HUMAN PHYSIOLOGY (normal)

LECTURE 4. Special Physiology of CNS. The Brain

Lyubomyr Vovkanych
Department of Anatomy & Physiology
LSUPhC

Main Principles of Brain coordination of Movements

Hierarchical organization:

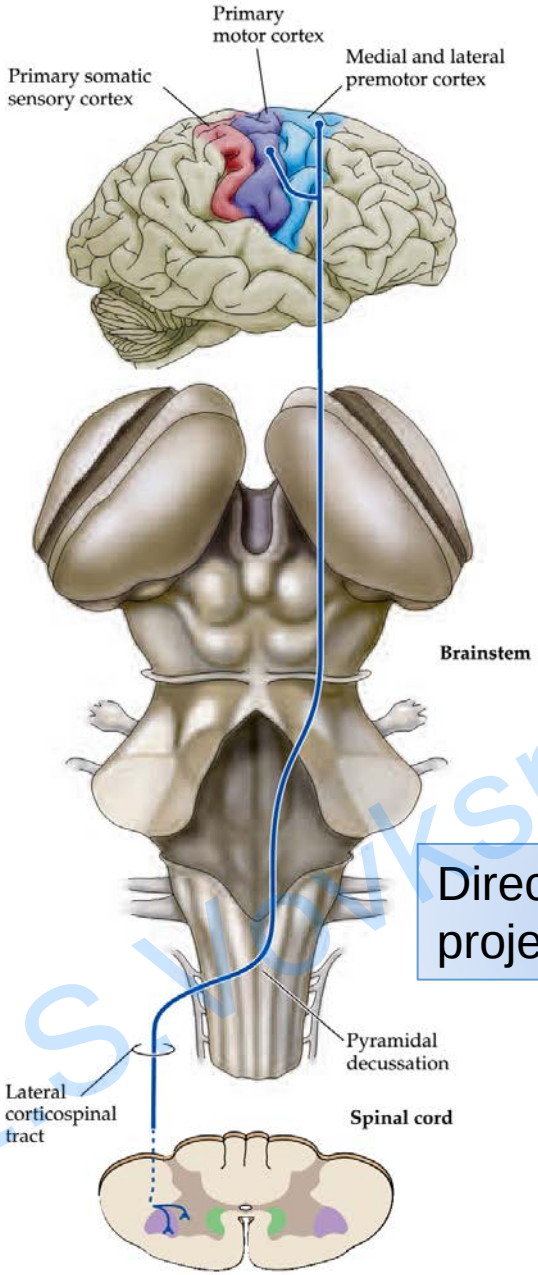
- The higher level centers (cortex) control the lower ones (brain stem, spinal cord);
- The lower the level, the simpler are its reflexes;
- Higher centers activate ready-made motion organization programs available at lower centers.

The non-standard movements are coordinated by the cerebral cortex

For the precise movements the correction systems (cerebellum, basal nuclei, etc.) are important

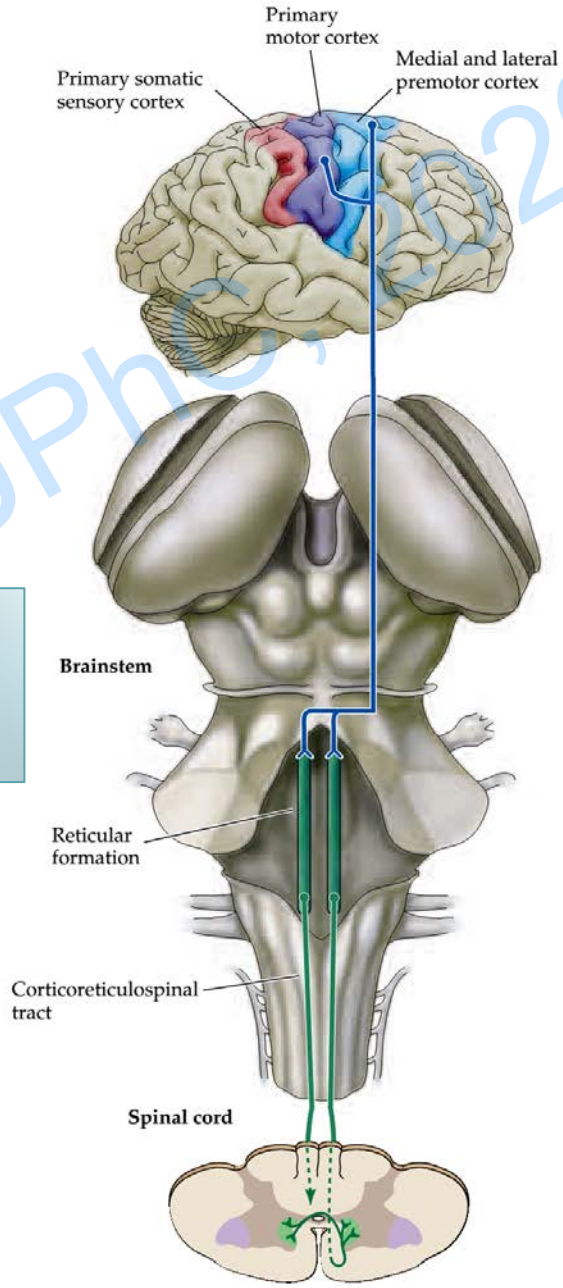
The presence of feedback, due to which there is a correction of movements

Motor cortex control of the spinal cord



Direct cortical projections

Indirect cortical projections



The Medulla Oblongata Functions

Relay station

- Contain the nucleus and tracts, which forms the ascending and descending pathways of the brain

Reflexes

- Motor nuclei – regulation of skeletal muscles contraction
- Autonomic nuclei – regulation of smooth mackles contraction, glands functioning etc.

- All the medullary centers and nuclei of cranial nerves **are controlled by higher centers**, located in brain stem, cerebral, cortex and hypothalamus

Relay Stations of the Medulla Oblongata

Nuclei	Functions
Nucleus gracilis and nucleus cuneatus	Pass somatic sensory information to thalamus and brain cortex
Olivary nuclei (olives)	Pass somatic sensory information to cerebellum
Solitary nucleus (nucleus of the solitary tract)	Pass sensory information from the facial, glossopharyngeal and vagus nerves to the reticular formation, hypothalamus and thalamus
Nuclei of glossopharyngeal and vagus nerves	Pass sensory information from visceral organs, tonsil, pharynx to brain centers

