receptors



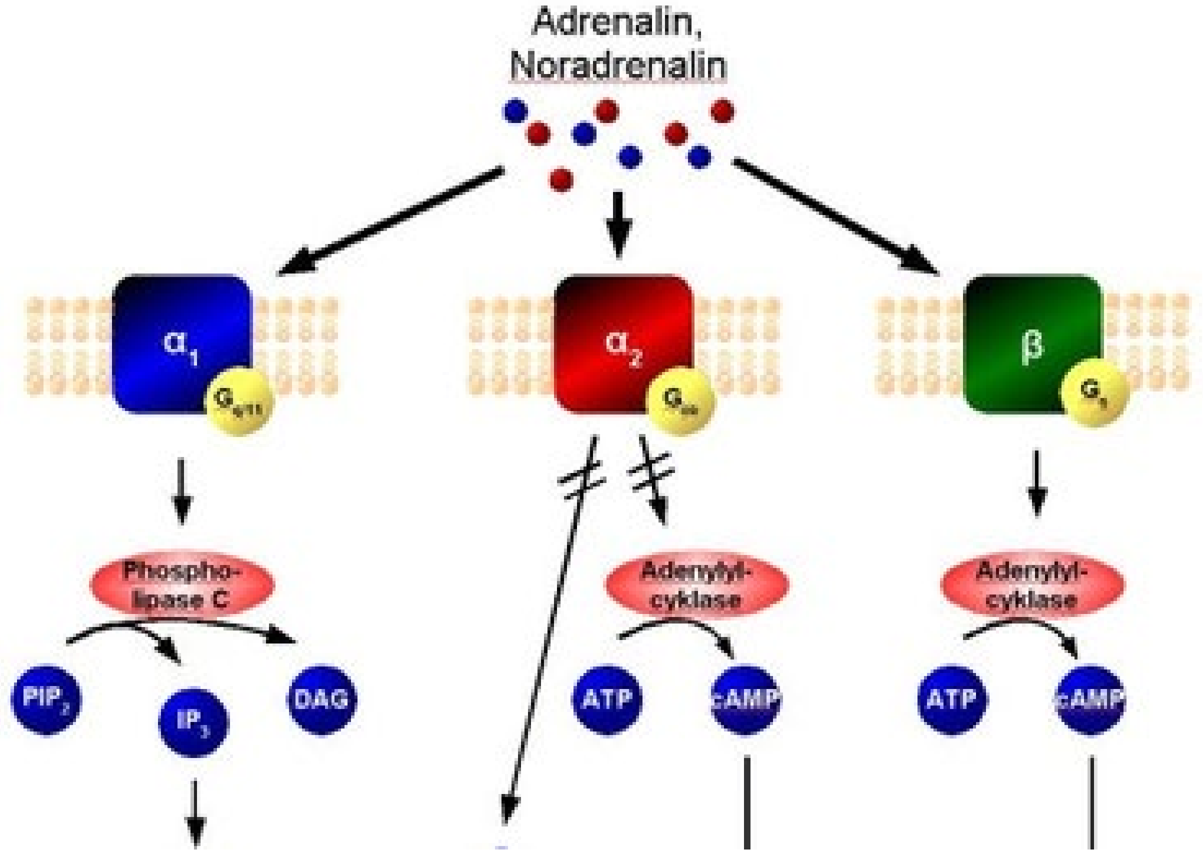
- There are two subtypes of cholinergic receptors (i.e., receptors that bind ACh), **nicotinic** and **muscarinic**.
- The name simply indicates that nicotine is an agonist of the nicotinic receptor and muscarine, found in some fungi, is an agonist of the muscarinic receptor.
- **Nicotinic acetylcholine receptors (nAChRs)** are present in the skeletal muscle as well as the central and autonomic nervous systems
- Activation of nicotinic receptors leads to generation of **excitatory postsynaptic potentials** (EPSPs).

Cholinergic receptors



- **Muscarinic acetylcholine receptors (mAChRs)** are present in the CNS and parasympathetic division of the autonomic nervous system
- There are several subtypes of muscarinic receptors (M1, M2, M3, etc.) and all are **coupled to G proteins**.
- Binding of neurotransmitters to their receptors leads to generation of either **excitatory or inhibitory postsynaptic graded potentials.**

