Human Physiology,
Motor System

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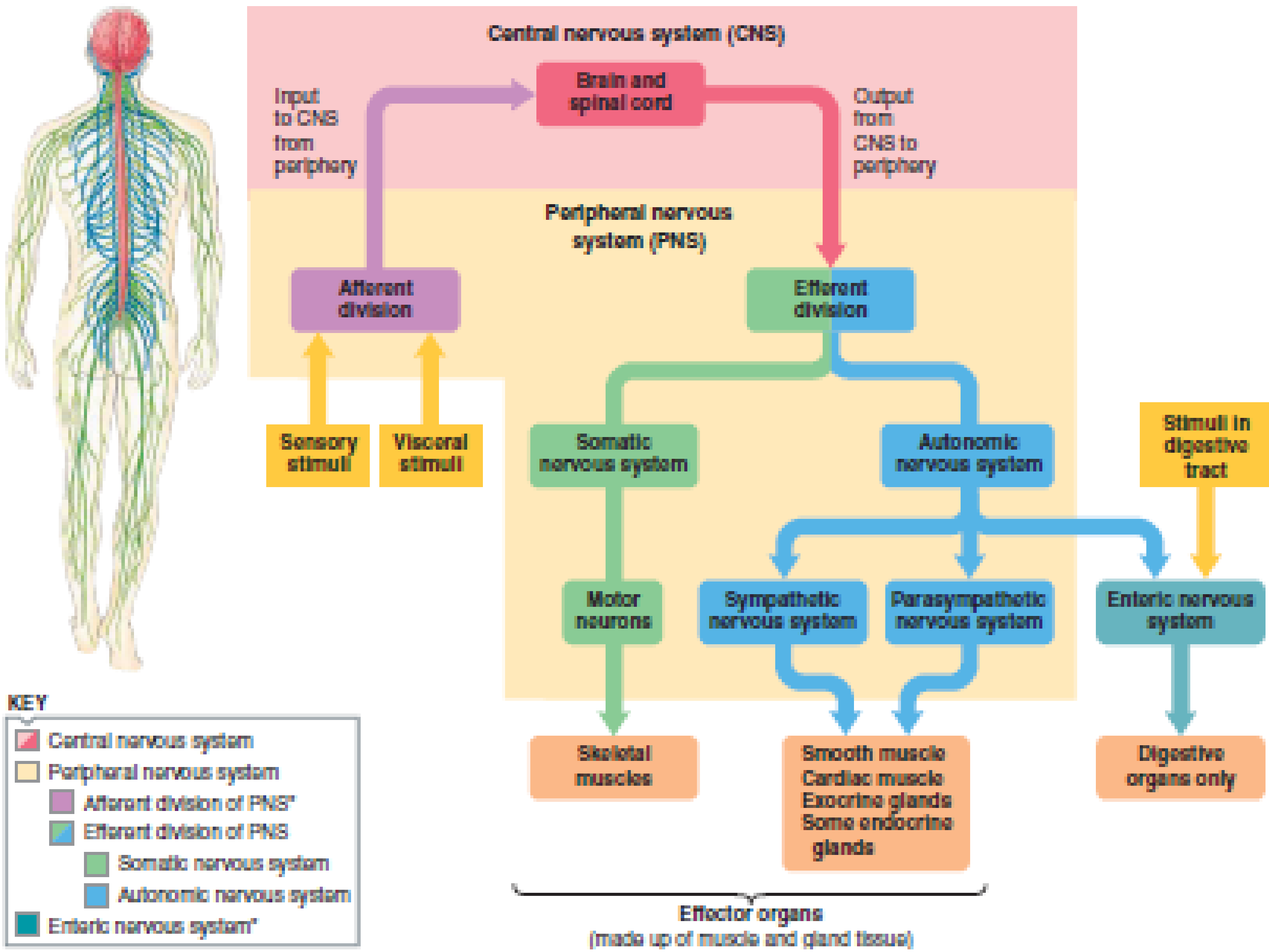
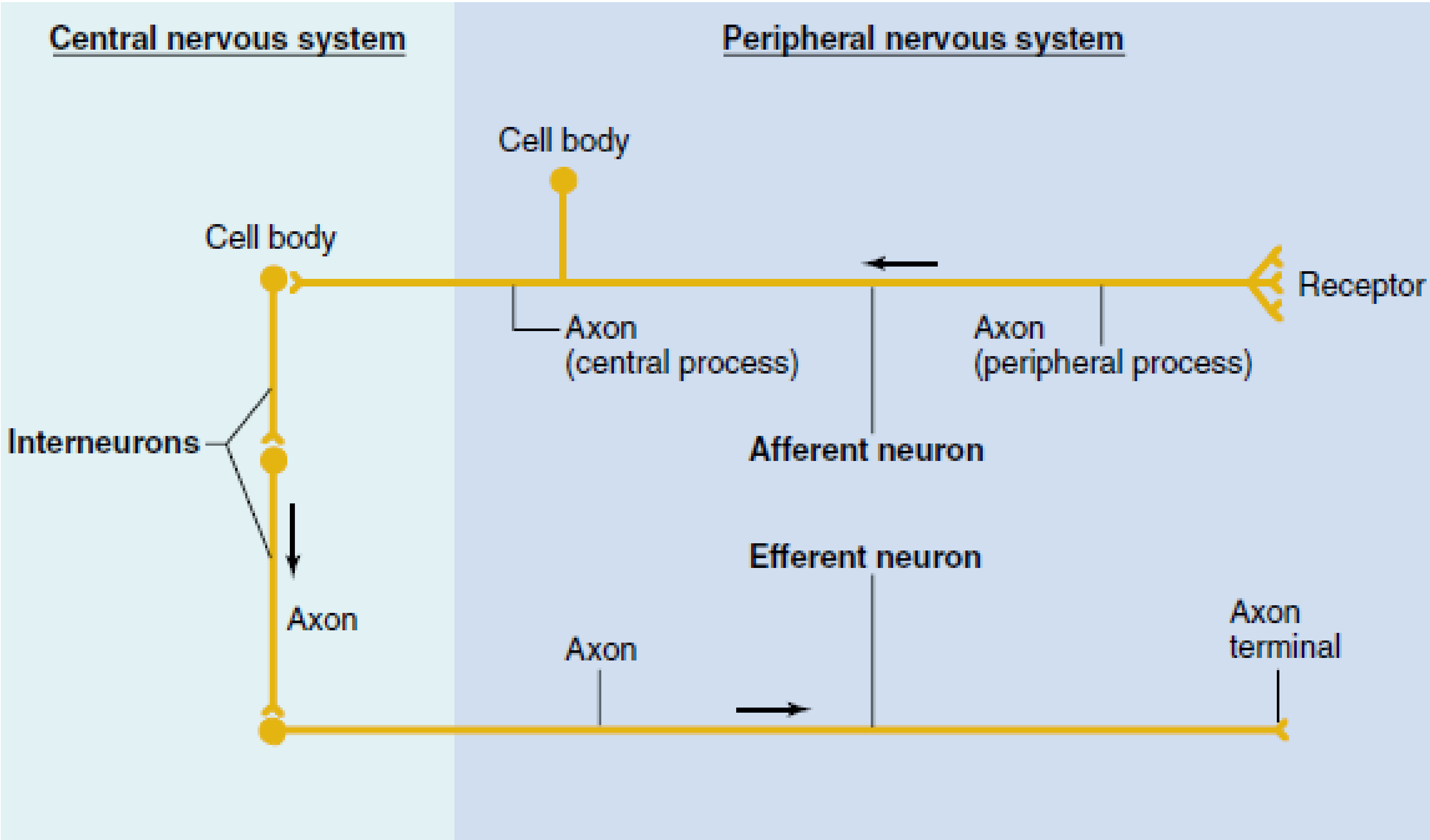
MBBS; PhD

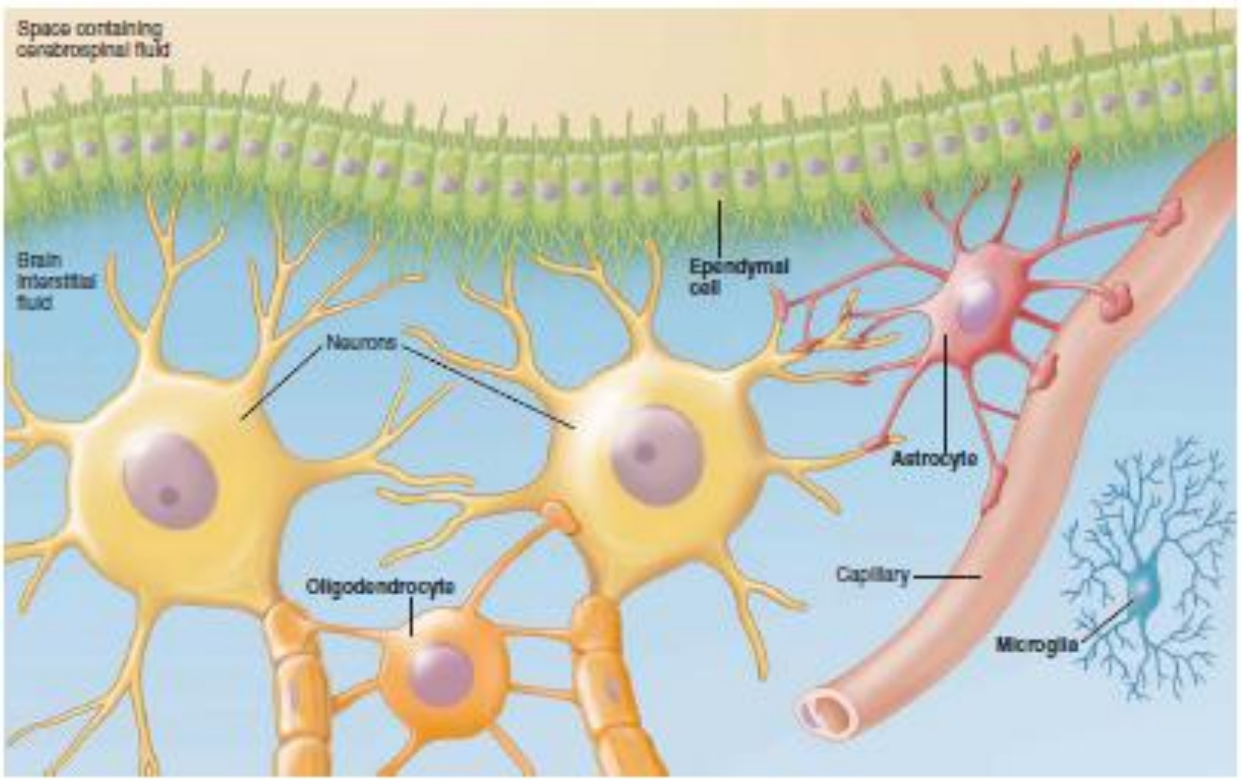
Organization & Cells of Nervous System

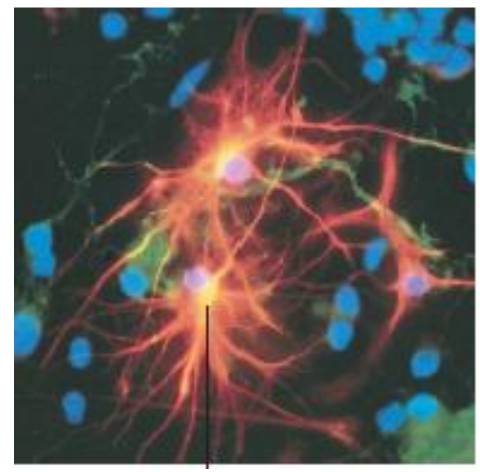


3 functional classes of neurons



Glial cells support the interneurons physically, metabollically and functionally



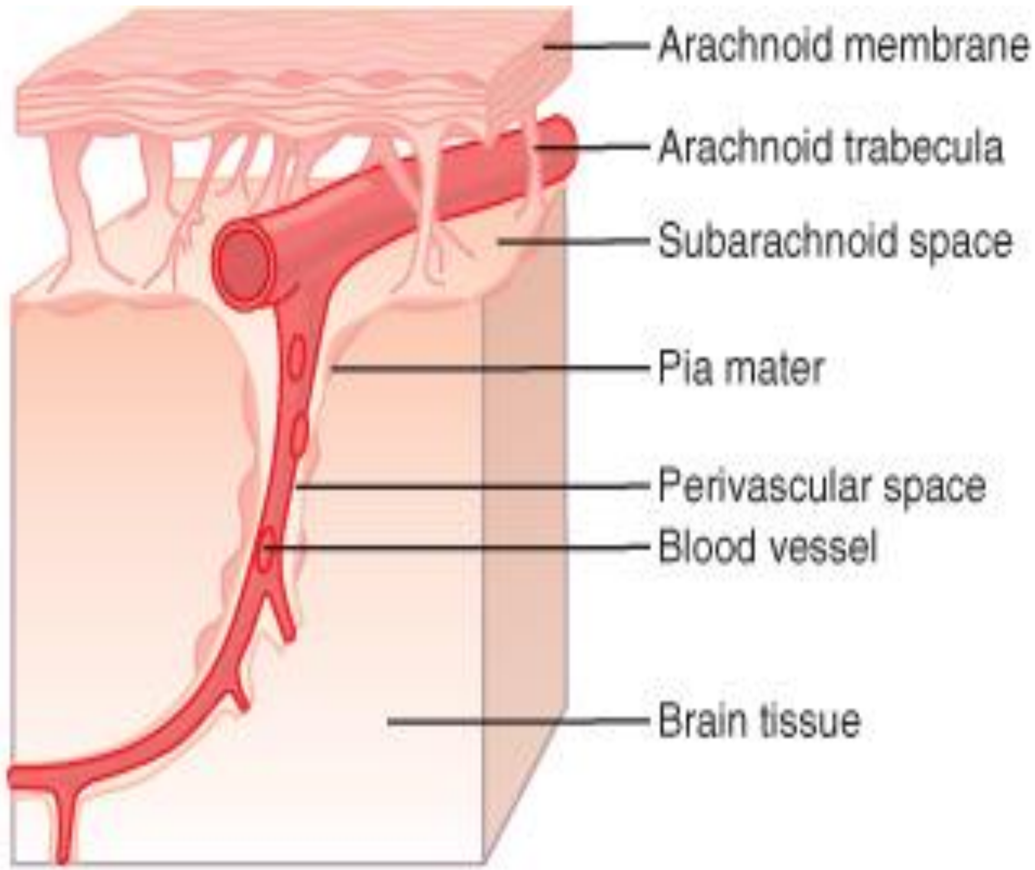


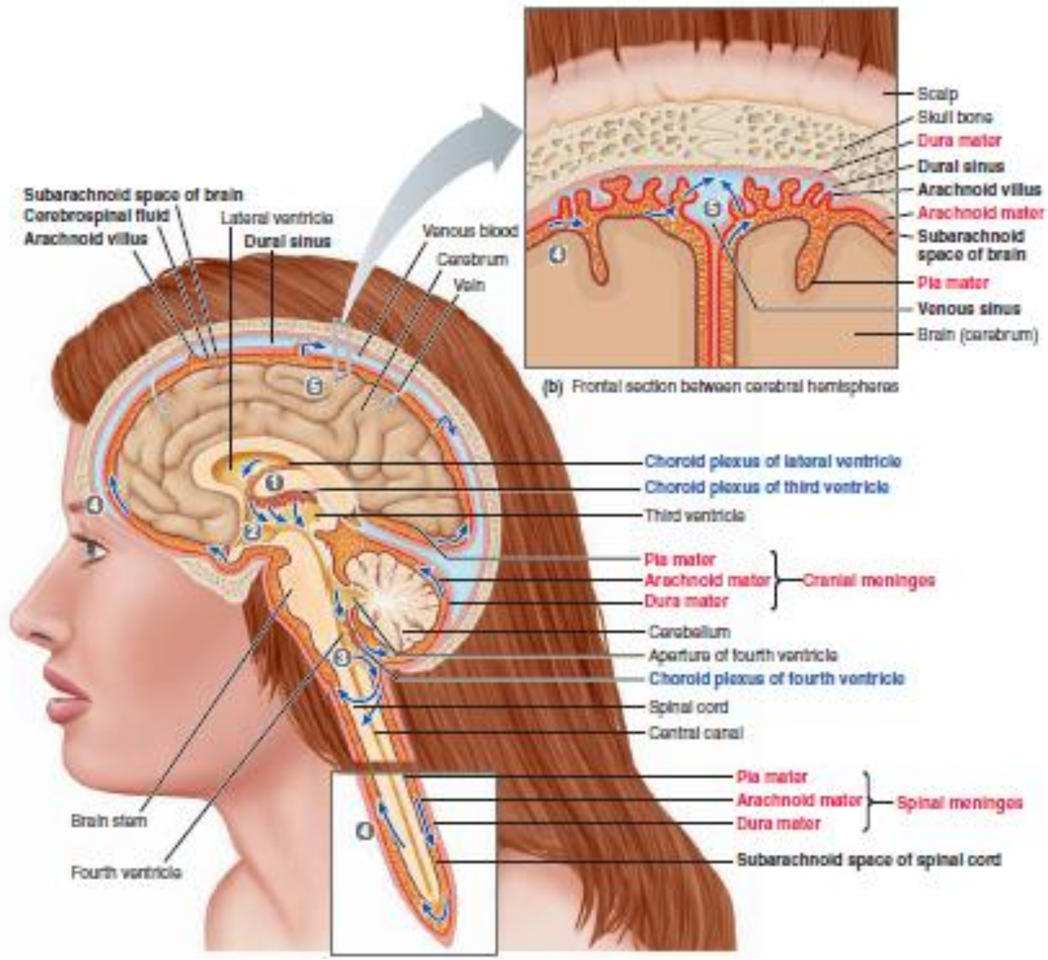
Astrocytes	Proper spatial relationship for neurons
	Scaffold during fetal brain development
	Induce formation of blood-brain-barrier
	Form neural scar tissue
	Degrade released neurotransmitters
	Synapse formation & communication
Oligodendroc -ytes	Form myelin sheaths in CNS
Microglia	Phagocytic scavengers
	Release nerve growth factor
Ependymal	CSF formation contribution
	Neural Stem Cells

Protection & nourishment of the brain

- Three meningial membranes wrap , protect and nourish the CNS
- The brain floats in its own special cerebrospinal fluid (CSF)
- A highly selective blood-brain-barrier regulates exchanges between the blood and brain
- The brain depends on constant delivery of oxygen and glucose by the blood

Meninges

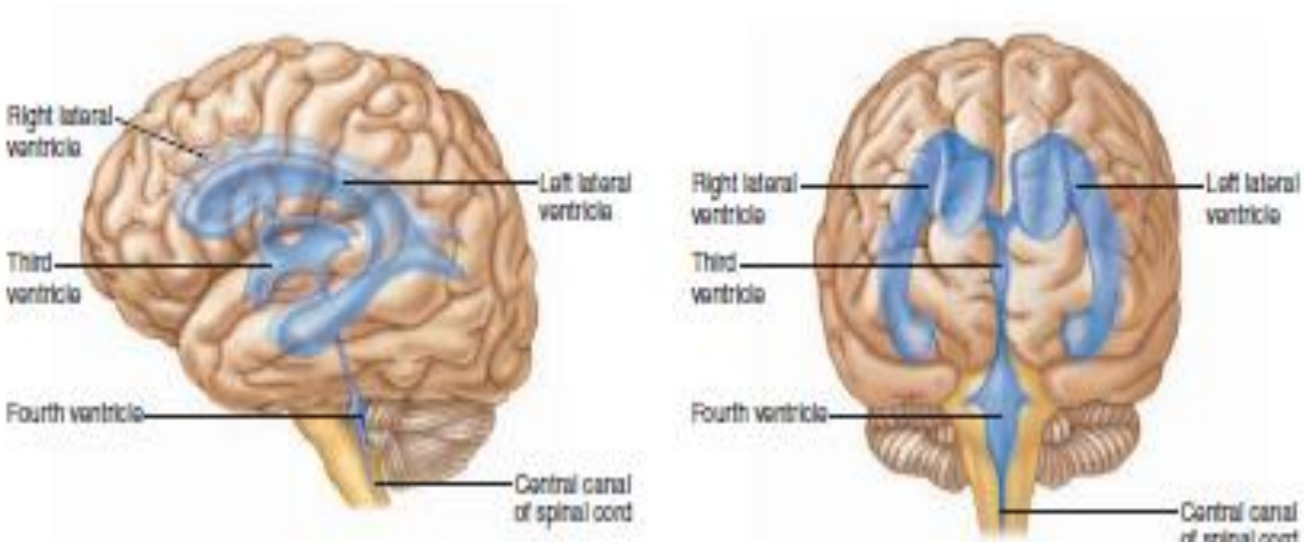

Arachnoid membrane
Arachnoid trabecula
Subarachnoid space
Pia mater
Perivascular space
Blood vessel
Brain tissue



Subarachnoid space of brain
Cerebrospinal fluid
Arachnoid villus
Lateral ventricle
Dural sinus
Venous blood
Cerebrum
Vein
Scalp
Skull bone
Dura mater
Dural sinus
Arachnoid villus
Arachnoid mater
Subarachnoid space of brain
Pia mater
Venous sinus
Brain (cerebrum)
(b) Frontal section between cerebral hemispheres
Choroid plexus of lateral ventricle
Choroid plexus of third ventricle
Third ventricle
Pia mater
Arachnoid mater
Dura mater
Cranial meninges
Cerebellum
Aperture of fourth ventricle
Choroid plexus of fourth ventricle
Spinal cord
Central canal
Pia mater
Arachnoid mater
Dura mater
Spinal meninges
Subarachnoid space of spinal cord
Brain stem
Fourth ventricle

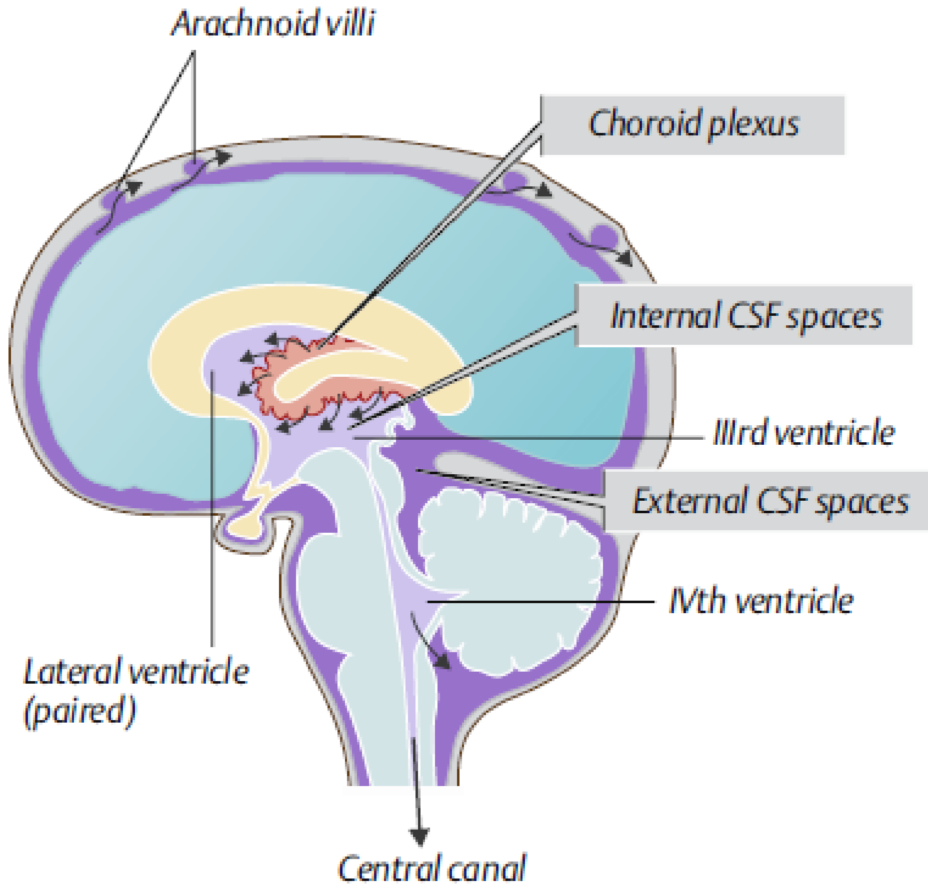
Cerebrospinal fluid

- Formation of CSF
- Composition of CSF
- Flow of CSF
- Absorption through Arachnoid villi
- Protection
- Cushion effect
- Nutrition
- Hydrocephalus



(a) Lateral view of ventricles

(b) Anterior view of ventricles



Arachnoid villi
Choroid plexus
Internal CSF spaces
IIIrd ventricle
External CSF spaces
IVth ventricle
Lateral ventricle
(paired)
Central canal

Blood-brain-barrier (BBB)

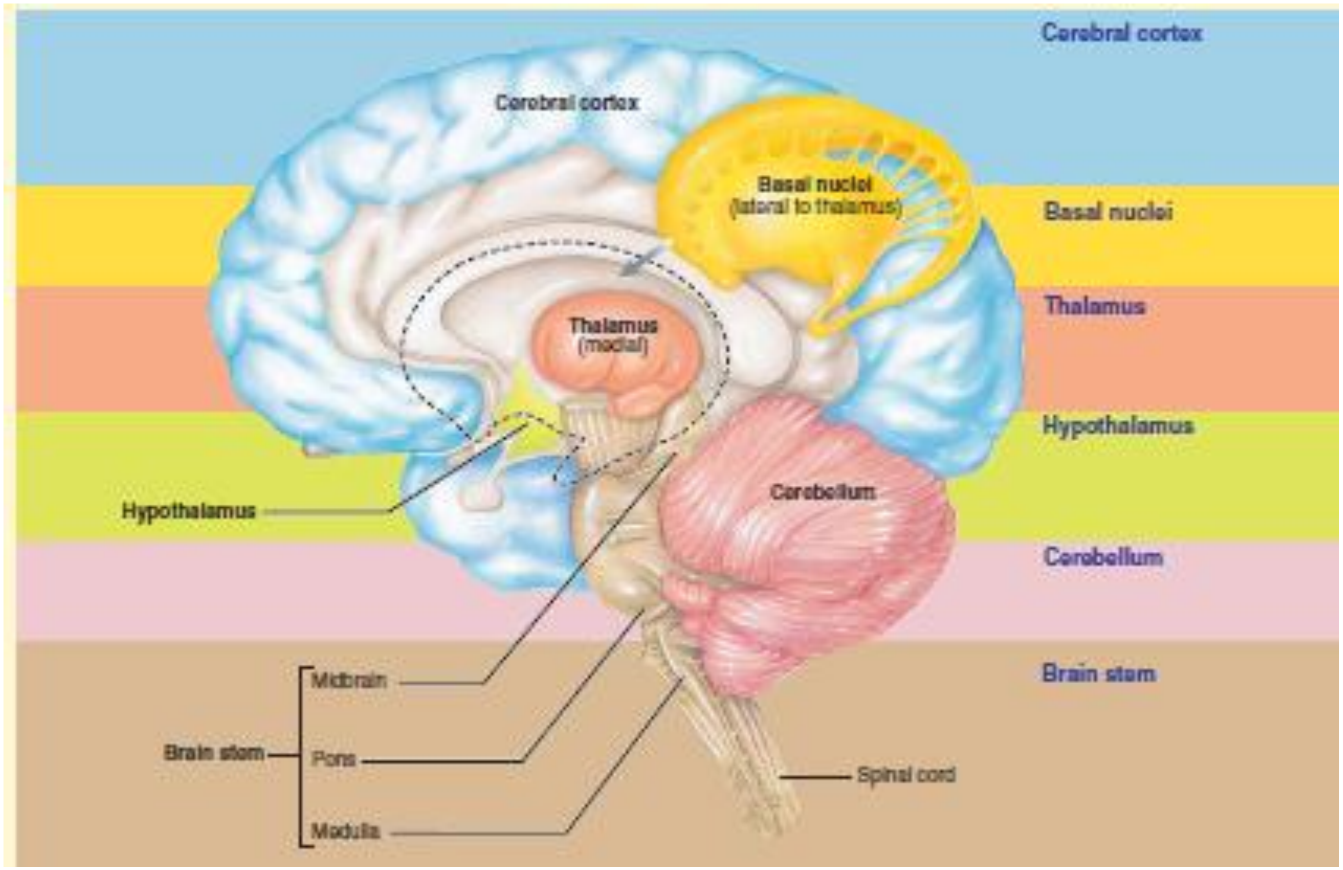
- Protects the brain from toxic substances that may be circulating in blood
- Selected, carefully regulated exchange
- Anatomoic & physiologic features-tight junctions
- Limited drug penetration-the negative side, sparing hypothalamus
- Role of astrocyte processes for BBB

Cerebral Circulation

- Brain receives 14% of the resting cardiac out put
- Most of the flow goes to grey matter
- A small portion go to white matter
- Arterioles in the cerebral circulation are short and thin walled
- Large cerebral arteries account for vascular resistance and they have rich autonomic innervation

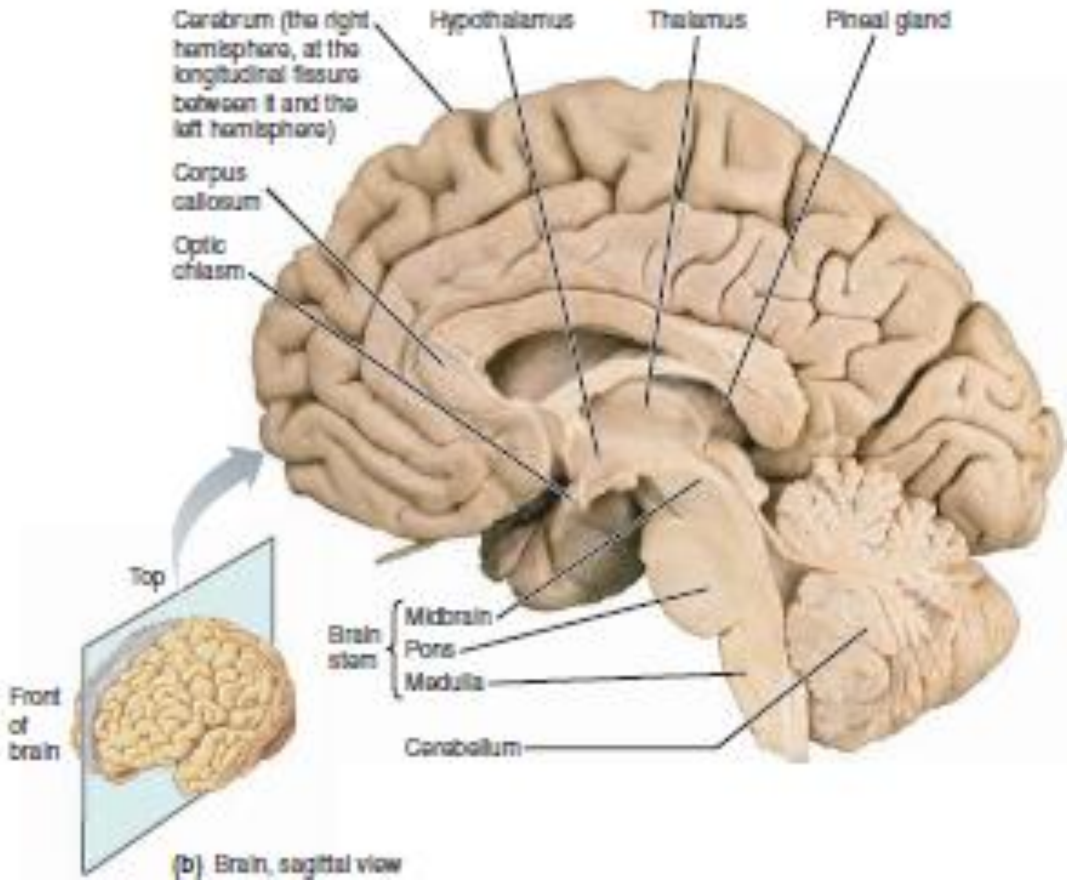
Strokes: a deadly domino effect

- Compromised blood supply which cause disturbance in functions of brain
- May be haemorrhagic or ischemic
- Excitotoxicity towards free redicals
- Treatment of ischemic stroke with tissue plasminogen activator
- Drugs that block NMDA receptors



Cerebral cortex
Cerebral cortex
Basal nuclei
(lateral to thalamus)
Basal nuclei
Thalamus
Thalamus
(medial)
Hypothalamus
Hypothalamus
Cerebellum
Cerebellum
Brain stem
Midbrain
Brain stem
Pons
Medulla
Spinal cord

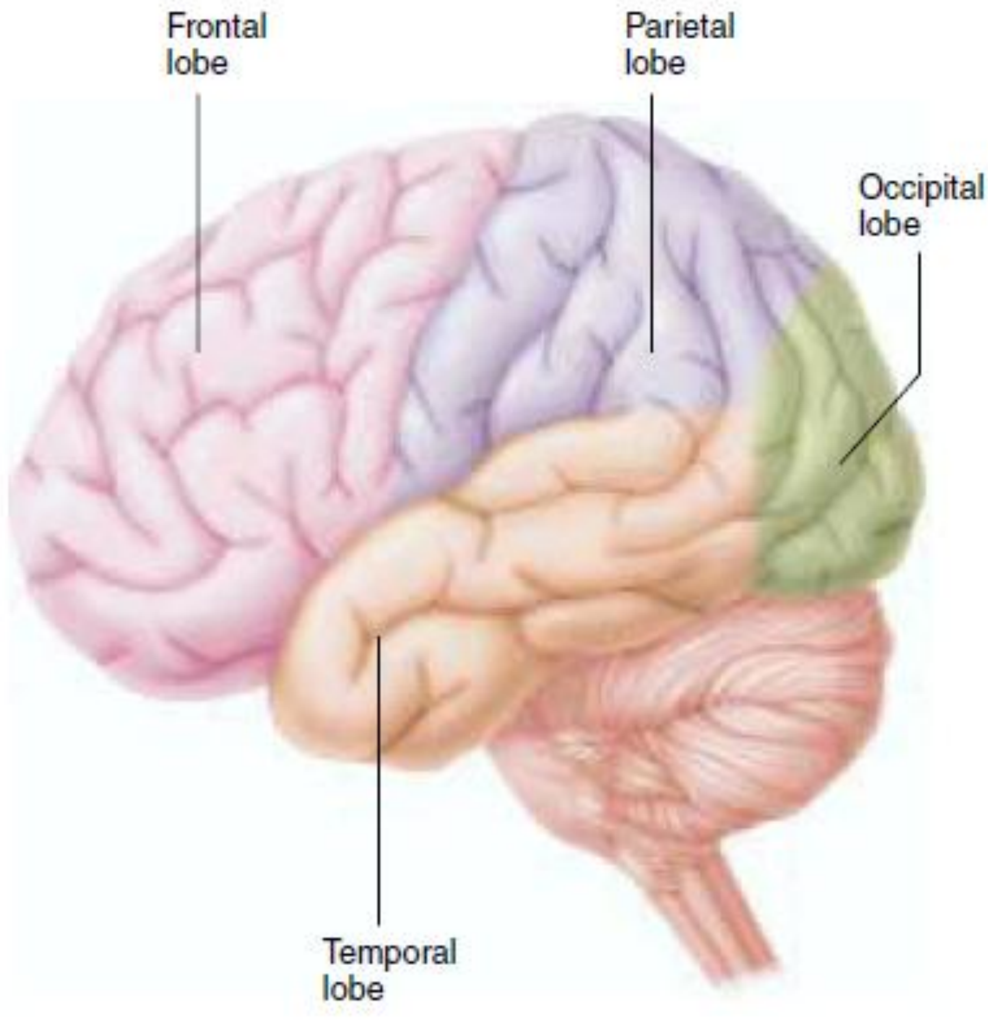
(a) Brain, dorsal view



(b) Brain, sagittal view

4 pairs of lobes in cerebral cortex are specialized for different activities

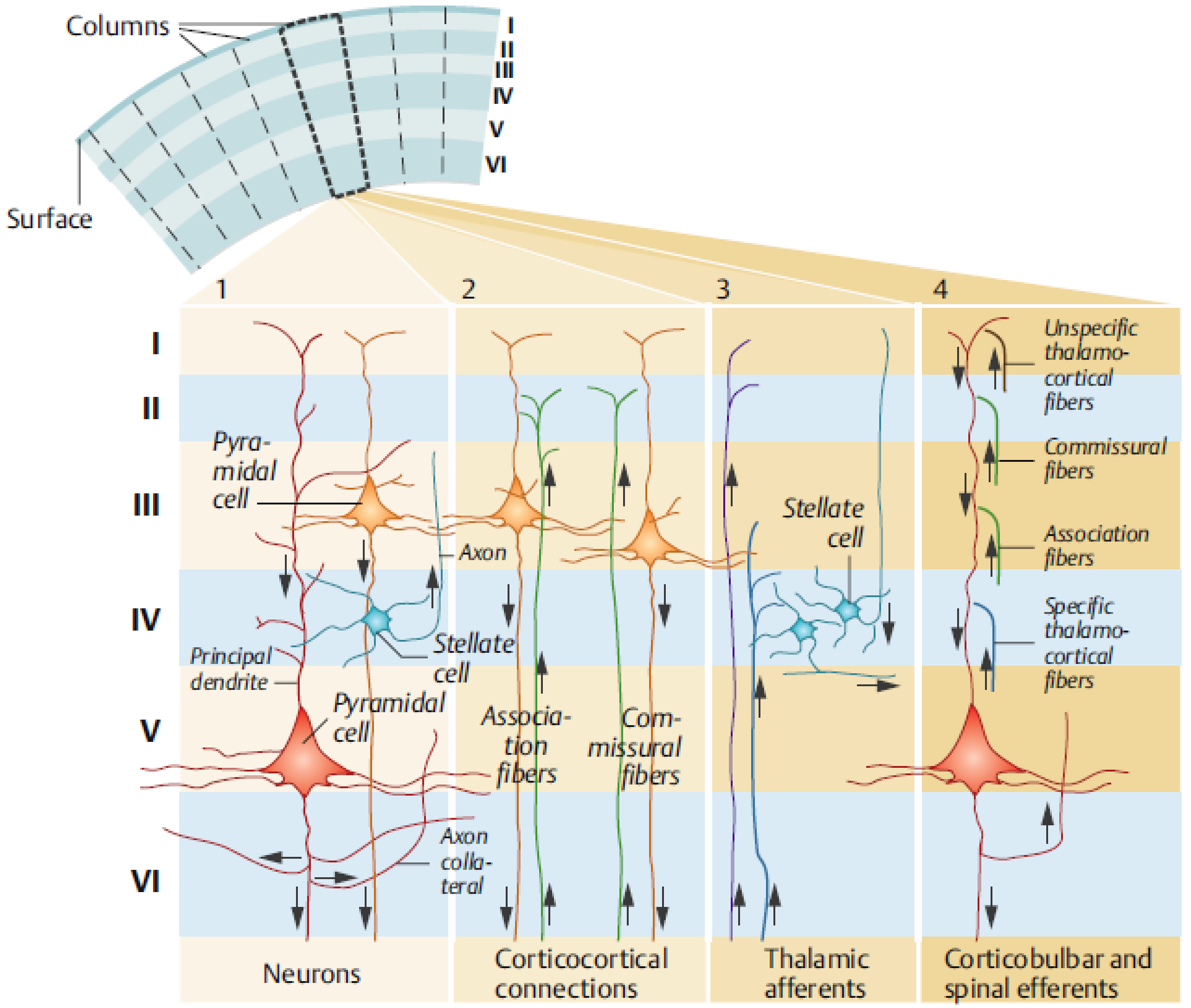
- The occipital lobes carry out the initial processing of visual input
- Temporal lobes for initial processing of auditory input
- The parietal lobes accomplish somatosensory processing
- The primary motor cortex located in the frontal lobes control the skeletal muscles
- The higher motor areas are also important in motor control