Autonomic Centers of the Medulla Oblongata

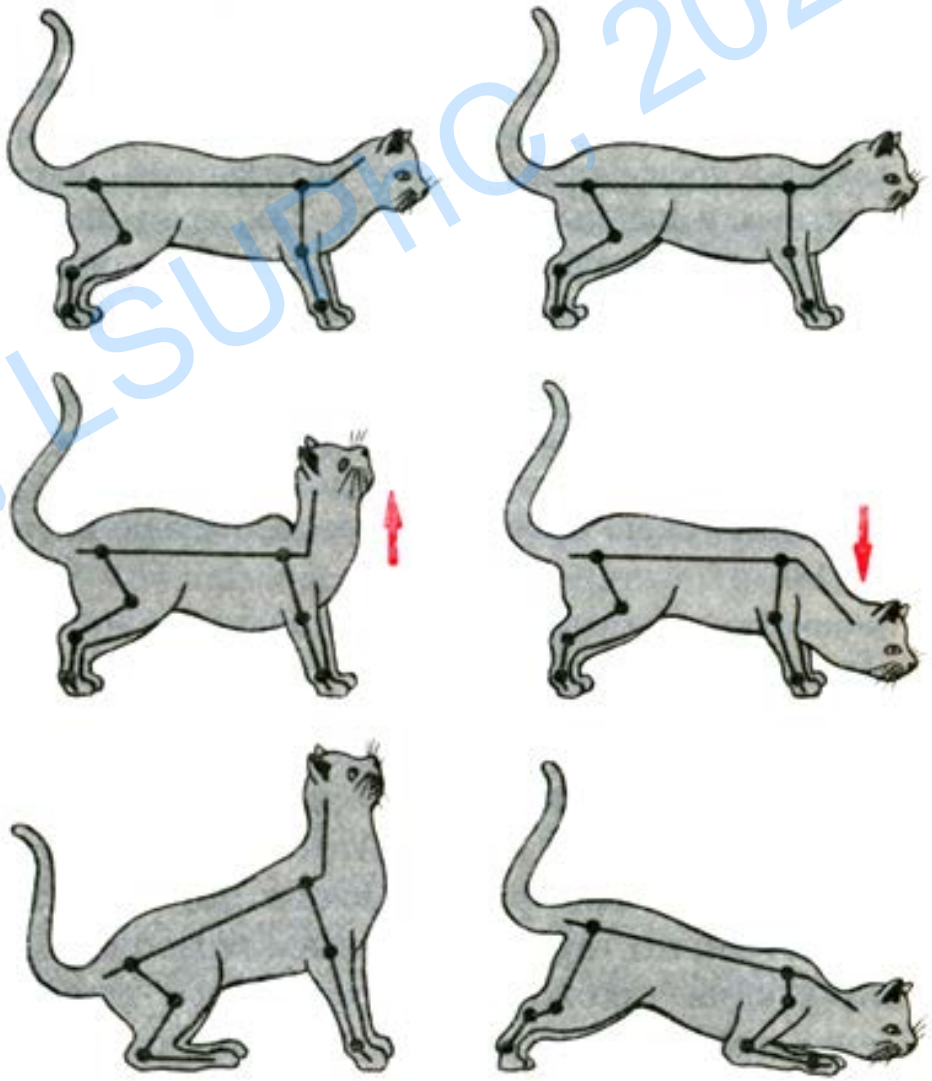
Centers	Reflexes
Glossopharyngeal nuclei	Control of salivation from parotid salivary gland
Vagus nuclei	Regulation of many visceral functions (cardiovascular system, respiratory system, gastrointestinal system etc.)
Reticular formation (vasomotor center, medullary respiratory center)	Maintains normal rhythmic respiration; Controls blood pressure and heart rate.

Motor Centers of the Medulla Oblongata

Centers	Reflexes
Glossopharyngeal and hypoglossal nuclei	Take part in chewing, swallowing and protective reflexes (sneezing, coughing, vomiting etc.)
Accessory nerve centers (with cervical segments of spinal cord)	Tonic neck reflex (see next picture)

Tonic Neck Reflex

- Includes the reflexes of **cervical** segments C1-C3
- Describes the **automatic positioning of the limbs** in response to a **movement of the head** on trunk (neck)
- When the head is moved in pitch on the trunk, dorsiflexion induces extension of the legs and arms, while flexion of the head induces flexion of the arms and head
- In it combines with the other vestibular reflexes



The Pons

Relay station

- Contain the nucleus and tracts, which forms the ascending and descending pathways of the brain
- Links cerebellum with mesencephalon, diencephalon, cerebrum, and spinal cord

Reflexes

- Motor nuclei – regulation of skeletal muscles contraction
- Autonomic nuclei – regulation of smooth mackles contraction, glands functioning etc.

Relay Functions of the Pons

Nuclei/Structures	Functions
Pontine nuclei	Form middle cerebellar peduncle (connection of cerebellar with medulla oblongata and spinal cord)
Pyramidal tracts	Connection of medulla oblongata and thalamus (and cortex)
Cerebellar peduncles	See below

Autonomic Centers of the Pons

Centers	Reflexes
Pneumotaxic and Apneustic centers	Modify respiratory rhythmicity center activity
Facial nuclei	Control of salivation and tears secretion (parasympathetic fibers to the submandibular and sublingual glands, nasal mucosa and the lacrimal gland)