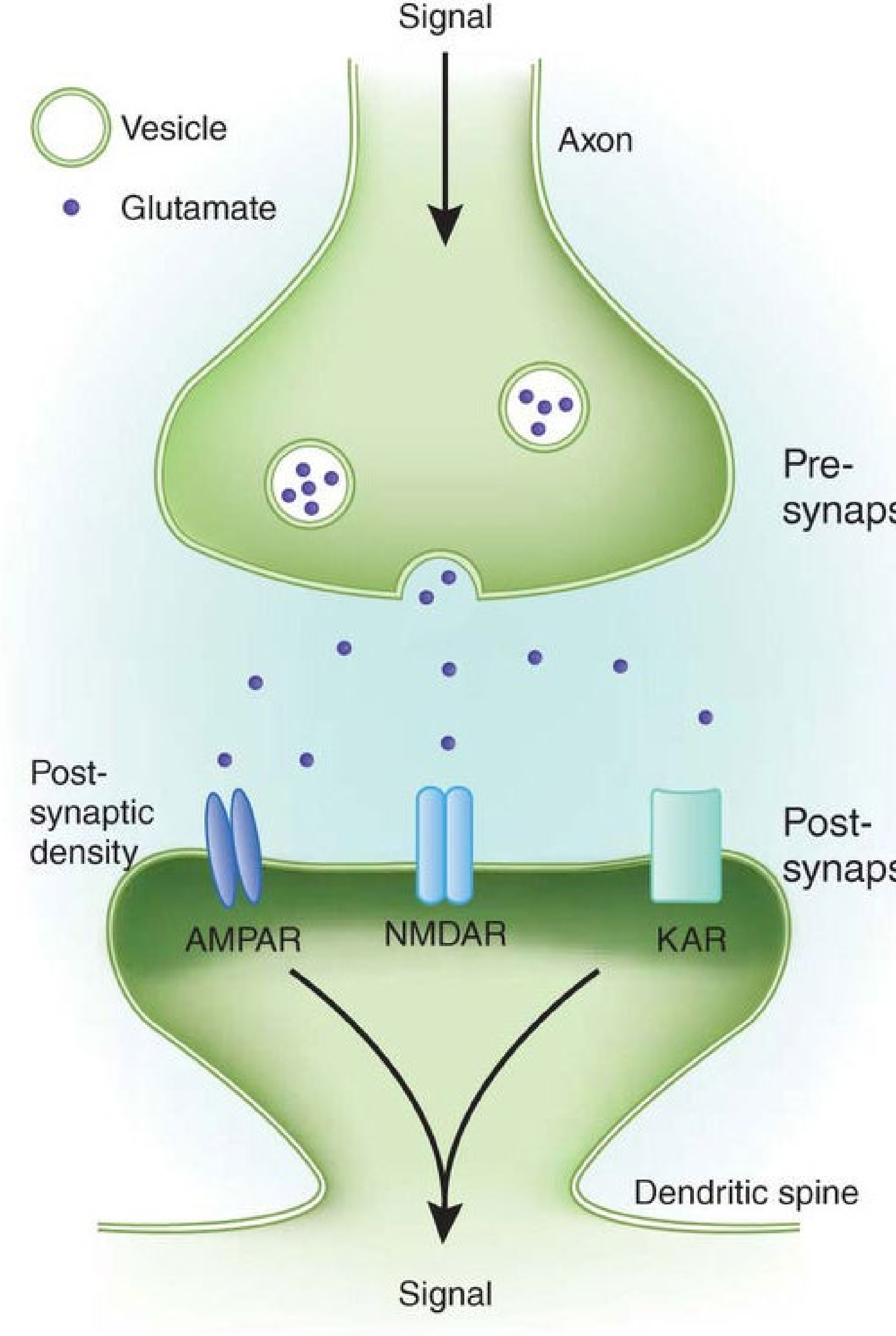
Adrenergic receptors

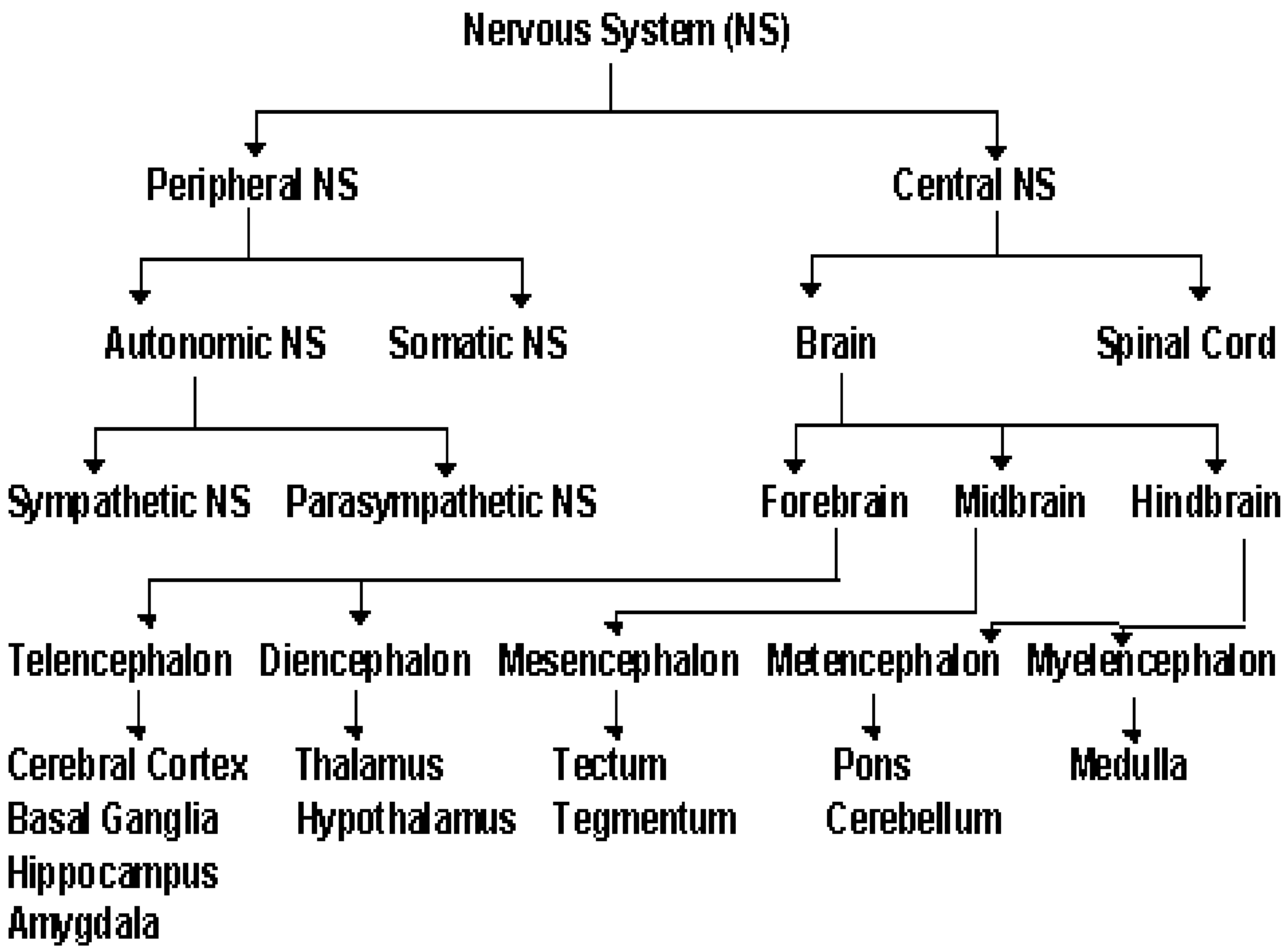


- There are two subtypes of **adrenergic receptors** (i.e., receptors that bind epinephrine and norepinephrine), the α and β.
- Adrenergic receptors are linked to G proteins and initiate second messenger cascades

Glutamate receptors

- The main excitatory neurotransmitter in the CNS is glutamate.
- There are two subtypes of glutamate receptors, NMDA (N-methyl-d-aspartate) and AMPA (α-amino-3-hydroxy-5- methyl-4-isoxazole propionic acid).
- NMDA receptors represent ligand-gated channels that allow passage of Na^+, K^+, and Ca^{2+}.
- AMPA receptors are also ligand-gated cation channels. Their binding with glutamate opens the channels for Na^+ influx, generating EPSPs.

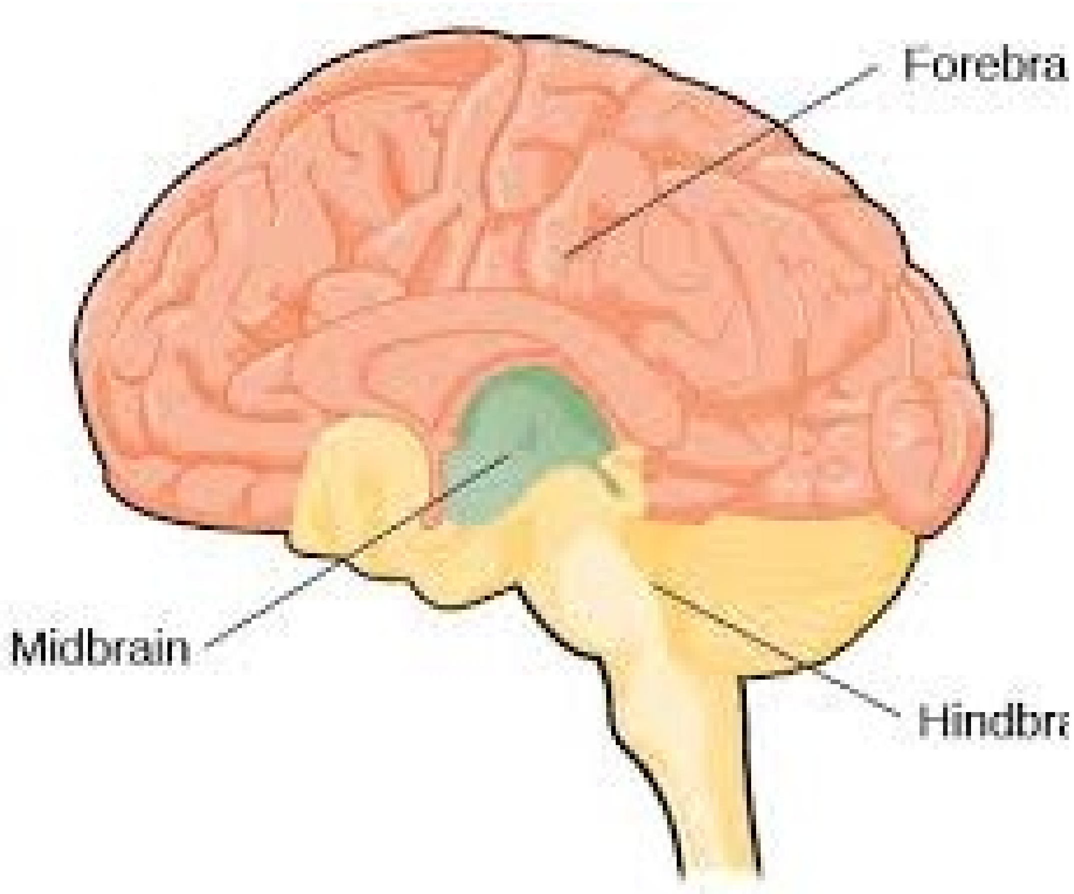




Nervous System (NS)
Peripheral NS
Central NS
Autonomic NS
Somatic NS
Brain
Spinal Cord
Sympathetic NS
Parasympathetic NS
Forebrain
Midbrain
Hindbrain
Telencephalon
Diencephalon
Mesencephalon
Metencephalon
Myelencephalon
Cerebral Cortex
Basal Ganglia
Hippocampus
Amygdala
Thalamus
Hypothalamus
Tectum
Tegmentum
Pons
Cerebellum
Medulla

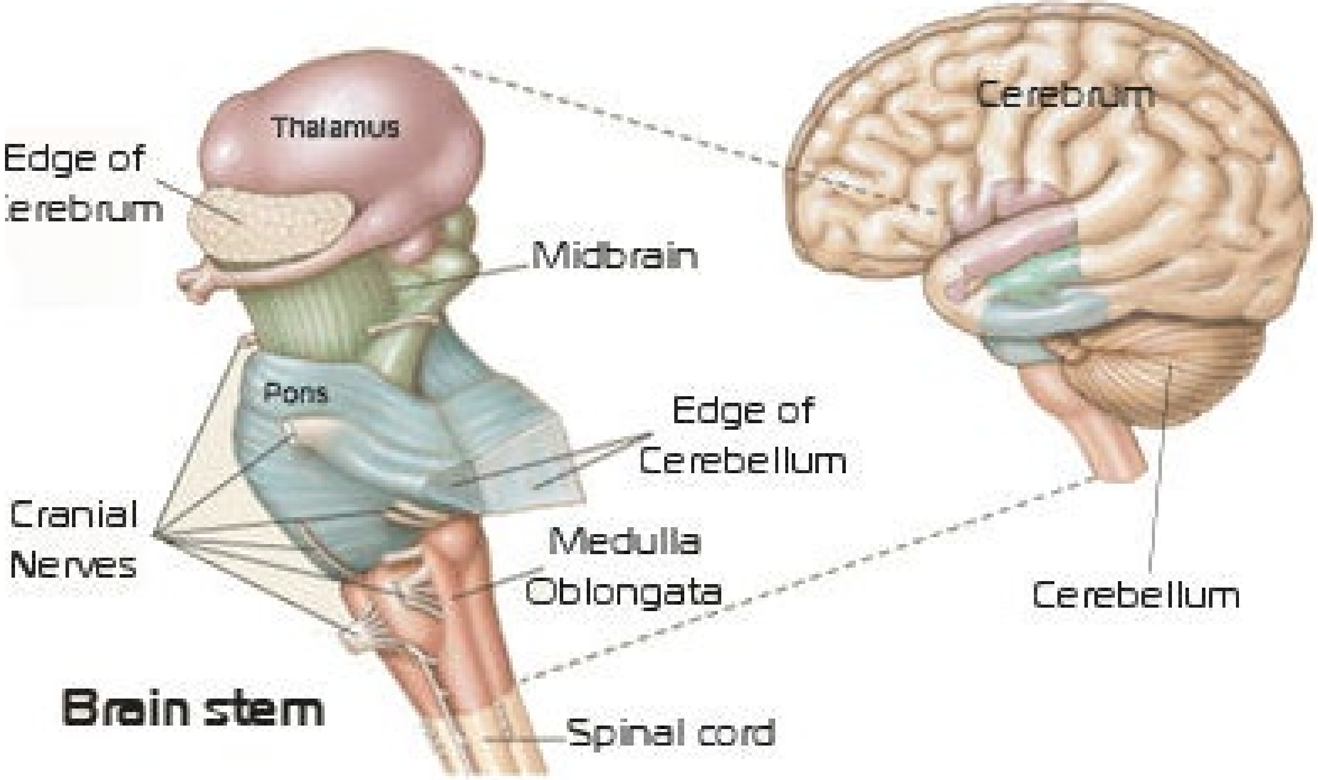
CENTRAL NERVOUS SYSTEM

- During development, the central nervous system forms from a long tube.
- As the anterior part of the tube, which becomes the brain, folds during its continuing formation, four different regions become apparent.
- These regions become the four subdivisions of the brain: **cerebrum, diencephalon, brainstem,** and **cerebellum**
- The cerebrum and diencephalon together constitute the **forebrain.**
- The brainstem consists of the **midbrain, pons,** and **medulla oblongata**