Frontal lobe
Parietal lobe
Occipital lobe
Temporal lobe

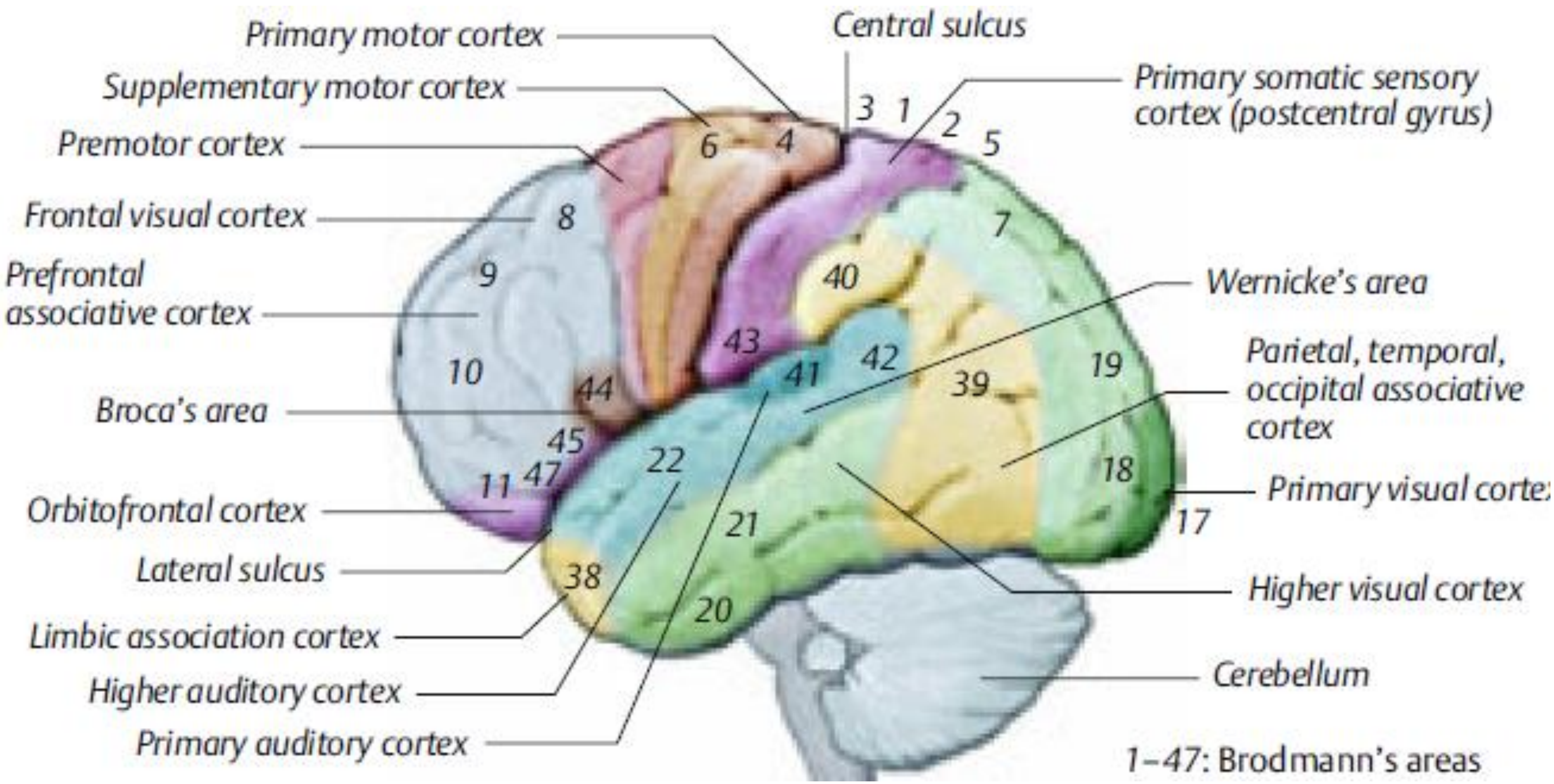
Six layers of Cerebral Cortex

1) Molecular or plexiform layer
1) External granular layer
2) External pyramidal layer
3) Internal granular layer
4) Internal pyramidal layer
5) Fusiform cell layer

- Layers 1,2,3 → perform most of the intracortical association functions
- Layer 4 →major input
- Layers 5,6 →major output

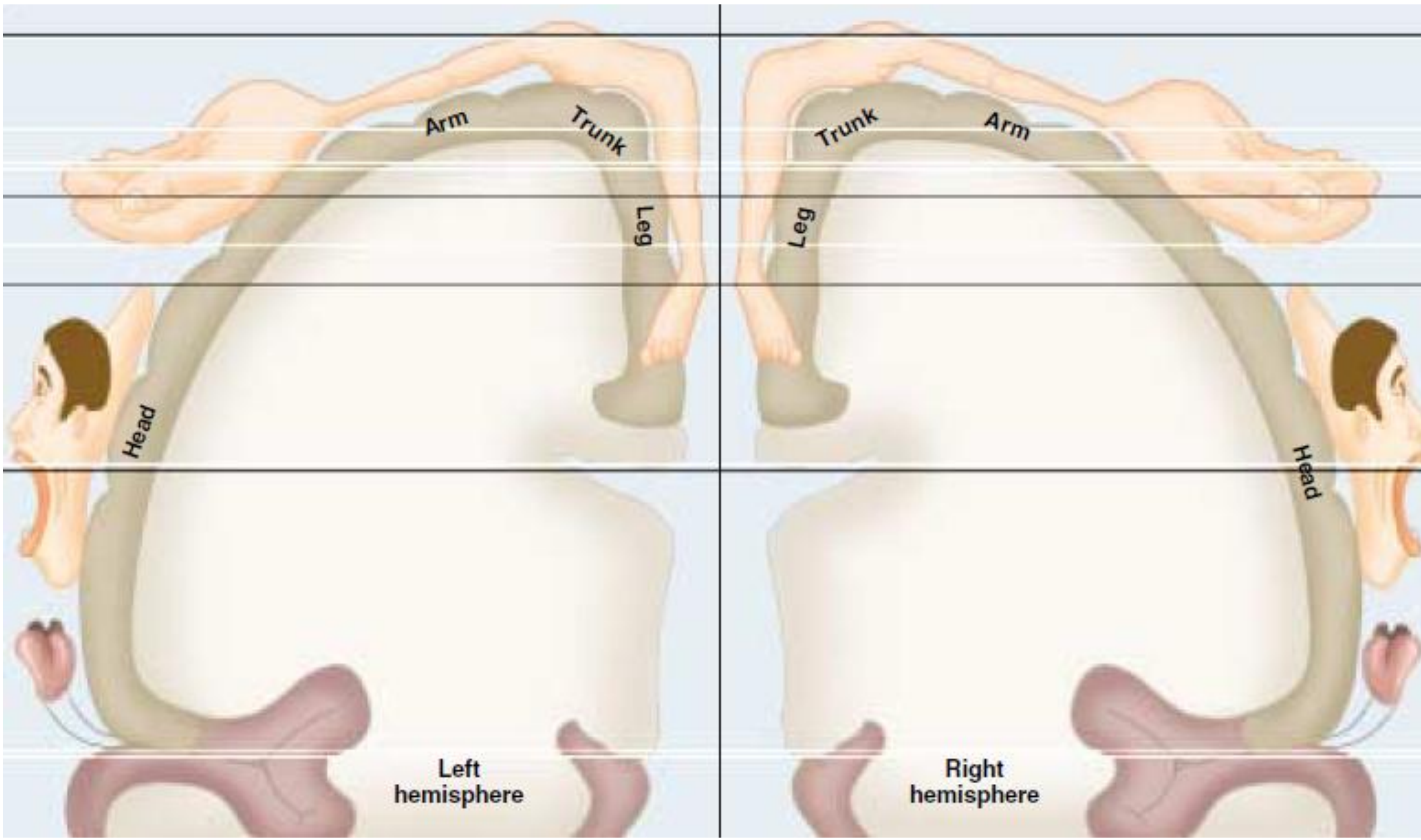


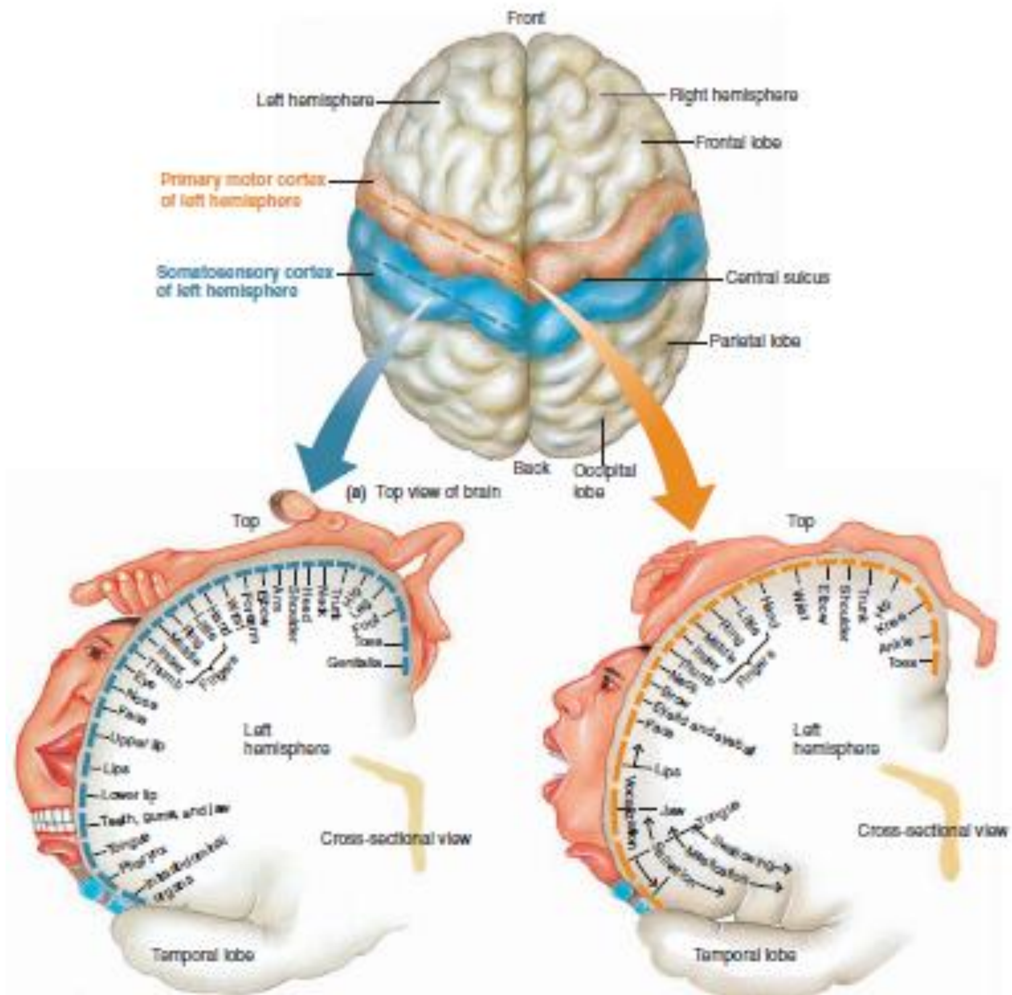
Columns
Surface
I
II
III
IV
V
VI
1
2
3
4
Pyra-
midal
cell
Axon
Stellate
cell
Principal
dendrite
Pyramidal
cell
Axon
colla-
teral
Neurons
Associa-
tion
fibers
Com-
missural
fibers
Corticocortical
connections
Stellate
cell
Thalamic
afferents
Unspecific
thalamo-
cortical
fibers
Commissural
fibers
Association
fibers
Specific
thalamo-
cortical
fibers
Corticobulbar and
spinal efferents



Primary motor cortex
Supplementary motor cortex
Premotor cortex
Frontal visual cortex
Prefrontal associative cortex
Broca's area
Orbitofrontal cortex
Lateral sulcus
Limbic association cortex
Higher auditory cortex
Primary auditory cortex
Central sulcus
Primary somatic sensory cortex (postcentral gyrus)
Wernicke's area
Parietal, temporal, occipital associative cortex
Primary visual cortex
Higher visual cortex
Cerebellum
3 1 2 5 6 4 8 9 10 44 45 47 11 7 40 43 41 42 39 19 22 18 17 21 38 20
1–47: Brodmann's areas

Somatotopic maps vary slightly b/w individuals and are dynamic, not static



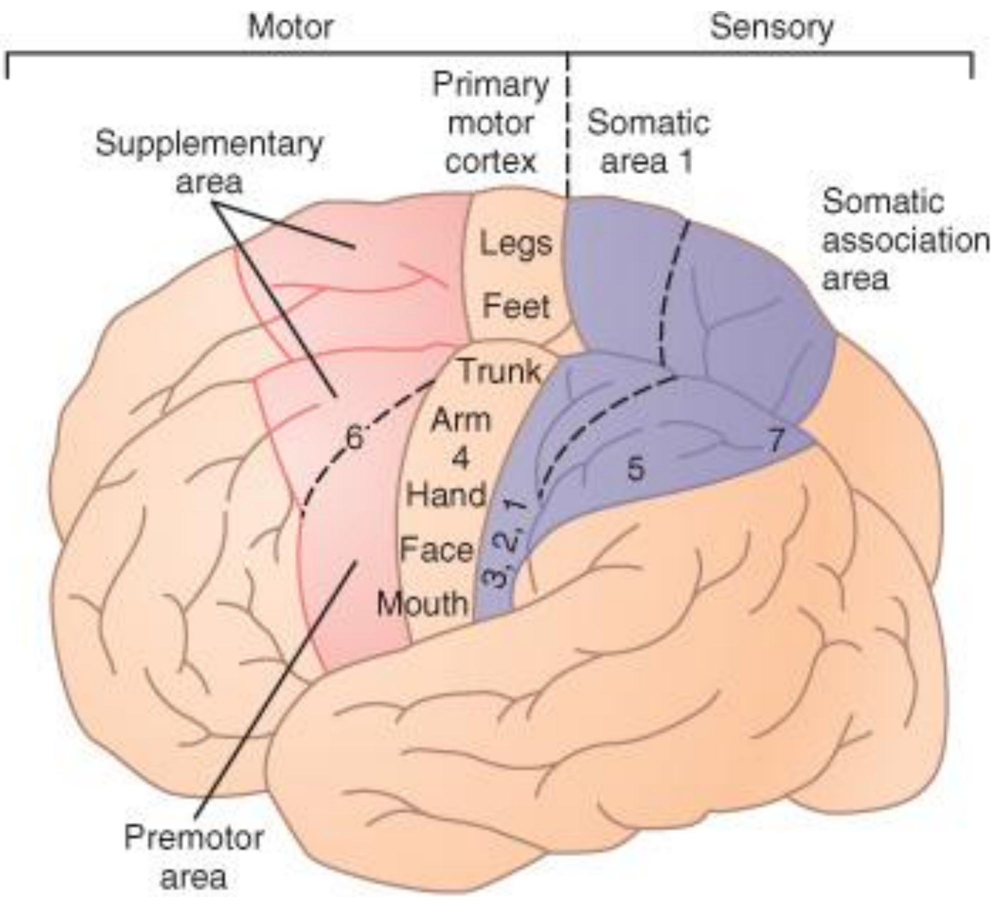


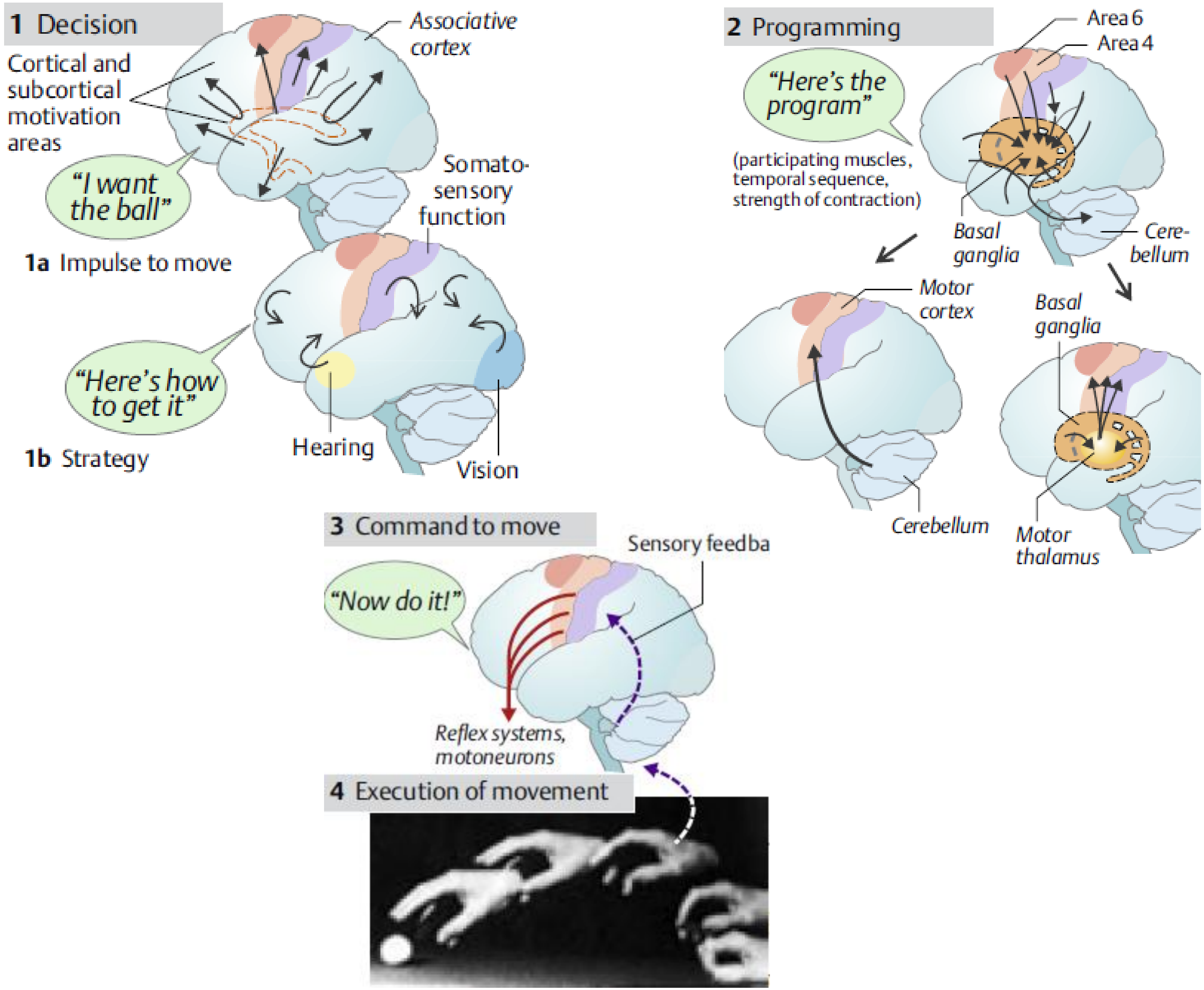
(a) Top view of brain

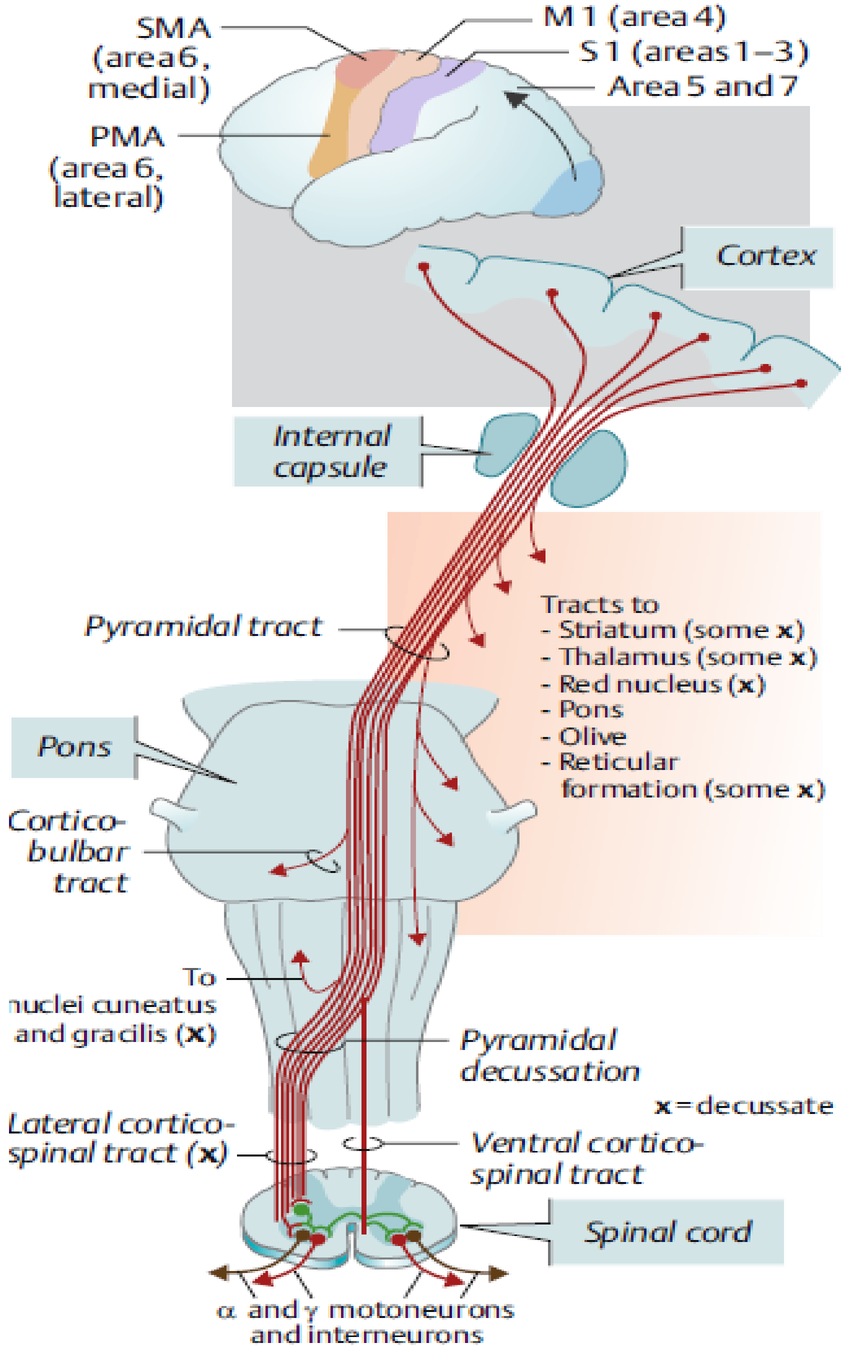
(b) Sensory homunculus

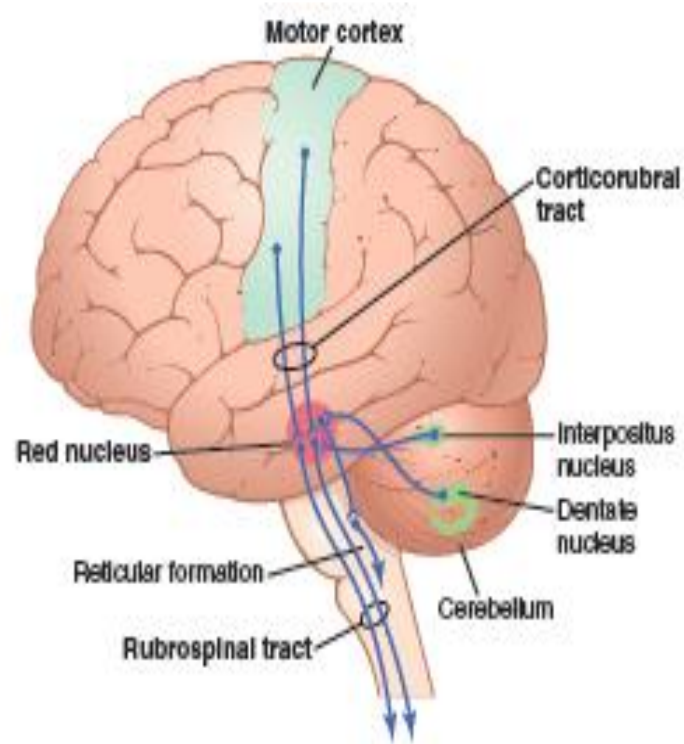
(c) Motor homunculus

Primary motor area (Brodmann's area 4)




1 Decision
Associative cortex
Cortical and subcortical motivation areas
"I want the ball"
Somato-sensory function
1a Impulse to move
"Here's how to get it"
Hearing
Vision
1b Strategy
2 Programming
Area 6
Area 4
"Here's the program"
(participating muscles, temporal sequence, strength of contraction)
Basal ganglia
Cere-bellum
Motor cortex
Basal ganglia
Cerebellum
Motor thalamus
3 Command to move
Sensory feedba
"Now do it!"
Reflex systems, motoneurons
4 Execution of movement

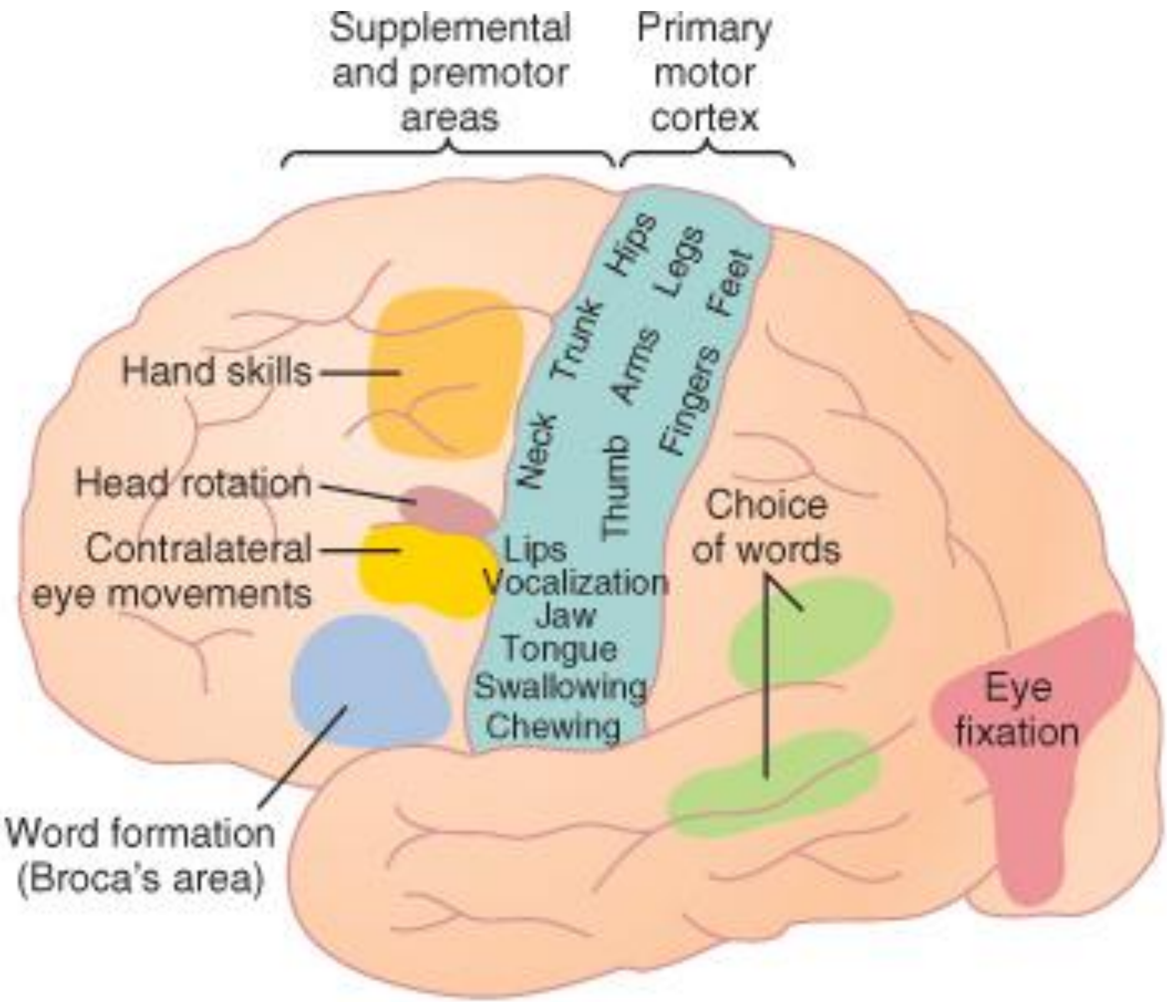

SMA
(area 6, medial)
M 1 (area 4)
S 1 (areas 1–3)
Area 5 and 7
PMA
(area 6, lateral)
Cortex
Internal capsule
Tracts to
- Striatum (some x)
- Thalamus (some x)
- Red nucleus (x)
- Pons
- Olive
- Reticular formation (some x)
Pyramidal tract
Pons
Cortico-bulbar tract
To nuclei cuneatus and gracilis (x)
Pyramidal decussation
x = decussate
Lateral cortico-spinal tract (x)
Ventral cortico-spinal tract
Spinal cord
α and γ motoneurons and interneurons


Motor cortex
Corticorubral tract
Red nucleus
Interpositus nucleus
Dentate nucleus
Reticular formation
Cerebellum
Rubrospinal tract

Pre motor area

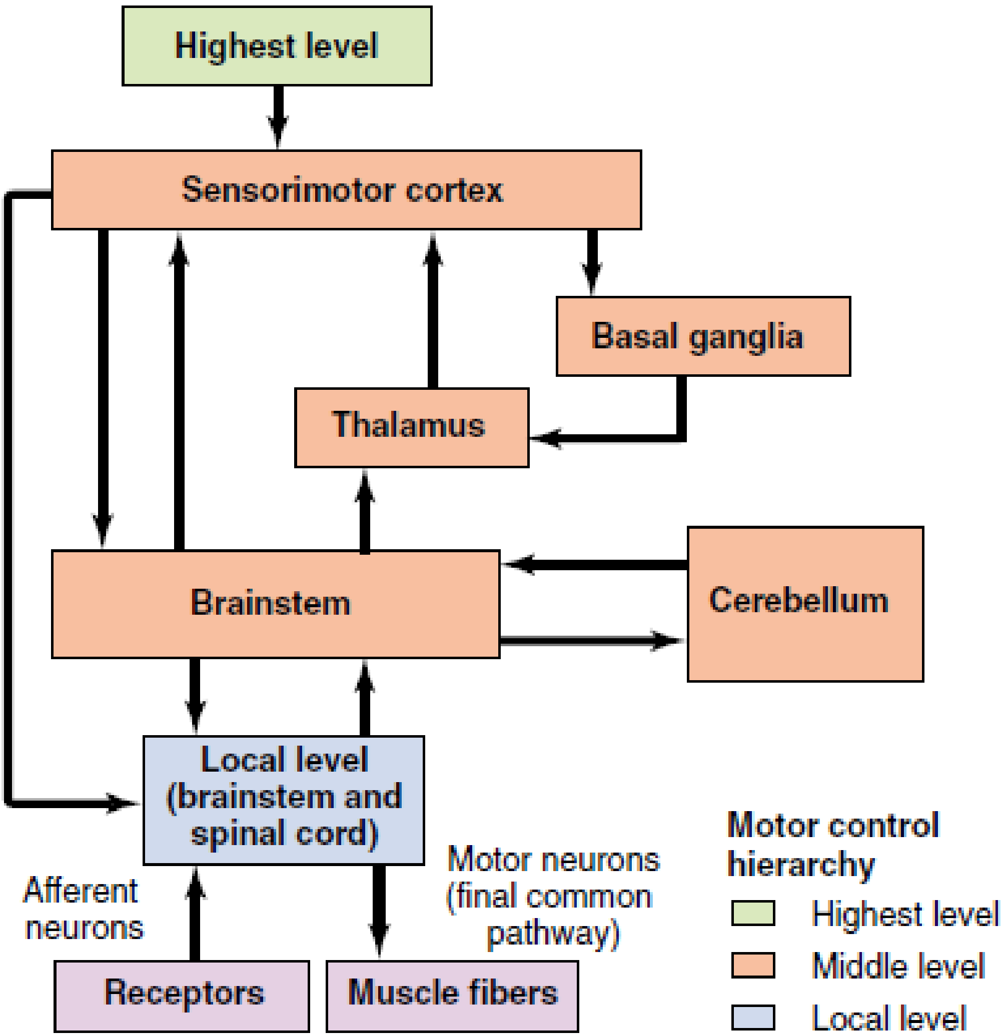
Location (lateral surface of each hemisphere in front of primary motor cortex

- It contributes
  - Descending fibres
  - pyramidal tract and
  - extra pyramidal fibres
  - Horizontal fibres
- Orienting the body and arms towards a specific target
- Guided by sensory input processed by **posterior parietal cortex**, a region posterior to primary somatosensory cortex

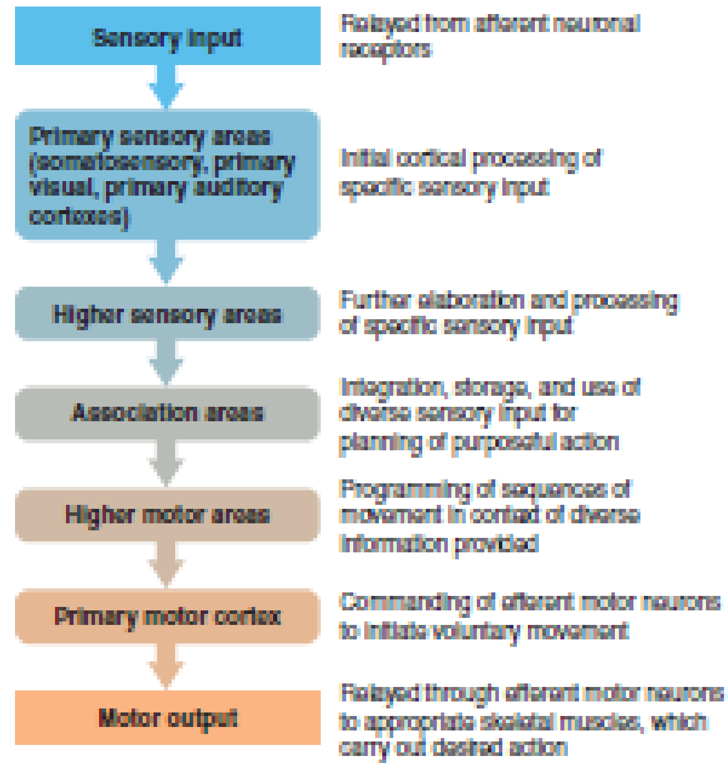

Supplemental and premotor areas
Primary motor cortex
Hips
Legs
Feet
Trunk
Arms
Fingers
Neck
Thumb
Hand skills
Head rotation
Contralateral eye movements
Lips
Vocalization
Jaw
Tongue
Swallowing
Chewing
Choice of words
Eye fixation
Word formation (Broca's area)

Supplimentary motor area

- Location (medial surface of each hemisphere anterior to primary motor area
- Preparatory role in programming complex sequence of movements
- Fixation movements of different segments of body, positional movements of the head and eyes, finer motor control of the arms and hands.