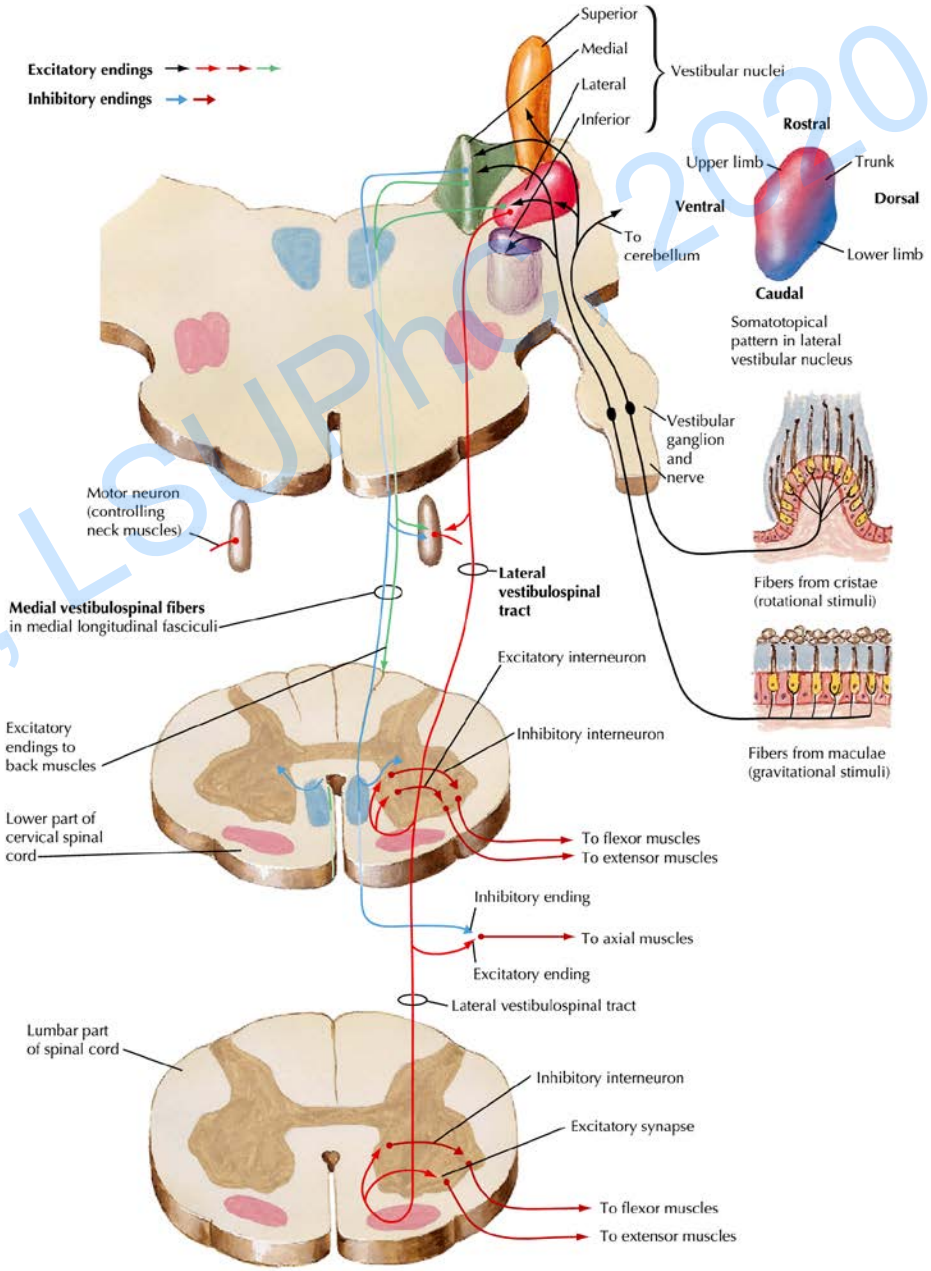
Sensor and Motor Centers of the Pons

Centers	Reflexes
Vestibular and Cochlear nuclei (sensor and motor nuclei)	Sensor part: sense of balance, equilibrium and hearing Motor part: vestibular reflexes
Facial nerve nuclei	Sensory part: taste receptors Motor part: control of facial expression, efferent limb of corneal reflex
Abducens nerve nuclei	Eye movement
Trigeminal nerve nuclei	Sensory part: provide tactile, proprioceptive, and nociceptive afference from the face and mouth Motor part: biting, chewing and swallowing

Postural reflexes

- Responsible for maintenance of **posture**
- Impulses arise from proprioceptors, **vestibular apparatus** and retina of eye
- Are generally **classified** into two groups:
  - **Static** reflexes
  - **Statokinetic** reflexes

Vestibular nuclei and vestibulospinal tract



Static reflexes

Static reflexes are the postural reflexes that maintain posture at rest. Static reflexes are of four types:

- **General** static reflexes or **righting** reflexes
- **Local** static reflexes or supporting reflexes
- **Segmental** static reflexes
- **Statotonic** or attitudinal reflexes.

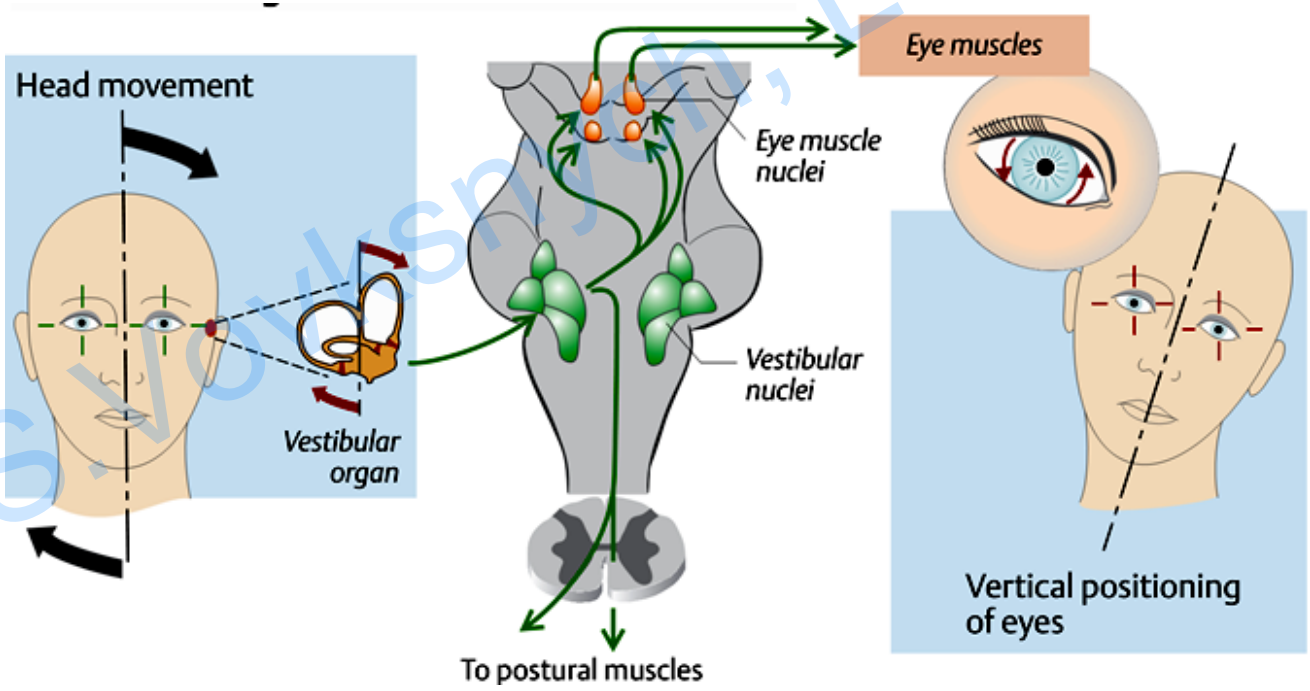
The sequence of events during righting reflexes:

- When the animal is placed upon its back, **labyrinthine reflexes** acting upon neck muscles turn the head into its normal position in space, in relation to body
- **Proprioceptive reflexes** of neck muscles then bring the body into its normal position in relation to position of head