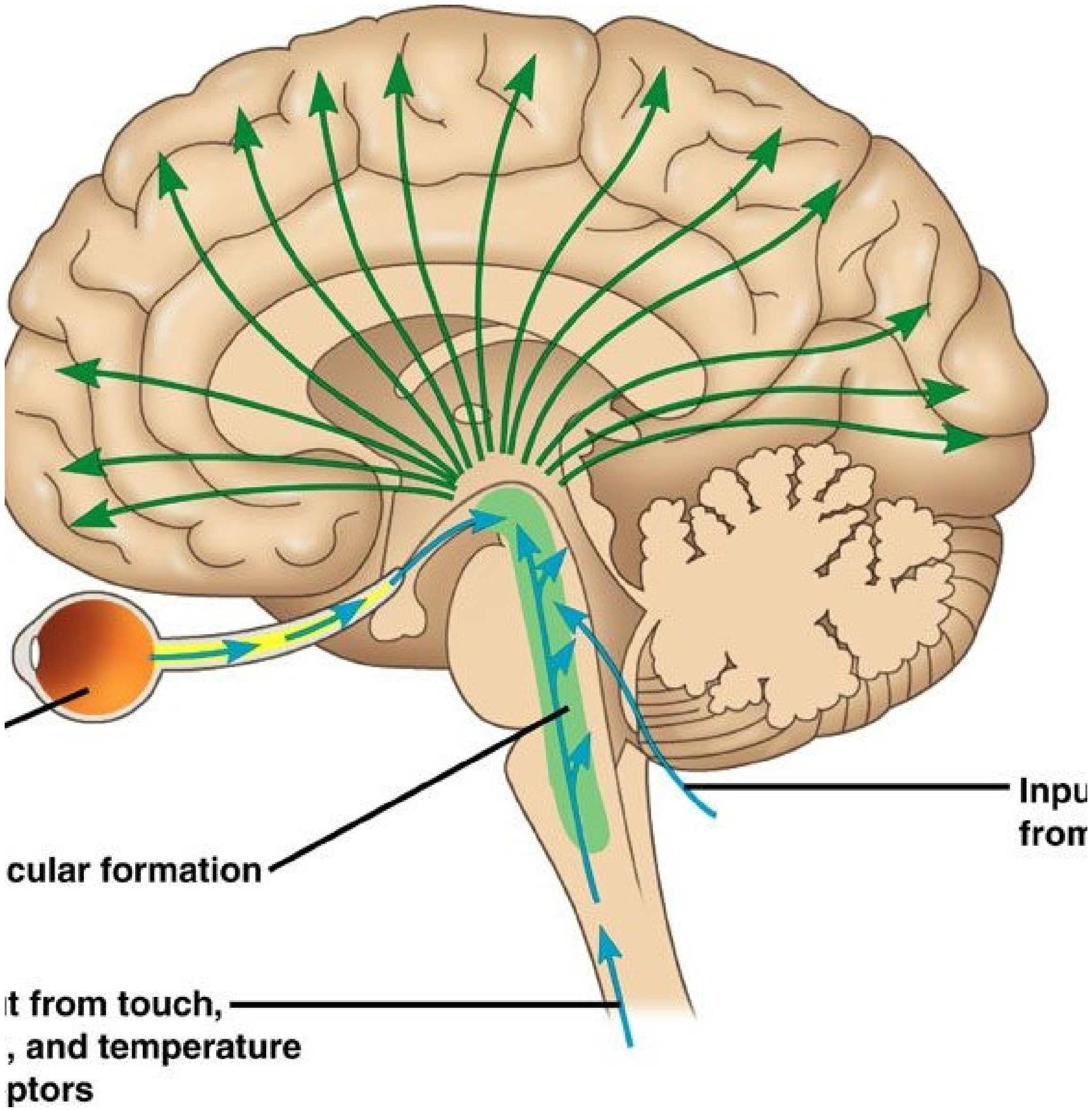
Brainstem

- The brain stem is a general term for the area of the brain between the thalamus and spinal cord.
- Structures within the brain stem include the **medulla, pons, tectum, reticular formation** and **tegmentum**.



Reticular formation

- All the nerve fibers that relay signals between the spinal cord, forebrain, and cerebellum pass through the brainstem.
- Running through the core of the brainstem and consisting of loosely arranged neuron cell bodies intermingled with bundles of axons is the **reticular formation**,
- RF is the one part of the brain absolutely essential for life.
- It receives and integrates input from all regions of the central nervous system and processes a great deal of neural information.



Reticular formation

- The reticular formation is involved in:

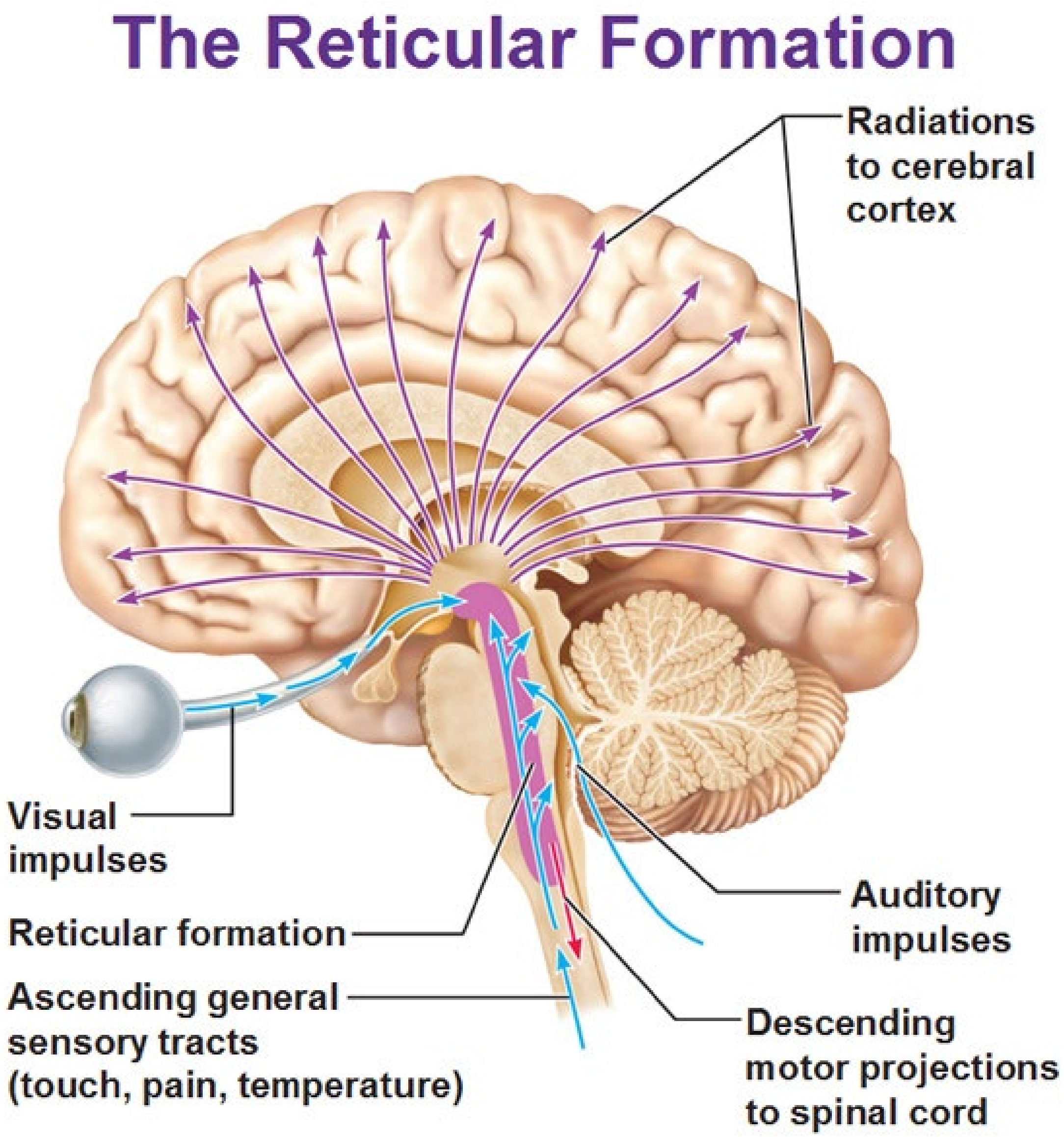
✓motor functions,

✓cardiovascular and

✓respiratory control,

✓and the mechanisms that regulate sleep and wakefulness and focus attention.

- Most of the biogenic amine neurotransmitters are released from the axons of cells in the reticular formation
- Because of the far-reaching projections of these cells, affect all levels of the nervous system.



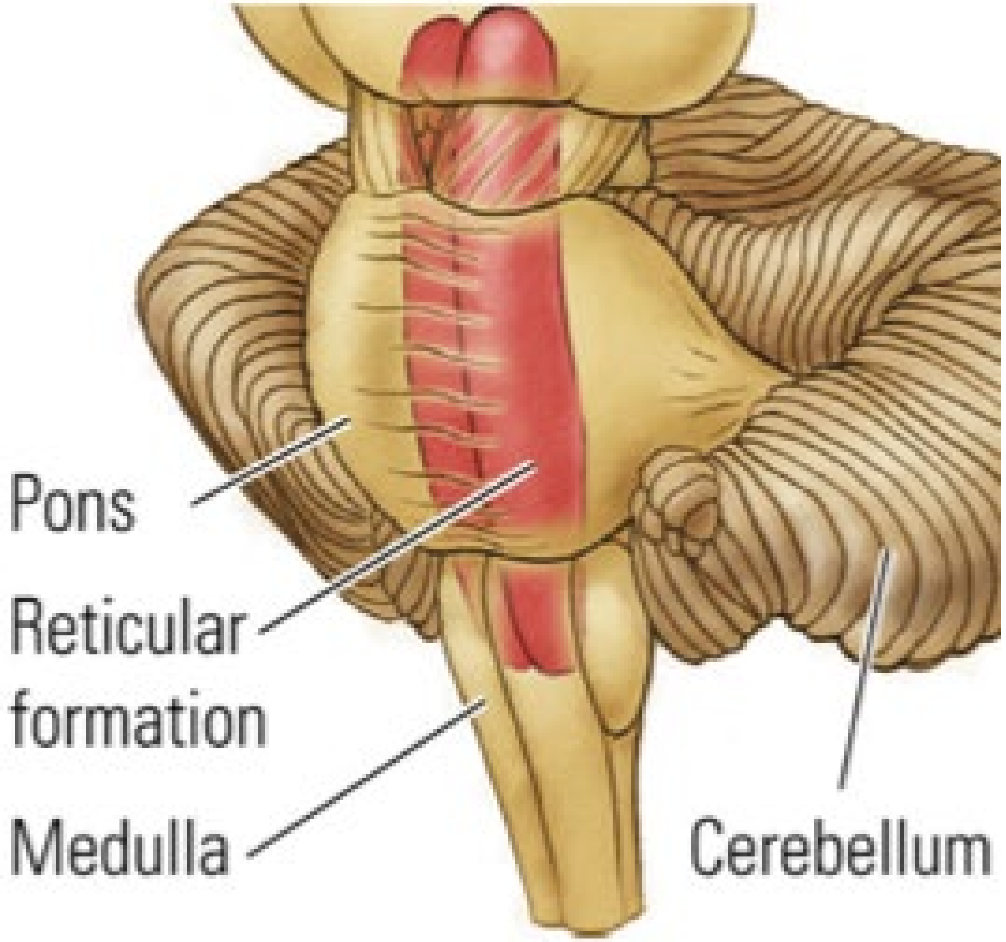
Reticular formation

- The pathways that convey information from the reticular formation to the upper portions of the brain:

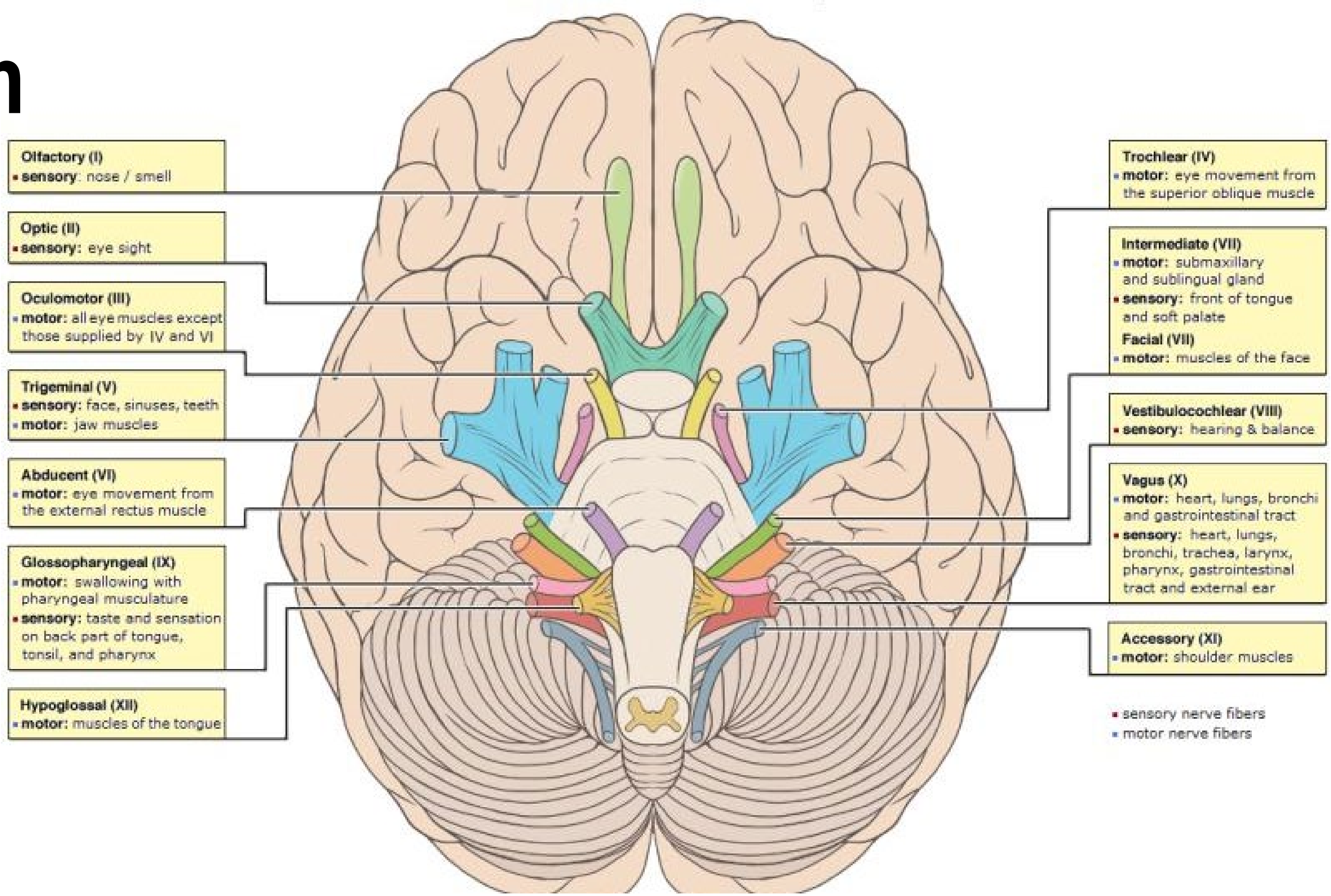
✓affect wakefulness and

✓the direction of attention to specific events by selectively facilitating neurons in some areas of the brain while inhibiting others.

- The fibers that descend from the reticular formation to the spinal cord influence activity in both efferent and afferent neurons.
- There is considerable interaction between the reticular pathways that go up to the forebrain, down to the spinal cord, and to the cerebellum.
- For example, all three components function in controlling muscle activity.



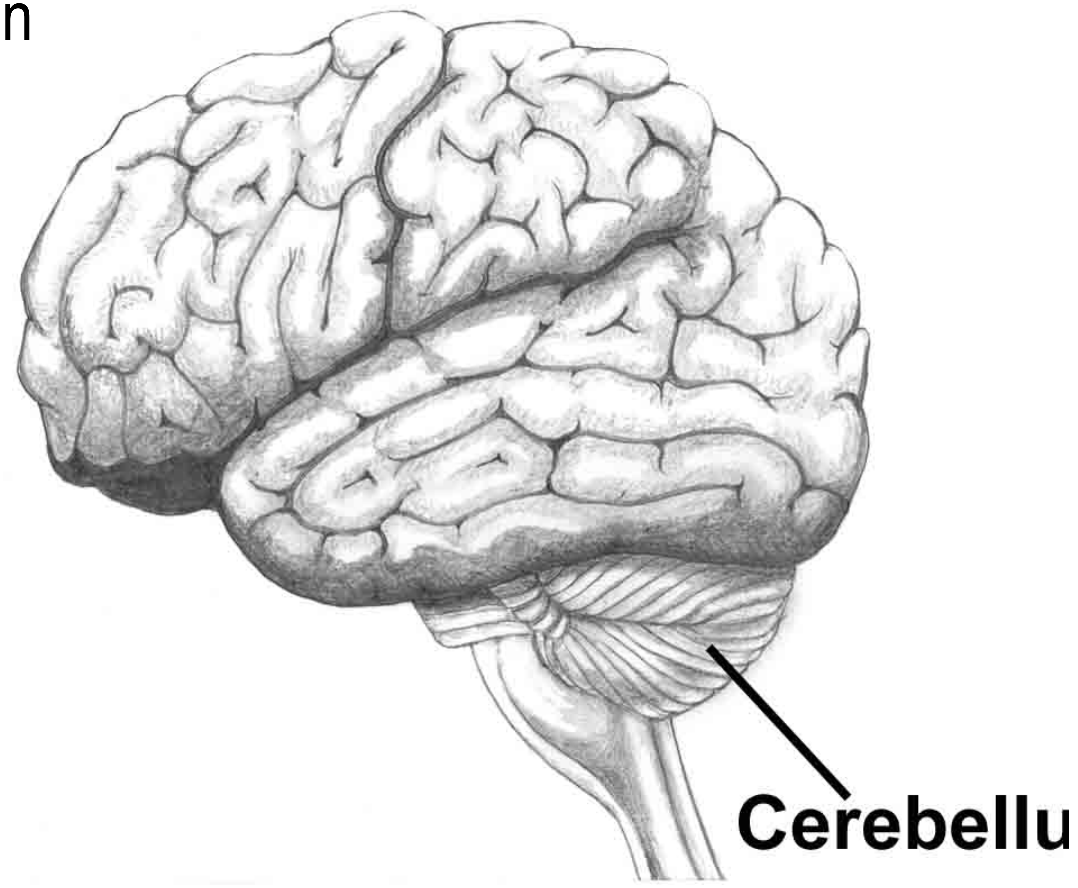
Brainstem



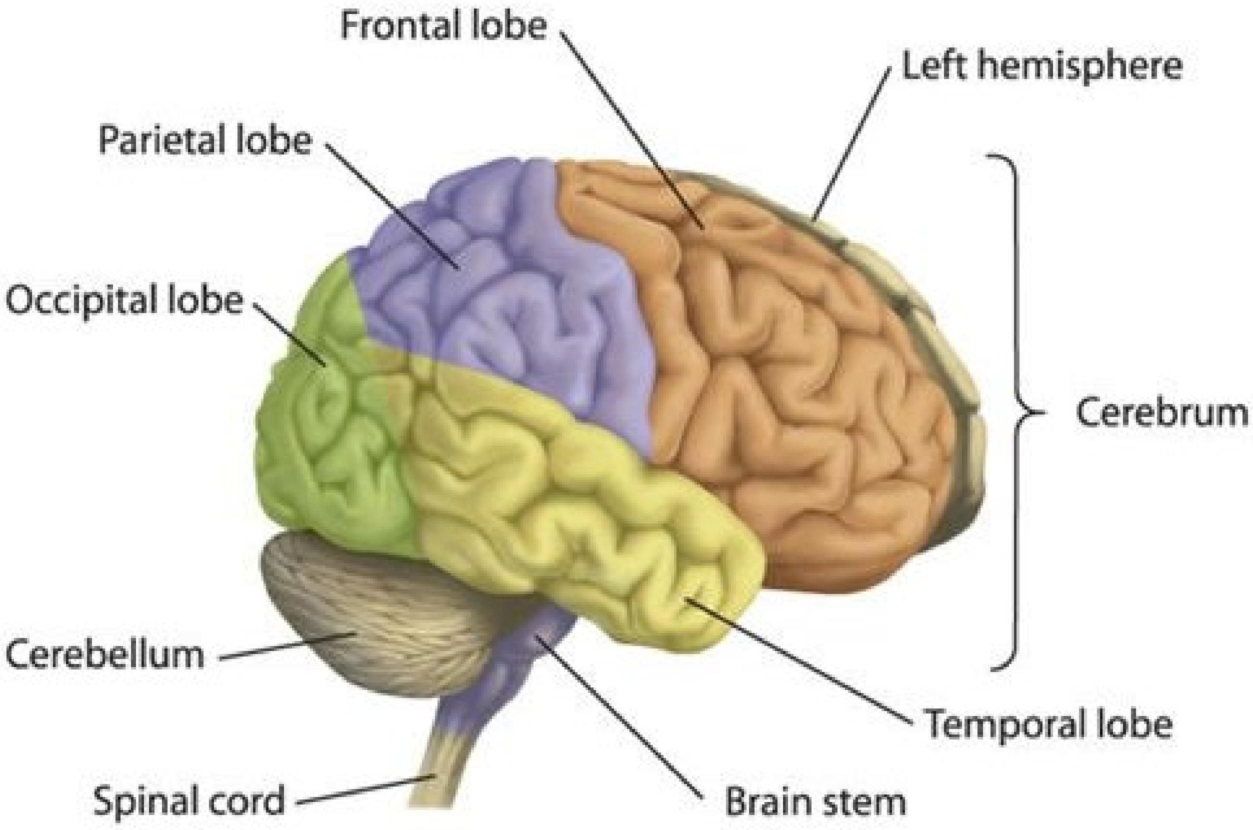
- The brainstem contains nuclei involved in processing information for 10 of the 12 pairs of cranial nerves.