Highest level
Sensorimotor cortex
Basal ganglia
Thalamus
Brainstem
Cerebellum
Local level (brainstem and spinal cord)
Afferent neurons
Motor neurons (final common pathway)
Receptors
Muscle fibers
Motor control hierarchy
Highest level
Middle level
Local level



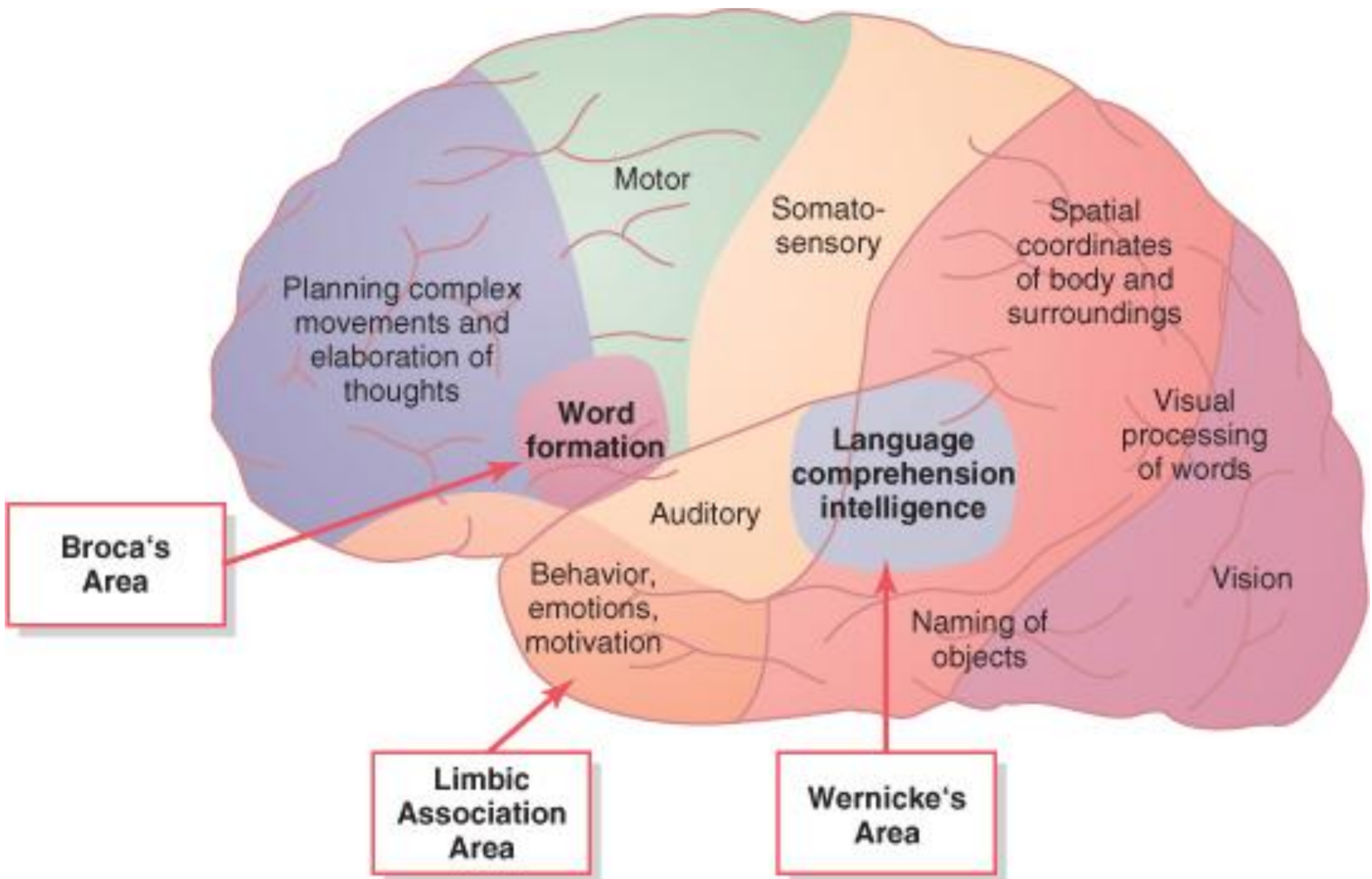
Sensory input
Relayed from afferent neuronal receptors
Primary sensory areas (somatosensory, primary visual, primary auditory cortexes)
Initial cortical processing of specific sensory input
Higher sensory areas
Further elaboration and processing of specific sensory input
Association areas
Integration, storage, and use of diverse sensory input for planning of purposeful action
Higher motor areas
Programming of sequences of movement in context of diverse information provided
Primary motor cortex
Commanding of efferent motor neurons to initiate voluntary movement
Motor output
Relayed through efferent motor neurons to appropriate skeletal muscles, which carry out desired action

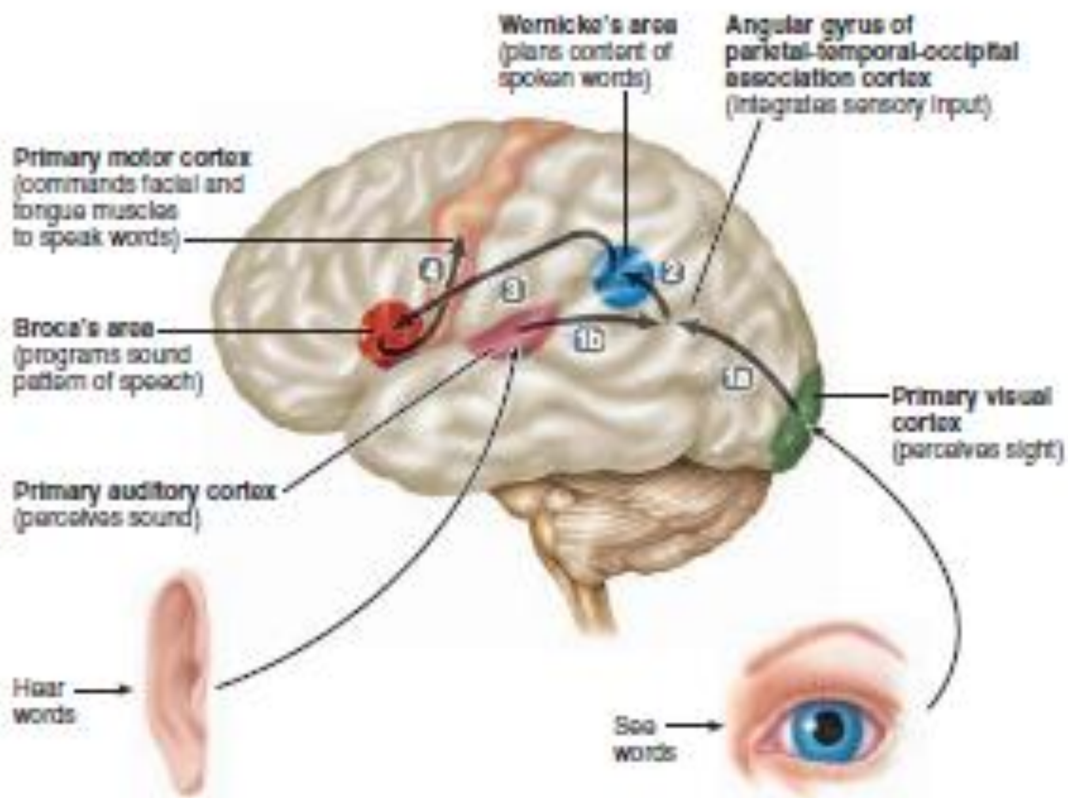
Language

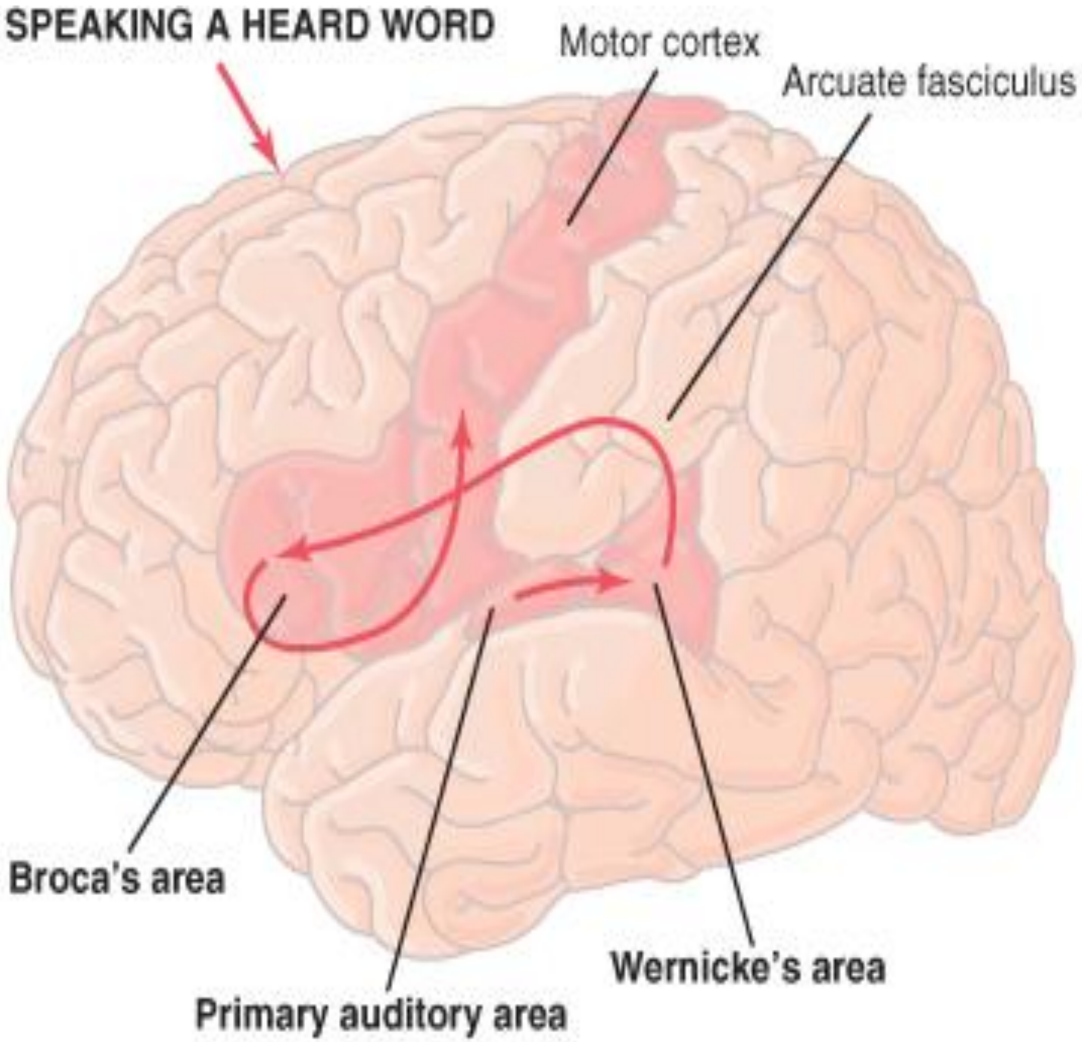
Two aspects of communication

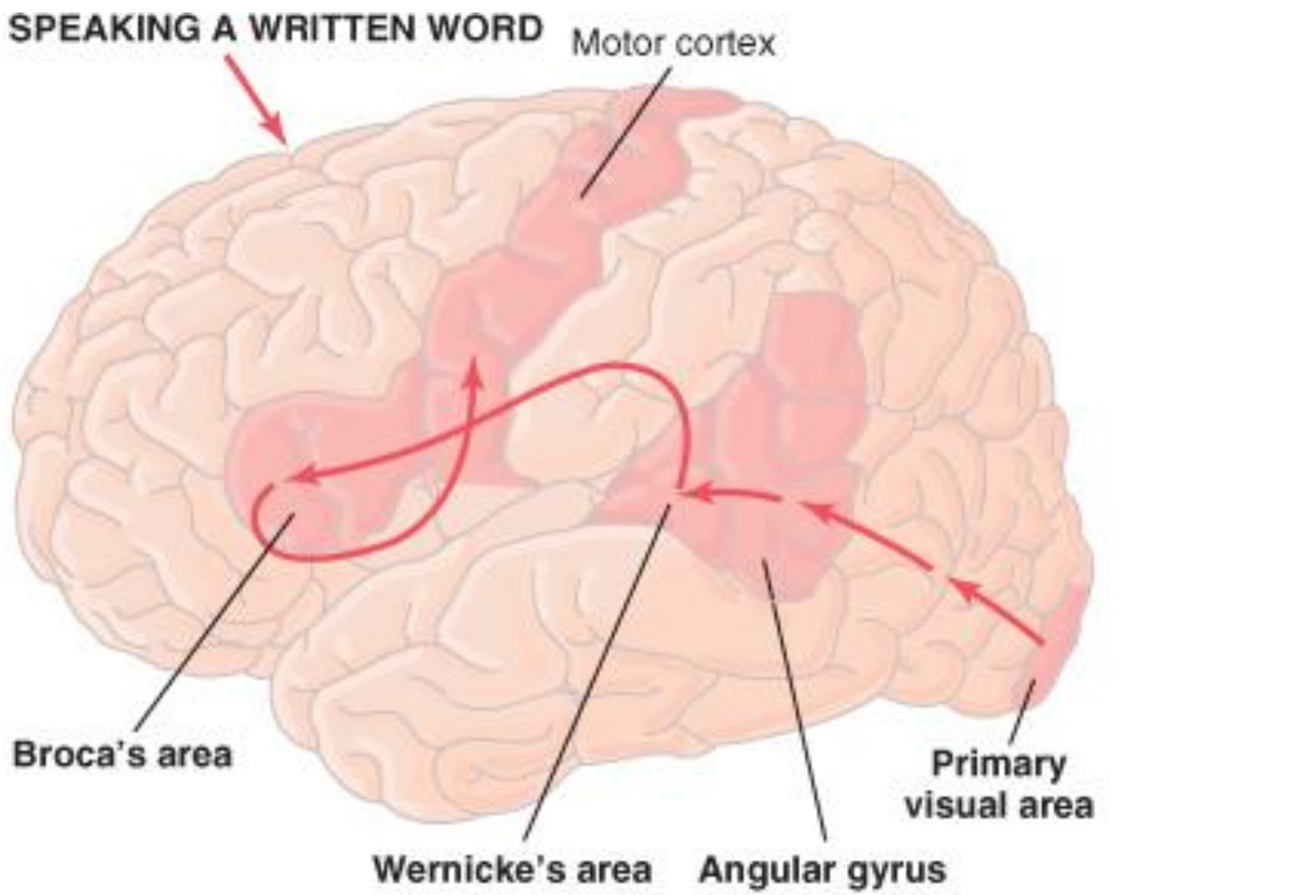
1. Sensory aspect (language input) →involves ear and eyes
2. Motor aspect (language output) →involves vocalization and its control

Different regions of the cortex control different aspects of language




Wernicke's area
(plans content of
spoken words)
Angular gyrus of
parietal-temporal-occipital
association cortex
(integrates sensory input)
Primary motor cortex
(commands facial and
tongue muscles
to speak words)
Broca's area
(programs sound
pattern of speech)
Primary visual
cortex
(perceives sight)
Primary auditory cortex
(perceives sound)
4
3
2
1b
1a
Hear
words
See
words


SPEAKING A HEARD WORD
Motor cortex
Arcuate fasciculus
Broca's area
Wernicke's area
Primary auditory area



SPEAKING A WRITTEN WORD
Motor cortex
Broca's area
Primary
visual area
Wernicke's area
Angular gyrus

Language disorders

- Auditory receptive aphasia (word deafness)
- Visual receptive aphasia (word blindness)
- Dyslexia → impaired ability to read because of lesion in visual association area
- Wernicke's aphasia

1) lesion in Wernicke's area of dominant hemisphere

2) Persons are capable of understanding the spoken or written word but are unable to interpret the thought that is expressed

3) Person is totally unable to understand and interpret the thought and cannot communicate (global aphasia)

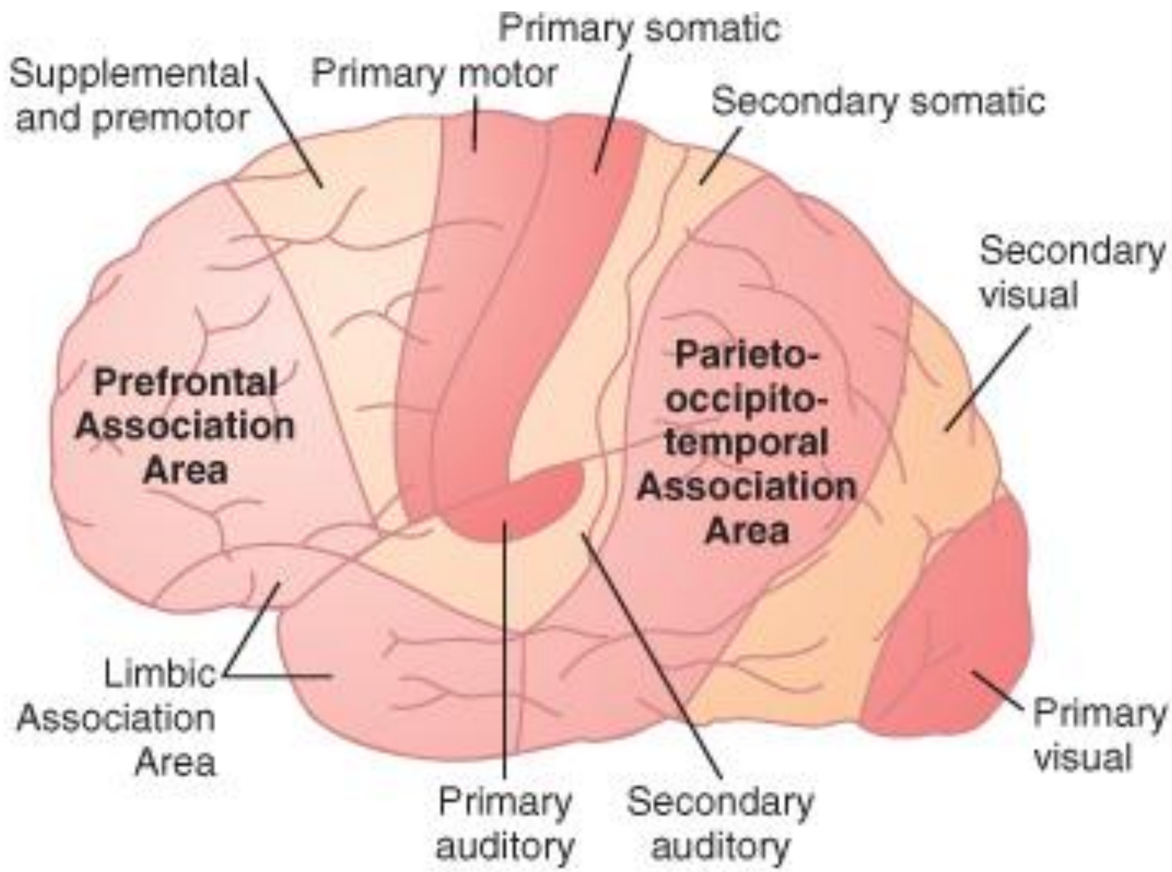
- Motor aphasia→ damage to Broca's area in dominant hemisphere

Person is capable of deciding what he or she wants to say but cannot make the vocal system emit words

Association areas of the cortex are involved in many higher functions

- They are so called because they contain association fibres which associates many areas together
- They receive & analyze signals simultaneously from multiple regions of both the motor and sensory cortices as well as from subcortical structures
- Most important association areas are

1. Parieto-occipito-temporal association area
2. Prefrontal association area
3. Limbic association area


Primary somatic
Supplemental
and premotor
Primary motor
Secondary somatic
Secondary
visual
Prefrontal
Association
Area
Parieto-
occipito-
temporal
Association
Area
Limbic
Association
Area
Primary
visual
Primary
auditory
Secondary
auditory

Parieto-occipito-temporal association area

- Location (lies at the interface of three lobes)

1. Analysis of spatial coordinates of all parts of the body as well as of the surroundings of the body
2. Area for language comprehension (connecting wernicke's area to visual and auditory cortex)
3. Area for initial processing of visual language (reading)
4. Area for naming objects

Prefrontal association area

- Is the front portion of the frontal lobe just anterior to the pre motor cortex
- It functions in close association with the motor cortex to plan complex patterns and sequences of motor movements
- It is essential to carry out thought processes in the mind → working memory (a type of memory that keeps information available, usually for short period, while the individual plans actions based on it
- Creativity
- Personality traits

Limbic association area

- Location (bottom and adjoining inner area of each temporal lobe)
- It is concerned with behavior,emotions motivations
- Is extensively involved in memory
- **Functions of working memory**
- Plan for the future
- Decision making
- Delay action in response to incoming sensory signals
- Considers the consequences of motor actions before they are performed
- Solve complicated mathematical, legal, philosophical problems

The cerebral hemispheres have some degree of specialization

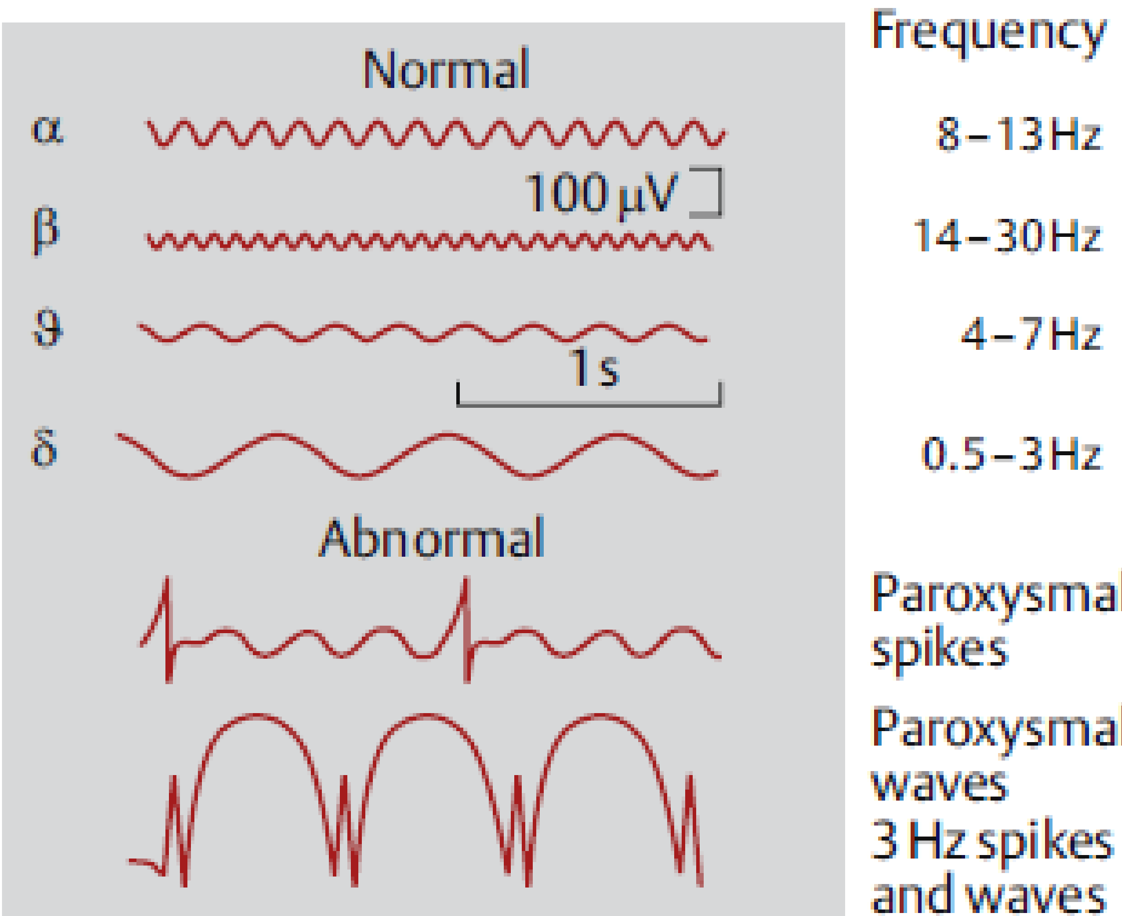
- Left cerebral hemispheres excels in logical, analytic, sequential and verbal tasks
- Right hemisphere excels in nonlanguage skills like spatial perception and artistic and musical talents
- Neurons in different regions of the cerebral cortex may fire in rhythmic synchrony

An electroencephalogram (EEG) is a record of postsynaptic activity of neurons

- Undulations in the recordings of electrical potential from the surface of brain or even from the outer surface of head.The entire record is called EEG
- As a clinical tool in diagnosis of cerebral dysfunction like epilepsy
- As a legal determination of brain death
- As to distinguish various stages of sleep

(a) Alpha rhythm (relaxed with eyes closed)

(b) Beta rhythm (alert)


Normal
α
β
ϑ
δ
100 µV
1 s
Abnormal
Frequency
8–13 Hz
14–30 Hz
4–7 Hz
0.5–3 Hz
Paroxysmal spikes
Paroxysmal waves
3 Hz spikes and waves

Alpha waves

- Character → rhythmical
- Frequency → 8-13cycles per sec.
- Voltage → about 50 micro volts
- Site of recording → almost intensely in occipital region but can also be recorded from parietal and frontal regions
- Occur normally in EEG of adult people when they are awake and in quiet,resting state

Beta waves

- Character → asynchronous
- Frequency →14-80 cycles per sec.
- Voltage → low voltage
- Site of recording → from parietal and frontal regions
- They occur when awake person's attention is directed to some specific type of mental activity e.g opening the eyes

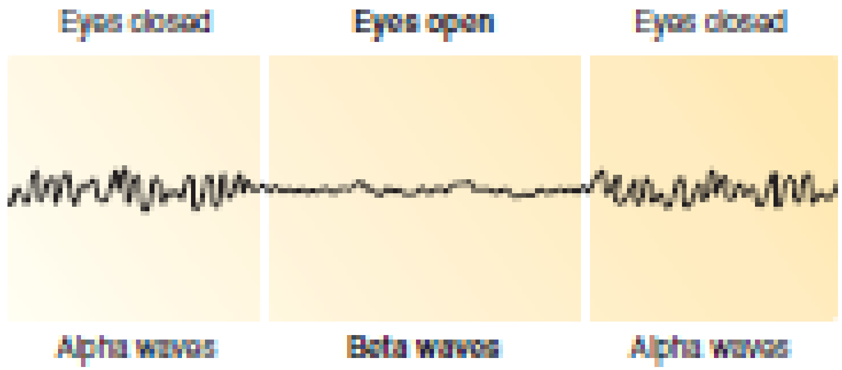
Theta waves

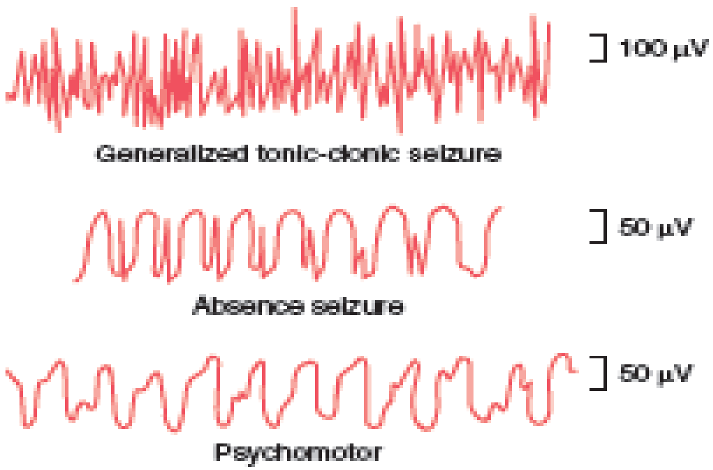
- Frequency → 4-7cycles per sec.
- Site of recording → from temporal and parietal regions of brain in children
- They occur normally in children but in adults in case of emotional stress

  In many brain disorders e.g degenerative brain states

Delta waves

- Character → synchronous
- Frequency → less than 3.5 cycles per sec.
- Voltage → 2-4 times greater than most of other brain waves
- They occur in very deep sleep,in infancy and in serious organic brain diseases


Eyes closed
Eyes open
Eyes closed
Alpha waves
Beta waves
Alpha waves


100 µV
Generalized tonic-clonic seizure
50 µV
Absence seizure
50 µV
Psychomotor

Grand mal epilepsy

- Extreme neuronal discharges in all areas of brain
- Signs and symptoms
  - Generalized tonic seizures
  - Tonic clonic seizures
  - Tongue bite
  - Difficult breathing
  - Cyanosis
  - Incontinence of urine and stool
  - post seizure depression
- EEG

High voltage,high frequency discharges occur over entire cortex

Hereditary predisposition

Factors that can increase the excitability of abnormal circuits are

→strong emotional stimuli

→alkalosis caused by over breathing

→drugs

→fever

→loud noises and flashing lights

- What stops the grand mal attack

→neuronal fatigue

→active inhibition by inhibitory neurons that have been activated by the attack

Petit mal epilepsy

- Extreme neuronal discharge in thalamocortical brain activating system
- Signs and symptoms

  3-30 seconds of unconsciousness

  Twitch like contractions of muscles usually in head region

  Blinking of eyes
- It is also called absence syndrome or absence epilepsy
- EEG

  spike and dome pattern

Focal epilepsy

- It can involve any local part of the brain
- Such localized organic lesion may be

  1) scar tissue in the brain that pulls on the adjacent neuronal tissue

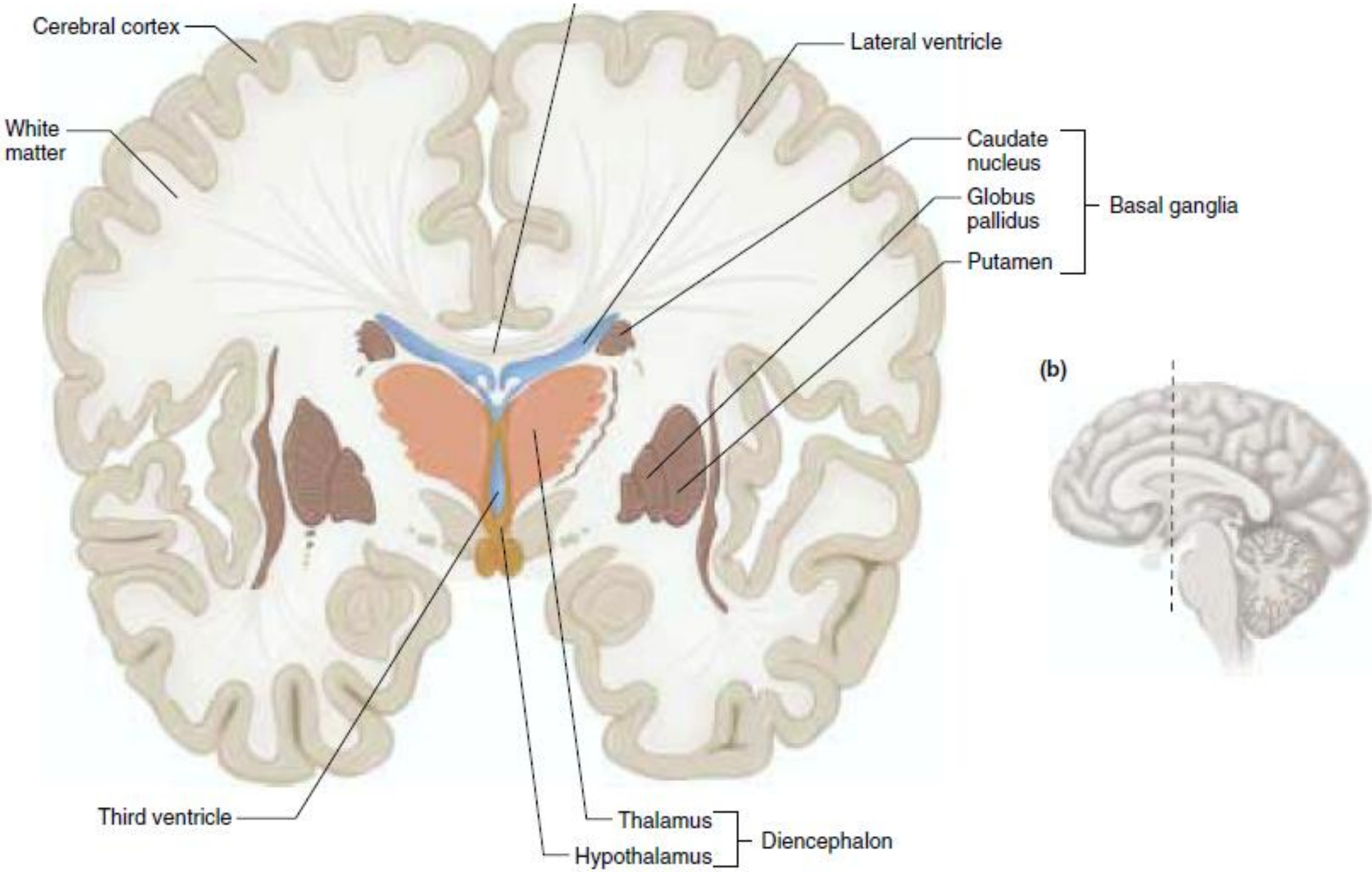
  2) a tumor that compresses an area of the brain

  A short period of amnesia

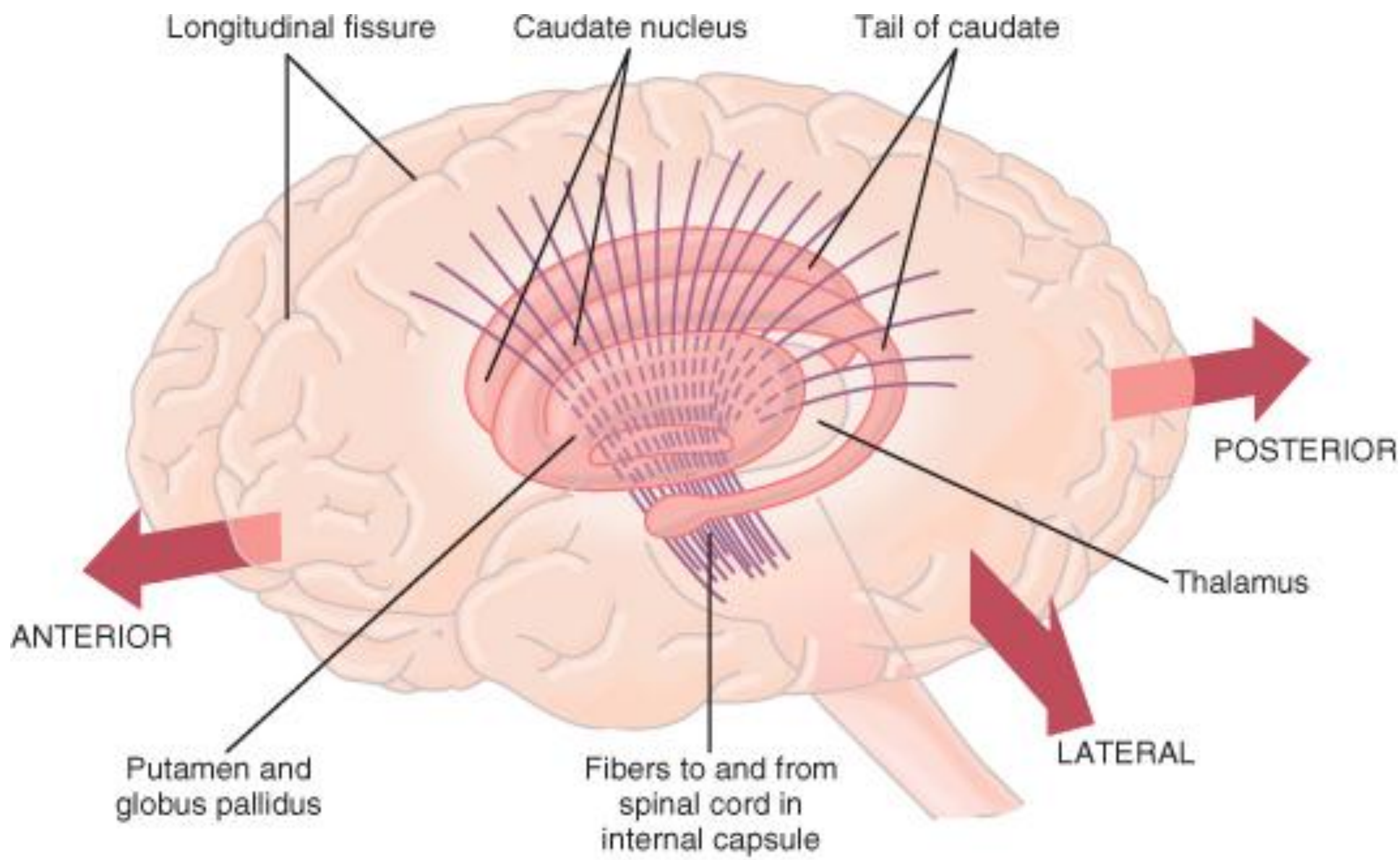
  Anxiety,discomfort and fear

  Incoherent speech
- EEG: low frequency , rectangular waves

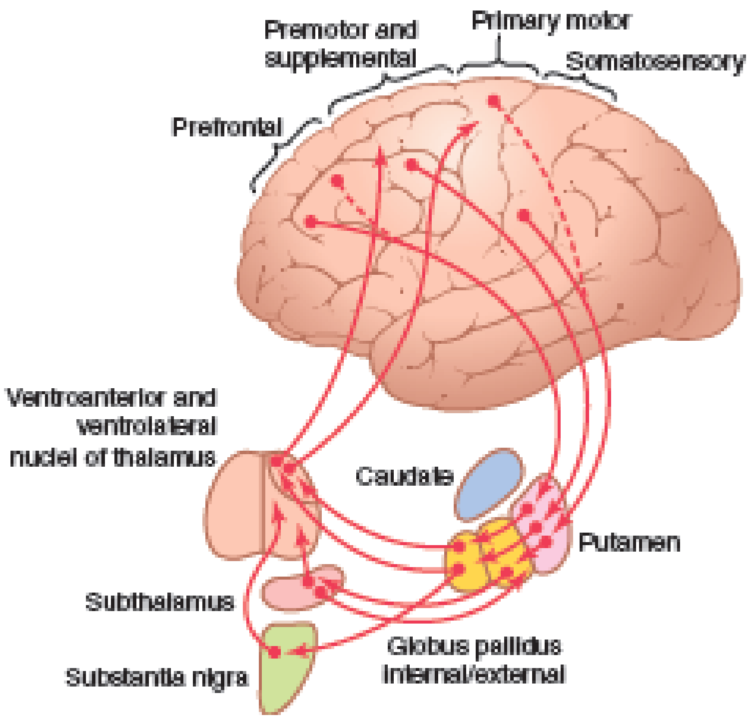
Basal Ganglia

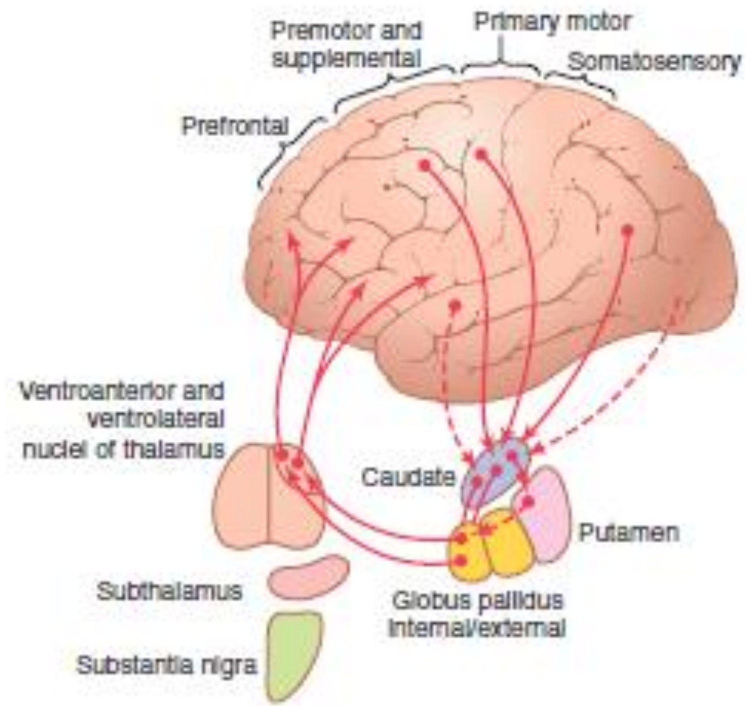


PHYSIOLOGICAL ANATOMY



NEURONAL CIRCUIT AND FUNCTIONS





<u>Putamen Circuit</u>

Functions:

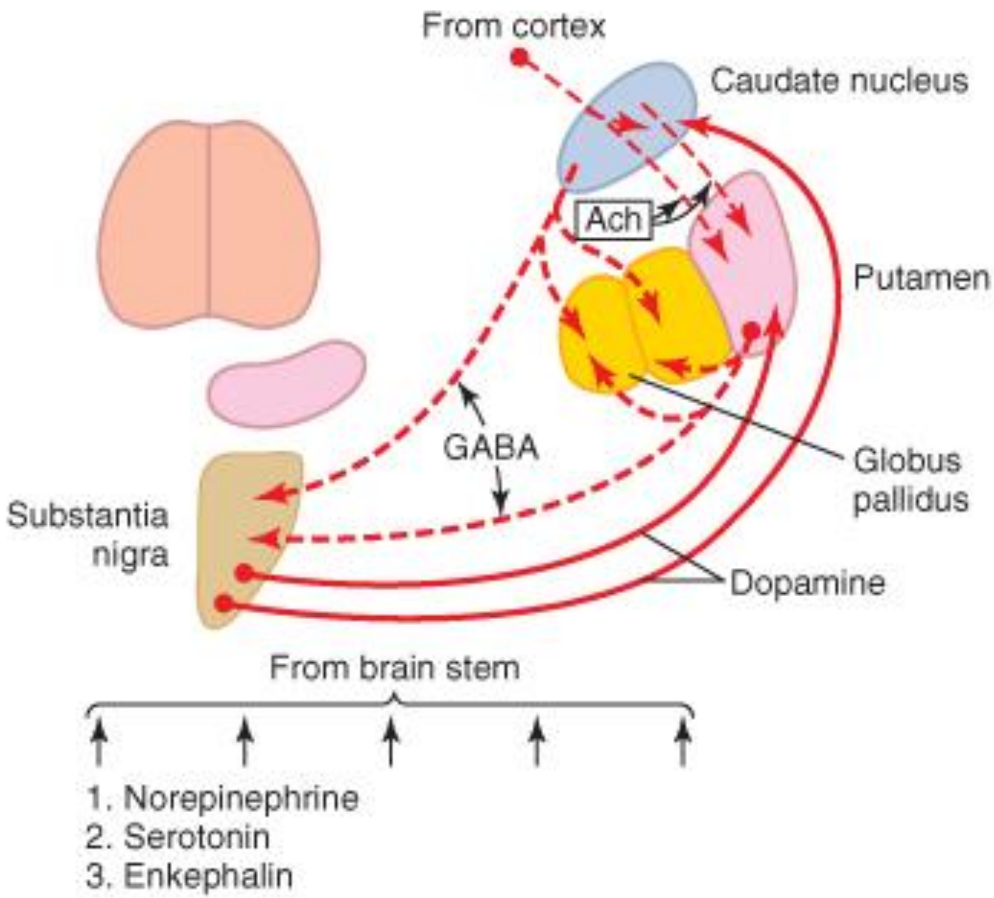
1. Writing letters of alphabets
2. Skilled movements

<u>Caudate Circuit</u>

Functions it control:

1) Cognitive control of sequences of movements e.g. a person seeing a lion approach & then responding
2) Change the timing & to scale the intensity of movements

Functions of specific neurotransmitter substances in the basal ganglia system



CLINICAL ABNORMALITIES

) Athetosis – lesion in globus pallidus

→ writing movements of hands, arm, neck or face

2) Hemiballismus- lesion in subthalamus

→ flailing movements of an entire limb

3) Chorea- lesion in putamen

→ flicking movements in the hands,face or other parts of body

Parkinson's disease

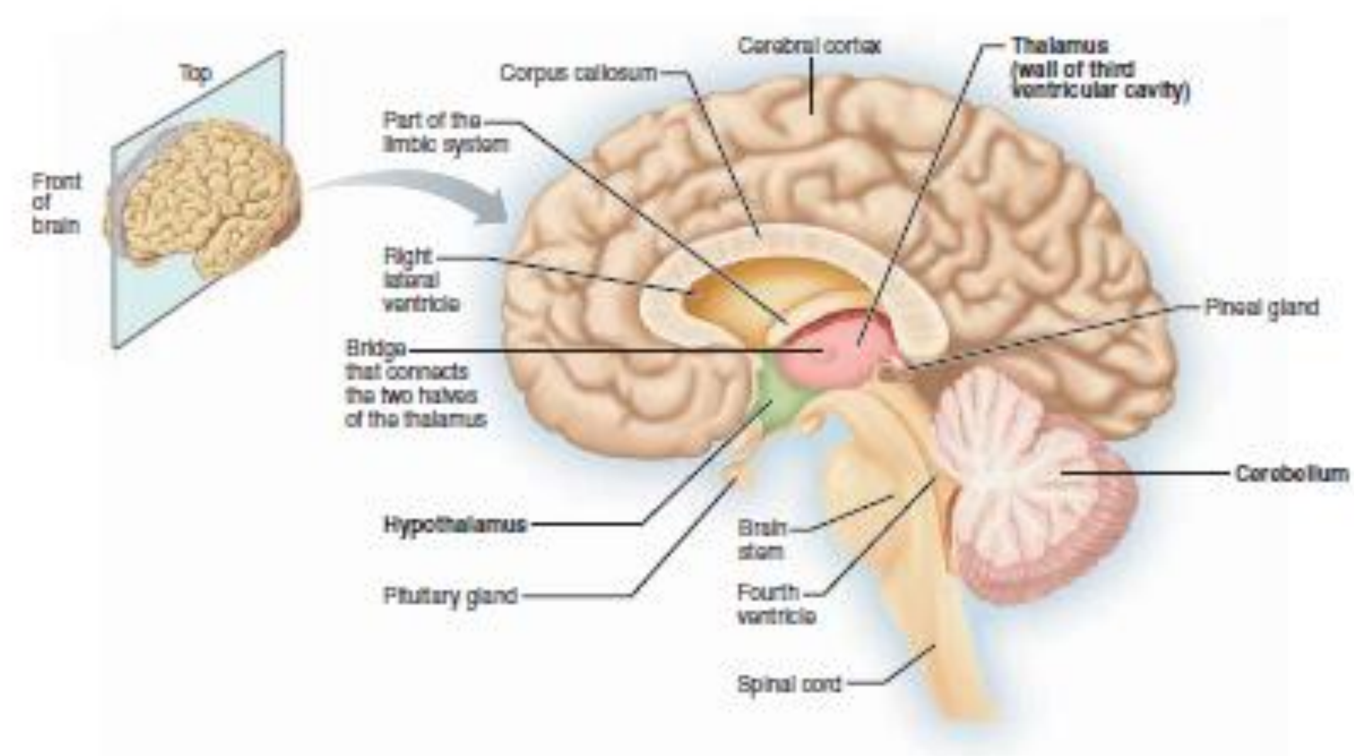
- Etiology
- Characterized by:
  - Rigidity
  - Involuntary tremors
  - Akinesia→difficulty in initiating movements
- Treatment
  - l-dopa
  - l-deprenyl
  - Transplanted fetal dopamine cells

Huntington’s disease

- Hereditary disorder
- Etiology

  loss of cell bodies of GABA secreting and acetylcholine secreting neurons
- Flicking movements in individual muscles and then progress to entire body
- dementia

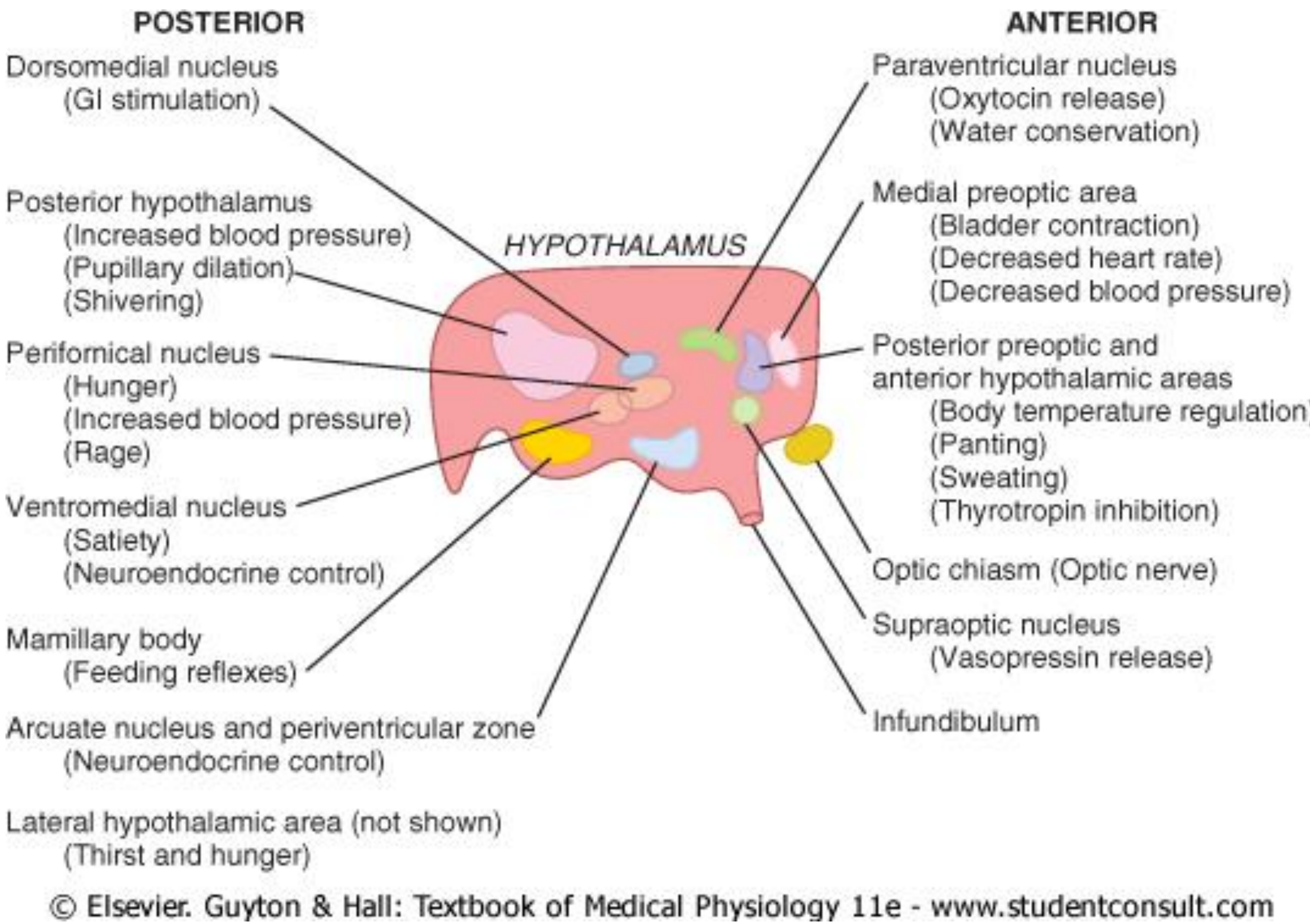
THE Thalamus & Hypothalamus

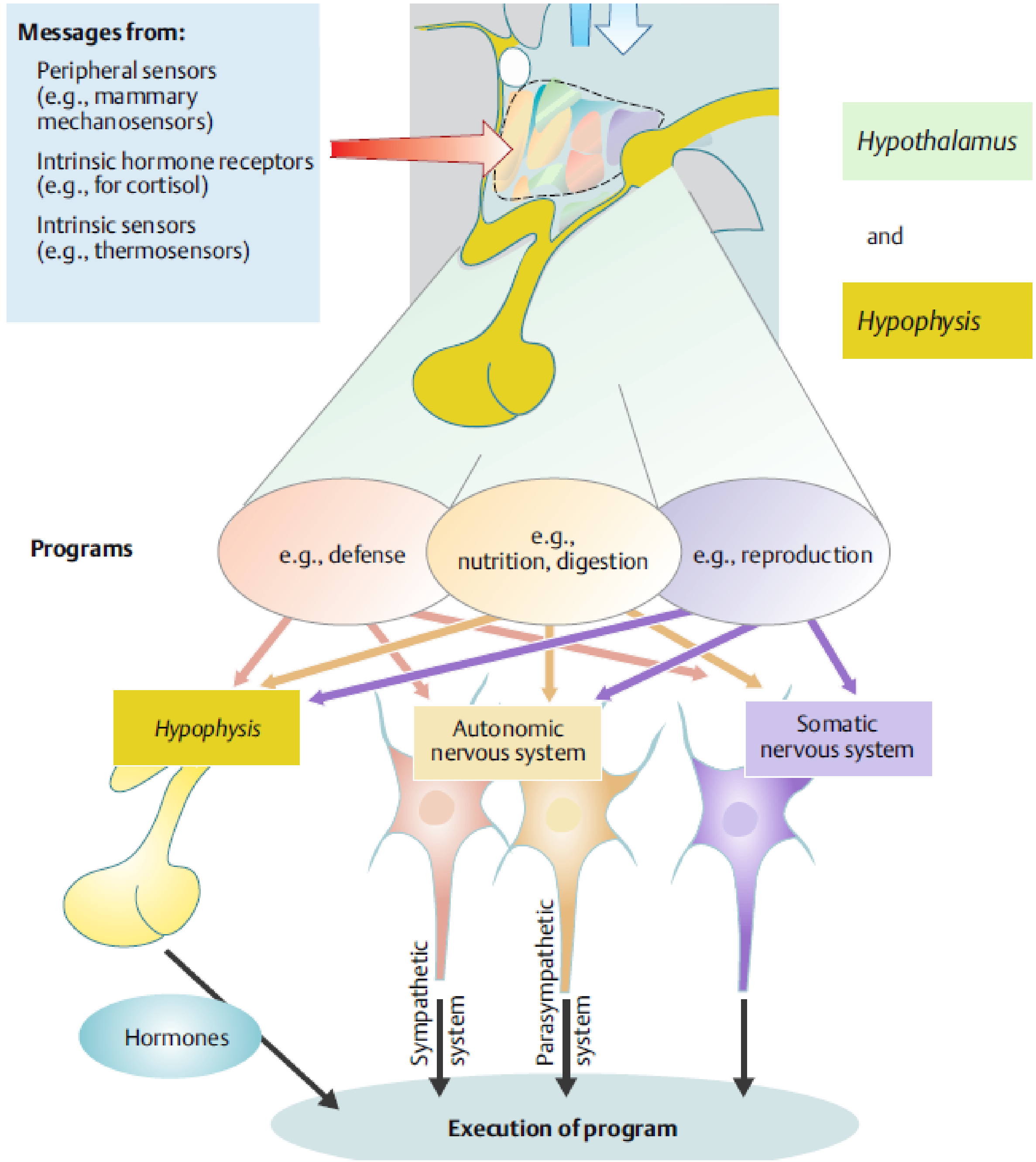


THE THALAMUS

- The thalamus is sensory relay station and is important in motor control
- Screen out insignificant signals and routes the important sensory impulses to somatosensory cortex
- Motor control by positively reinforcing voluntary motor behavior initiated by the cortex

Hypothalamus




Messages from:
Peripheral sensors (e.g., mammary mechanosensors)
Intrinsic hormone receptors (e.g., for cortisol)
Intrinsic sensors (e.g., thermosensors)
Hypothalamus
and
Hypophysis
Programs
e.g., defense
e.g., nutrition, digestion
e.g., reproduction
Hypophysis
Autonomic nervous system
Somatic nervous system
Sympathetic system
Parasympathetic system
Hormones
Execution of program

Cardiovascular regulation

- Stimulation of posterior and lateral hypothalamus increases the arterial pressure and heart rate
- Stimulating the pre optic area decreases both heart rate and arterial pressure
- These effects are transmitted through specific cardiovascular centers in reticular regions of pons and medulla

Regulation of body water

- Hypothalamus regulates body water in two ways

1- By creating the sensation of thirst. When fluid electrolytes in this center become too much concentrated, the animal develops an intense desire to drink water

2- By controlling the excretion of water into the urine. Centers in the supra optic nuclei

- When the body fluids become too concentrated, the neurons of this area become stimulated
- Send fibers through infundibulum to posterior pituitary
- Nerve endings secrete ADH, absorbed into blood, transported to kidneys, increase absorption of water in collecting ducts

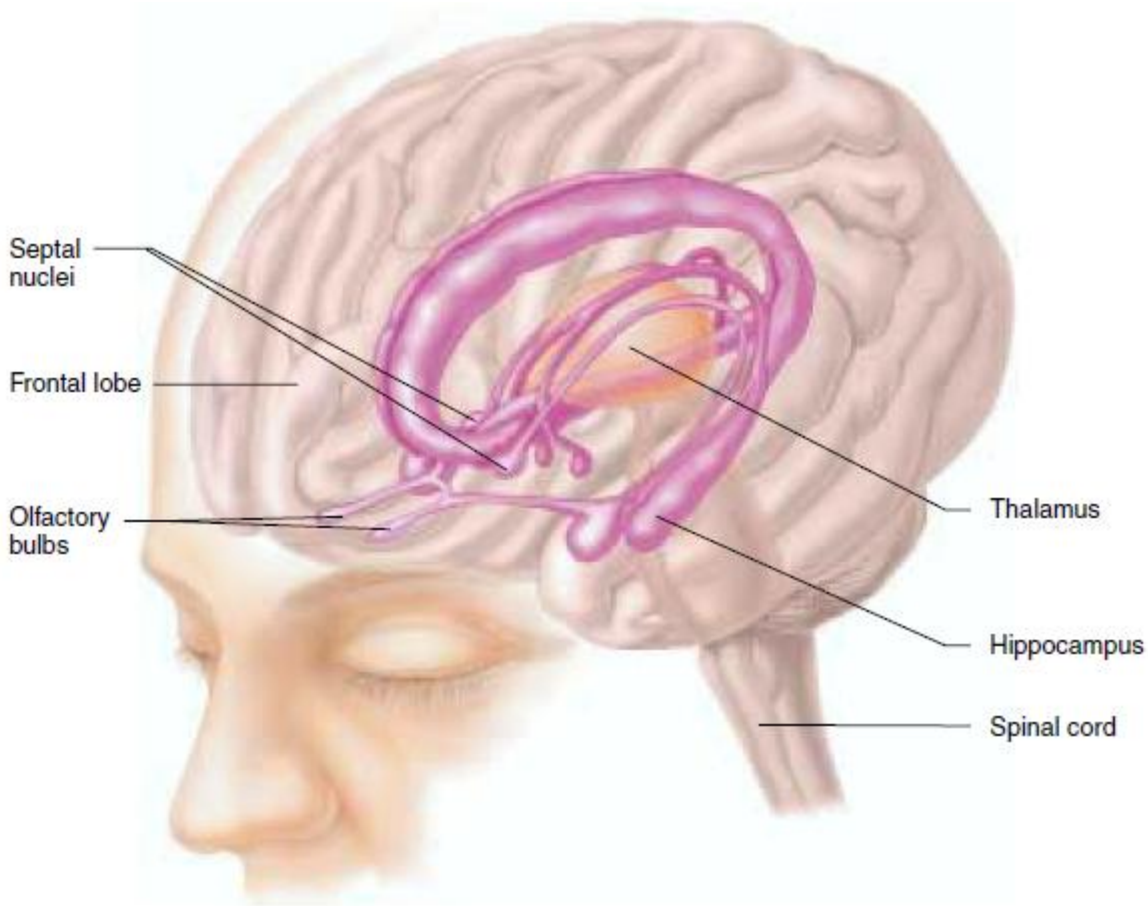
Regulation of uterine contraction and milk ejection

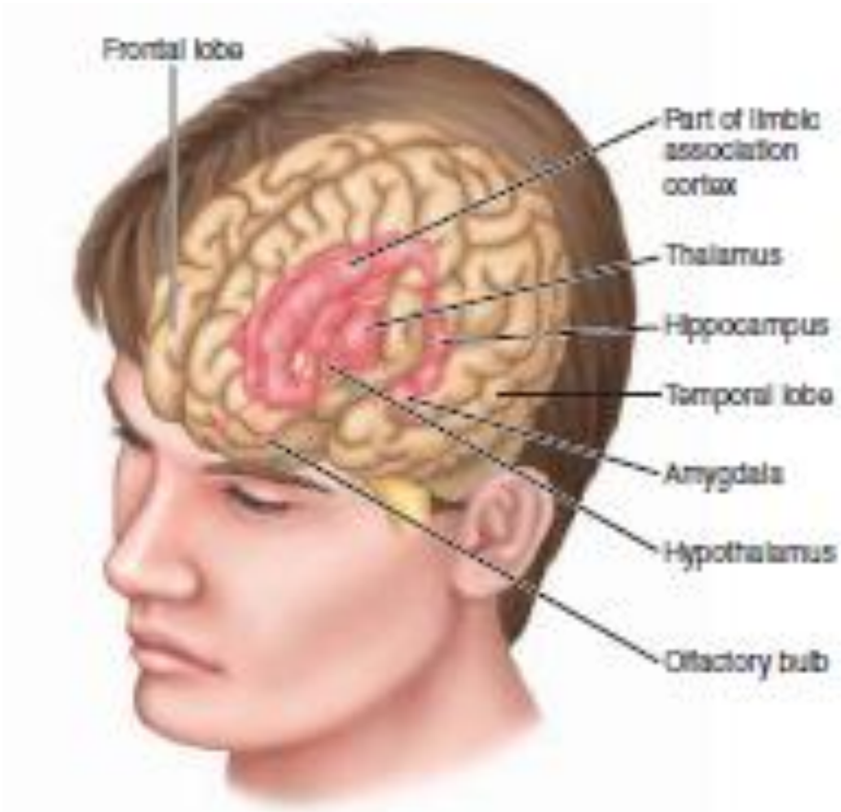
- Centers in paraventricular nuclei
- Secrete oxytocin in posterior hypothalamus
- Increase contractility of uterus
- Increase contractility of myoepithelial cells surrounding the alveoli of breast

Regulation of body temperature

- Pre optic area of anterior hypothalamus regulates the body temperature
- Mechanism of temperature regulation

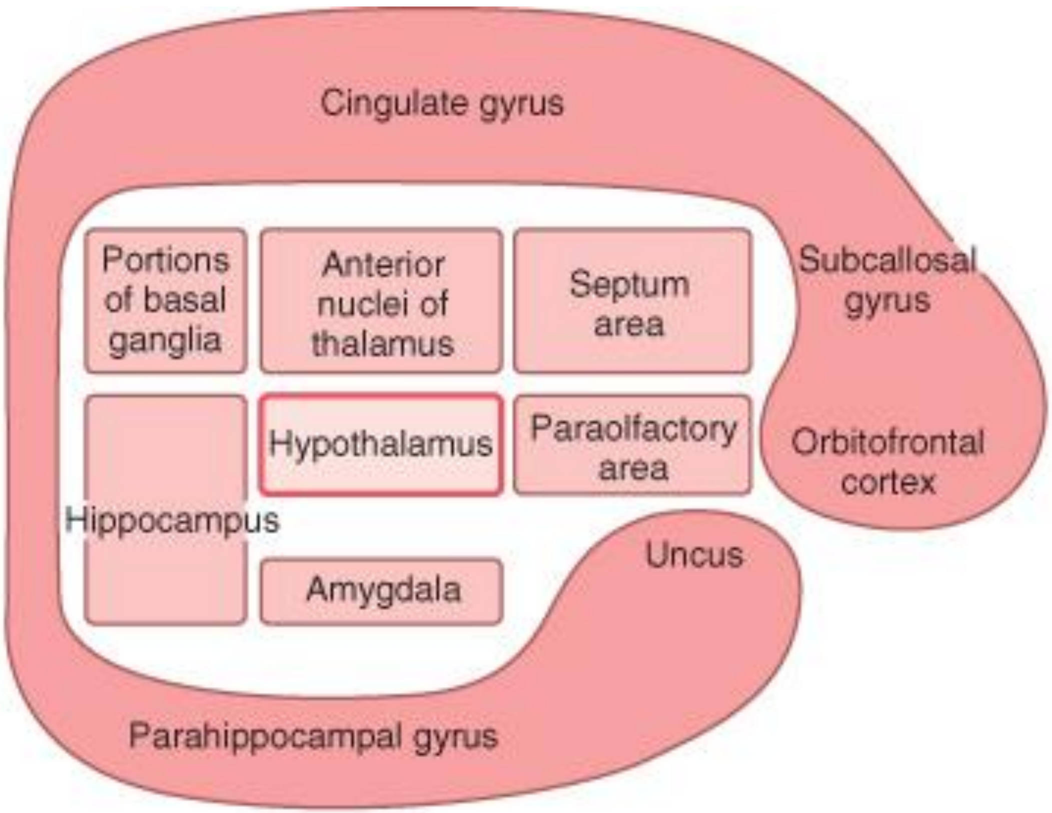
LIMBIC SYSTEM





Frontal lobe
Part of limbic association cortex
Thalamus
Hippocampus
Temporal lobe
Amygdala
Hypothalamus
Olfactory bulb

Components


Cingulate gyrus
Portions of basal ganglia
Anterior nuclei of thalamus
Septum area
Subcallosal gyrus
Hypothalamus
Paraolfactory area
Orbitofrontal cortex
Hippocampus
Uncus
Amygdala
Parahippocampal gyrus

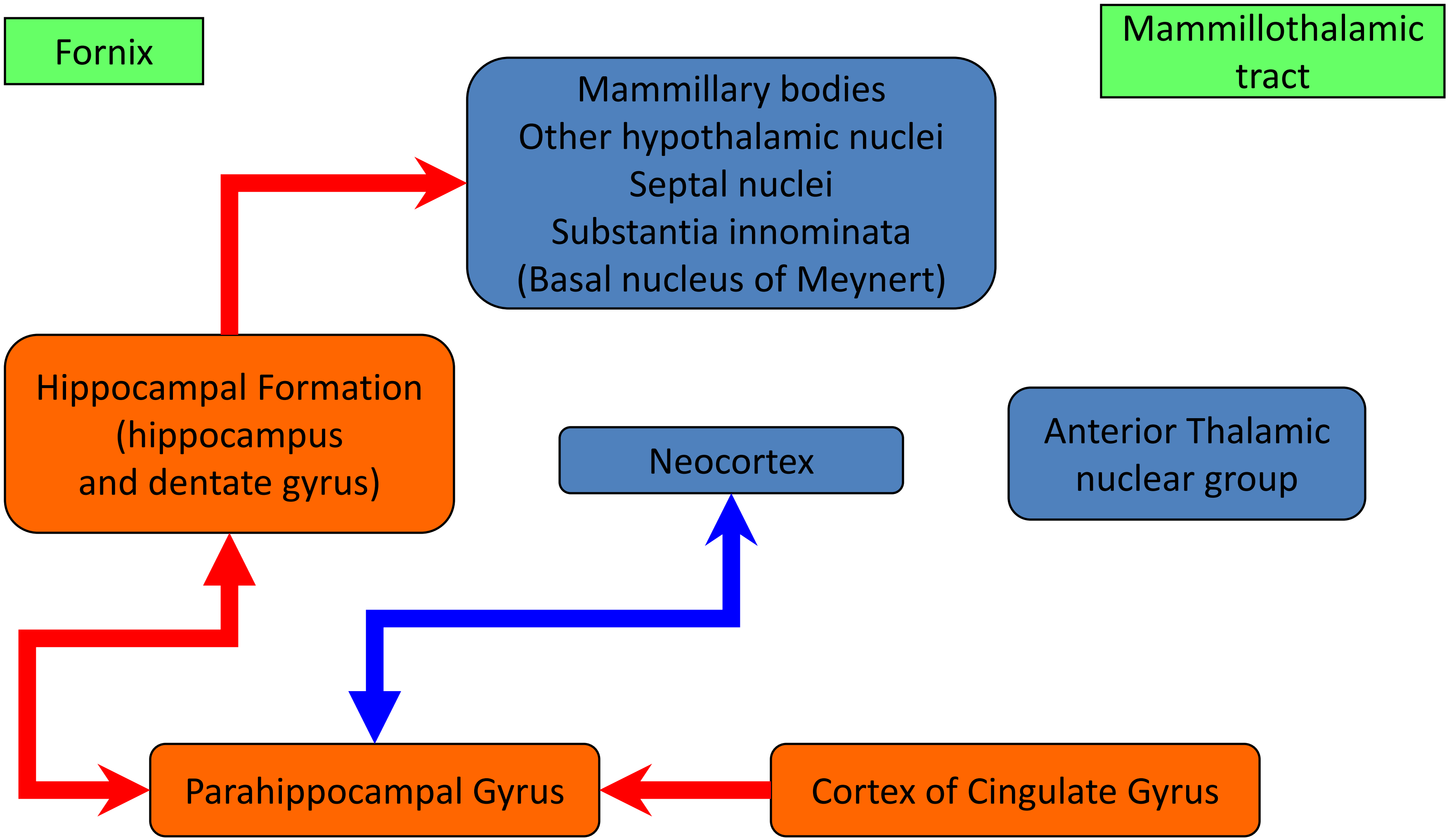
Functions

- “Emotional brain
  - Emotional and motivational aspects of behavior.
  - Provides emotional component to learning process:
    - Especially the amygdala.
- Associated with memory
  - Especially the hippocampus.
- Associated with pain/pleasure, rage

Emotions and Behaviour

- The limbic system plays a key role in emotions
- Love
- Hate
- Joy
- Shame
- Guilt
- Fear
- Anxiety

Papez Circuit (Emotions)



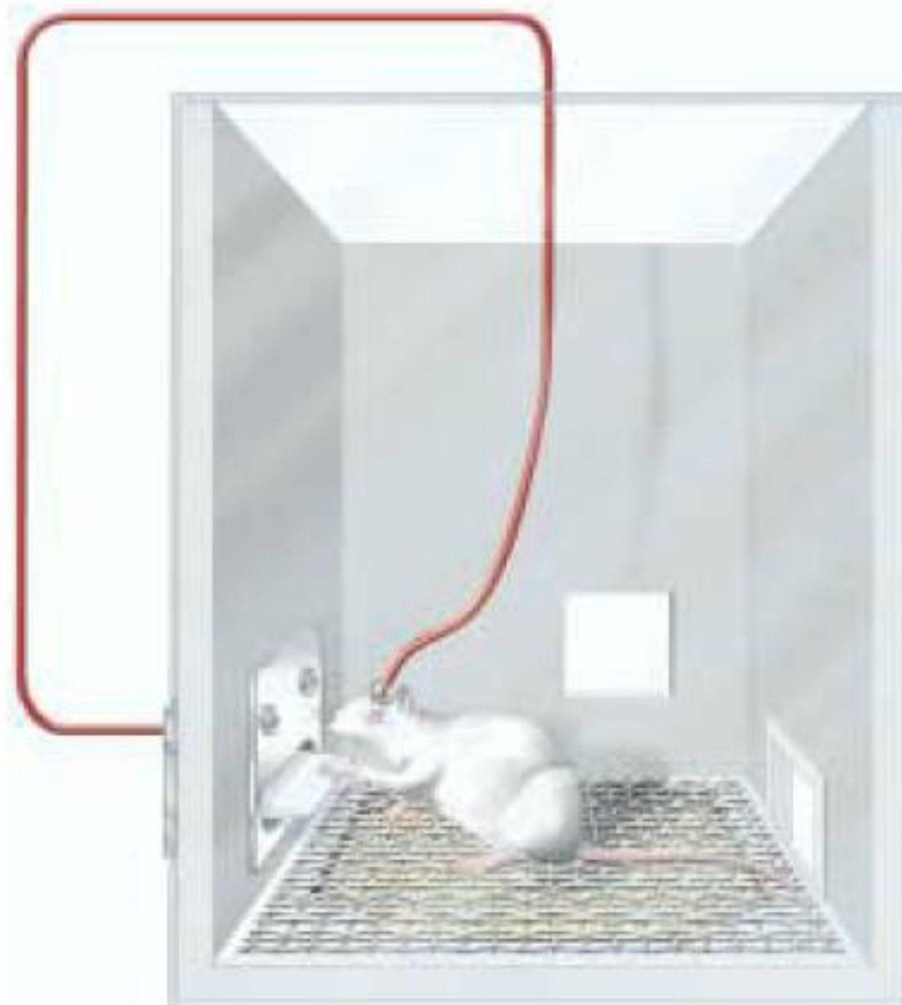
Reward and punishment functions of limbic system

- Whether the sensations are pleasant or unpleasant
- Major reward centers

→located along the course of the medial forebrain bundle,especially in lateral and ventromedial nuclei of hypothalamus

- Less potent reward centers

→septum, amygdala, certain areas of thalamus and basal ganglia



Punishment centers

- Most potent areas

→ central gray area surrounding the aqueduct of sylvius in the mesencephalon extending upward in the periventrivular zones of hypothalamus and thalamus

- Less potent punishment areas

→amygdala, hippocampus

Administration of a tranquilizer such as chlorpromazine, inhibits both reward and punishment centers

Functions of hippocampus

- Location
- Sensory experience → activation of some part of hippocampus → many out going signals to the anterior thalamus, hypothalamus and other parts of limbic system especially through the fornix→ Pleasure, rage, excess, sex drive etc
- Hyperexcitability of hippocampus

  → psychomotor effects including olfactory,visual, auditory, tactile and other types of hallucinations
- It's lesion leads to anterograde amnesia (unable to establish new long term memories)

Amygdala

- Large nuclear group in temporal lobe.
- Afferents:

Olfactory tract

Solitary nucleus

Parabrachial nucleus

Limbic neocortex:

Cingulate gyrus

Parahippocampal gyrus

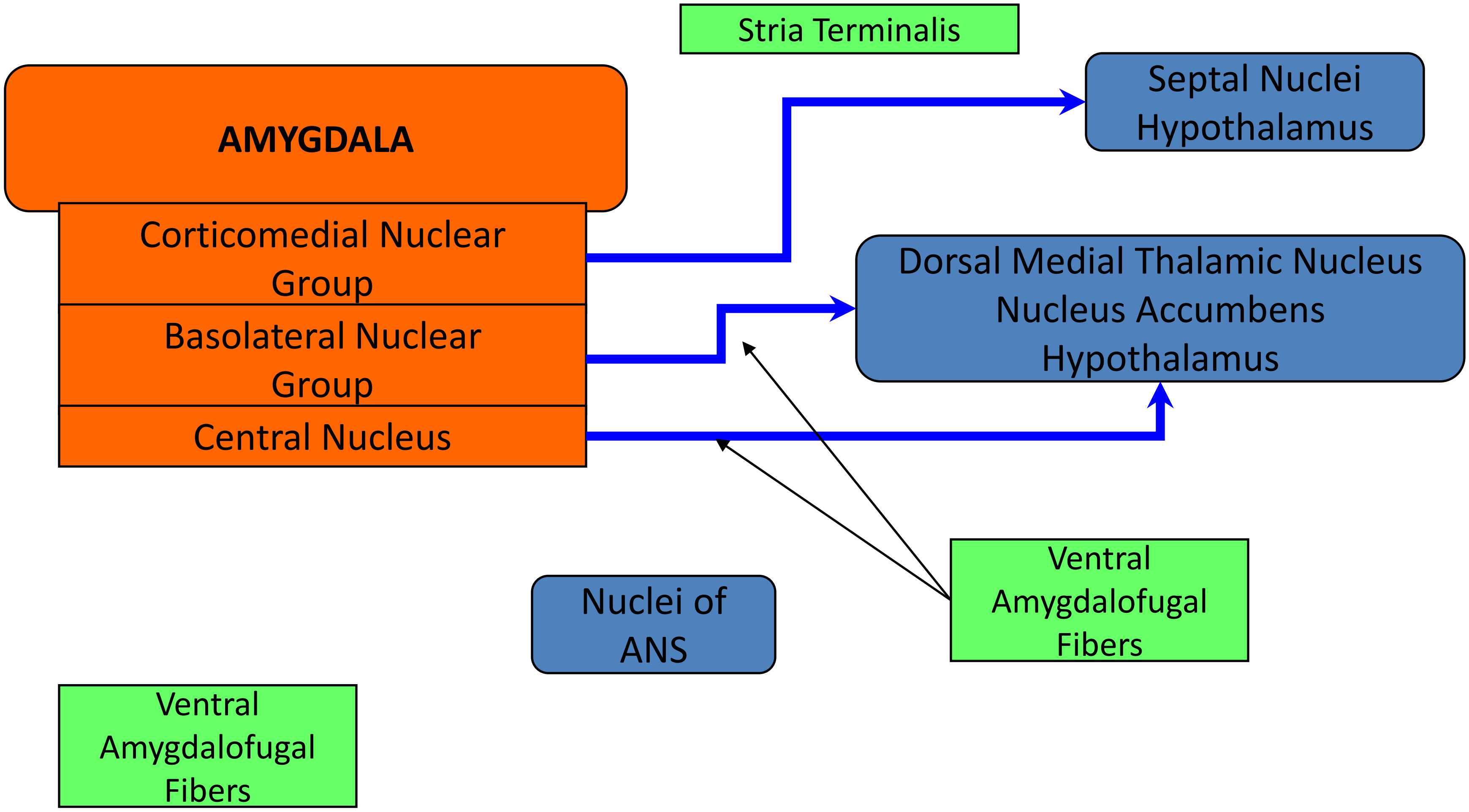
- Large basolateral region:

  Provides direct input to basal ganglia and motor system.
- Small corticomedial group of nuclei:

  Related to olfactory cortex.
- Medial and central nuclei:

  Connected to hypothalamus.