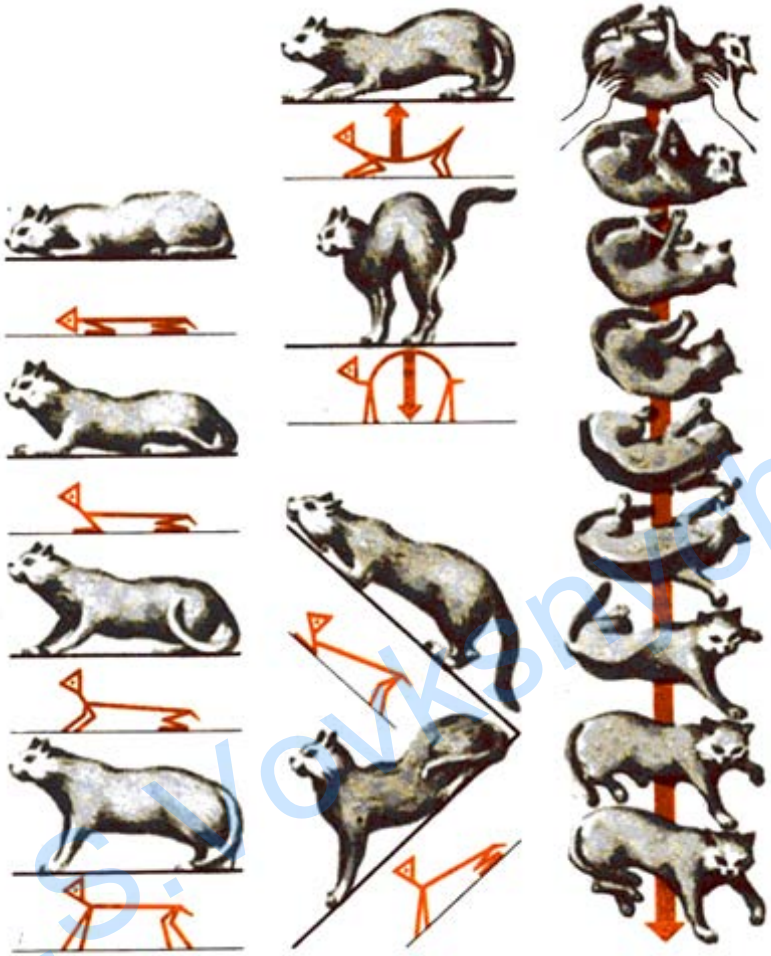
Statokinetic reflexes

Statokinetic reflexes are the postural reflexes that maintain posture during movement.

Through stimulation of the receptors in the neck muscles and semicircular canals, brings about movements of the limbs and eyes appropriate to a given movement of the head in space.

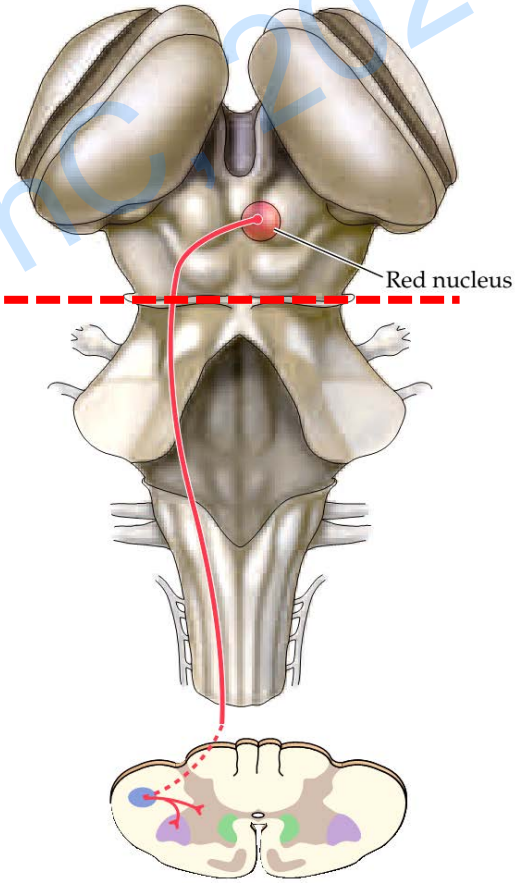


Control of Posture. Mesencephalon



Mesencephalic animal.
Red nuclei active. Posture maintained

Decerebrate rigidity is the rigid extension of all the limbs due to decerebration. **No influence of red nuclei**



The Cerebellum

- Plays an important role in **coordinating of movements**
- Influences **descending motor pathways** to produce fine, smooth, and coordinated motion

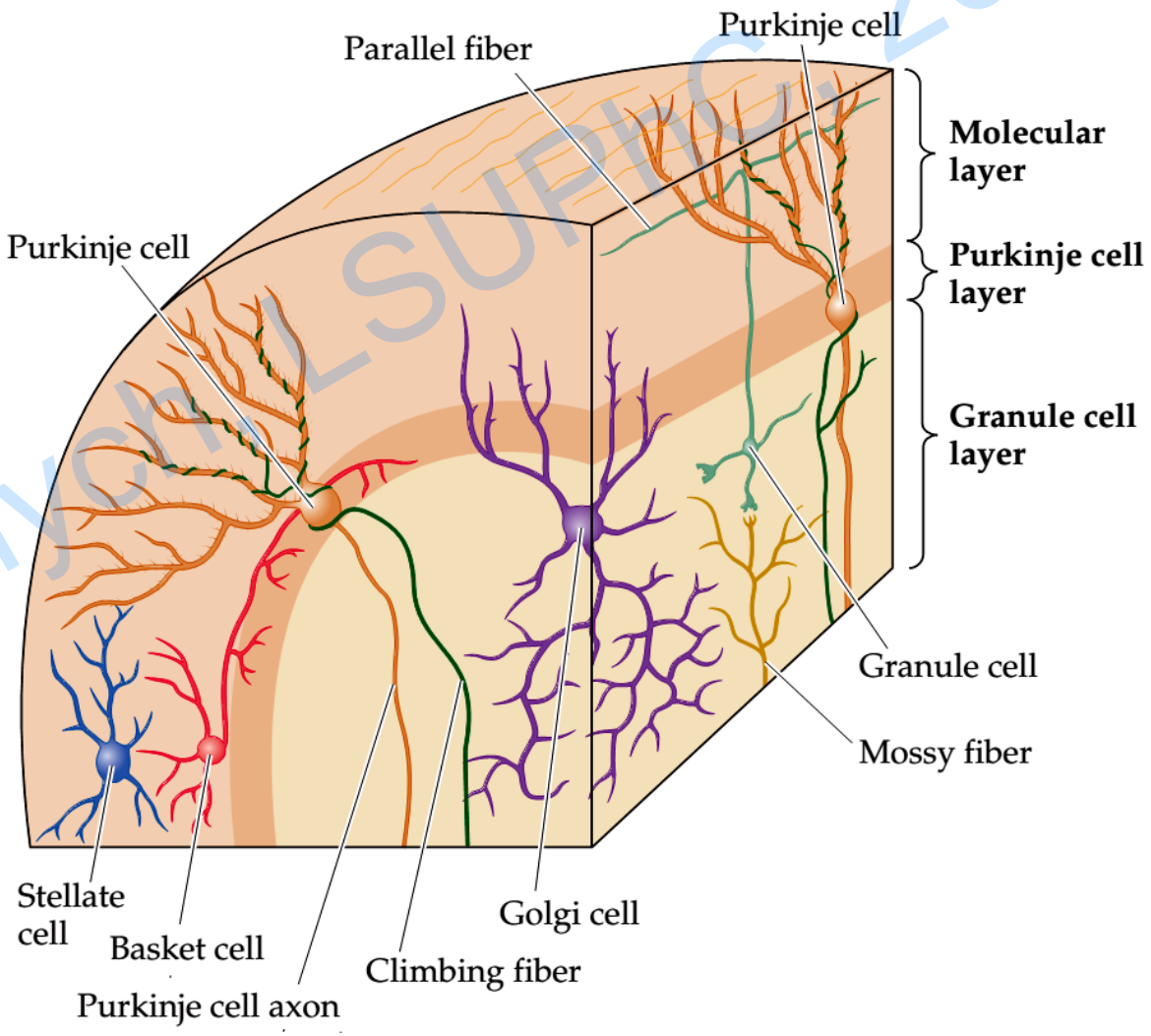
- Cerebellum **is divided into** three general areas:
  - **archicerebellum** (vestibulocerebellum)
  - **paleocerebellum** (spinocerebellum)
  - **neocerebellum** (cerebrocerebellum)