Cerebellum

- The word "cerebellum" comes from the Latin word for "little brain."
- The cerebellum is located behind the brain stem.
- In some ways, the cerebellum is similar to the cerebral cortex: the cerebellum is divided into hemispheres and has a cortex that surrounds these hemispheres.
- **Functions:**
- Movement
- Balance
- Posture



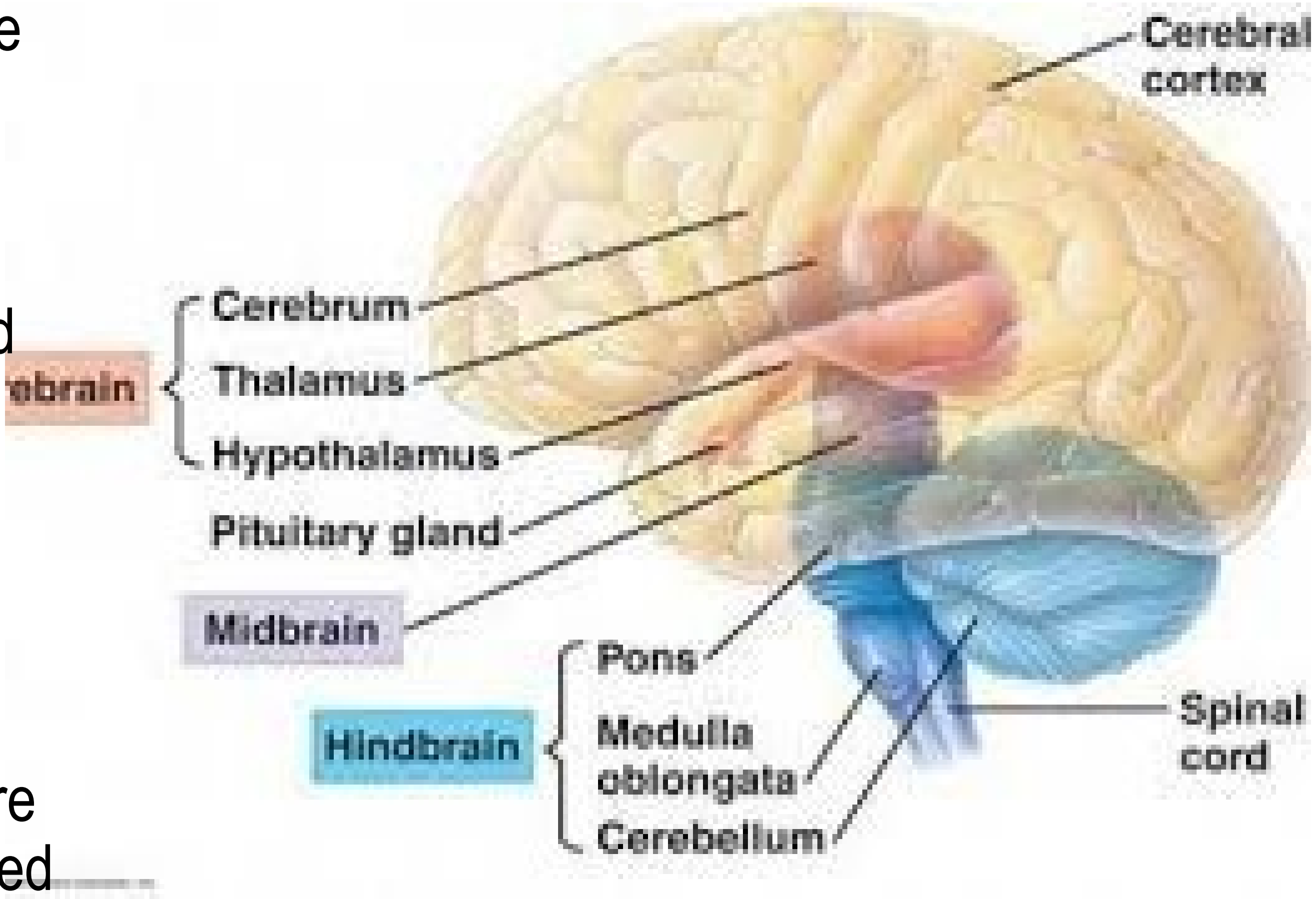
Cerebellum



- Although the cerebellum does not initiate voluntary movements, it is an important center for coordinating movements and for controlling posture and balance.
- In order to carry out these functions, the cerebellum receives information from the muscles and joints, skin, eyes and ears, viscera, and the parts of the brain involved in control of movement.
- Although the cerebellum's function is almost exclusively motor, it is implicated in some forms of learning.

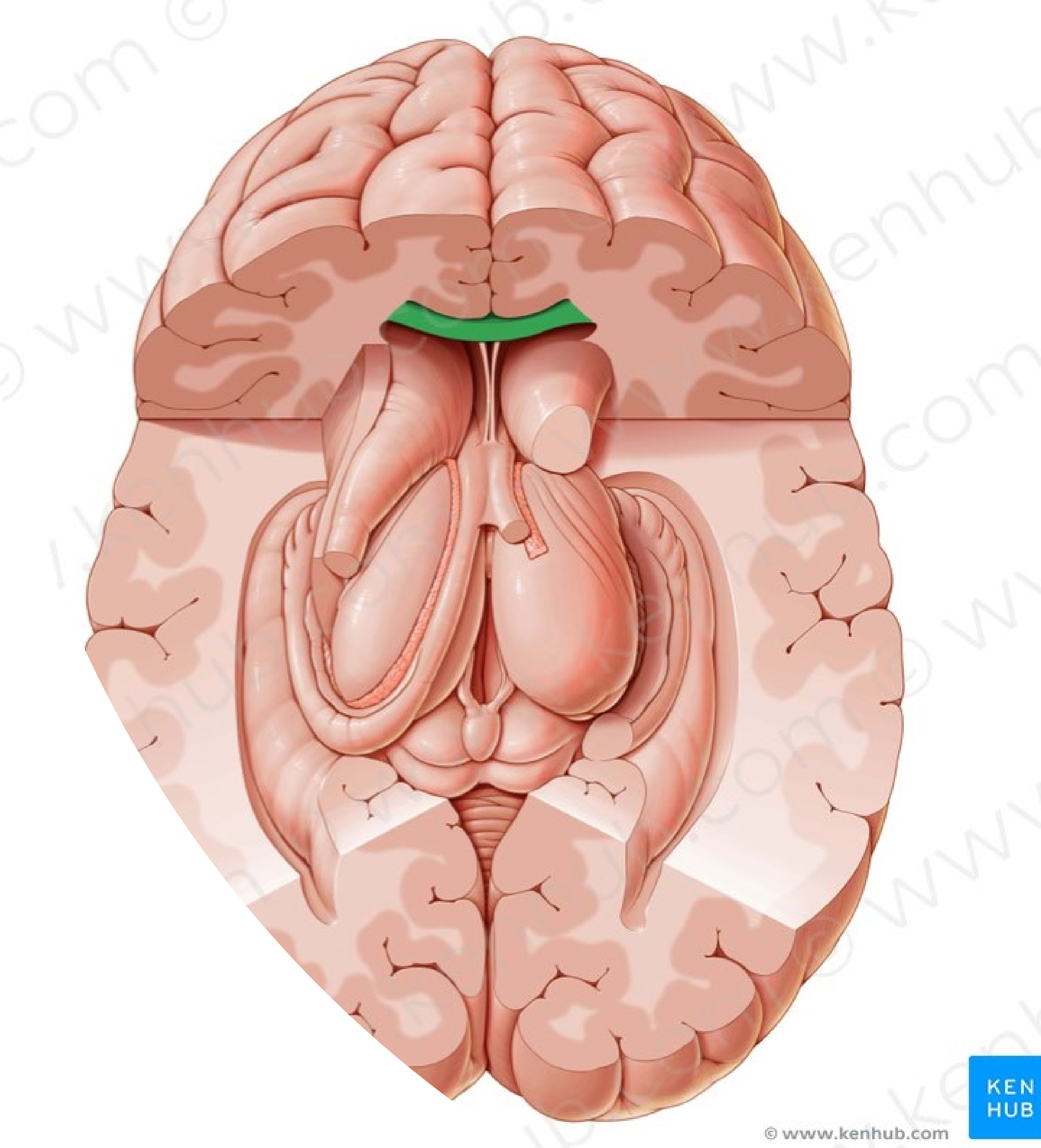
Forebrain

- The larger component of the forebrain, the cerebrum, consists of the right and left cerebral hemispheres as well as certain other structures.
- The central core of the forebrain is formed by the **diencephalon.**
- The cerebral hemispheres consist of the **cerebral cortex**, an outer shell of gray matter covering myelinated fiber tracts, which form the white matter.
- This in turn overlies cell clusters, which are also gray matter and are collectively termed the **subcortical nuclei**.