Amygdala Outputs



Functions

- Relate environmental stimuli to coordinated behavioral autonomic and endocrine responses seen in species-preservation.
- Responses include:

  Feeding and drinking

  Agnostic (fighting) behavior

  Mating and maternal care

  Responses to physical or emotional stresses.

Lesions

- Voracious appetite
- Increased (perverse) sexual activity
- Docility:

    Loss of normal fear/anger response

- Memory loss:

    Damage to hippocampus portion:

    Cells undergoing calcium-induced changes associated with memory

Kluver-Bucy Syndrome:

- Results from bilateral destruction of amygdala.
- Characteristics:

Increase in sexual activity.

Compulsive tendency to place objects in mouth.

Decreased emotionality.

Changes in eating behavior.

Visual agnosia.

Learning & Memory

- Learning is the acquisition of knowledge as a result of experience
- Memory is laid down in stages
- Memory traces
- Consolidation
- Working memory (*function of prefrontal cortex)
- Short term memory→ that lasts for seconds or minutes unless they are converted into long term memory
- Intermediate long term memory → that lasts for days to weeks but then fade away
- Long term memory→ which once stored can be recalled up to years or even life time later

Functions of working memory

- Plan for the future
- Decision making
- Delay action in response to incoming sensory signals
- Considers the consequences of motor actions before they are performed
- Solve complicated mathematical, legal, philosophical problems

Consolidation of memory

- Short term memory if activated repeatedly will initiate chemical, physical and anatomical changes in the synapses
- Requires 5-10 min. for minimal and 1 hr. for strong consolidation
- Brain convulsions and deep general anesthesia can prevent consolidation
- Person can remember small amounts of information studied in depth far better than large amount of information studied only superficialy
- A person who is wide awake can consolidate memories far better than a person who is in a state of mental fatigue

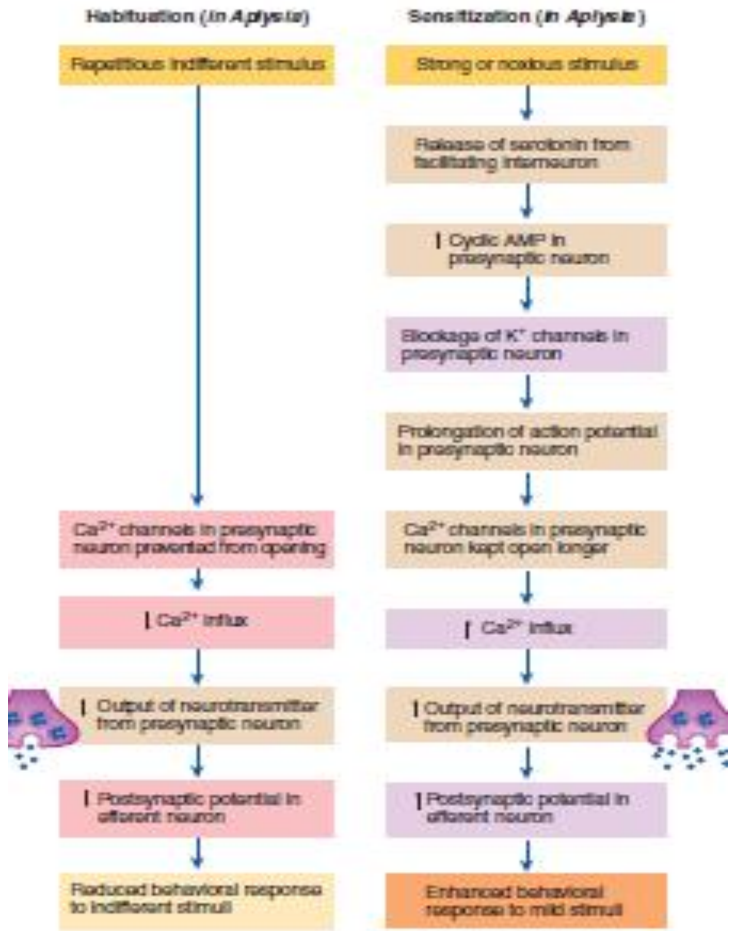
Comparison of short term and long tem memory

- Time of storage after acquisition of new information
- Duration
- Capacity of storage
- Retrieval time (remembering)
- Inability to retrieve (forgetting)
- Mechanism of storage
- Amnesia

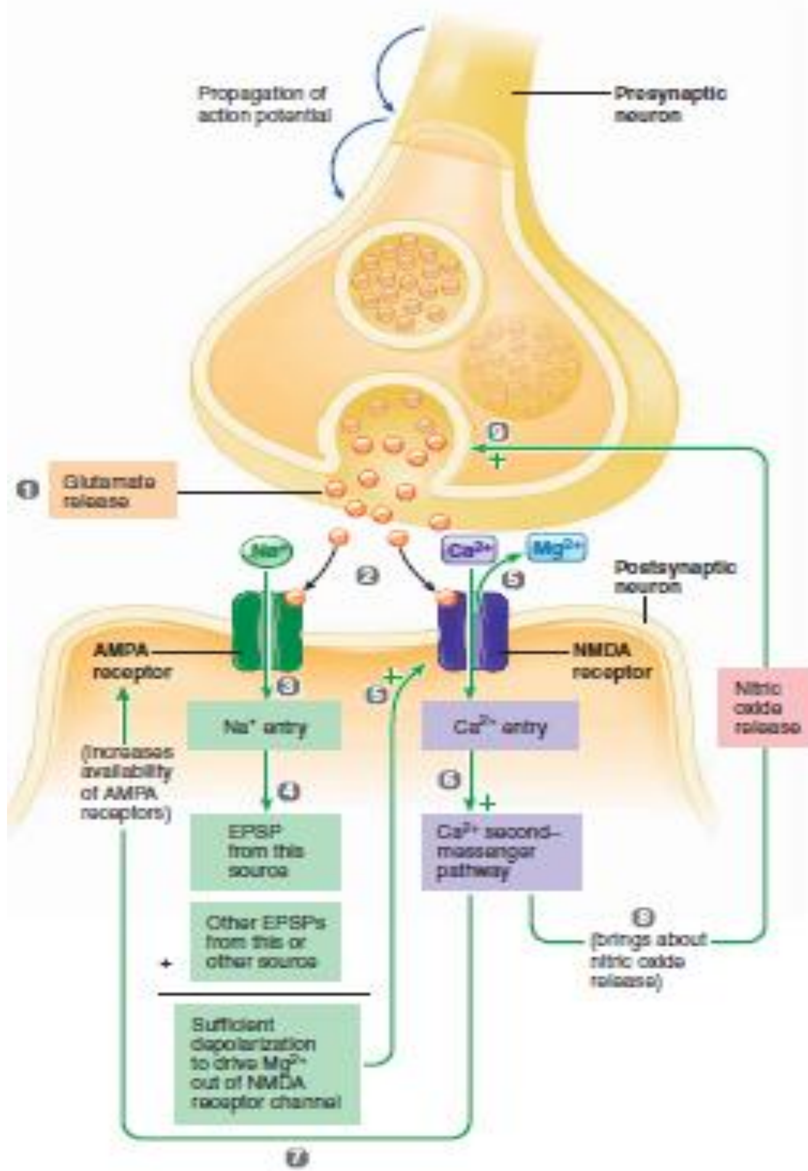
Characteristic	Short-Term Memory	Long-Term Memory
Time of Storage after Acquisition of New Information	Immediate	Later; must be transferred from short-term to long-term memory through consolidation; enhanced by practice or recycling of information through short-term mode
Duration	Lasts for seconds to hours	Retained for days to years
Capacity of Storage	Limited	Very large
Retrieval Time (remembering)	Rapid retrieval	Slower retrieval, except for thoroughly ingrained memories, which are rapidly retrieved
Inability to Retrieve (forgetting)	Permanently forgotten; memory fades quickly unless consolidated into long-term memory	Usually only transiently unable to access; relatively stable memory trace
Mechanism of Storage	Involves transient modifications in functions of preexisting synapses, such as altering amount of neurotransmitter released	Involves relatively permanent functional or structural changes between existing neurons, such as formation of new synapses; synthesis of new proteins plays a key role

Short-term & Long-term memory involve different molecular mechanisms

- Short-term memory involves transient changes in synaptic activity
- Mechanism of habituation
- Mechanism of sensitization
- Mechanism of long term potentiation (LTP)
- Long-term memory involves formation of permanent synaptic connections
- Memory traces are present in multiple regions of the brain



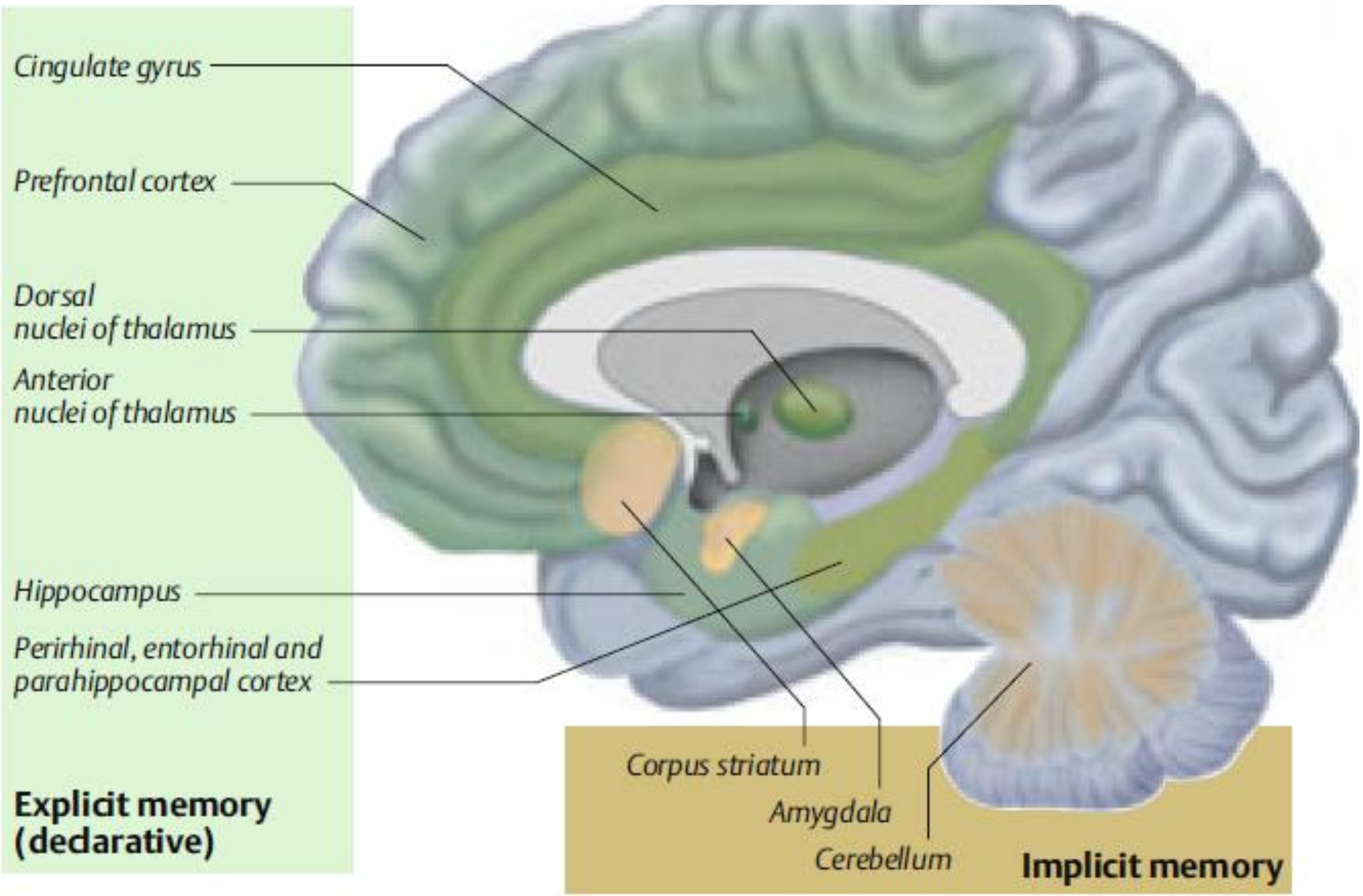
Habituation (in Aplysia)
Repetitious indifferent stimulus
Ca2+ channels in presynaptic neuron prevented from opening
Ca2+ influx
Output of neurotransmitter from presynaptic neuron
Postsynaptic potential in efferent neuron
Reduced behavioral response to indifferent stimuli
Sensitization (in Aplysia)
Strong or noxious stimulus
Release of serotonin from facilitating interneuron
Cyclic AMP in presynaptic neuron
Blockage of K+ channels in presynaptic neuron
Prolongation of action potential in presynaptic neuron
Ca2+ channels in presynaptic neuron kept open longer
Ca2+ influx
Output of neurotransmitter from presynaptic neuron
Postsynaptic potential in efferent neuron
Enhanced behavioral response to mild stimuli


Propagation of action potential
Presynaptic neuron
1 Glutamate release
7
+
Na+
Ca2+
Mg2+
2
5
Postsynaptic neuron
AMPA receptor
NMDA receptor
3
5
+
Na+ entry
Ca2+ entry
Nitric oxide release
(Increases availability of AMPA receptors)
4
6
+
EPSP from this source
Ca2+ second-messenger pathway
Other EPSPs from this or other source
+
8
(brings about nitric oxide release)
Sufficient depolarization to drive Mg2+ out of NMDA receptor channel
7

Neural changes in long-term memory

- Structural changes occur in synapses instead of chemical changes

1. Increase in vesicle release sites
2. Increase in number of vesicles
3. Increase in number of presynaptic terminals
4. Changes in structures of dendritic spines
5. Number of neurons and their connections often change during learning →soon after birth, a principle, use it or lose it


Cingulate gyrus
Prefrontal cortex
Dorsal nuclei of thalamus
Anterior nuclei of thalamus
Hippocampus
Perirhinal, entorhinal and parahippocampal cortex
Explicit memory (declarative)
Corpus striatum
Amygdala
Cerebellum
Implicit memory

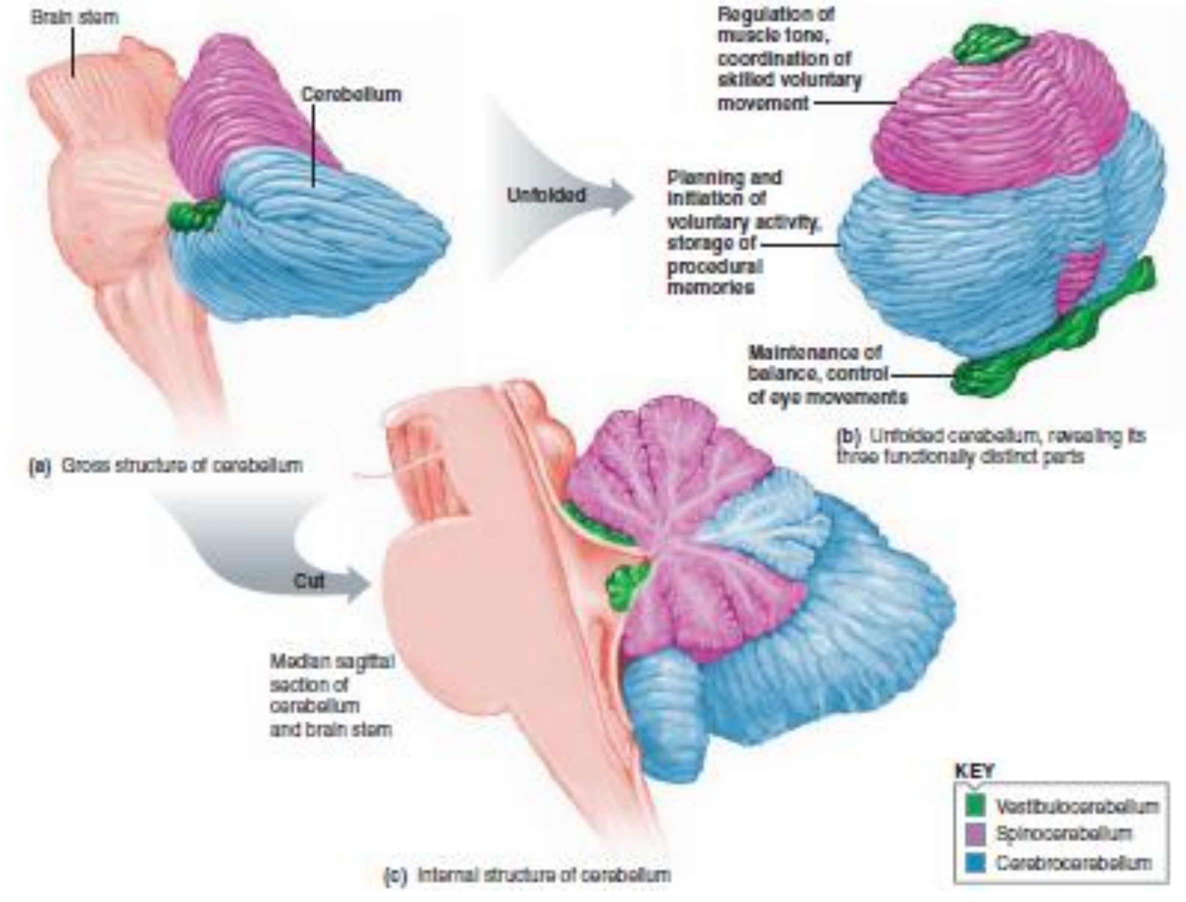
Amnesia

- **Anterograde amnesia:**
- Hippocampal lesion
- Unable to establish new long term memories
- **Retrograde amnesia:**
- Inabilities to recall memories from the past
- Damage to thalamic areas
- May be related to hippocampal lesions

Hippocampus damage: Alzheimr's disease

- Symptoms
- Characteristic brain lesion:
- Underlying pathology
- Possible causes
- Treatment

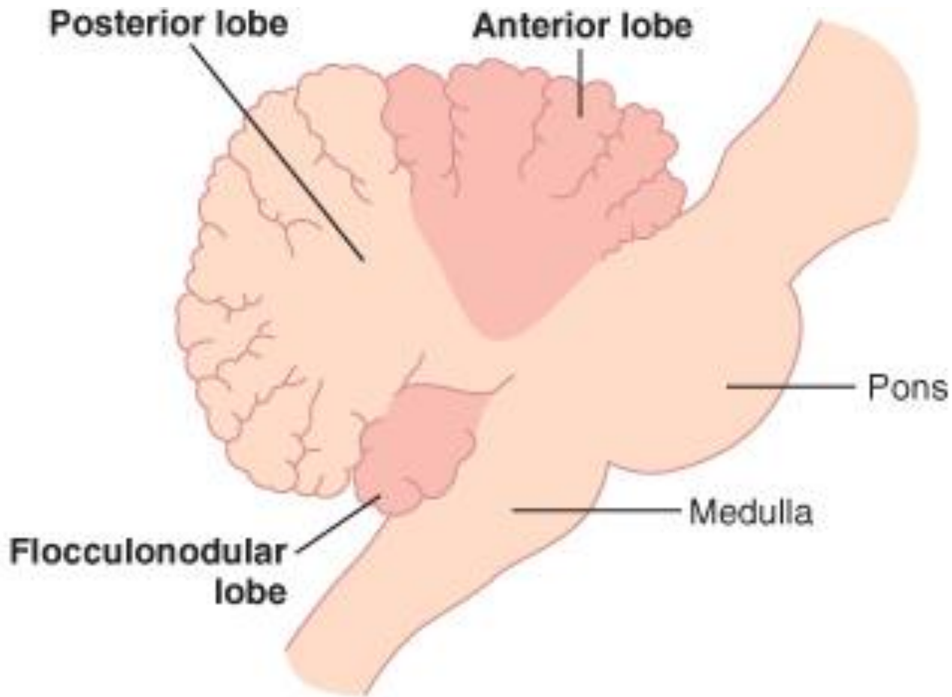
Cerebellum

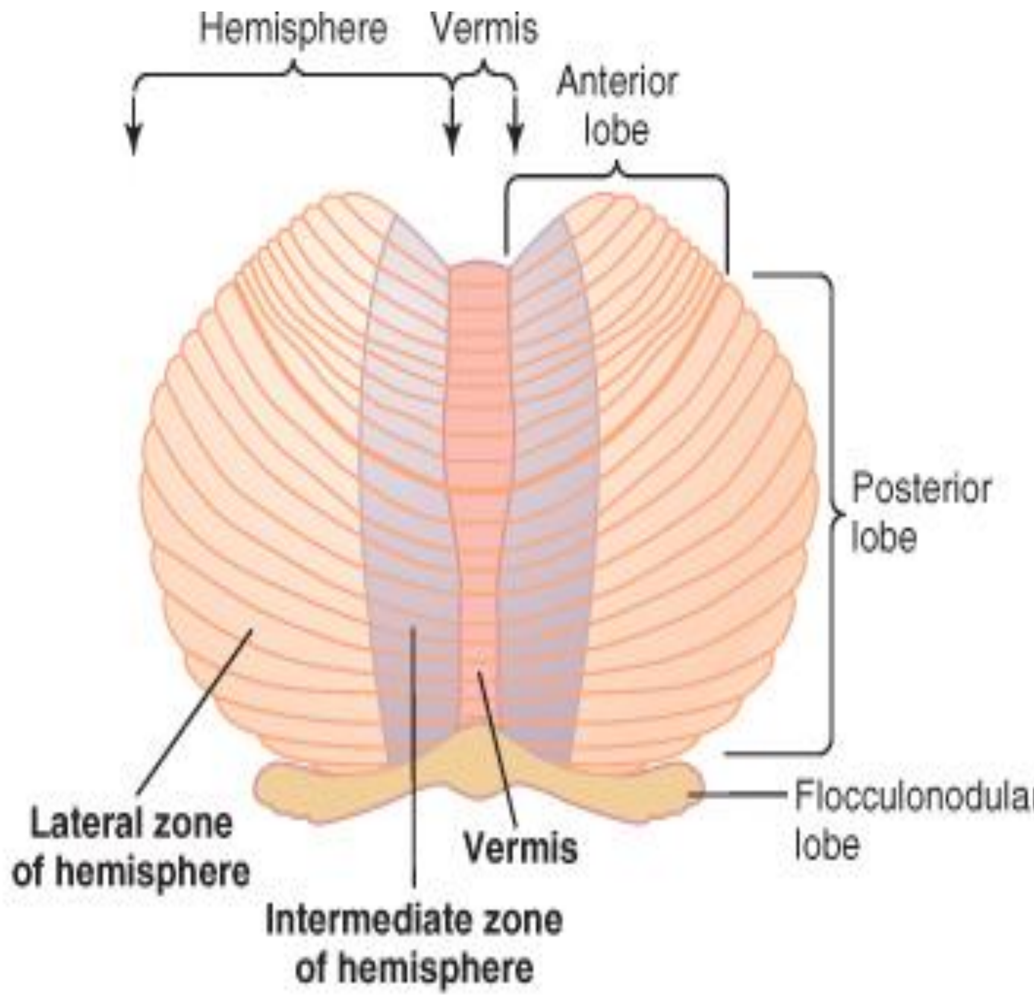


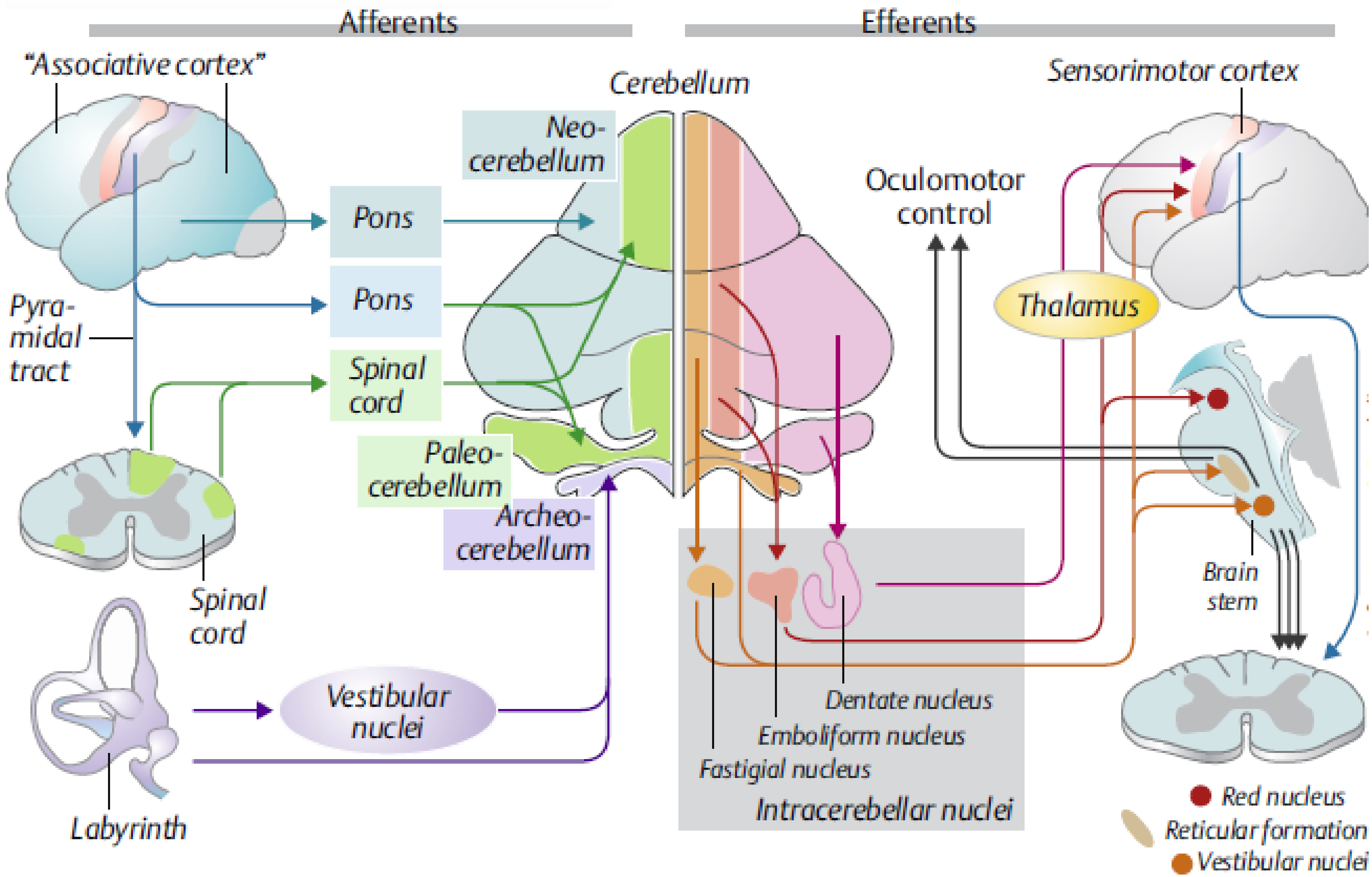
Brain stem
Cerebellum
Unfolded
Regulation of muscle tone, coordination of skilled voluntary movement
Planning and initiation of voluntary activity, storage of procedural memories
Maintenance of balance, control of eye movements
(a) Gross structure of cerebellum
(b) Unfolded cerebellum, revealing its three functionally distinct parts
Cut
Median sagittal section of cerebellum and brain stem
(c) Internal structure of cerebellum
KEY
Vestibulocerebellum
Spinocerebellum
Cerebrocerebellum

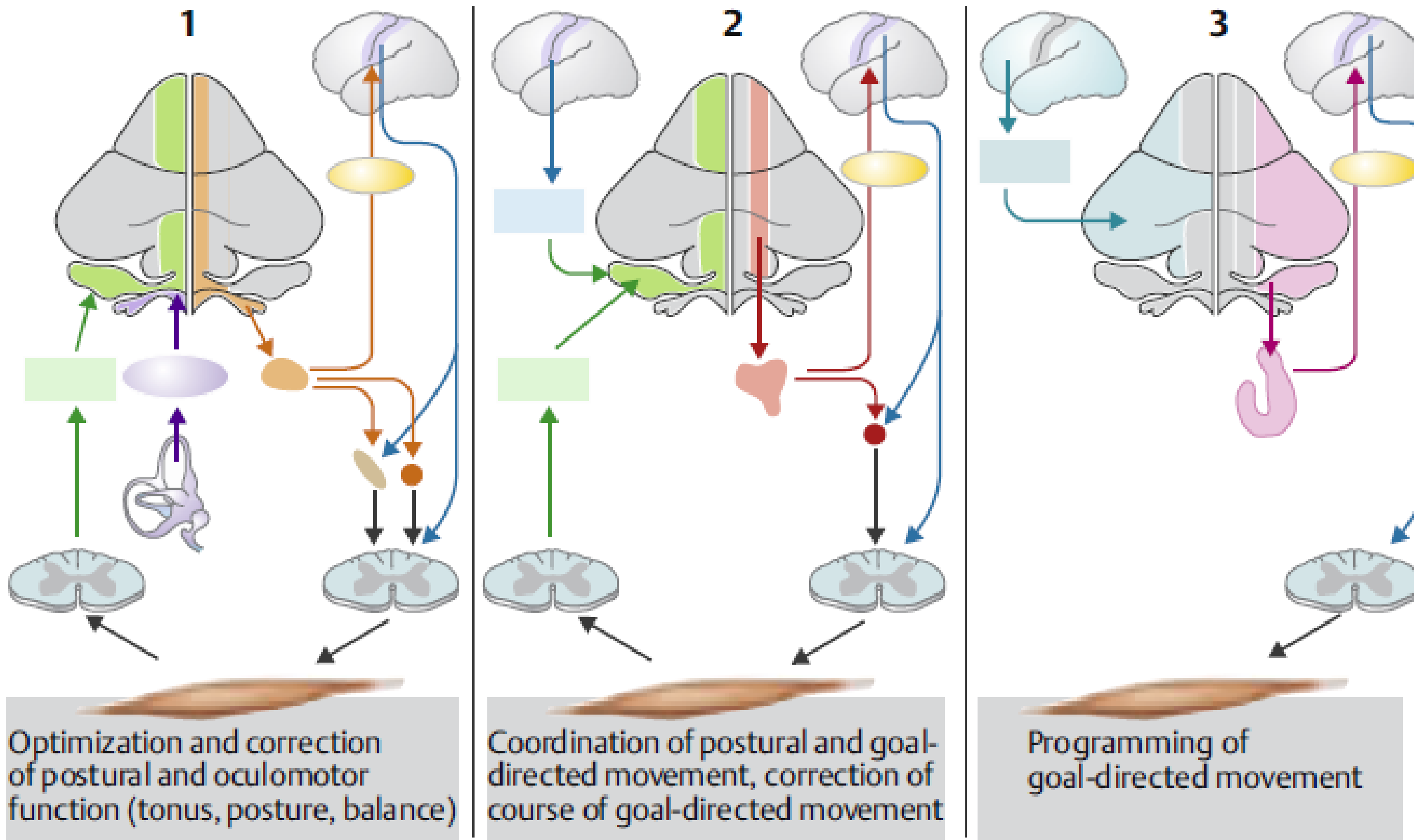
PHYSIOLOGICAL ANATOMY

1. Anatomical divisions
2. Functional divisions
3. Topographical representation in Cerebellum

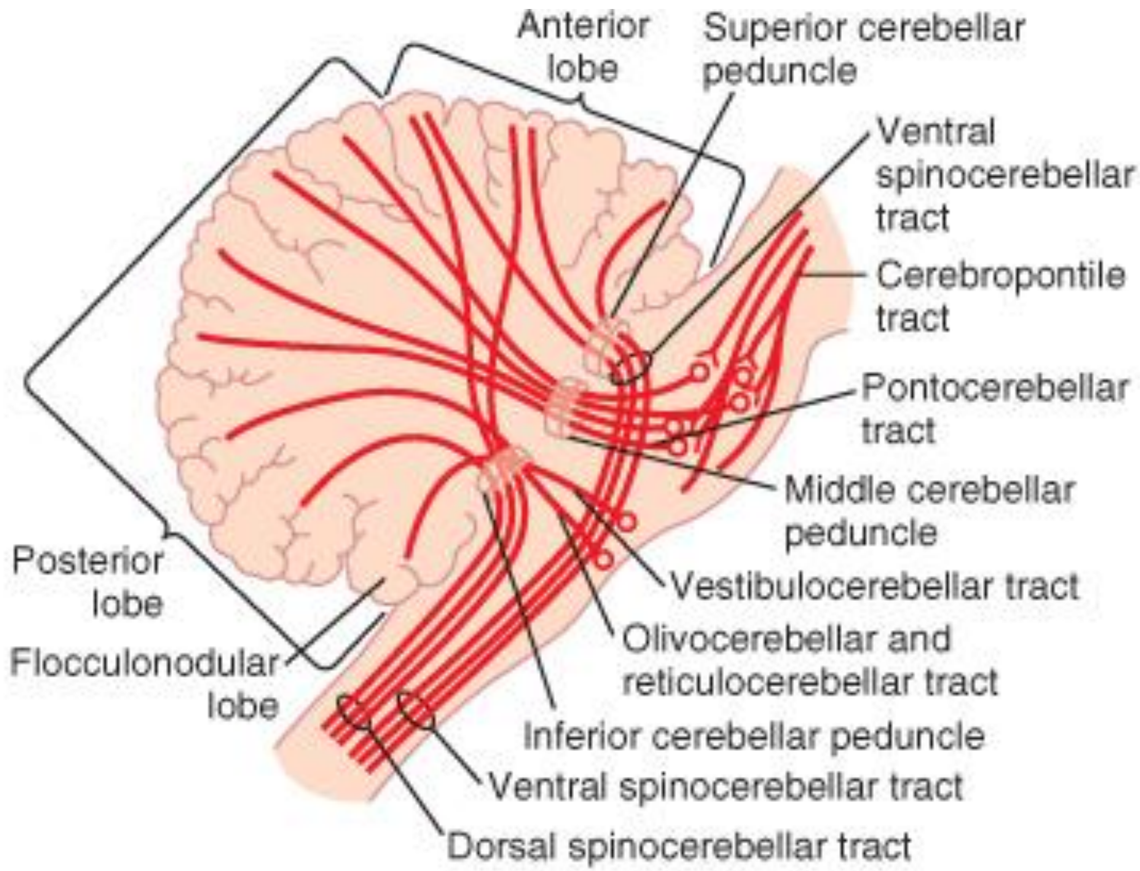

Posterior lobe
Anterior lobe
Pons
Medulla
Flocculonodular lobe


Hemisphere
Vermis
Anterior lobe
Posterior lobe
Flocculonodular lobe
Lateral zone of hemisphere
Vermis
Intermediate zone of hemisphere


Afferents
Efferents
"Associative cortex"
Cerebellum
Sensorimotor cortex
Neo-cerebellum
Pons
Pons
Spinal cord
Paleo-cerebellum
Archeo-cerebellum
Pyra-midal tract
Spinal cord
Labyrinth
Vestibular nuclei
Oculomotor control
Thalamus
Brain stem
Dentate nucleus
Emboliform nucleus
Fastigial nucleus
Intracerebellar nuclei
Red nucleus
Reticular formation
Vestibular nuclei


1
Optimization and correction of postural and oculomotor function (tonus, posture, balance)
2
Coordination of postural and goal-directed movement, correction of course of goal-directed movement
3
Programming of goal-directed movement