- Cerebellum is made up of outer gray matter or **cerebellar cortex** and an **inner white matter**.
- **White matter** is formed by afferent and efferent nerve fibers of cerebellum.
- **Gray masses** called **cerebellar nuclei** are located within the white matter.

Cerebellar Cortex

Gray matter or **cerebellar cortex** is made up of structures arranged in **three layers**

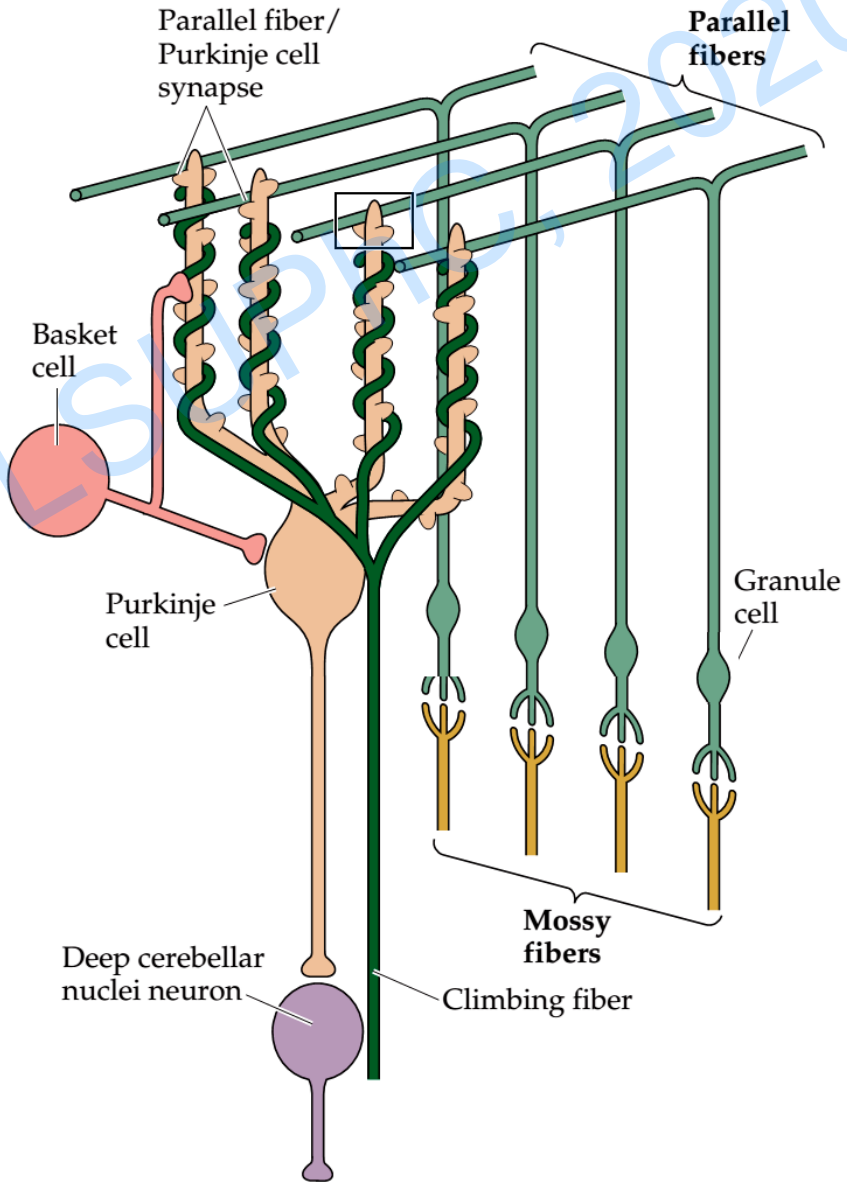
- **Outer molecular** or plexiform layer
- **Intermediate Purkinje** layer ('final common path')
- **Inner granular** layer.



Afferent Fibers to Cerebellar Cortex

Two types of fibers:

- **Climbing** fibers arise from the neurons of inferior **olivary nucleus** (transmit proprioceptive impulses from different parts of the body and vestibular system)
- **Mossy** fibers have many sources of origin - motor areas of cerebral cortex, pons, medulla and spinal cord



Cerebellar peduncles (Projection fibers)

Projection fibers are the afferent and efferent nerve fibers which connect cerebellum with other parts of CNS. They are arranged **in three bundles**:

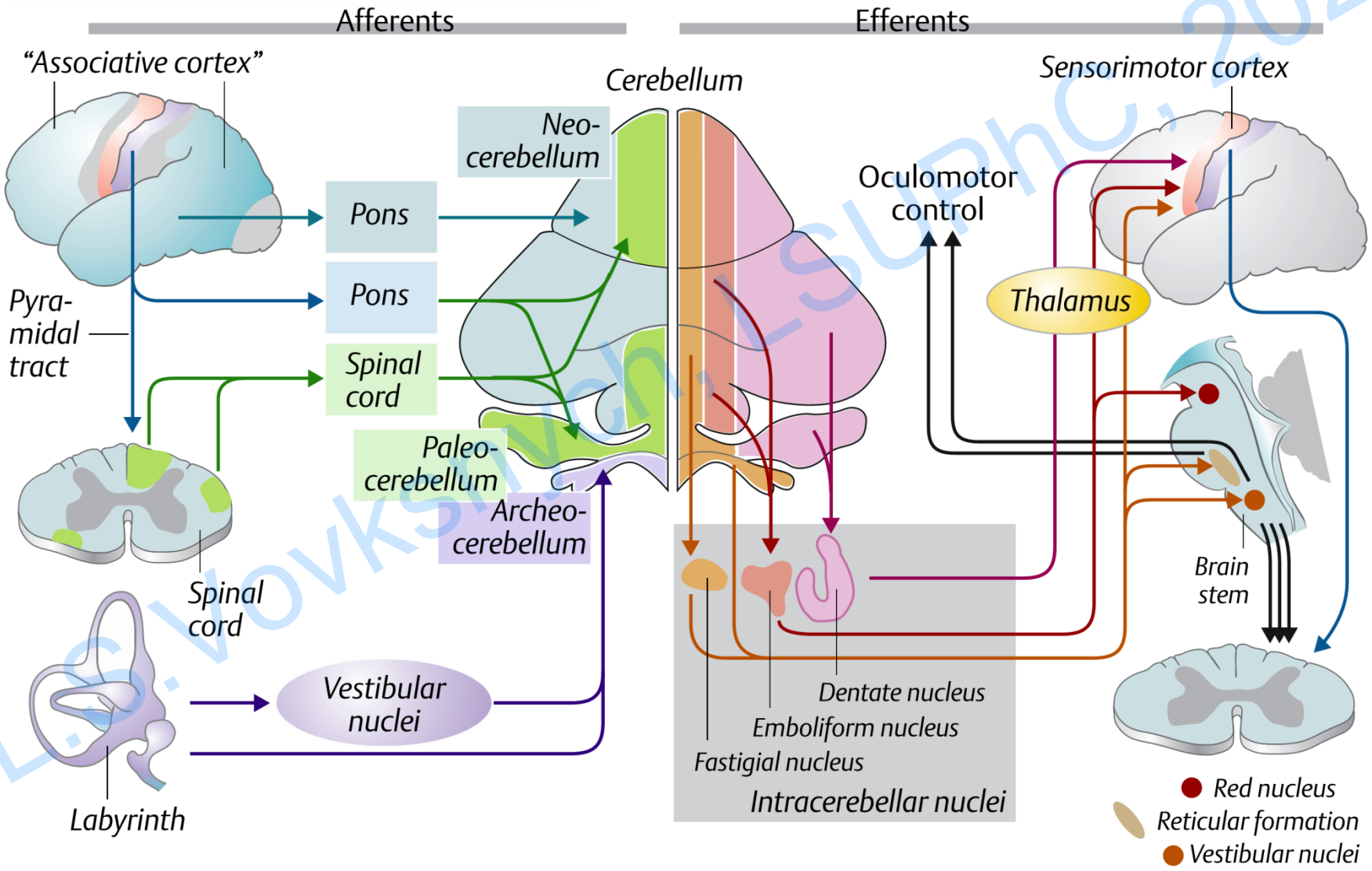
- **Inferior cerebellar peduncles** (between cerebellum and medulla oblongata, predominantly afferent fibers, transmit the impulses from tactile receptors, proprioceptors and receptors in vestibular apparatus)
- **Middle cerebellar peduncles** (between cerebellum and pons, predominantly afferent fibers, most of them are commissural fibers of cerebellar cortex)
- **Superior cerebellar peduncles (**between cerebellum and midbrain, contain predominantly efferent fibers)

Cerebellar nuclei

Efferents from the cerebellum derive from the **deep nuclei**:

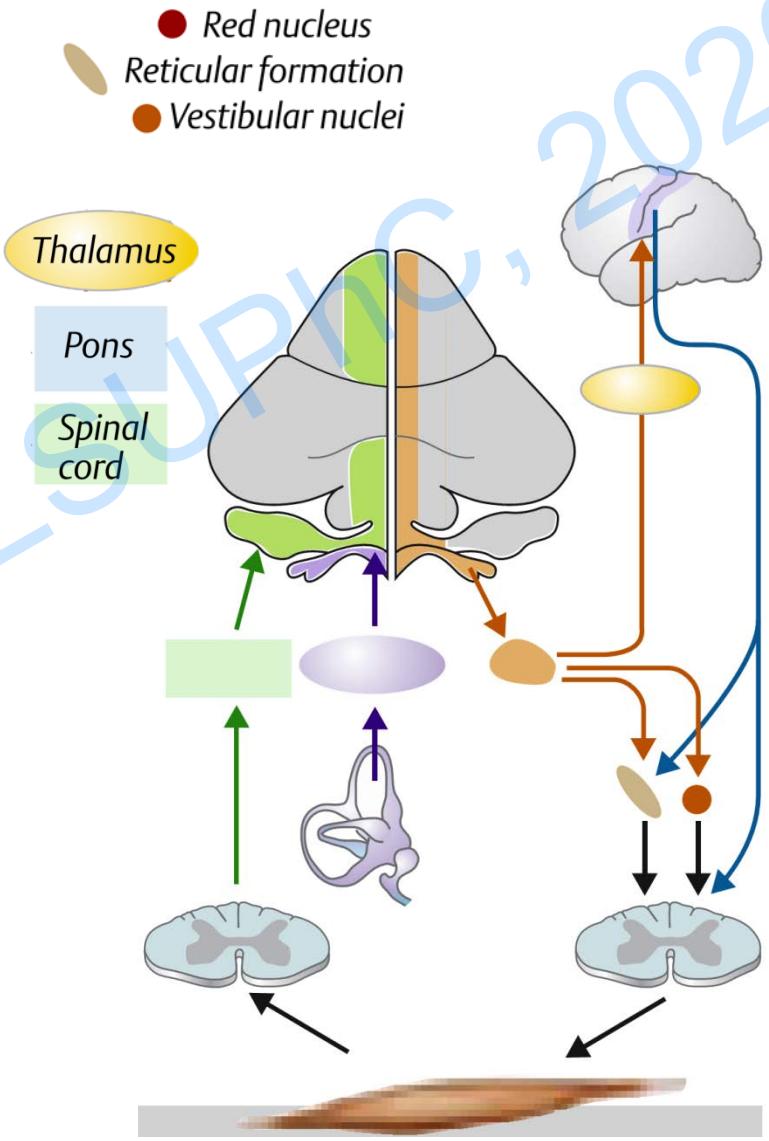
- From the **fastigial nucleus** through the inferior cerebellar peduncle and terminate in the lateral **vestibular nucleus**, **pontine** and **medullary reticular nuclei**
- From **globose and emboliform** nuclei project mainly through the superior cerebellar peduncle to the **red nucleus**
- From **dentate** nucleus project through the superior cerebellar peduncle to the VL and VA **nuclei** of the **thalamus**, mainly modulate the activity of the corticospinal tract