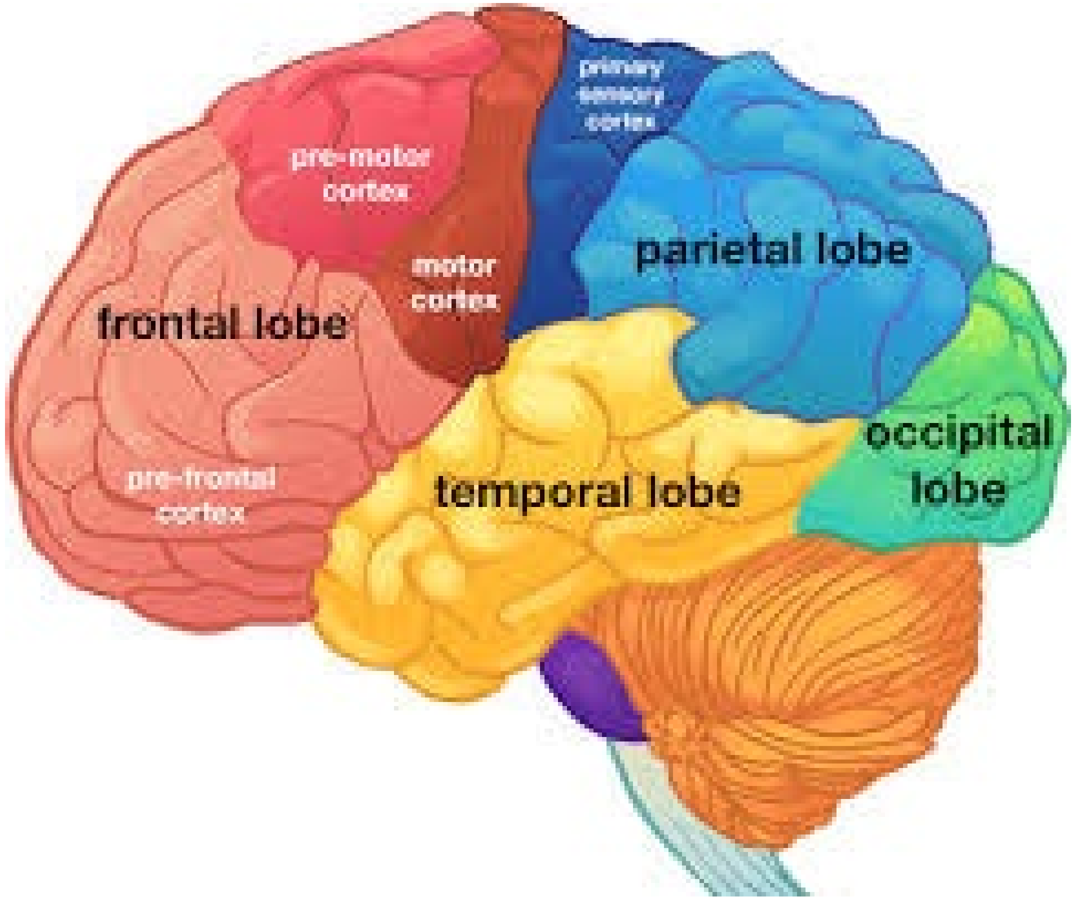
Forebrain

- The cortex layers of the two cerebral hemispheres, although largely separated by a longitudinal division, are connected by a massive bundle of nerve fibers known as the **corpus callosum.**



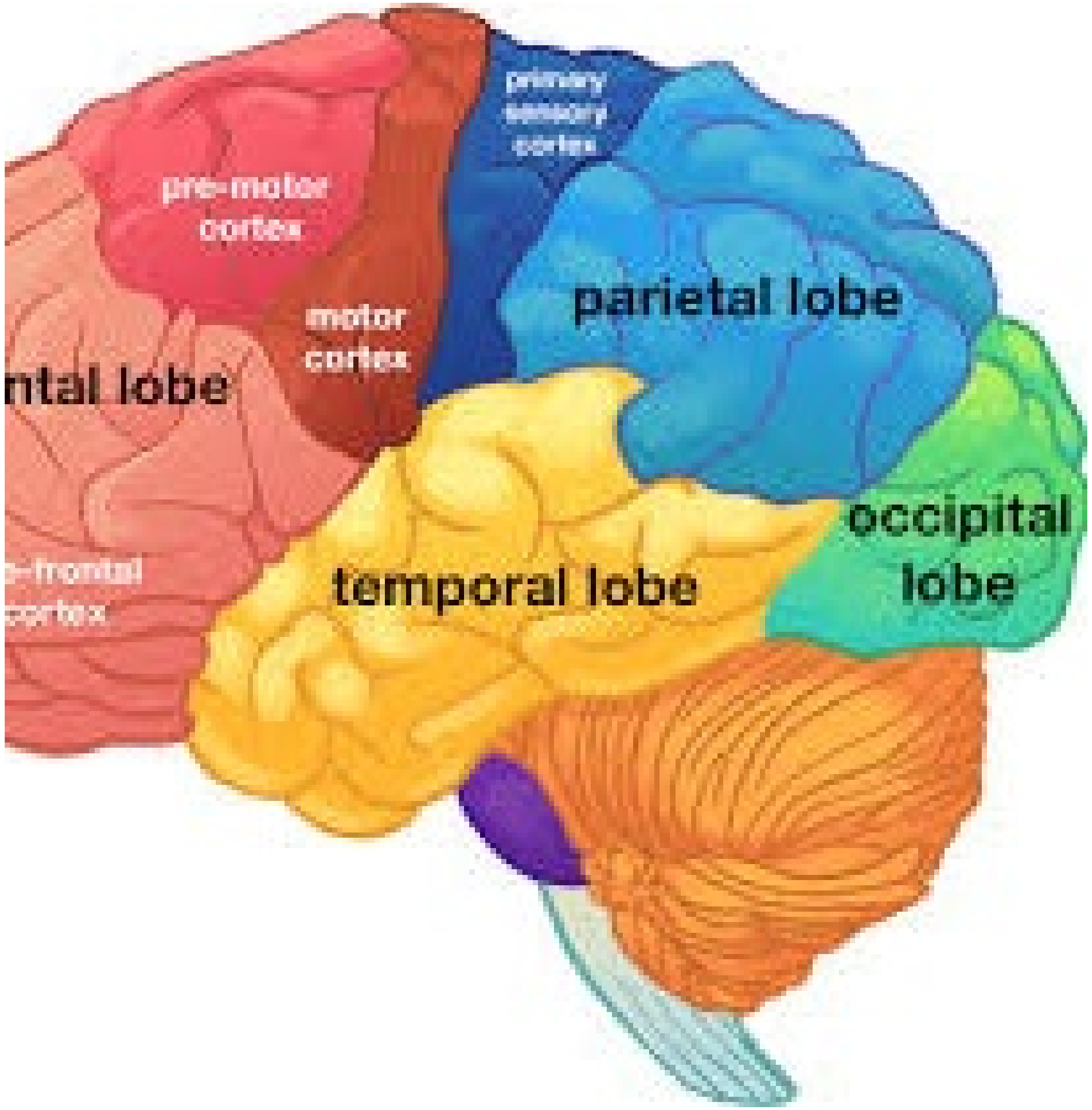
LOBES OF THE BRAIN

- **FRONTAL LOBE:**
- Located in front of the central sulcus.
- Concerned with reasoning, planning, parts of speech and movement (motor cortex), emotions, and problem-solving.
- **PARIETAL LOBE**
- Located behind the central sulcus.
- Concerned with perception of stimuli related to touch, pressure, temperature and pain.



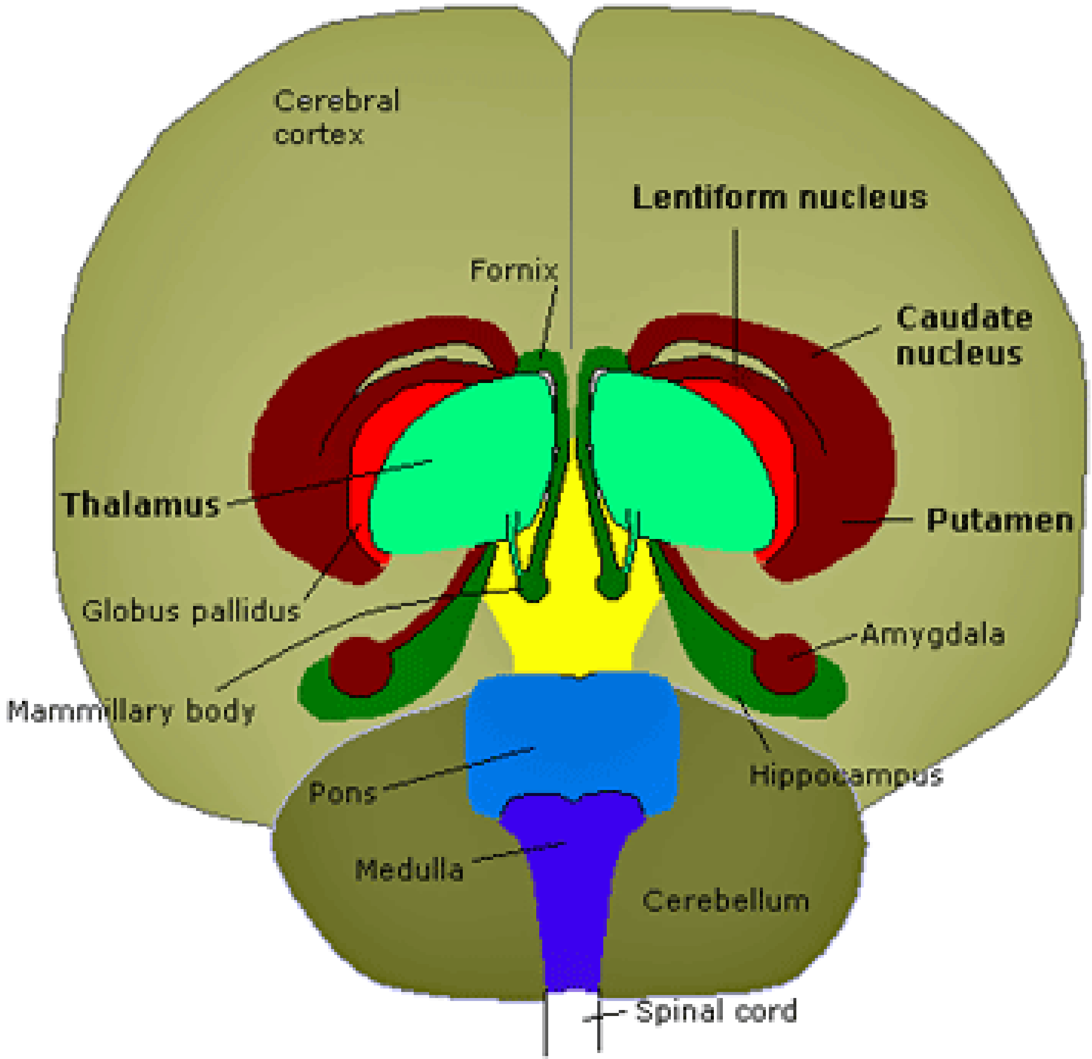
LOBES OF THE BRAIN

- **TEMPORAL LOBE**
- Located below the lateral fissure.
- Concerned with perception and recognition of auditory stimuli (hearing) and memory (hippocampus).
- **OCCIPITAL LOBE**
- Located at the back of the brain, behind the parietal lobe and temporal lobe.
- Concerned with many aspects of vision.