NEURONAL CIRCUIT OF CEREBELLUM: Inputs



Dorsal Spinocerebellar Tracts

- Sensations
  - Mainly from muscle spindle
  - To a lesser extent from Golgi Tendon organs, joint receptors and tactile receptors of the skin
- Remains on the same side
- Enter into Cerebellum through inferior cerebellar peduncle
- Ends in Vermis and intermediate zone of the same side
- Cerebellum controls following functions in response of these signals
  - Muscle contractions
  - Degree of tension on muscle tendon
  - Position and rate of movements of the parts of the body
  - Forces acting on the surface of the body

Ventral Spinocerebellar Tracts

- Sensations
  - Less information from peripheral receptors
  - Mostly carry information from lower motor neurons in anterior horn of the Spinal cord which are excited by
    - Corticospinal tracts
    - Rubrospinal tracts

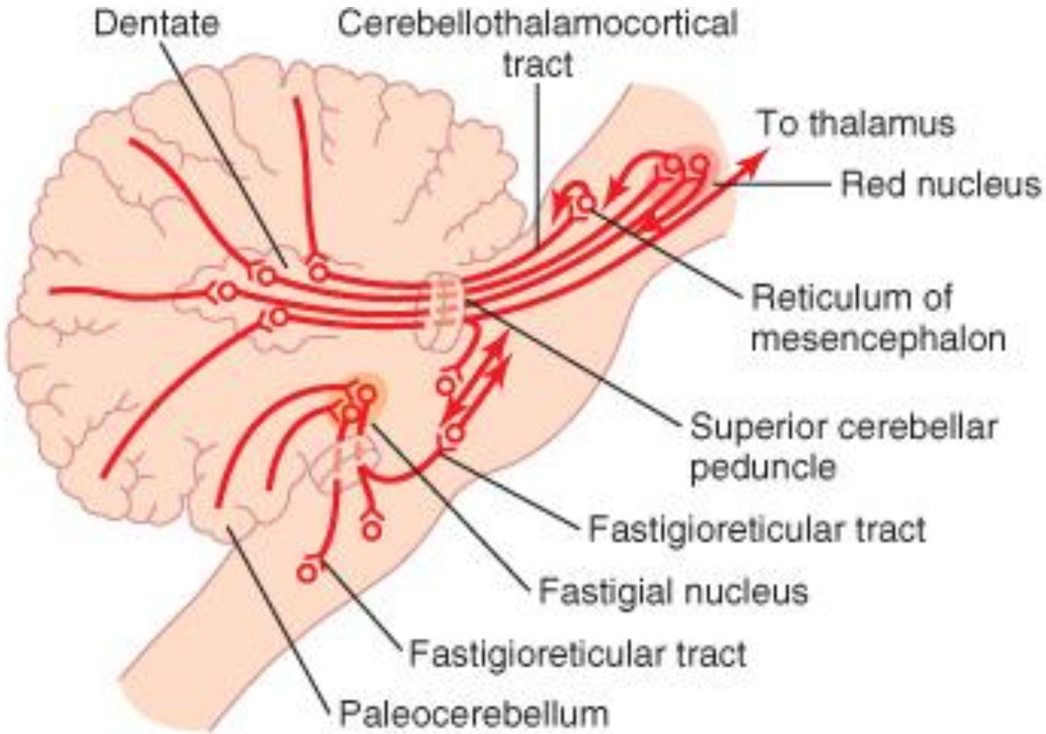
    Anterior horn motor drive
- Few fibers cross to opposite side, few remain on the same side to terminate in both sides of the Cerebellum
- Enter through Superior Cerebellar Peduncle

Outputs

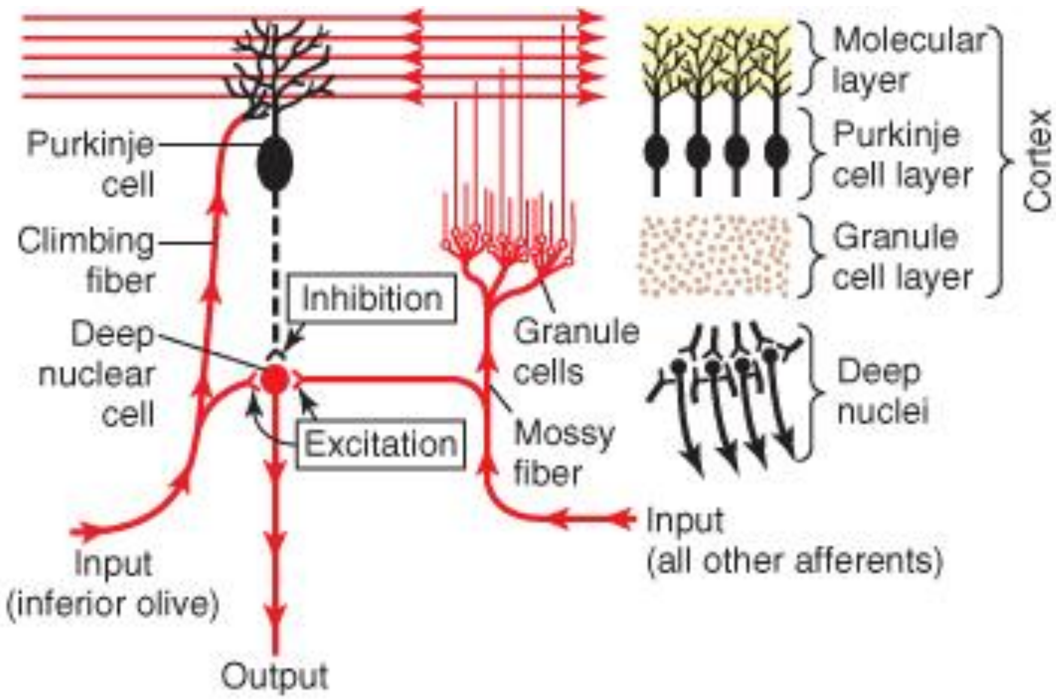
- Vermis →fastigial nucleus→ brain stem (reticular formation)→ fastigioreticular tract (vestibular nuclei)
- From lateral zone → dentate nucleus→ VA and VL nuclei of thalamus → cerebral cortex (coordinate sequential motor activities of cerebral cortex)
- From intermediate zone→ interposed nuclei→ red nucleus

reticular formation of midbrain

thalamus (coordinate reciprocal contractions of agonists and antagonists of limbs)


Dentate
Cerebellothalamocortical tract
To thalamus
Red nucleus
Reticulum of mesencephalon
Superior cerebellar peduncle
Fastigioreticular tract
Fastigial nucleus
Fastigioreticular tract
Paleocerebellum

The Purkinje Cell & The Deep Nuclear Cell – Functional Unit Of Cerebellar Cortex



How This Functional Unit Works

1) Purkinje cells & deep nuclear cells fire continuously under normal resting condition
2) Balance between excitation & inhibition at the deep cerebellar nuclei – Damping Function
3) Other inhibitory cells in cerebellum: Basket cells & Stellate cells (in molecular layers for lateral inhibition)
4) Turn on/turn off & turn off/turn on signals from the cerebellum
5) Purkinje cells learn to correct motor errors – role of climbing fibers

FUNCTIONS OF CEREBELLUM

It performs its functions at three major levels

1. Spinocerebellum (Paleocerebellum)
2. Cerebrocerebellum (Neocerebellum or Pontocerebellum)
3. Vestibulocerebellum (Archicerebellum)

Spinoc-erebellum

- Consists of vermis and intermediate zone
- It coordinates movements of distal portions of limbs and make smooth contractions of agonists and antagonists muscles for purposeful movements

CEREBRO-CEREBELLUM

- Planning of sequential movements
  - Two way communications between Cerebral Cortex with lateral zone of Cerebellum
  - It controls what will be happening during the next sequential movement a fraction of a second later
- Timing Function
- Extra motor functions in auditory and visual phenomena

VESTIBULO-CEREBELLUM

- Function of Flocculonodular lobe and Vermis
- The Vestibulocerebellum originated at the same time that the vestibular apparatus in the inner ear developed
- Control equilibrium of postural movements

CLINICAL ABNORMALITIES OF CEREBELLUM

. Dysmetria

- Ataxia
- Past pointing

2. Failure of progression in repetitive movements

- Dysdiadochokinesia
- Dysartheria

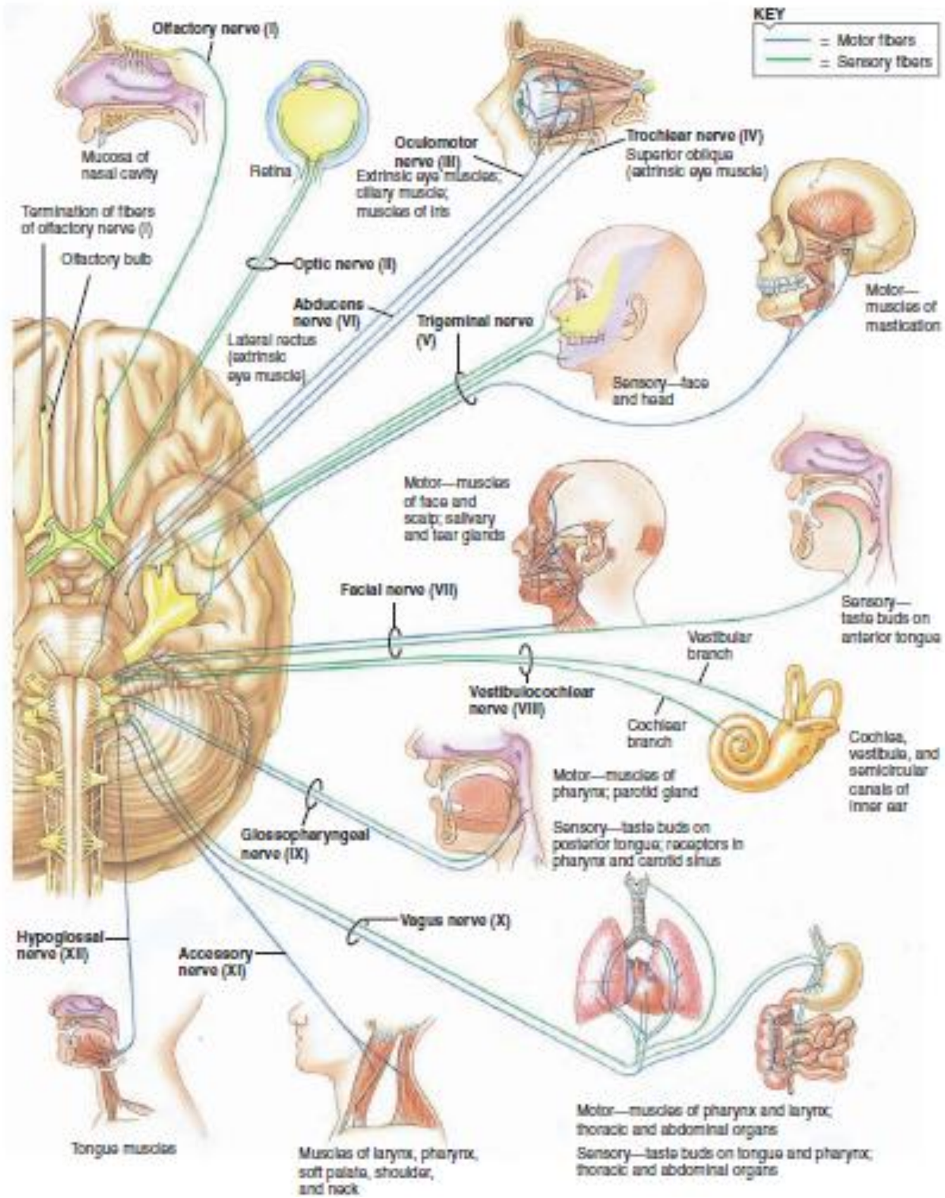
3. Cerebellar Tremors

- Intention tremors
- Kinetic tremors
- Static tremors
- Cerebellar nystagmus

4. Exaggerated Reflexes

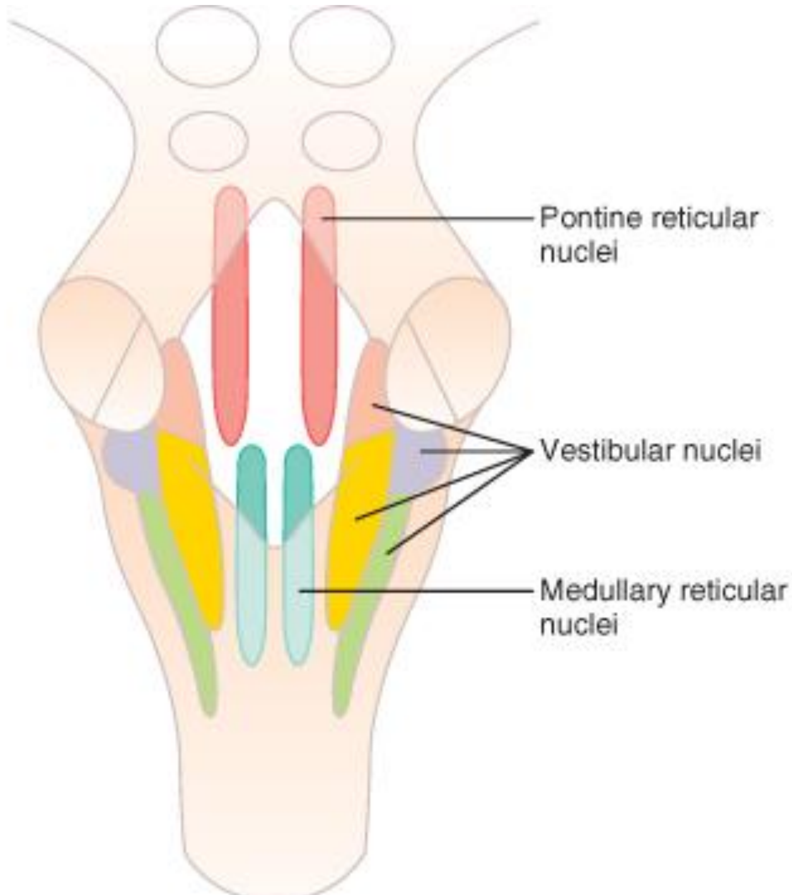
BRAIN STEM

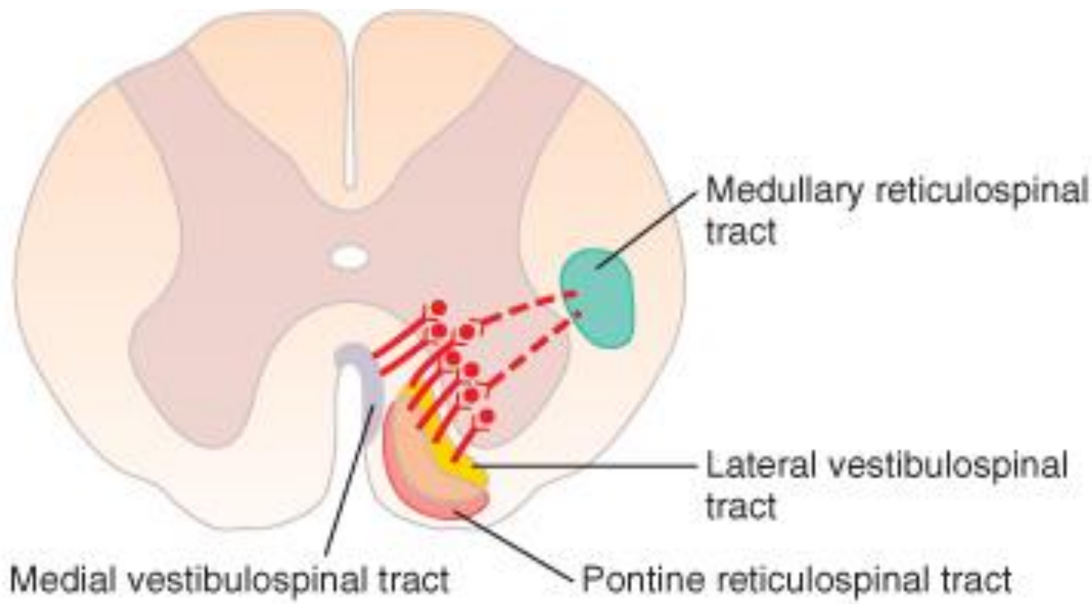
- The brain stem is a vital link b/w the spinal cord and higher brain regions
- Way station for command signals from higher centres
- Origin of majority of 12 pairs of cranial nerves
- Neural control centre for CVC, GIT and Respiration
- Role in RAS, regulating equilibrium and posture and in sleep



KEY
= Motor fibers
= Sensory fibers
Olfactory nerve (I)
Mucosa of nasal cavity
Retina
Termination of fibers of olfactory nerve (I)
Olfactory bulb
Optic nerve (II)
Oculomotor nerve (III)
Extrinsic eye muscles; ciliary muscle; muscles of iris
Trochlear nerve (IV)
Superior oblique (extrinsic eye muscle)
Abducens nerve (VI)
Lateral rectus (extrinsic eye muscle)
Trigeminal nerve (V)
Motor—muscles of mastication
Sensory—face and head
Motor—muscles of face and scalp; salivary and tear glands
Facial nerve (VII)
Sensory—taste buds on anterior tongue
Vestibular branch
Vestibulocochlear nerve (VIII)
Cochlear branch
Cochlea, vestibule, and semicircular canals of inner ear
Motor—muscles of pharynx; parotid gland
Sensory—taste buds on posterior tongue; receptors in pharynx and carotid sinus
Glossopharyngeal nerve (IX)
Vagus nerve (X)
Hypoglossal nerve (XII)
Accessory nerve (XI)
Tongue muscles
Muscles of larynx, pharynx, soft palate, shoulder, and neck
Motor—muscles of pharynx and larynx; thoracic and abdominal organs
Sensory—taste buds on tongue and pharynx; thoracic and abdominal organs

Number and Name	Function(s)
I Olfactory	• Sense of smell
II Optic	• Sense of sight
III Oculomotor	• Movement of the eyeball; constriction of pupil in bright light or for near vision
IV Trochlear	• Movement of eyeball
V Trigeminal	• Sensation in face, scalp, and teeth; contraction of chewing muscles
VI Abducens	• Movement of the eyeball
VII Facial	• Sense of taste; contraction of facial muscles; secretion of saliva
VIII Acoustic (vestibulocochlear)	• Sense of hearing; sense of equilibrium
IX Glossopharyngeal	• Sense of taste; sensory for cardiac, respiratory, and blood pressure reflexes; contraction of pharynx; secretion of saliva
X Vagus	• Sensory in cardiac, respiratory, and blood pressure reflexes; sensory and motor to larynx (speaking); decreases heart rate; contraction of alimentary tube (peristalsis); increases digestive secretions
XI Accessory	• Contraction of neck and shoulder muscles; motor to larynx (speaking)
XII Hypoglossal	• Movement of the tongue


Pontine reticular nuclei
Vestibular nuclei
Medullary reticular nuclei



Medullary reticulospinal tract
Lateral vestibulospinal tract
Medial vestibulospinal tract
Pontine reticulospinal tract

Motor control of brain stem

- Control of cerebral activity through brain stem is by two ways

1- controlled directly by neuronal activity (RAS)

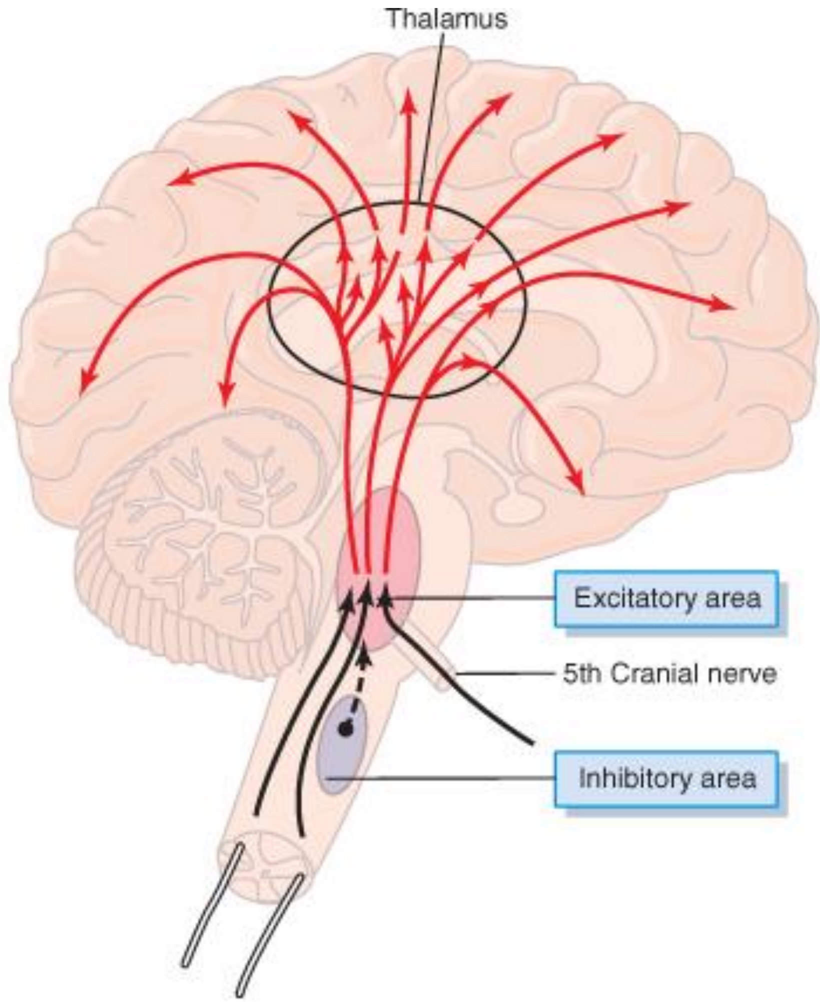
2- by activating neurohormonal system

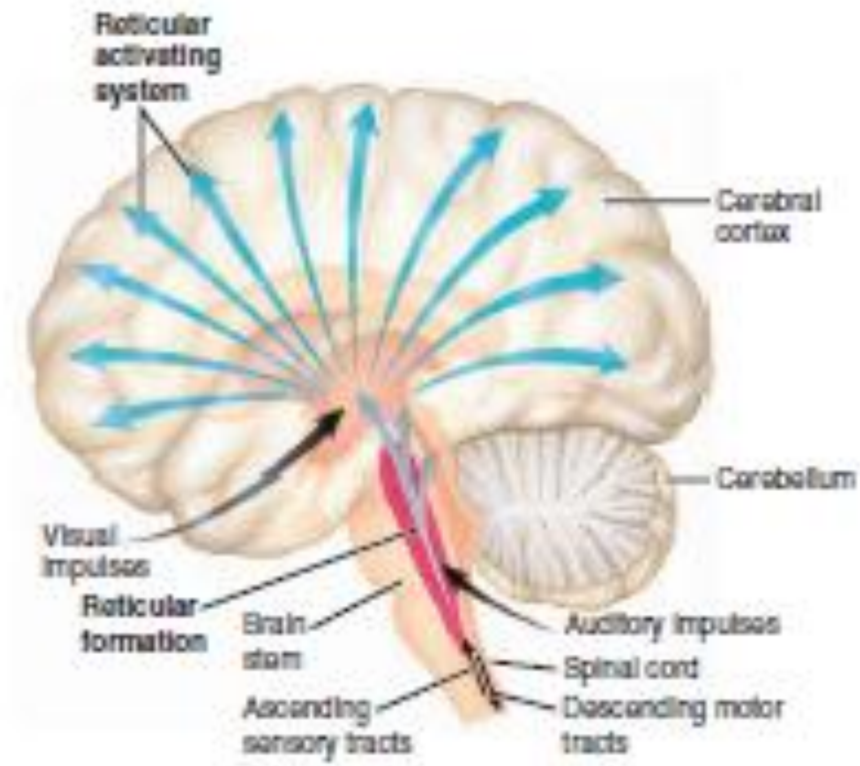
Direct control (RAS) is by 2 ways:

1- reticular excitatory area(bulbo reticular facilitatory area)

2- reticular inhibitory area

Pontine & Medullary reticular system

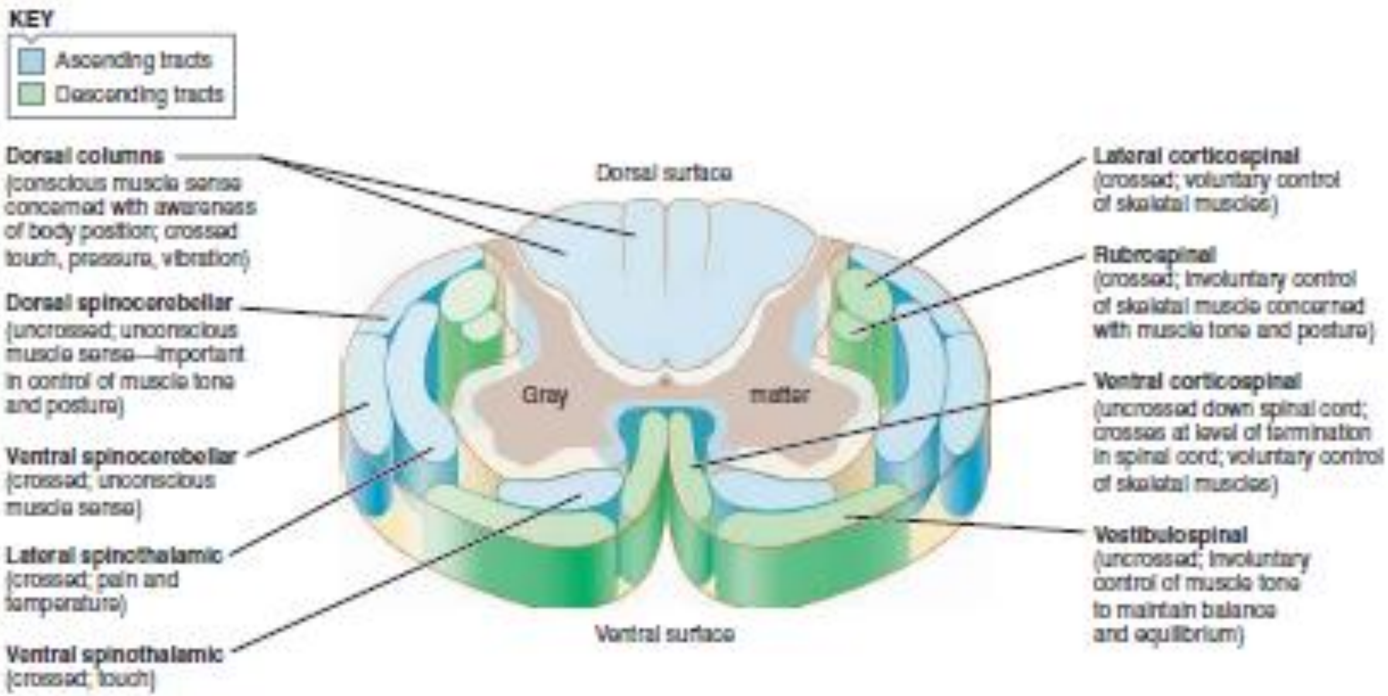


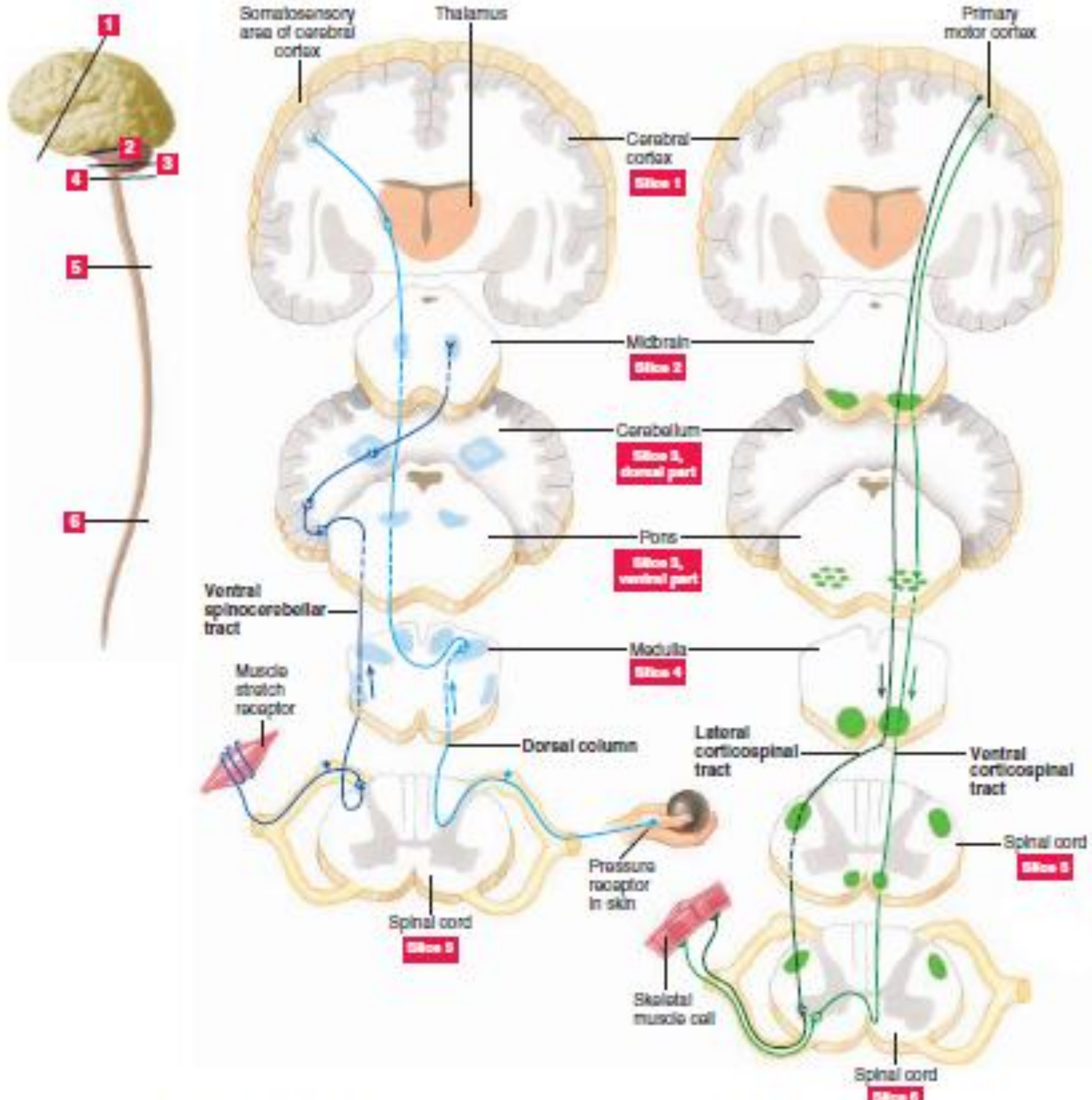


Reticular activating system
Cerebral cortex
Cerebellum
Visual impulses
Reticular formation
Brain stem
Auditory impulses
Spinal cord
Ascending sensory tracts
Descending motor tracts

Descending tracts through brain stem

1. Cortico spinal tract
2. Rubrospinal tract
3. Reticulospinal tract
4. Vestibulospinal tract
5. Tactospinal tract


KEY
Ascending tracts
Descending tracts
Dorsal columns
(conscious muscle sense concerned with awareness of body position; crossed touch, pressure, vibration)
Dorsal spinocerebellar
(uncrossed; unconscious muscle sense—important in control of muscle tone and posture)
Ventral spinocerebellar
(crossed; unconscious muscle sense)
Lateral spinothalamic
(crossed; pain and temperature)
Ventral spinothalamic
(crossed; touch)
Dorsal surface
Gray
matter
Ventral surface
Lateral corticospinal
(crossed; voluntary control of skeletal muscles)
Rubrospinal
(crossed; involuntary control of skeletal muscle concerned with muscle tone and posture)
Ventral corticospinal
(uncrossed down spinal cord; crosses at level of termination in spinal cord; voluntary control of skeletal muscles)
Vestibulospinal
(uncrossed; involuntary control of muscle tone to maintain balance and equilibrium)



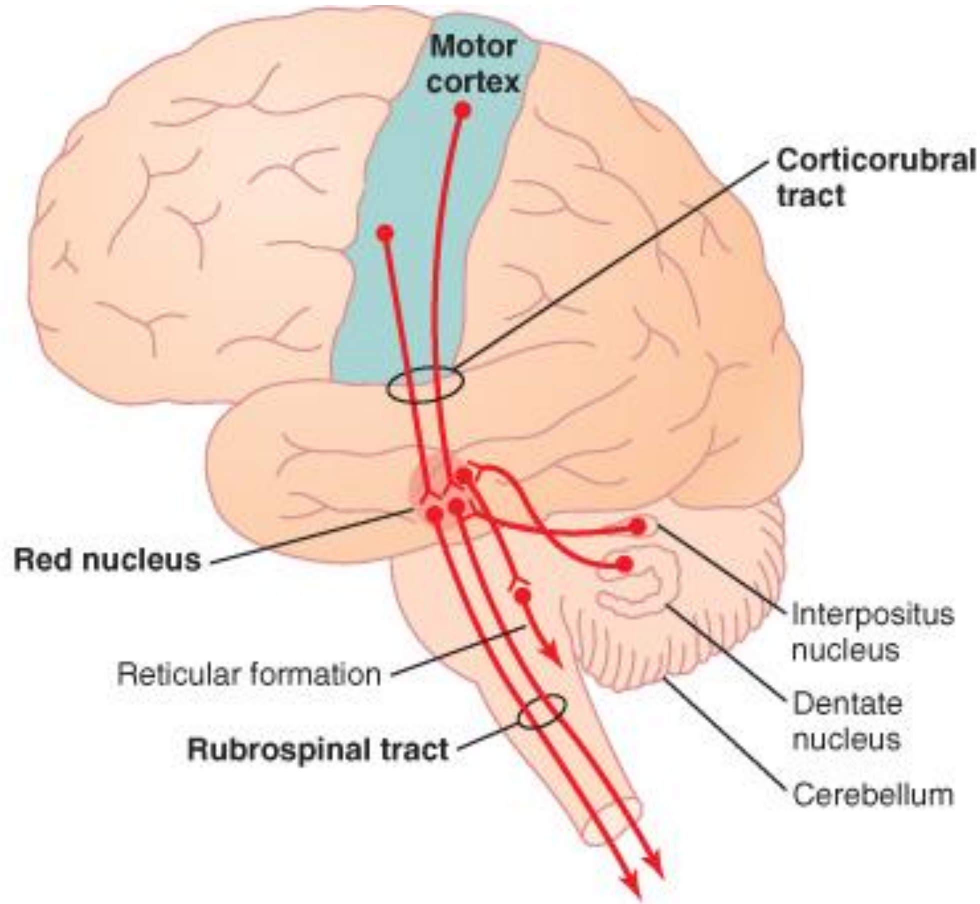
(a) Ascending tracts

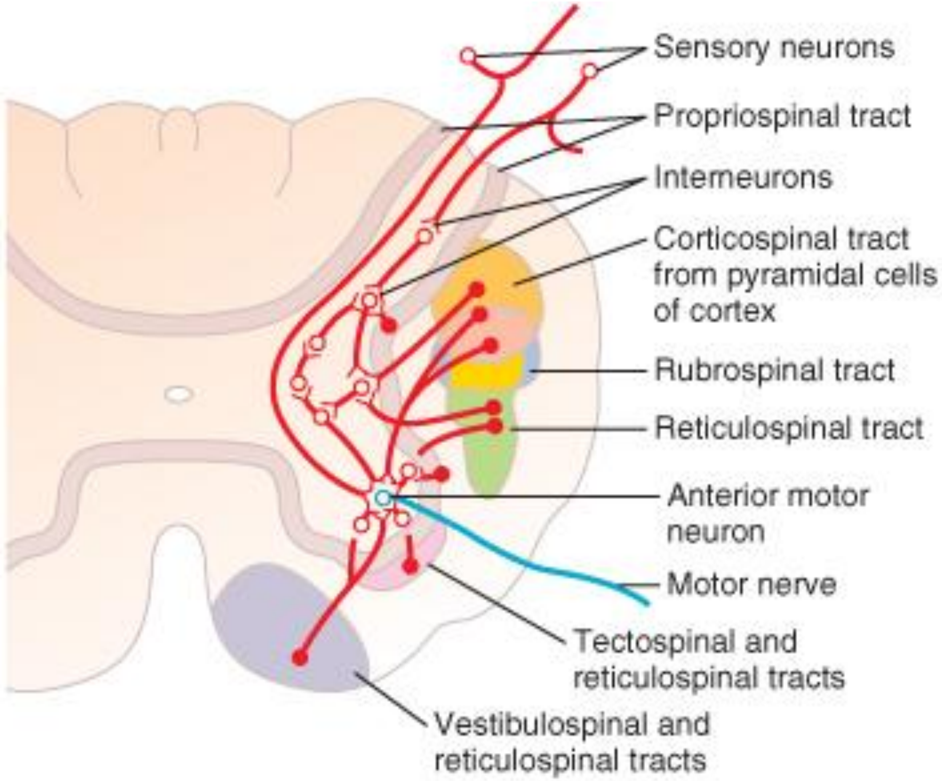
(b) Descending tracts

Rubrospinal tract (corticorubro spinal tract)

- Site (mesencephlon)
- Inputs to red nucleus (corticorubral & corticospinal fibers)
- Pathway
- Termination (interneurons of intermediate grey matter of cord)
- Functions

1) Magnocellular portion of red nucleus has a somatographic representation of all the muscles of body
2) Serves as an accessory route for transmission of relatively discrete signals from motor cortex to spinal cord


Motor cortex
Corticorubral tract
Red nucleus
Interpositus nucleus
Reticular formation
Dentate nucleus
Rubrospinal tract
Cerebellum