Tracts and function of cerebellum



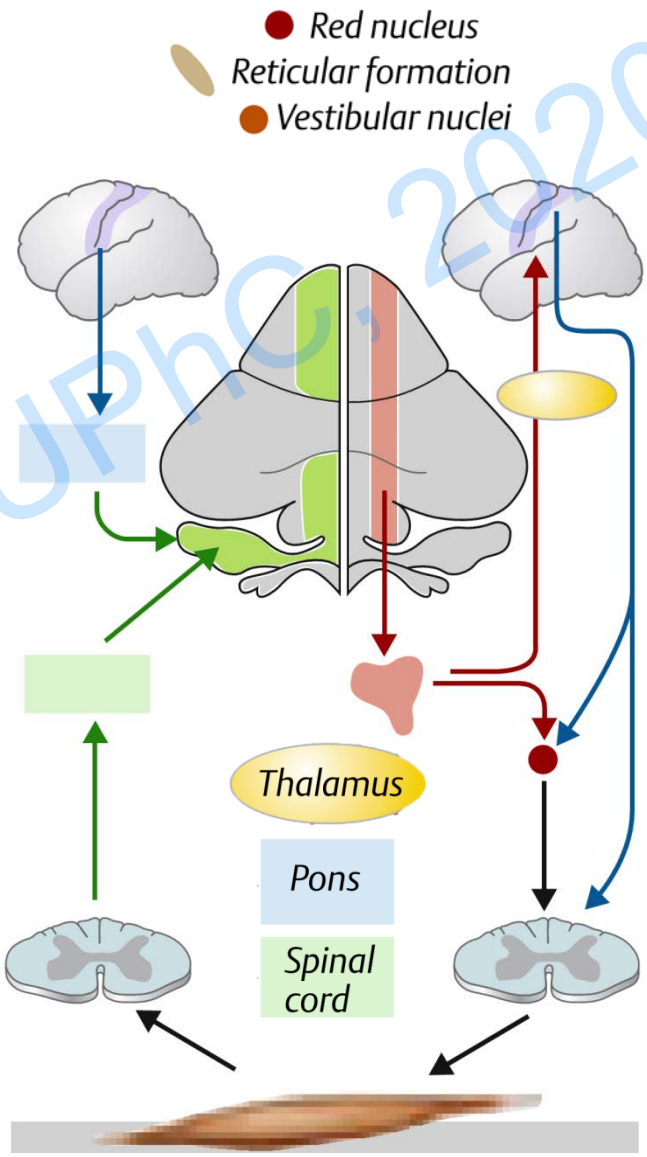
Archicerebellum (vestibulocerebellum)

- Is primarily involved in controlling **muscle tone**, **posture** and **balance**, as well as the movement of the head and eyes.
- It receives afferent signals from the vestibular apparatus
- It sends efferent fibers to the appropriate descending motor pathways



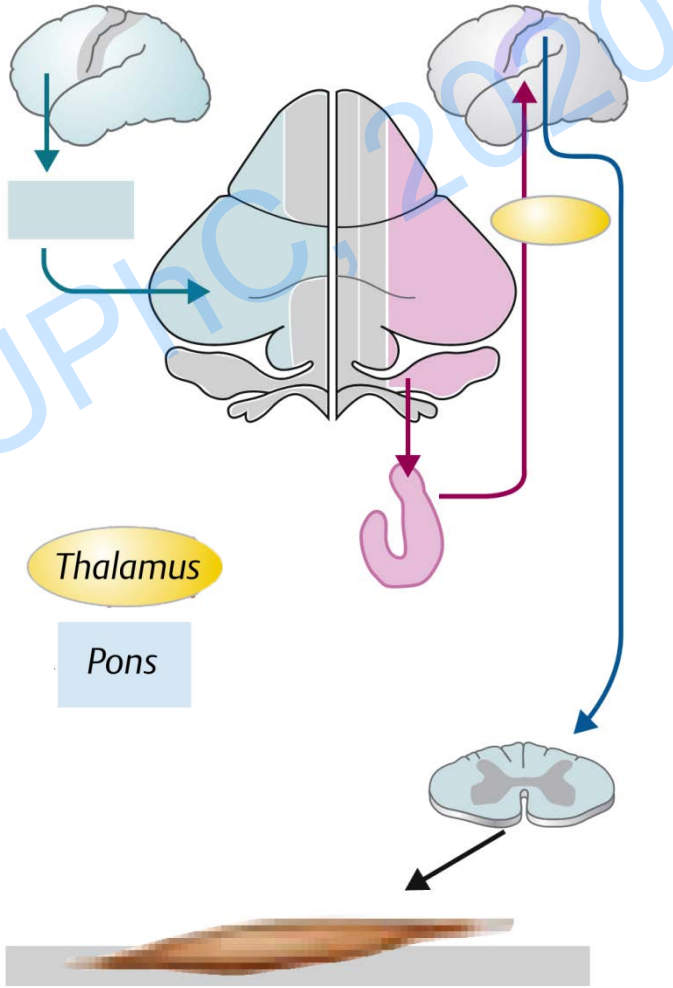
Paleocerebellum (spinocerebellum)

- Primarily controls **muscle tone** and **anticipatory adjustment** of muscle contraction during movement, **controls the movement** of the limbs.
- It receives sensory information on limb position and muscle tone and then modifies it
- It coordinates these movements through efferent pathways to the appropriate descending motor pathways



Neocerebellum (corticocerebellum)

- It is concerned with **planning, programming and coordination** of skilled movements
- Helps in making the voluntary movements **smooth and accurate**
- Controls the **ballistic movements**
- Plays an important role in timing and programming the movements, particularly **during learning process**
- It receives input **from the cerebral cortex** and thus helps in the planning of motor activity
- It coordinates these movements through efferent pathways to the **thalamus** and **motor cortex**



Cerebellar Lesions

Disturbances in tone and posture

- Atonia (loss of muscle tone) and hypotonia (reduction in muscle tone), etc.

Disturbances in equilibrium

- **Body sways** side-to-side with oscillations of the head
- **Drunken-like gait** is observed

Disturbances in movements

- **Ataxia**: lack of coordination of movements.
- **Asynergia**: lack of coordination between different groups of muscles
- **Asthenia**: weakness, easy fatigability and slowness of muscles
- **Dysmetria**: inability to check exact strength and duration of muscular
- **Intention tremor**: tremor that occurs while attempting to do any voluntary act
- **Astasia**: unsteady voluntary movements
- **Dysarthria**: disturbance in speech

The Mesencephalon

Relay station

- Cerebral peduncles (nerve fiber bundles on ventrolateral surfaces, contain descending fibers to cerebellum and motor command fibers - pyramidal tract fibers in the middle, temporopontine fibers laterally and frontopontine fibers medially)

Reflexes

- Motor nuclei – regulation of skeletal muscles contraction
- Autonomic nuclei – regulation of smooth muscles contraction, glands functioning etc.