SUBCORTICAL NUCLEI

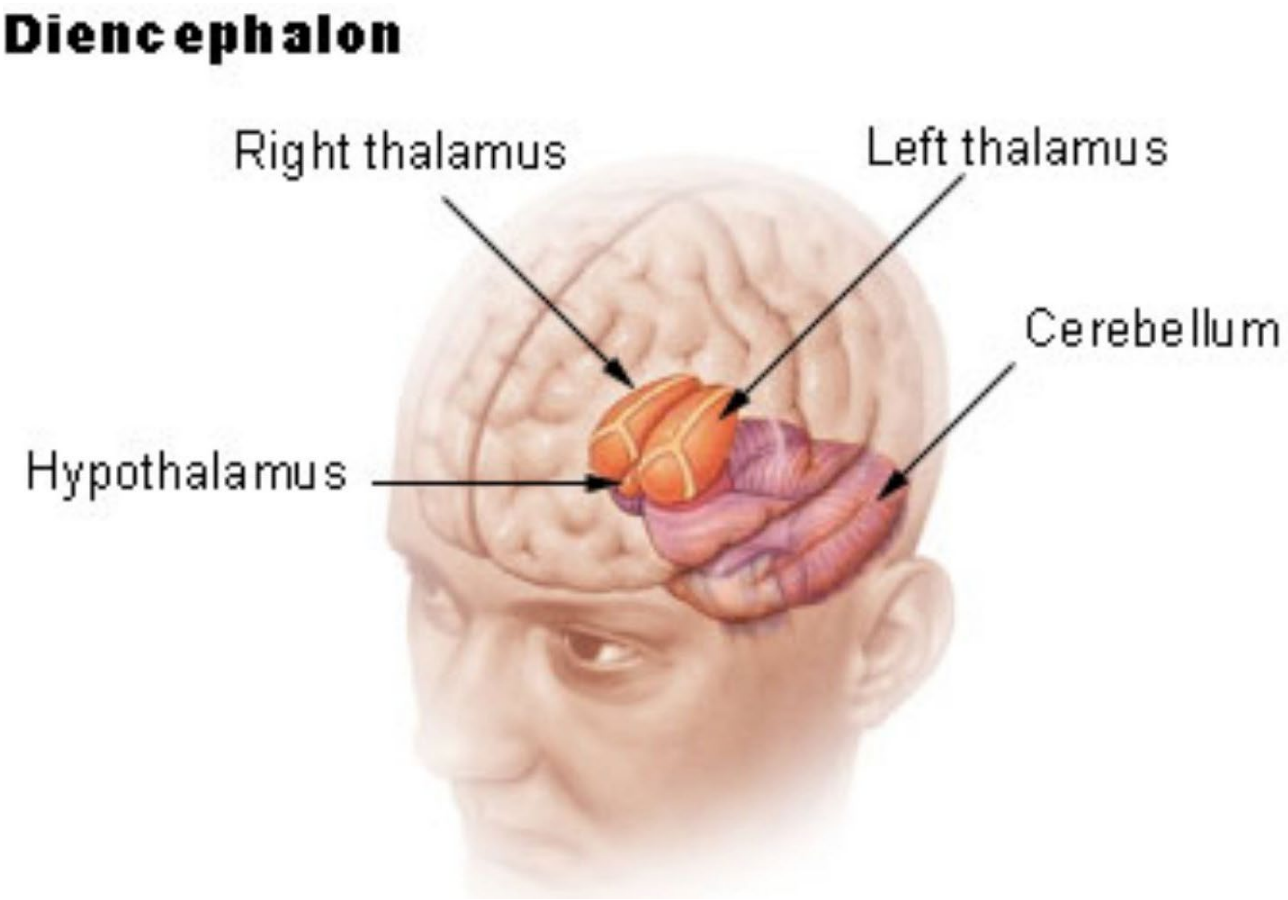
- The subcortical nuclei are heterogeneous groups of gray matter that lie deep within the cerebral hemispheres.
- Predominant among them are the **basal ganglia**, which play an important role in the control of movement and posture and in more complex aspects of behavior.



The brain as viewed from the underside and front. The thalamus, corpus striatum (putamen and caudate nucleus),

DIENCEPHALON

- The **diencephalon**, which is divided in two by the third ventricle, is the second component of the forebrain.
- It contains two major parts: the **thalamus** and the **hypothalamus**

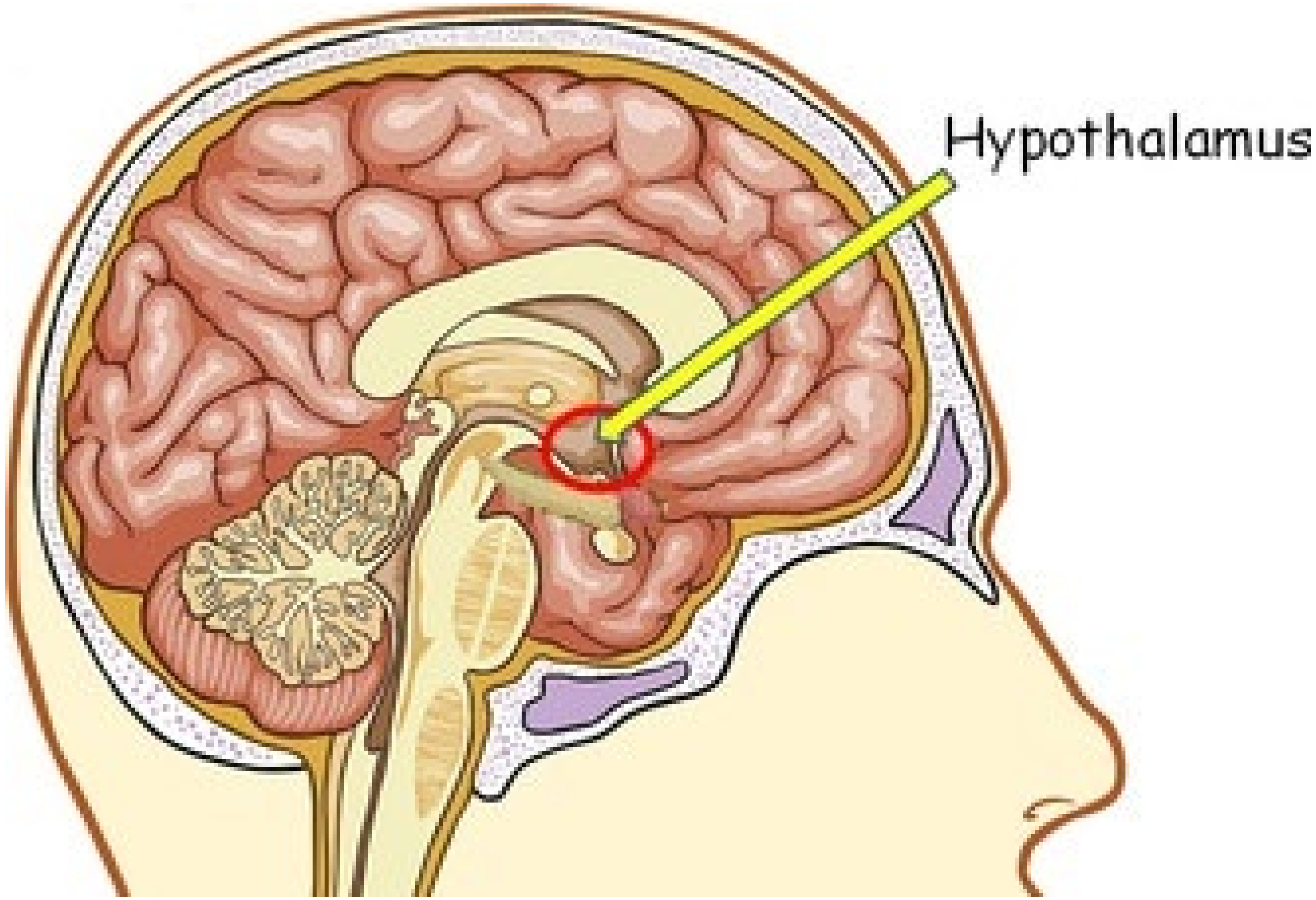


HYPOTHALAMUS

- Lies below the thalamus and is on the undersurface of the brain.
- Although it is a tiny region that accounts for less than 1 percent of the brain’s weight, it contains different cell groups and pathways that form the **master command center for neural and endocrine coordination.**

HYPOTHALAMUS

- The hypothalamus is the single most important control area for **homeostatic regulation** of the internal environment and behaviors having to do with preservation of the individual
- for example: eating, drinking, reproduction.