Sensory neurons
Propriospinal tract
Interneurons
Corticospinal tract
from pyramidal cells
of cortex
Rubrospinal tract
Reticulospinal tract
Anterior motor
neuron
Motor nerve
Tectospinal and
reticulospinal tracts
Vestibulospinal and
reticulospinal tracts

By activating neurohormonal system

- Four neurohormonal systems

1- Locus ceruleus and nor epinephrine system

2- Substantia nigra and dopamine system

3- Raphe nuclei and serotonin system

4- Gigantocellular neurons in reticular excitatory area and acetylcholine system

Locus ceruleus and nor epinephrine system

- Site (posteriorly at the juncture of pons and mesencephlon)
- Nerve fibres spread throughout the brain
- Secrete nor epinephrine
- Nor epinephrine generally excites the brain
- It has inhibitory effect in few brain areas because of inhibitory receptors at certain neuronal synapses
- Important role in causing dreaming in REM sleep

Substantia nigra and dopamine system

- Site (anteriorly in superior mesencephlon)
- Send neurons to caudate nucleus and putamen
- Secrete dopamine
- It is an inhibitory neurotransmitter in the basal ganglia but in some other areas of brain it is possibly excitato

The raphe nuclei and serotonin system

- Site (in the midline of pons and medulla)
- Send fibres to cerebrum , diencephalon and spinal cord
- Secrete serotonin
- The serotonin secreted at the cord has the ability to suppress pain
- The serotonin released in the cerebrum plays an essential inhibitory role in normal sleep

Neurons of reticular excitatory area and acetylcholine system

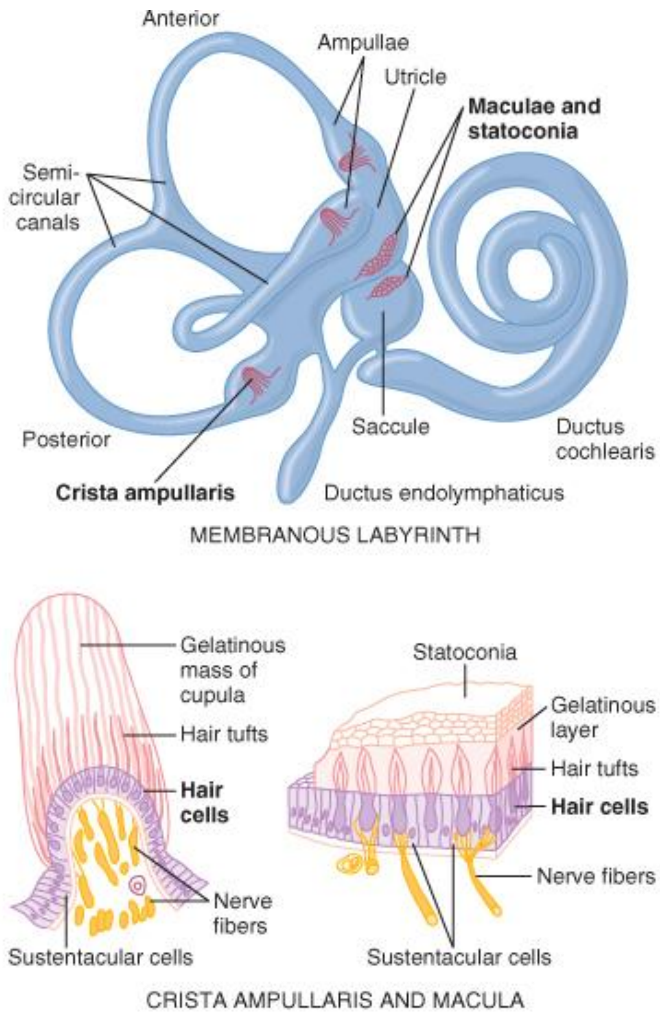
- Gigantocellular neurons in reticular excitatory area of pons and mid brain
- Fibres from these large cells divide immediately in to two branches
- One to higher levels of brain and other to spinal cord
- Secrete acetylcholine
- Excitatory neurotransmitter

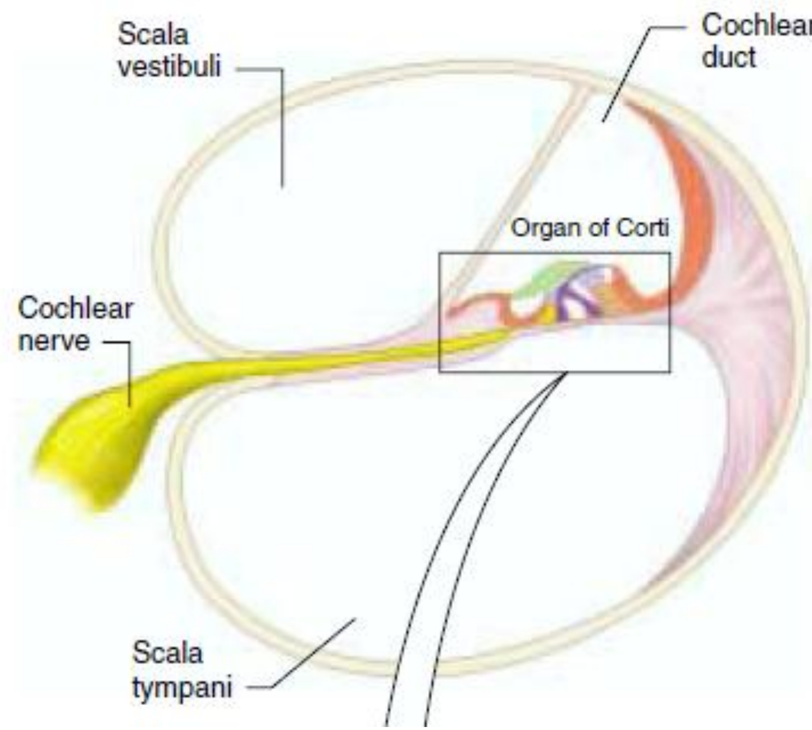
Role of brain stem in Maintenance of equilibrium-Vestibular nuclei

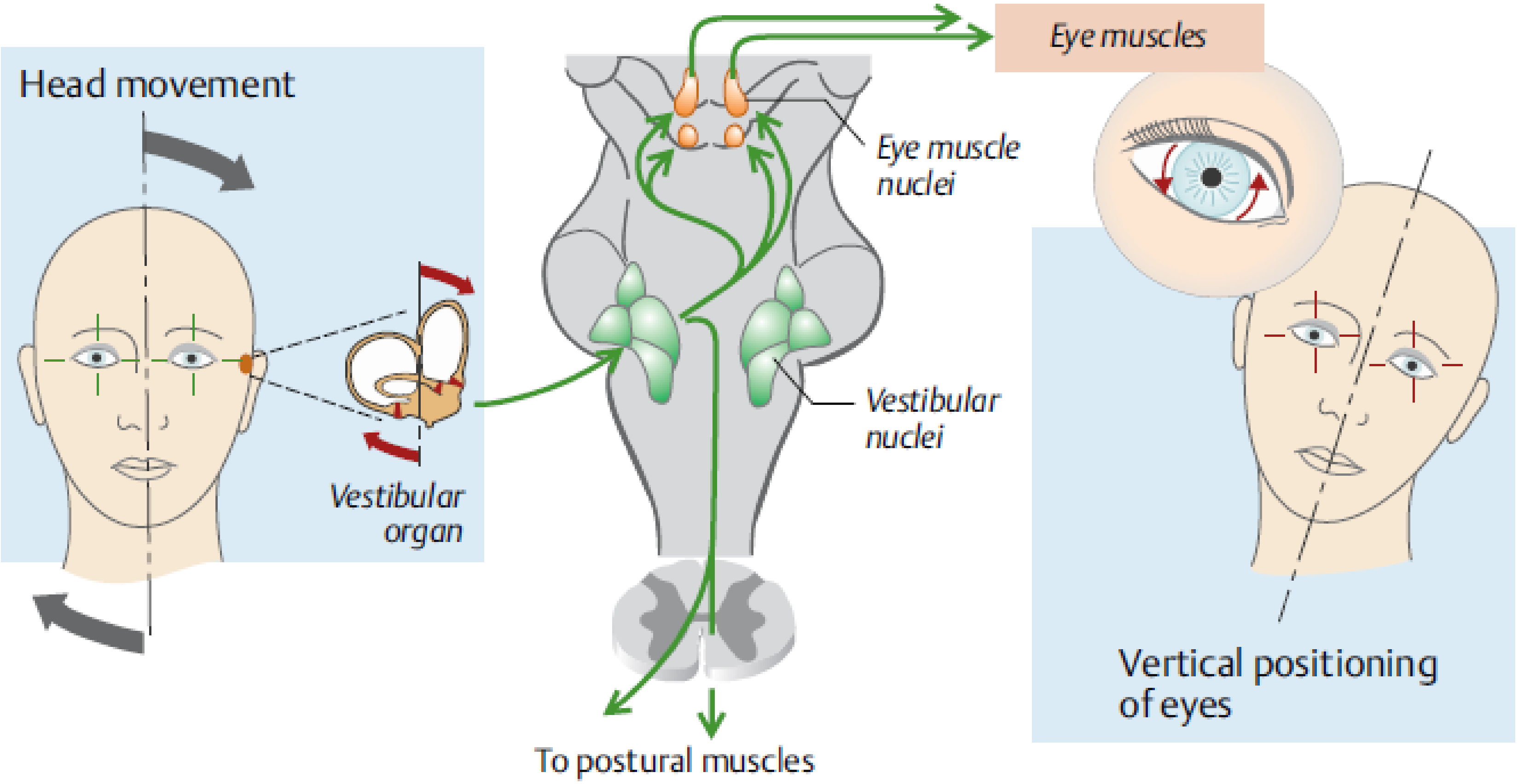
- Location
- They give lateral and medial vestibulospinal tracts
- Functions

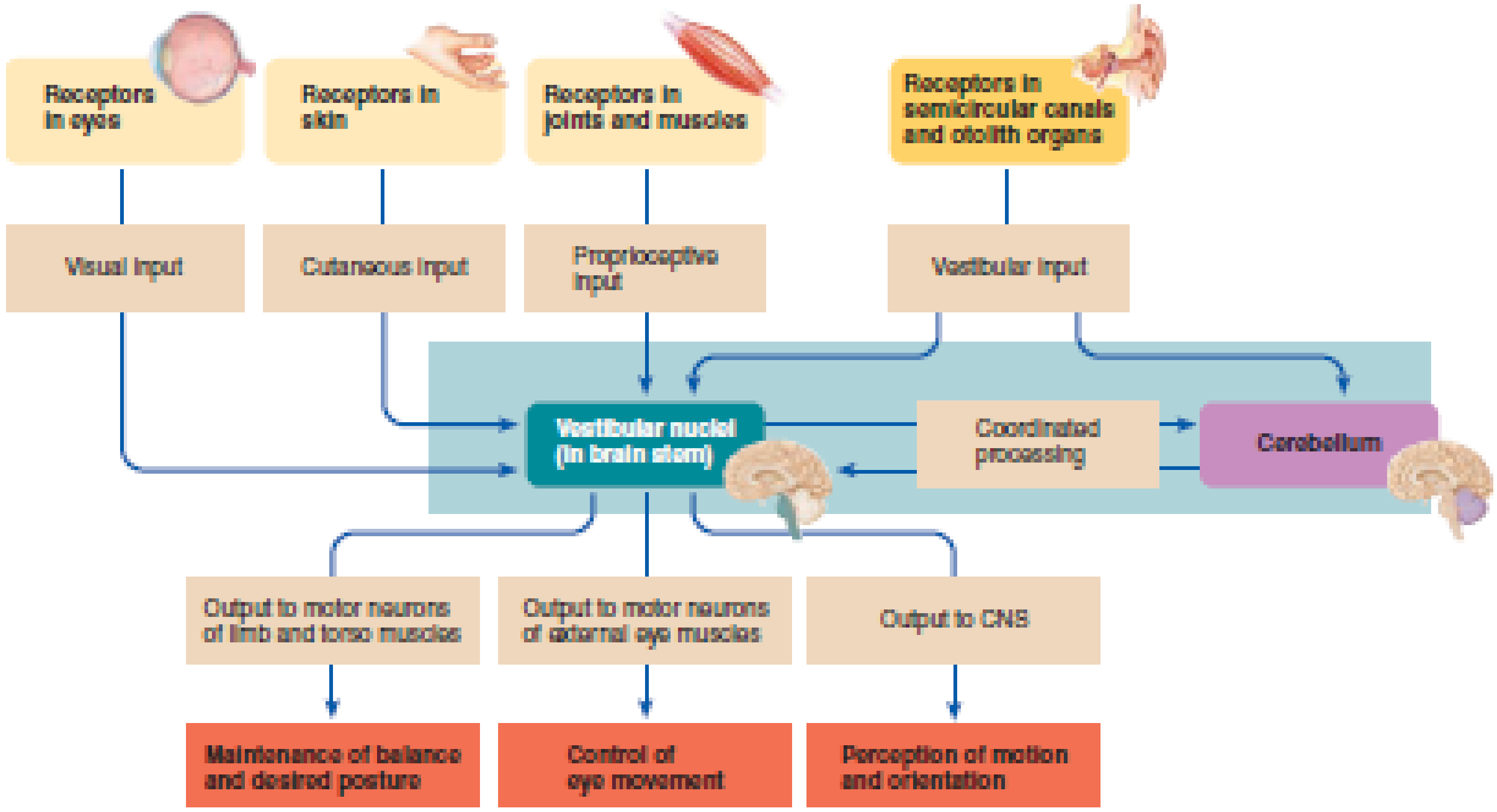
1. Function in association with pontine reticular nuclei to control the antigravity muscles
2. They help to maintain equilibrium in response to signals from vestibular apparatus

Vestibular Apparatus






Head movement
Vestibular organ
Eye muscles
Eye muscle nuclei
Vestibular nuclei
To postural muscles
Vertical positioning of eyes


Receptors in eyes
Receptors in skin
Receptors in joints and muscles
Receptors in semicircular canals and otolith organs
Visual input
Cutaneous input
Proprioceptive input
Vestibular input
Vestibular nuclei (in brain stem)
Coordinated processing
Cerebellum
Output to motor neurons of limb and torso muscles
Output to motor neurons of external eye muscles
Output to CNS
Maintenance of balance and desired posture
Control of eye movement
Perception of motion and orientation

Sleep

- Consciousness
- Stages of consciousness

1- Maximum alertness

2- Wakefullness

3- Sleep (Several different types)

4- Coma

- Sleep-wake cycle
- Sleep is an active process of unconsciousness from which the person can be aroused by sensory or other stimuli

Types

- Slow wave sleep
- Paradoxical sleep or rapid eye movement sleep (REM

Slow wave sleep

Duration (30-45 minutes)

→ most sleep during each night

→ deep restful sleep

→ physical changes

Decrease peripheral vascular tone

Decrease blood pressure

Decrease respiratory rate

Decrease BMR

Stages of slow wave sleep

- Four stages
- **Stage 1**

→when person becomes drowsy and begins to sleep

→lasting only a few minutes

→eyes make slow rolling movements

→EEG becomes less regular

→one is most easily awakened

- **Stage 2**

→slightly deeper
→may last for 5-15 min.
→eye movements almost cease
→EEG: sleep spindle

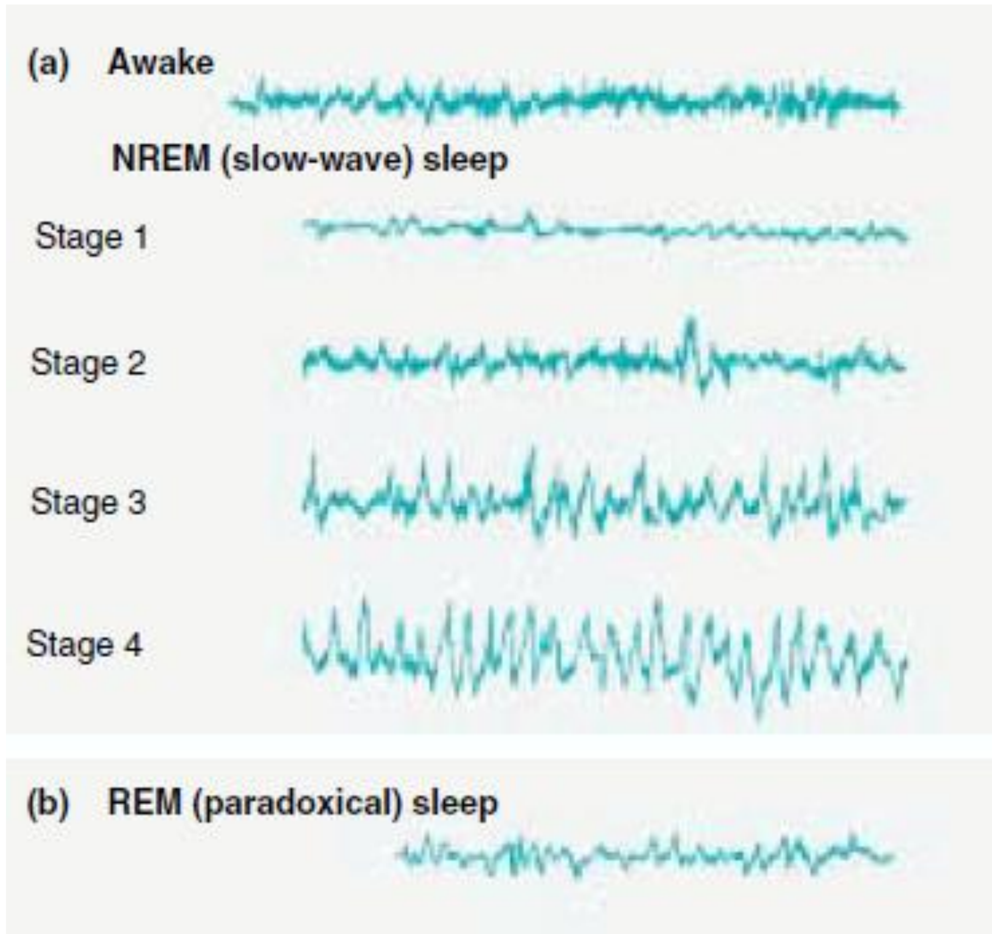
- **Stage 3**

→eye and body movements are absent
→EEG: frequency of brain waves becomes progressively slower

- **Stage 4**

→deepest stage of sleep
→EEG: delta waves

Children have more total sleep time and stage 4 sleep than adults


(a) Awake
NREM (slow-wave) sleep
Stage 1
Stage 2
Stage 3
Stage 4
(b) REM (paradoxical) sleep

REM Sleep

- Duration (10-15-minutes)
- Associated with active dreaming and active eye muscle movements
- Muscle tone throughout the body is depressed
- Heart rate and respiratory rate usually becomes irregular
- Brain is highly active in REM sleep and EEG shows a pattern of brain waves similar to those that occur during wakefulness

Characteristic	TYPE OF SLEEP	
	Slow-Wave Sleep	Paradoxical Sleep
EEG	Displays slow waves	Similar to EEG of alert, awake person
Motor Activity	Considerable muscle tone; frequent shifting	Abrupt inhibition of muscle tone; no movement
Heart Rate, Respiratory Rate, Blood Pressure	Minor reductions	Irregular
Dreaming	Rare (mental activity is extension of waking-time thoughts)	Common
Arousal	Sleeper easily awakened	Sleeper hard to arouse but apt to wake up spontaneously
Percentage of Sleeping Time	80%	20%
Other Important Characteristics	Has four stages; sleeper must pass through this type of sleep first	Rapid eye movements

Theories of Sleep

- The sleep wave-wake cycle is controlled by interaction among three neural systems

1-Arousal system

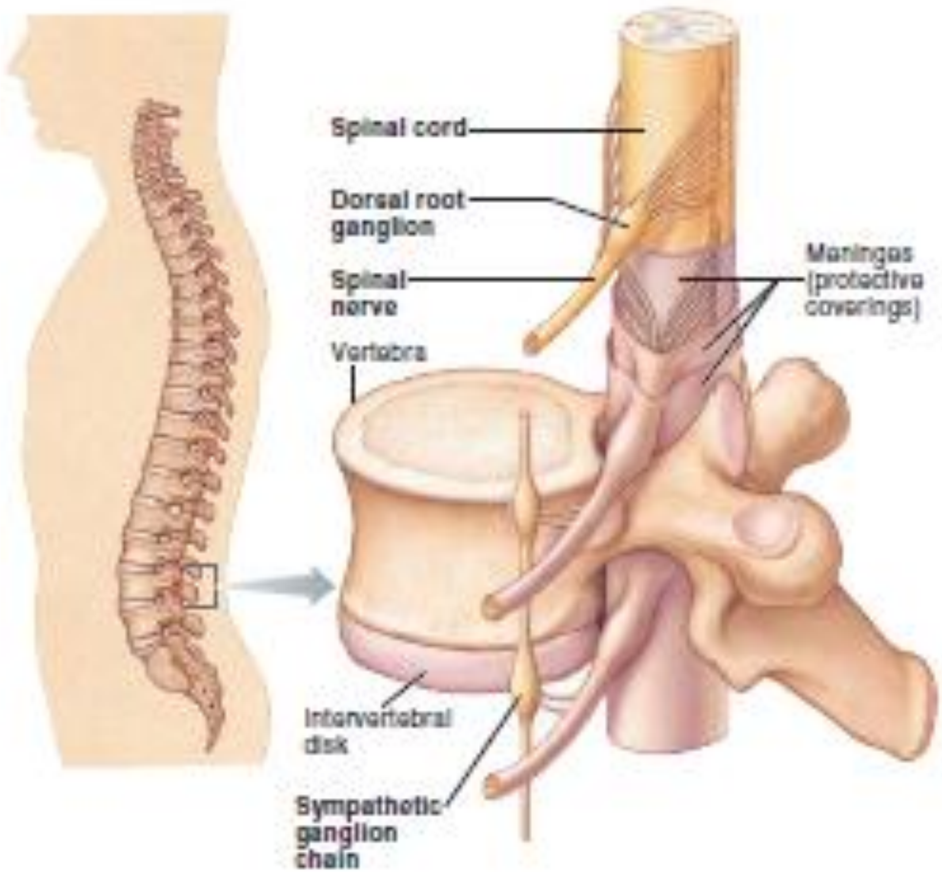
2-Slow-wave sleep centre

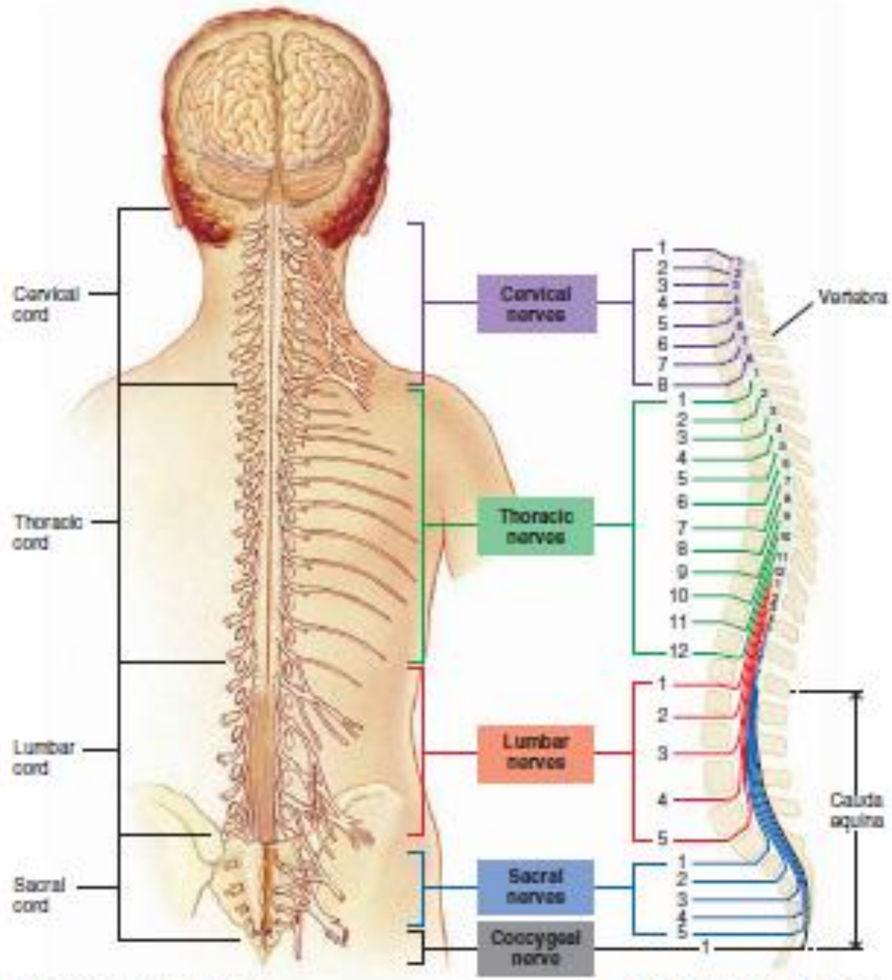
3-Paradoxical sleep centre

- The function of sleep is unclear
- Narcolepsy

Spinal Cord

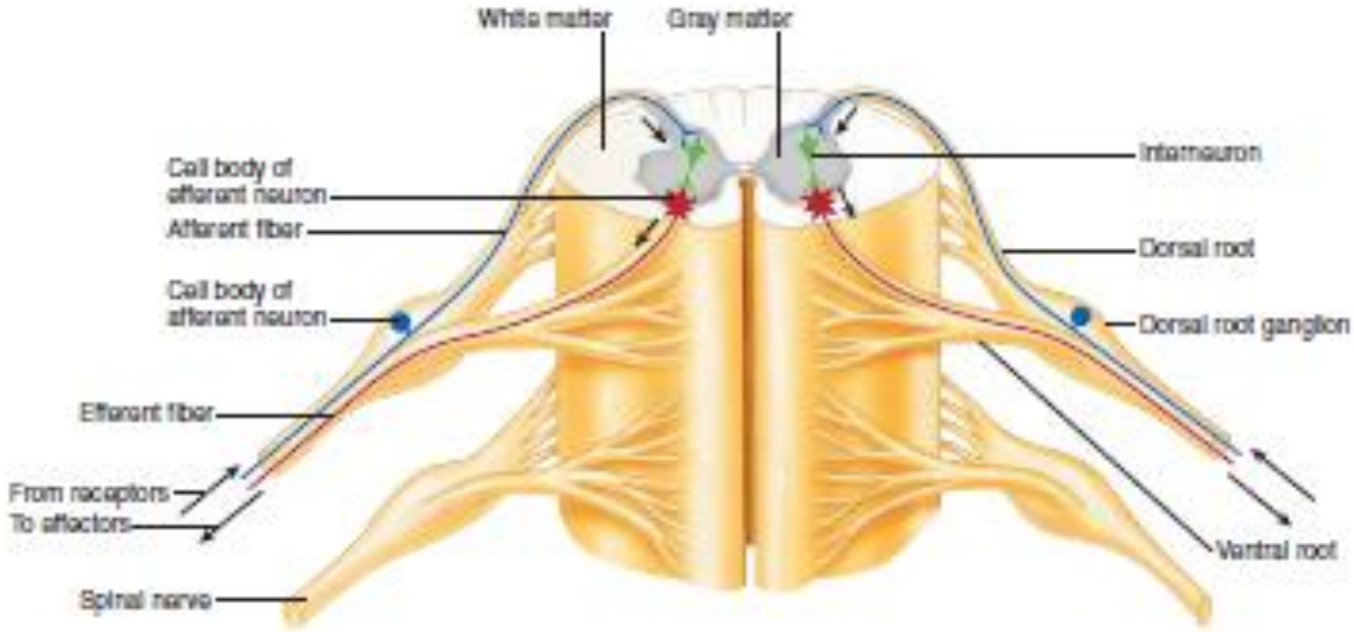
- Spinal cord extends through the vertebral canal and is connected to the spinal nerves
- The white matter of spinal cord is organized into tracts
- Each horn of spinal cord houses a different type of neuronal cell body
- Spinal nerves carry both afferent and efferent fibers

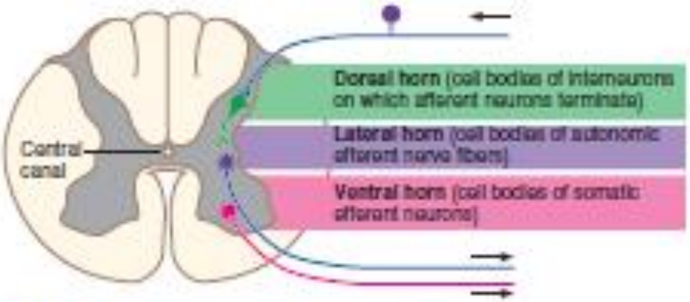

Spinal cord
Dorsal root ganglion
Spinal nerve
Vertebra
Meninges (protective coverings)
Intervertebral disk
Sympathetic ganglion chain



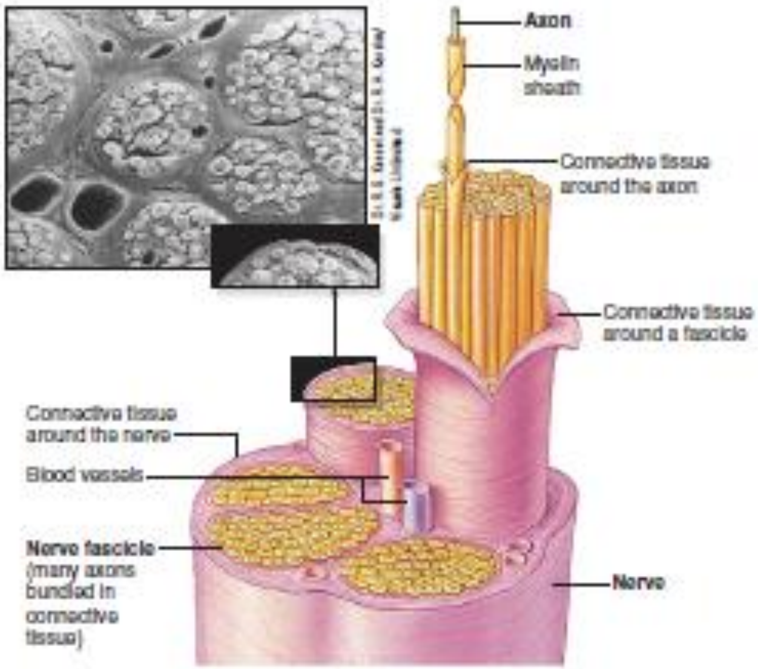
(a) Posterior view of spinal cord

(b) Lateral view of spinal cord


White matter
Gray matter
Interneuron
Cell body of
efferent neuron
Afferent fiber
Dorsal root
Cell body of
afferent neuron
Dorsal root ganglion
Efferent fiber
From receptors
To effectors
Ventral root
Spinal nerve



● FIGURE 5-29 Regions of the gray matter.



ORGANIZATION OF SPINAL CORD FOR MOTOR FUNCTION

- Each segment of spinal cord has several million neurons in its grey matter
- Aside from sensory relay neurons, other neurons are motor neurons

- 2 types of lower motor neurons:
  - Anterior motor neurons
  - Interneurons

ANTERIOR MOTOR NEURONS

- Located in anterior horns of cord grey matter
- Innervate skeletal muscle fibers
- 2 types:
  - A- alpha motor neurons
  - B- gamma motor neurons

A. ALPHA MOTOR NEURONS

- Give rise to large type A alpha motor nerve fibers
- 14 µm in diameter
- Innervate extrafusal muscle fibers
- Motor unit
- Inputs to alpha motor neurons

B. GAMMA MOTOR NEURONS

- Give rise to smaller type gamma motor nerve fibers
- 5µm in diameter
- Innervate the special skeletal muscle fibers – intrafusal fibers – middle of the muscle spindle – control basic muscle tone

INTERNEURONS

- Located in all areas of cord grey matter
- Are about 30 times as numerous as anterior motor neurons
- Are small and highly excitable
- They have many interconnections with one another and many of them directly synapse with anterior motor neurons
- These interconnections between interneurons and anterior motor neurons are responsible for most of the integrative functions of the spinal cord
- Function of the interneuron – integration and processing of information

RENSHAW CELLS

- In anterior horn of grey matter
- These are inhibitory cells
- Stimulation of each motor neuron tends to inhibit adjacent motor neurons called lateral inhibition
- This is to focus or sharpen these signals

Muscle receptors provide afferent information needed to control skeletal muscle activity

MUSCLE SPINDLE

Location - distributed throughout the belly of skeletal muscle & send information to nervous system about muscle length

Length 3 – 10 mm

Structure - Intrafusal fibers

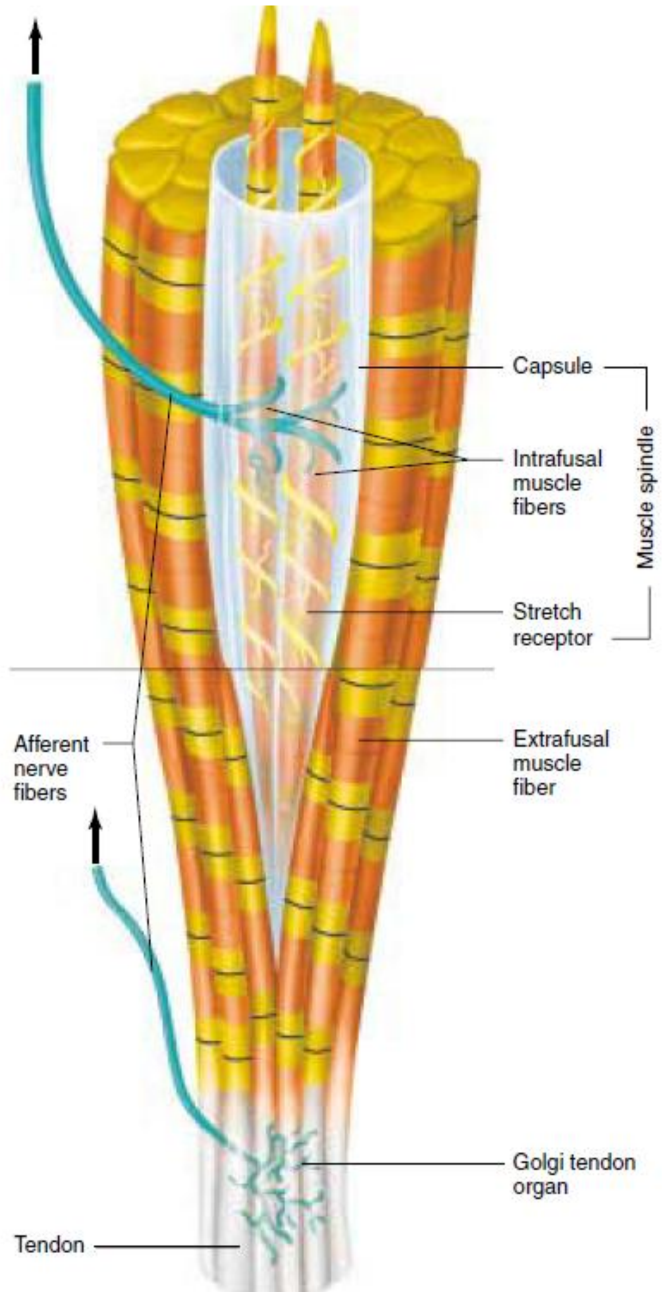
1. Nuclear bag fibers
2. Nuclear chain fibers

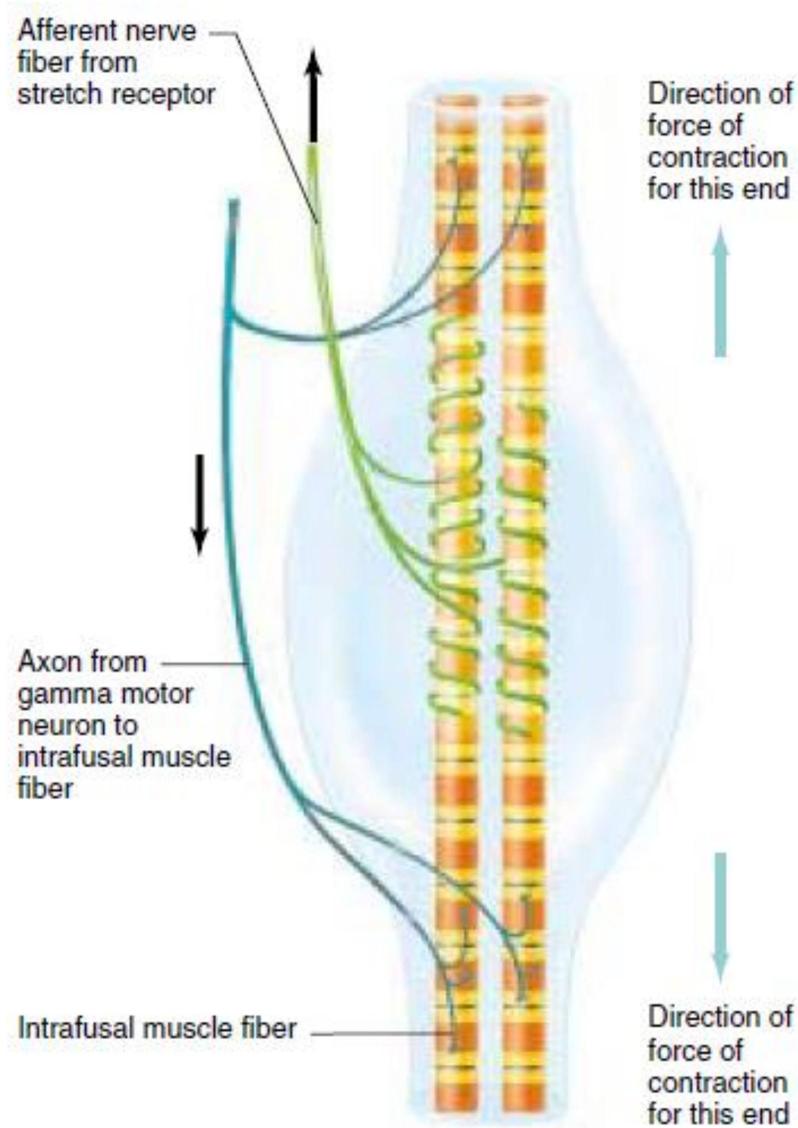
Motor Innervation

- Central portion of muscle spindle has few or no actin & myosin filaments
- It acts as sensory receptors
- End portion of muscle spindle has actin & myosin filaments
- End portion is excited by gamma efferent fibers (co-activation of gamma and alpha motor neurons is required)

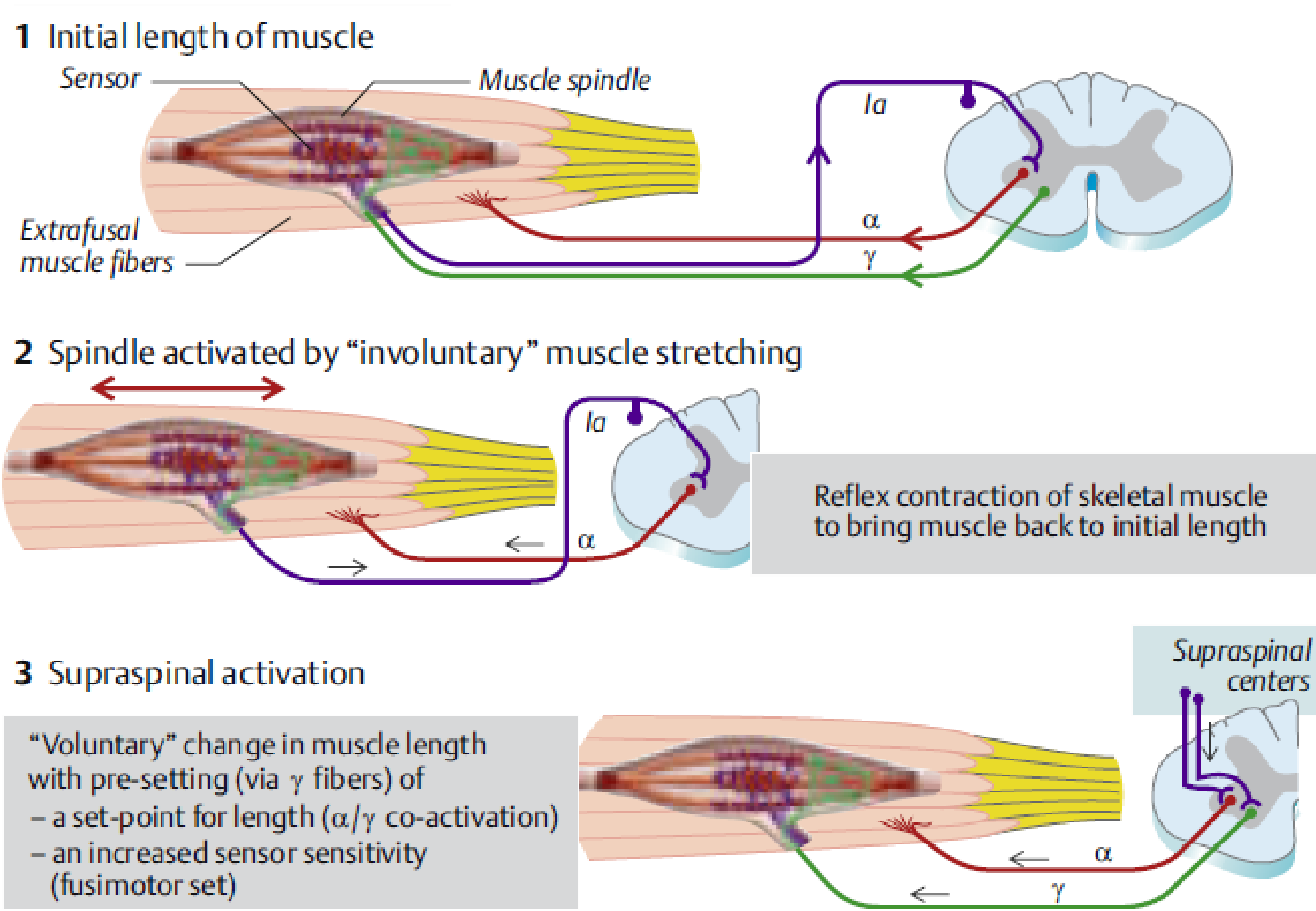
Sensory Innervation

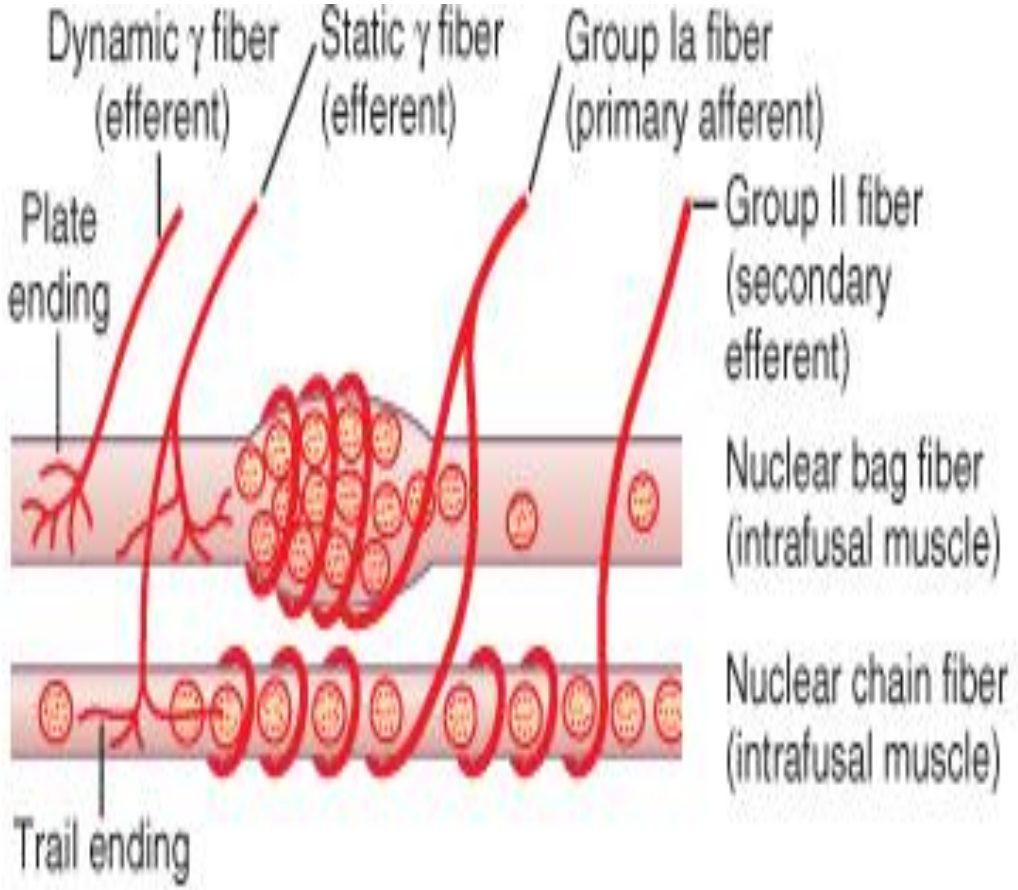
- 2 types of sensory nerve fibers
  - primary endings or annulospiral endings
    Diameter 17 µm
    Conduction velocity 70-120 m/sec
  - secondary endings or flower spray endings
    Diameter 8 µm


Capsule
Intrafusal muscle fibers
Muscle spindle
Stretch receptor
Afferent nerve fibers
Extrafusal muscle fiber
Golgi tendon organ
Tendon

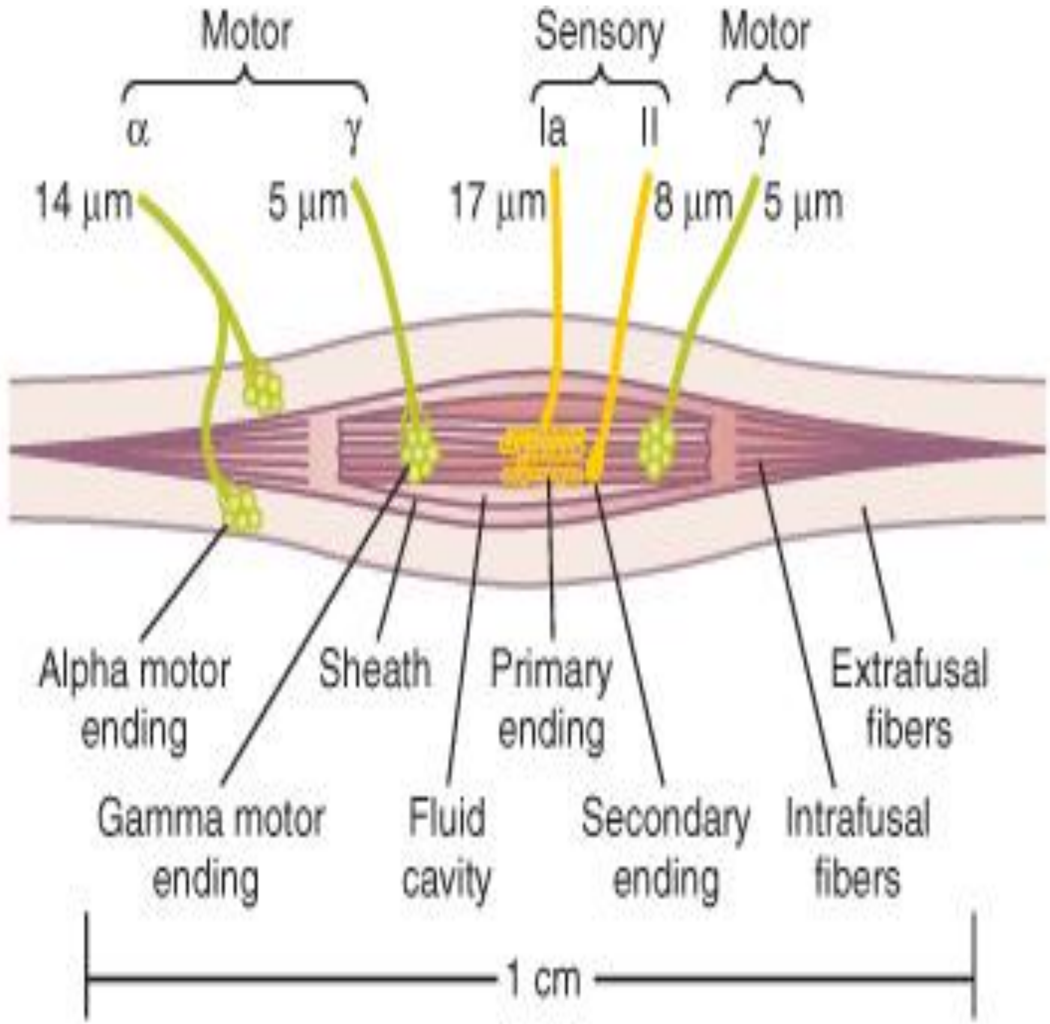


Afferent nerve fiber from stretch receptor
Direction of force of contraction for this end
Axon from gamma motor neuron to intrafusal muscle fiber
Intrafusal muscle fiber
Direction of force of contraction for this end


1 Initial length of muscle
Sensor
Muscle spindle
Ia
Extrafusal
muscle fibers
α
γ
2 Spindle activated by “involuntary” muscle stretching
Ia
α
Reflex contraction of skeletal muscle
to bring muscle back to initial length
3 Supraspinal activation
“Voluntary” change in muscle length
with pre-setting (via γ fibers) of
– a set-point for length (α/γ co-activation)
– an increased sensor sensitivity
(fusimotor set)
Supraspinal
centers
α
γ



Dynamic γ fiber
(efferent)
Static γ fiber
(efferent)
Group Ia fiber
(primary afferent)
Group II fiber
(secondary
efferent)
Plate
ending
Nuclear bag fiber
(intrafusal muscle)
Nuclear chain fiber
(intrafusal muscle)
Trail ending



Motor
Sensory
Motor
α
γ
Ia
II
γ
14 µm
5 µm
17 µm
8 µm
5 µm
Alpha motor ending
Sheath
Primary ending
Extrafusal fibers
Gamma motor ending
Fluid cavity
Secondary ending
Intrafusal fibers
1 cm

GOLGI TENDON ORGAN

- *Location* – at the junction of muscle with its tendon
- Encapsulated and 10-15 muscle fibers are usually connected to each golgi tendon organ
- *Stimulation* – by tension produced in the muscle either by contraction or the stretching of the muscle
- It has both dynamic and static response
- Sensory nerve fibers are Ib fibers with an average diameter of 16 μm

Spinal Cord Reflexes

- ❖ The spinal cord is responsible for the integration of many basic reflexes
- ❖ Reflex arc

1- Sensory receptors

2- Afferent pathway

3- Integrating centre

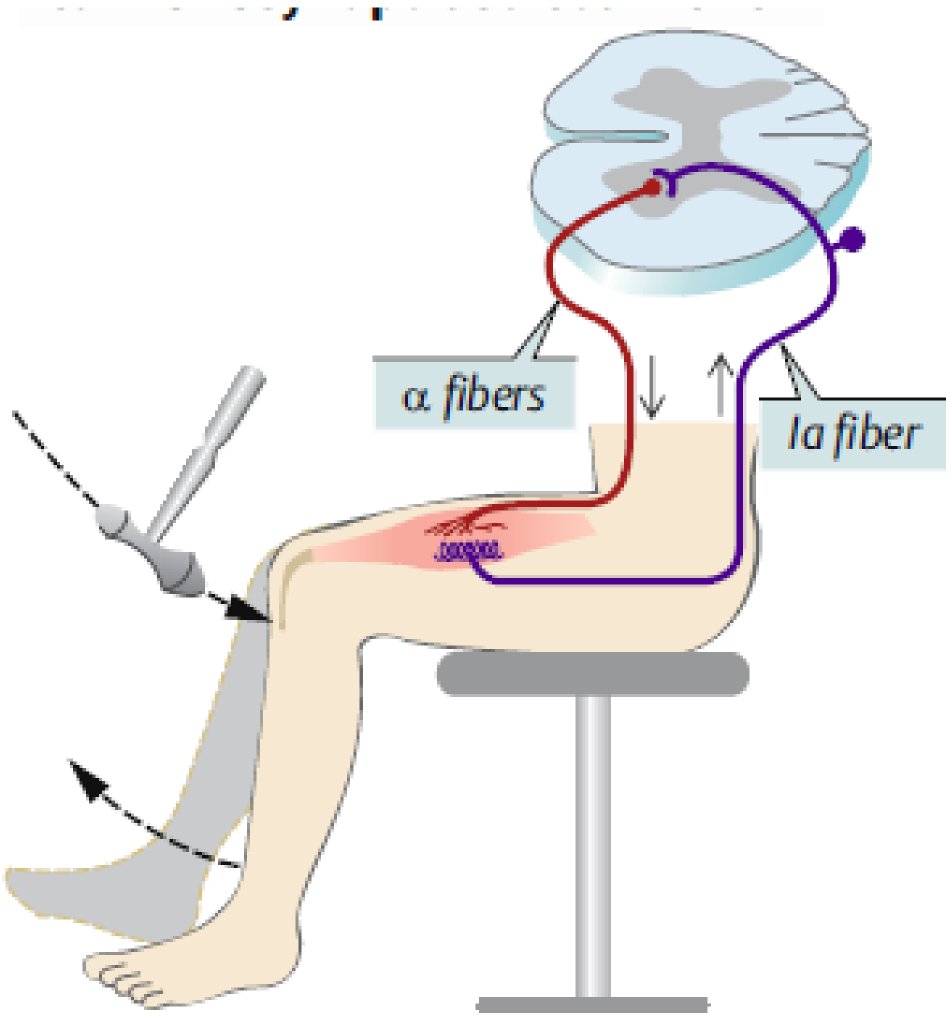
4- Efferent pathway

5- Effectors

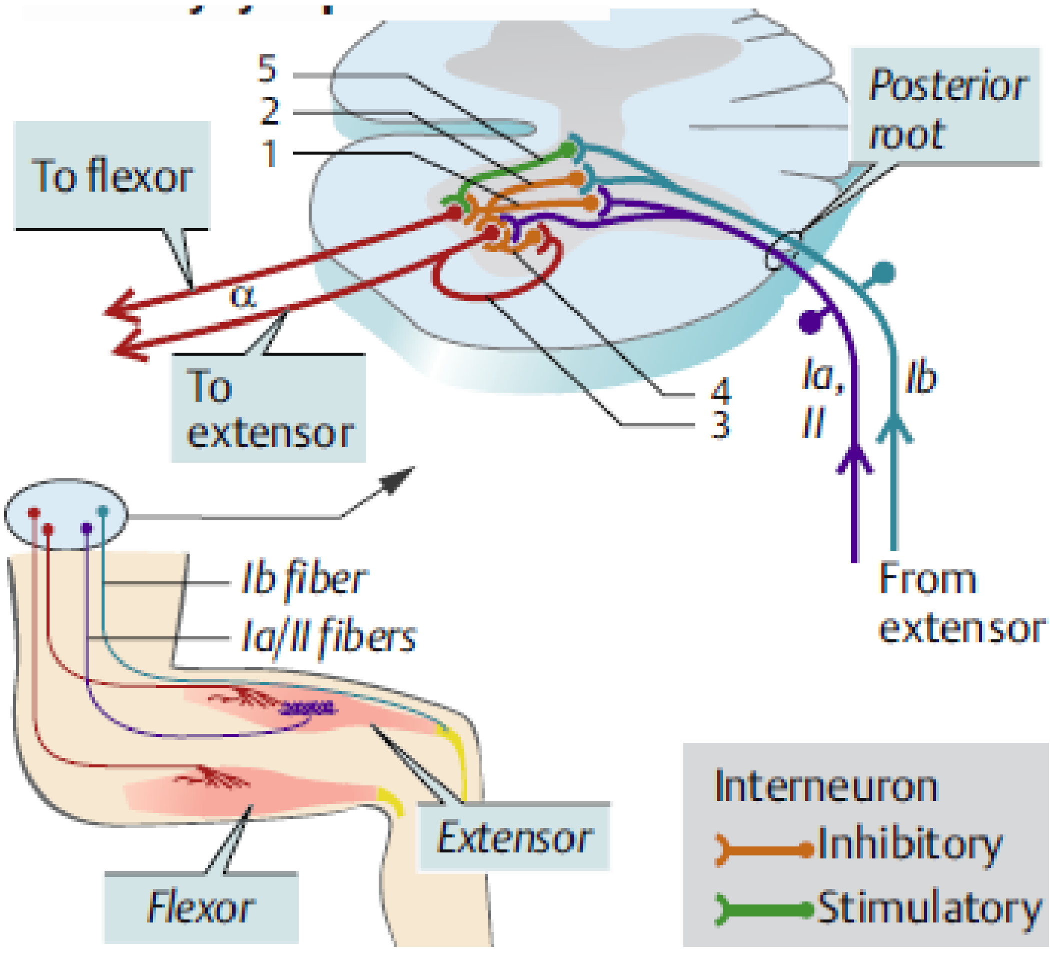
Spinal Cord Reflexes

- Muscles stretch reflex
- Withdrawl reflex
- Flexor reflex or Nociceptive reflex or Pain reflex
- Crossed extensor reflex
- Golgi tendon Reflex

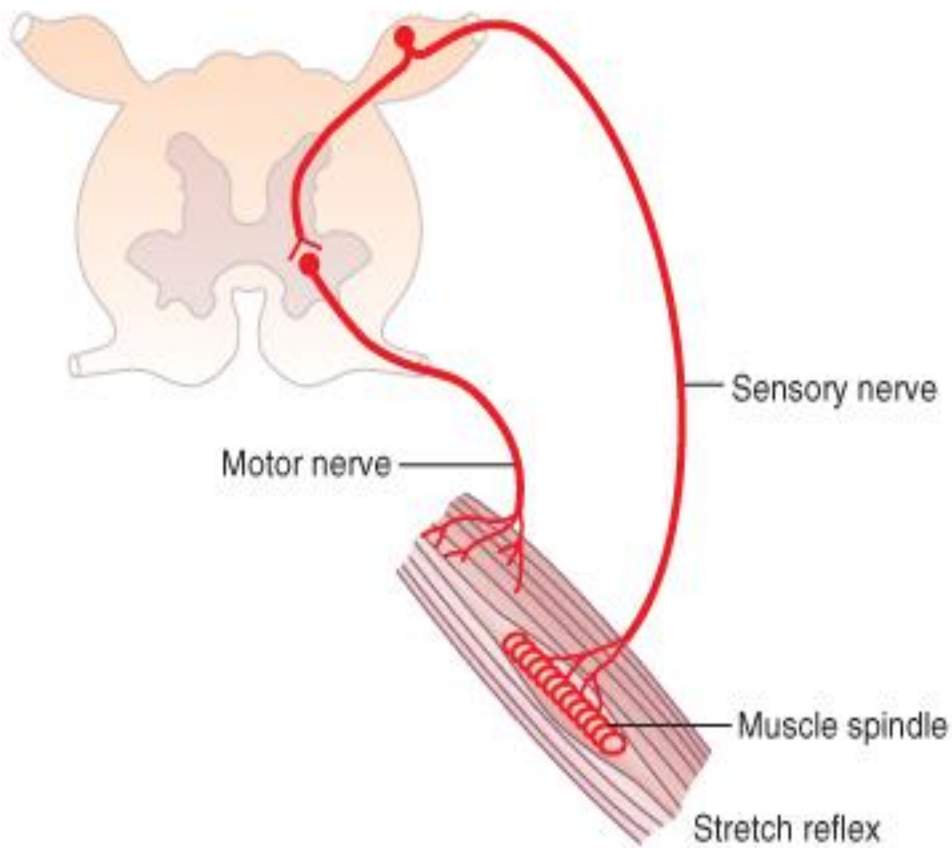
Monosynaptic



Polysynaptic



Muscles stretch reflex



FUNCTIONS OF STRETCH REFLEX

Damping Function or Signal Averaging Function

- it is the ability to prevent oscillation or jerkiness of body movements
- Signals from spinal cord are often transmitted to a muscle in an unsmooth form
- Muscle spindle causes smoothening of muscle contraction

Role in Voluntary Motor Activity

Whenever signals are transmitted from motor cortex to the alpha motor neurons, in most instances the gamma motor neurons are stimulated simultaneously called co-activation of alpha and gamma motor neurons

FUNCTIONS OF STRETCH REFLEX

Stabilizes body position during tense action

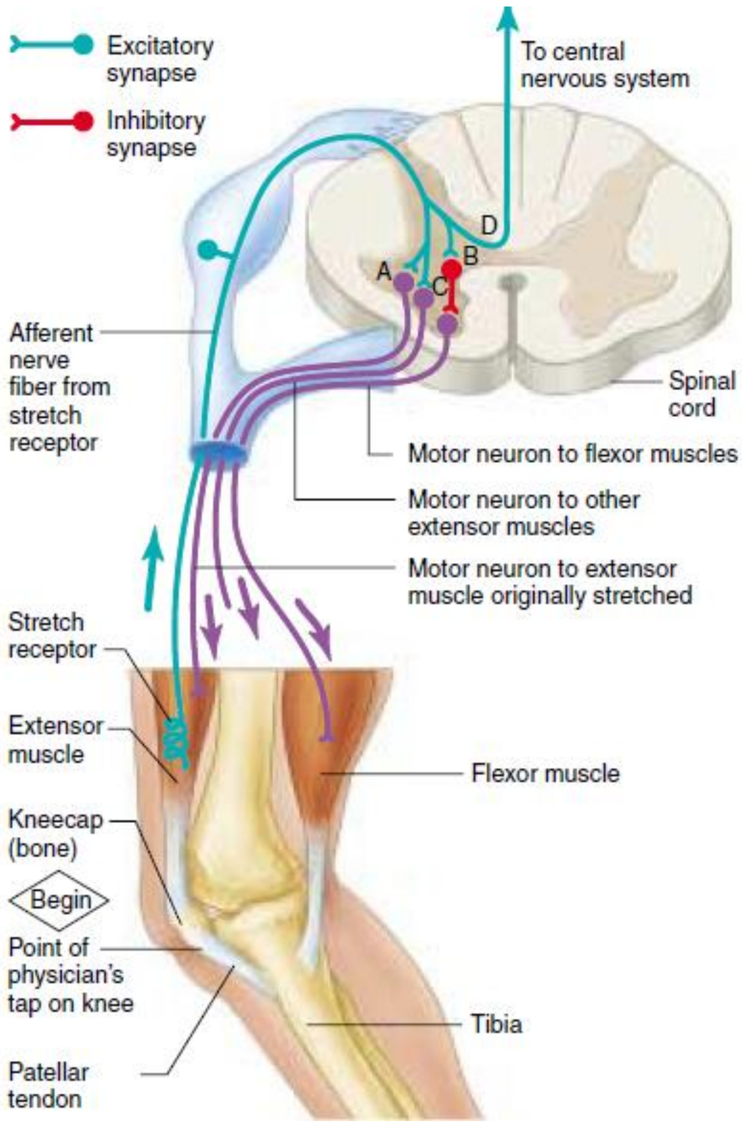
- Bulbo-reticular facilitatory region and its allied areas of brain stem transmit excitatory signals through the gamma nerve fibers to the intra-fusal fibers of muscle spindles
- Spindles on both sides of each joint are activated at the same time → reflex excitation of the skeletal muscles on both sides of the joint → produces tense muscle contractions opposing each other at the joint

Helps in motor control from higher levels of brain

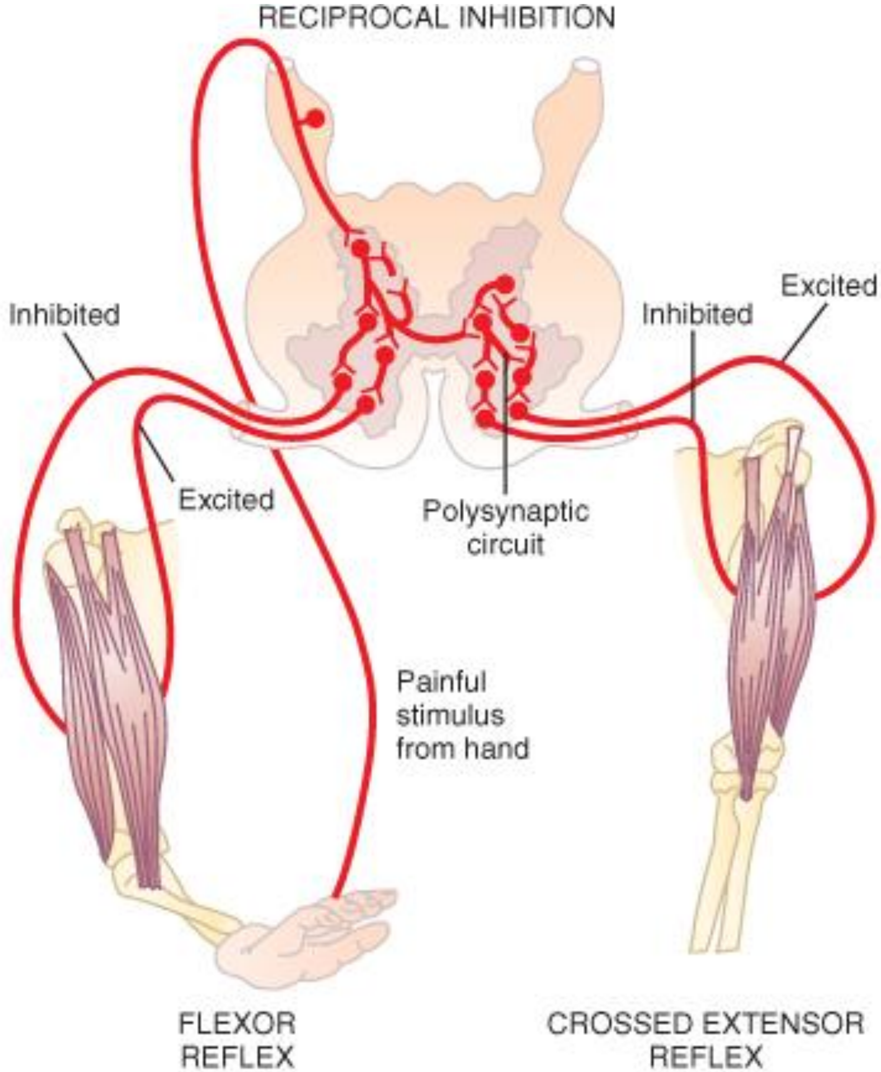
CLINICAL APPLICATIONS

- Knee jerk
- Other muscle jerks
  - Exaggerated muscle jerks → large lesions in motor areas of cerebral cortex
  - clonus→ oscillation of muscle jerks – it occurs only when the stretch reflex is highly sensitized by facilitatory impulses from the brain

Knee Jerk



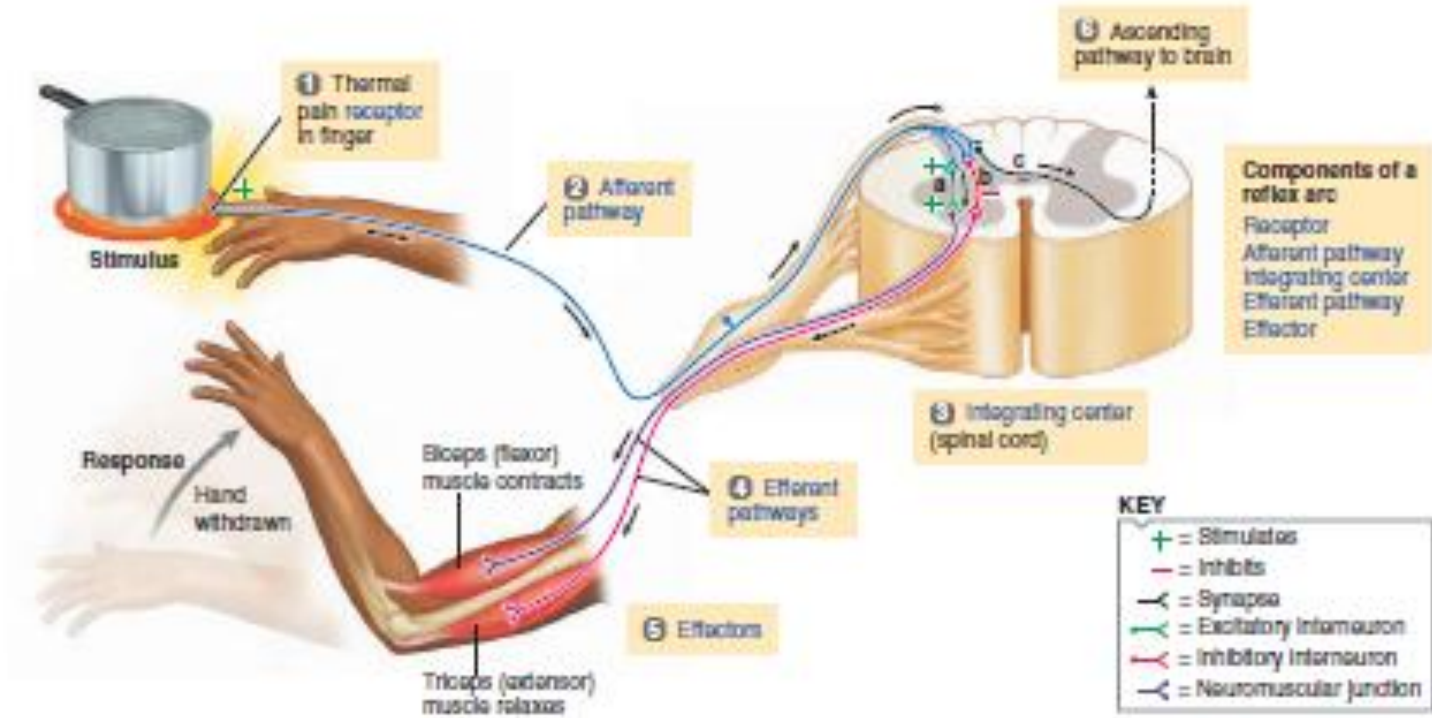
Excitatory synapse
Inhibitory synapse
To central nervous system
D
B
A
C
Afferent nerve fiber from stretch receptor
Spinal cord
Motor neuron to flexor muscles
Motor neuron to other extensor muscles
Motor neuron to extensor muscle originally stretched
Stretch receptor
Extensor muscle
Flexor muscle
Kneecap (bone)
Begin
Point of physician's tap on knee
Tibia
Patellar tendon


RECIPROCAL INHIBITION
Inhibited
Excited
Inhibited
Excited
Polysynaptic
circuit
Painful
stimulus
from hand
FLEXOR
REFLEX
CROSSED EXTENSOR
REFLEX

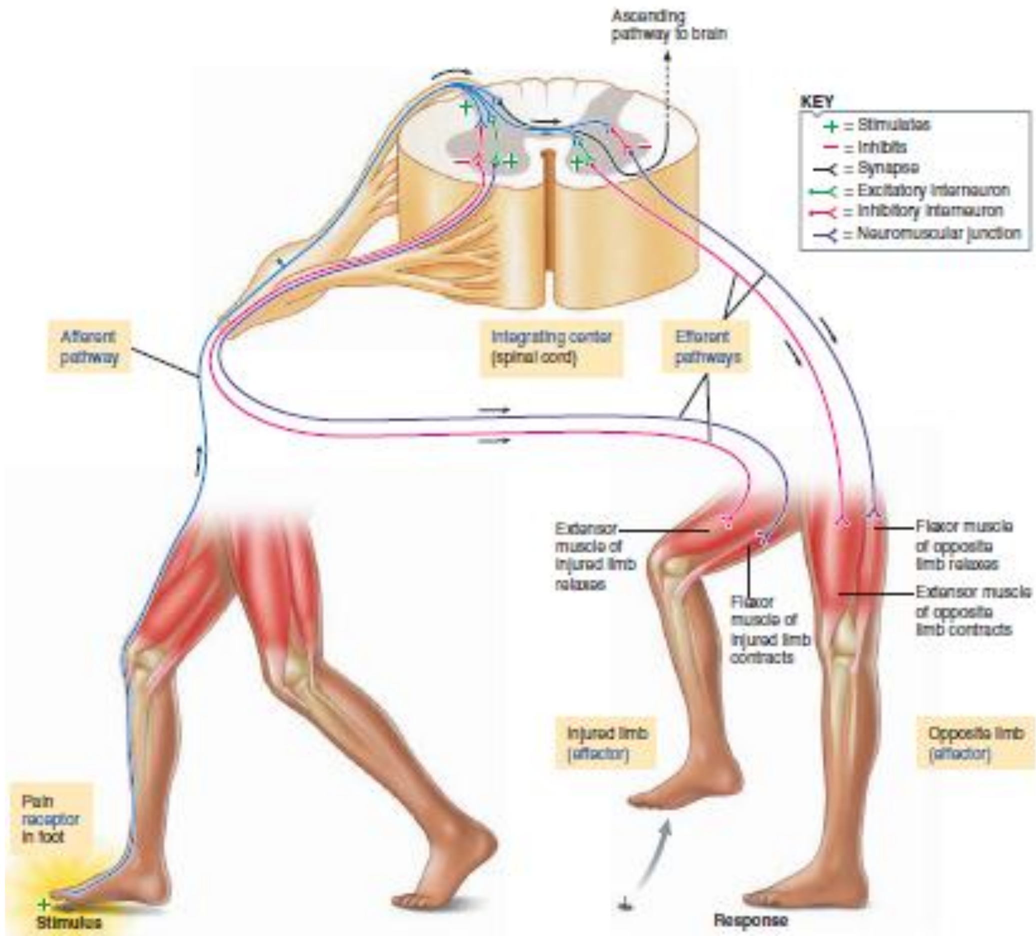
- Withdrawl reflex

  Crossed extensor reflex

  Reflexes of posture & locomotion



1 Thermal pain receptor in finger
Stimulus
2 Afferent pathway
6 Ascending pathway to brain
Components of a reflex arc
Receptor
Afferent pathway
Integrating center
Efferent pathway
Effector
3 Integrating center (spinal cord)
Response
Hand withdrawn
Biceps (flexor) muscle contracts
4 Efferent pathways
5 Effectors
Triceps (extensor) muscle relaxes
KEY
+ = Stimulates
– = Inhibits
= Synapse
= Excitatory interneuron
= Inhibitory interneuron
= Neuromuscular junction


Ascending pathway to brain
KEY
+ = Stimulates
− = Inhibits
= Synapse
= Excitatory interneuron
= Inhibitory interneuron
= Neuromuscular junction
Afferent pathway
Integrating center (spinal cord)
Efferent pathways
Extensor muscle of injured limb relaxes
Flexor muscle of injured limb contracts
Flexor muscle of opposite limb relaxes
Extensor muscle of opposite limb contracts
Injured limb (effector)
Opposite limb (effector)
Pain receptor in foot
Stimulus
Response

Autonomic reflexes in spinal cord

- Changes in vascular tone resulting from changes in local skin heat
- Sweating which results from localized heat on the surface of body
- Peritoneointestinal reflexes
- Evacuation reflexes
- Mass reflex

Spinal Shock

- When the spinal cord is suddenly transected in the neck,at first, all cord functions,including cord reflexes immediately depressed to a point of complete silence, a reaction called spinal shock
- The reason for spinal shock
- Clinical features