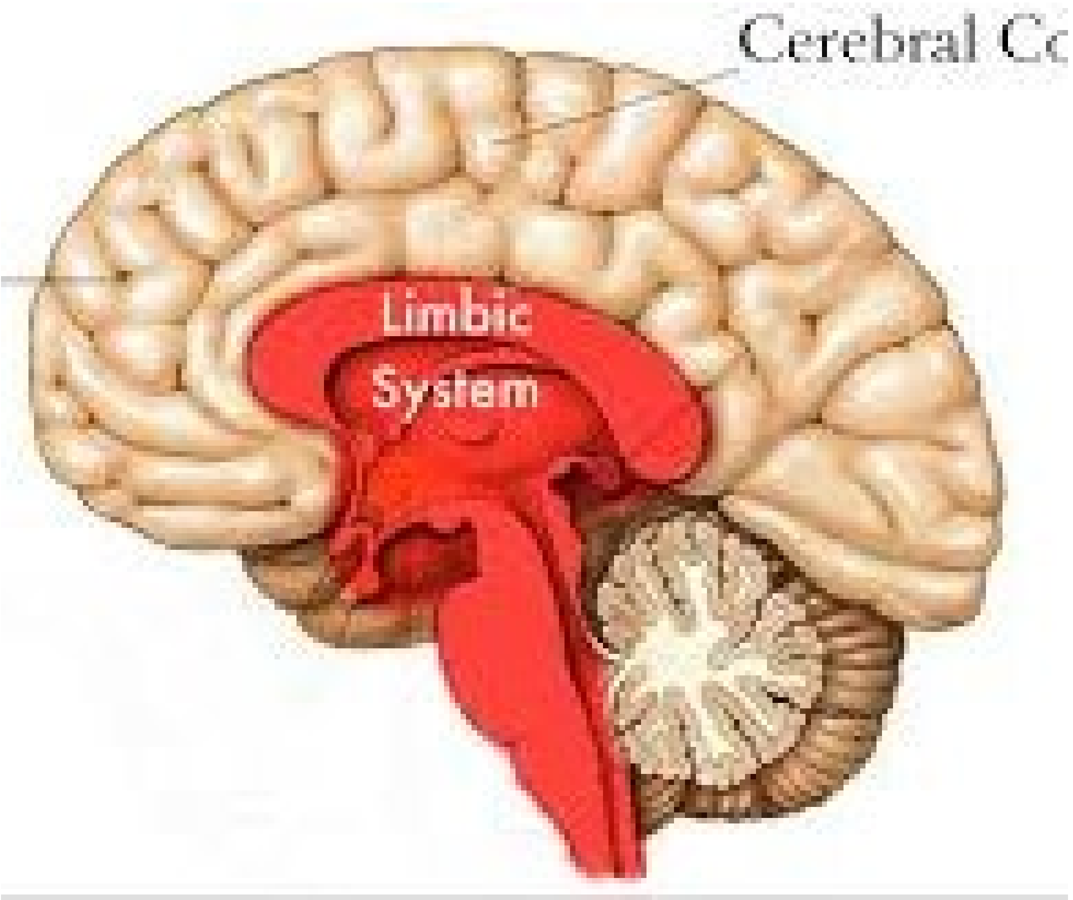


THALAMUS

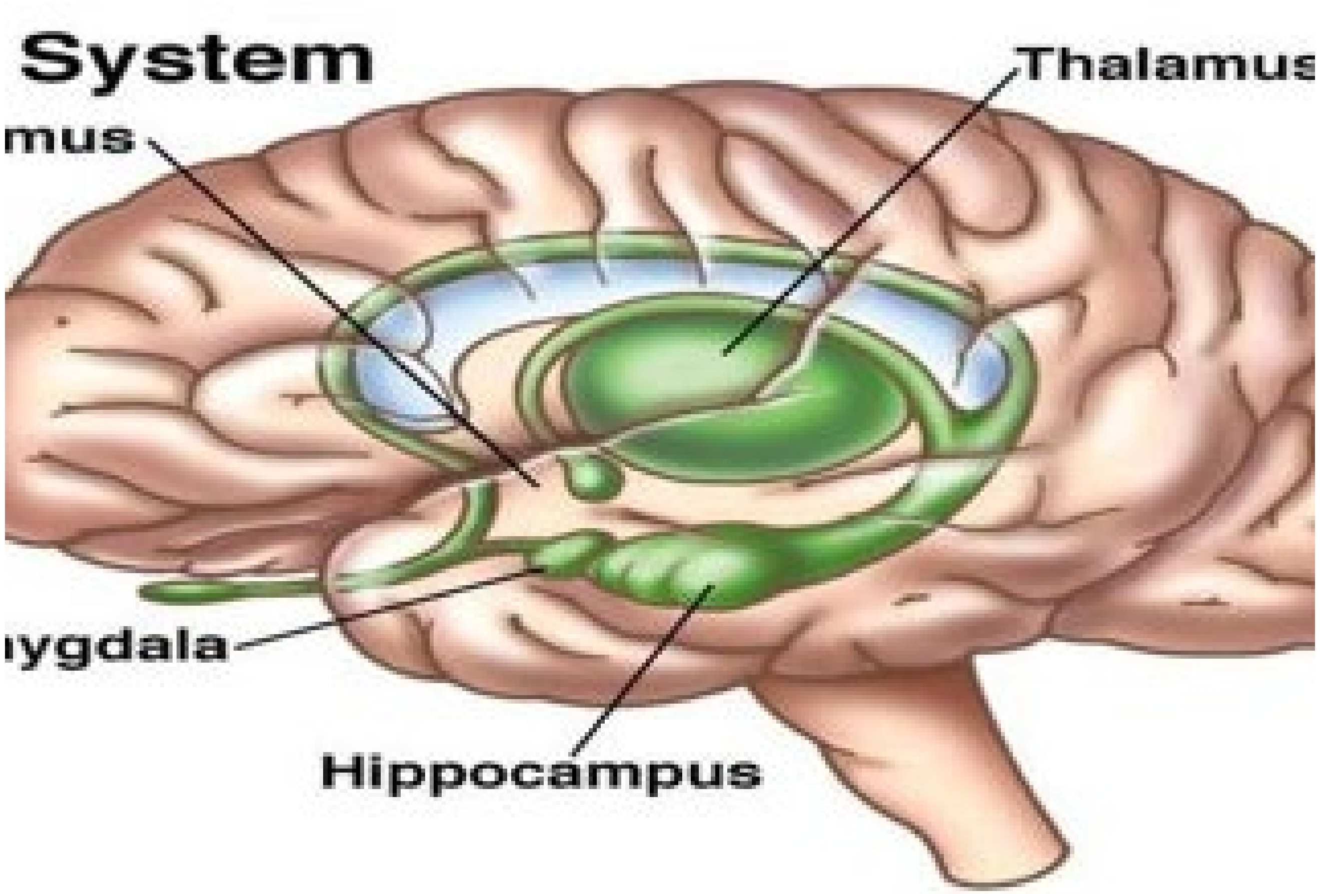
- It consists of collection of several large nuclei that serve as **synaptic relay stations** and important integrating centers for most inputs to the cortex.
- It also plays a key role in **nonspecific arousal** and **focused attention**.
- **Other Functions:**
- Sensory processing
- Movement

LIMBIC SYSTEM

- Some of these forebrain areas, consisting of both gray and white matter, are also classified together in a functional system, termed the **limbic system**.
- This interconnected group of brain structures includes portions of **frontal-lobe cortex, temporal lobe, thalamus**, and **hypothalamus**, as well as the **circuitous fiber pathways that connect them**.
- Besides being connected with each other, the parts of the limbic system are connected with many other parts of the central nervous system.



LIMBIC SYSTEM



- Structures within the limbic system are associated with:

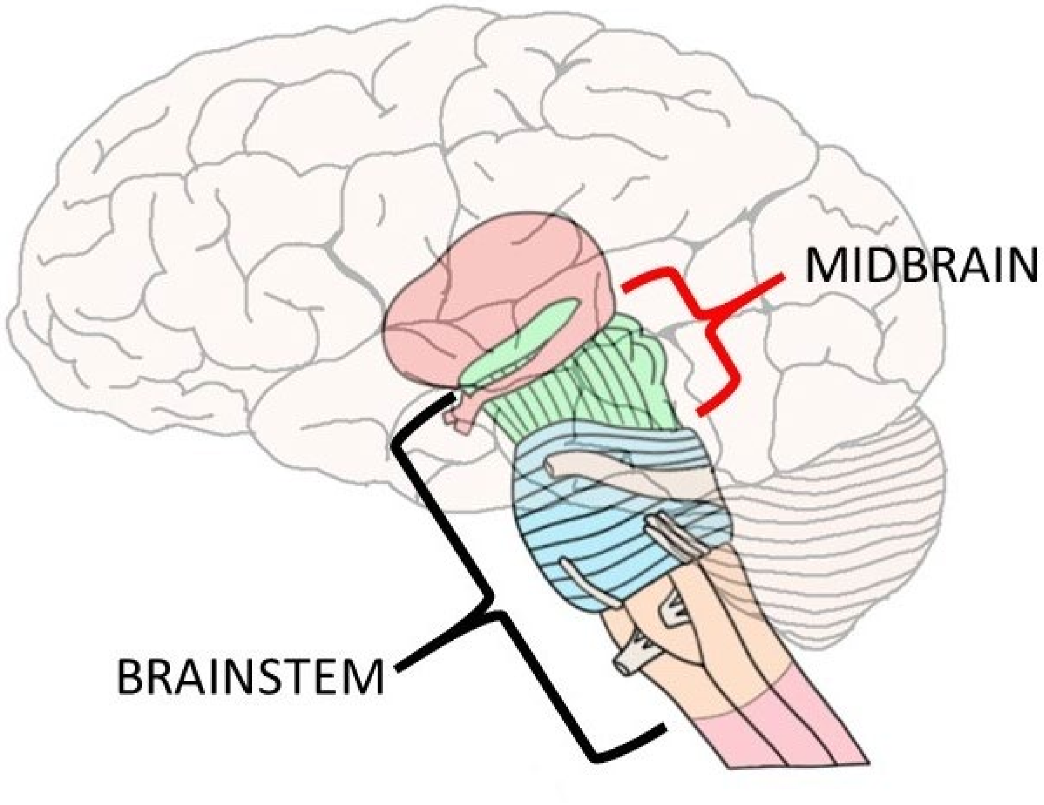
✓learning,

✓emotional experience and behavior, and

✓a wide variety of visceral and endocrine functions.

- In fact, much of the output of the limbic system is coordinated by the hypothalamus into behavioral and endocrine responses.

MIDBRAIN



- The midbrain includes structures such as the superior and inferior colliculi and red nucleus.

Functions:

- Vision
- Audition
- Eye Movement
- Body Movement

ANY QUESTIONS?