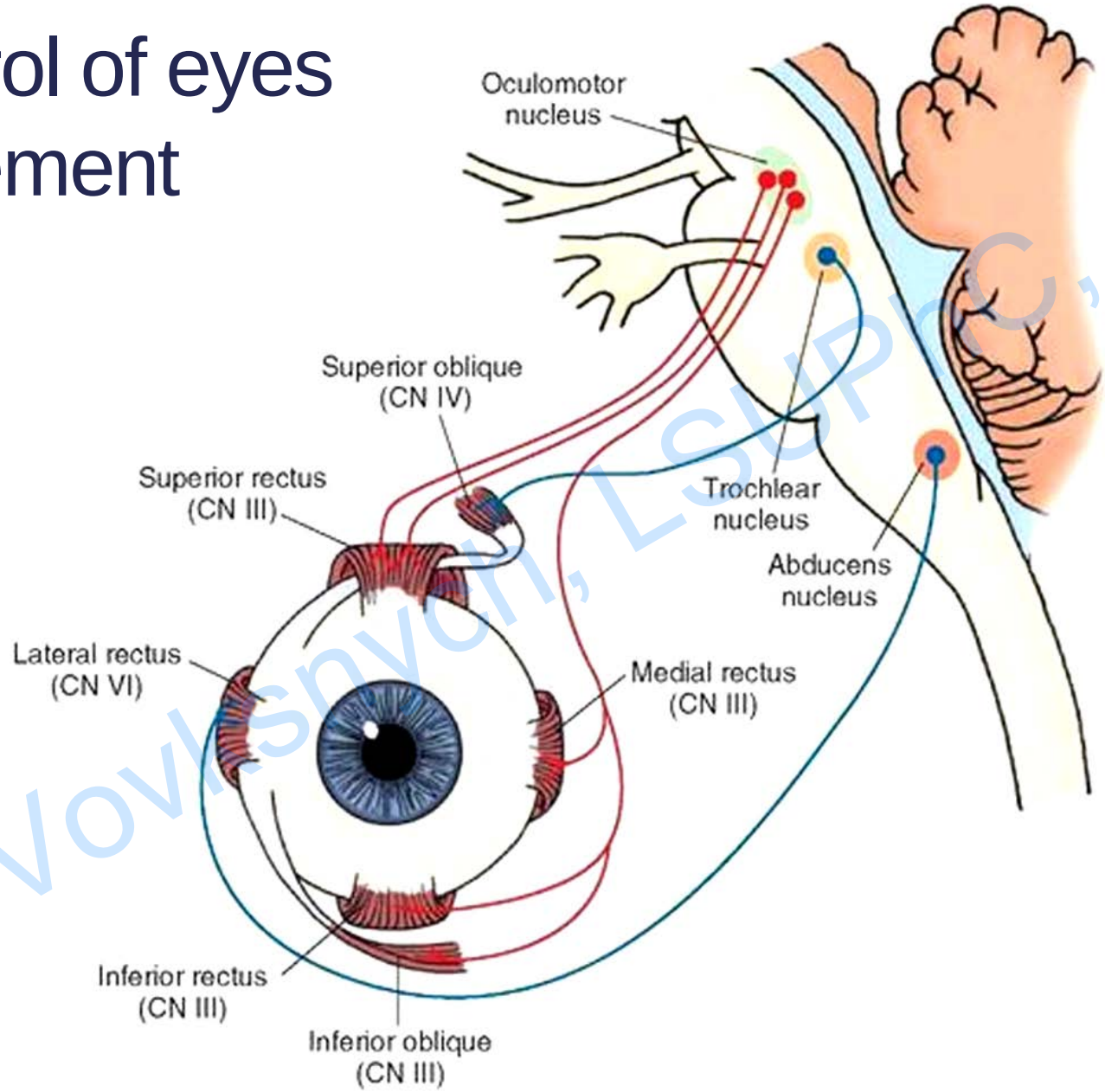
Sensor and Motor Centers of the Mesencephalon

Centers	Reflexes
Superior colliculus	Initiate the responses for the **visual stimuli – orientation reflexes** (movements of the eyes, head, trunk and limbs in response to visual stimuli)
Inferior colliculus	**Orientation** reflexes to **auditory** stimuli, relay auditory information to medial geniculate nuclei

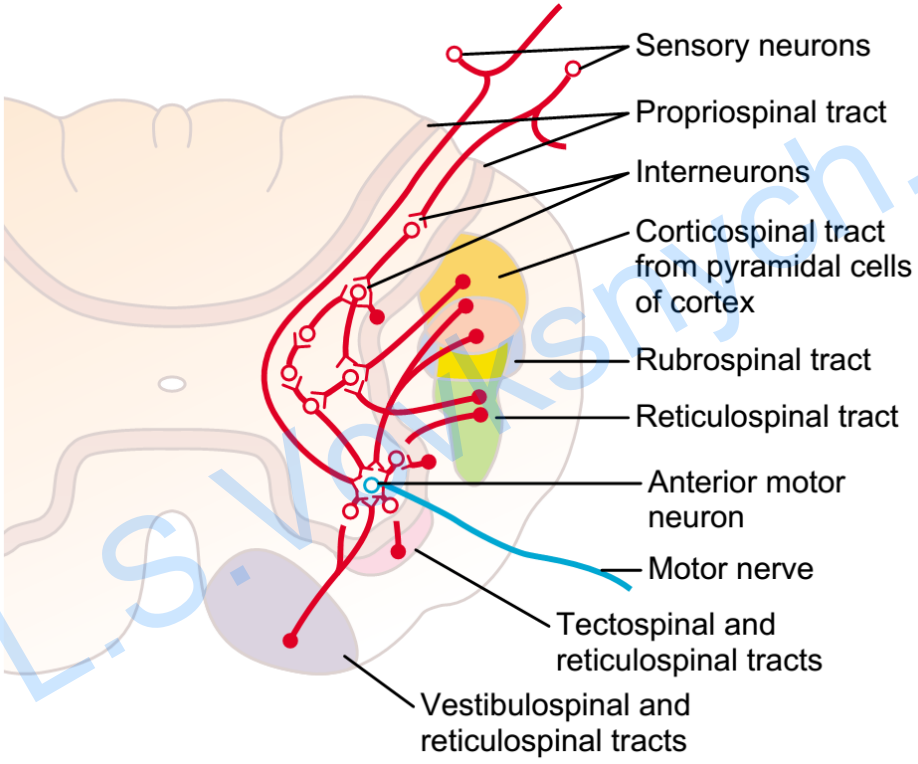
Motor Centers of the Mesencephalon

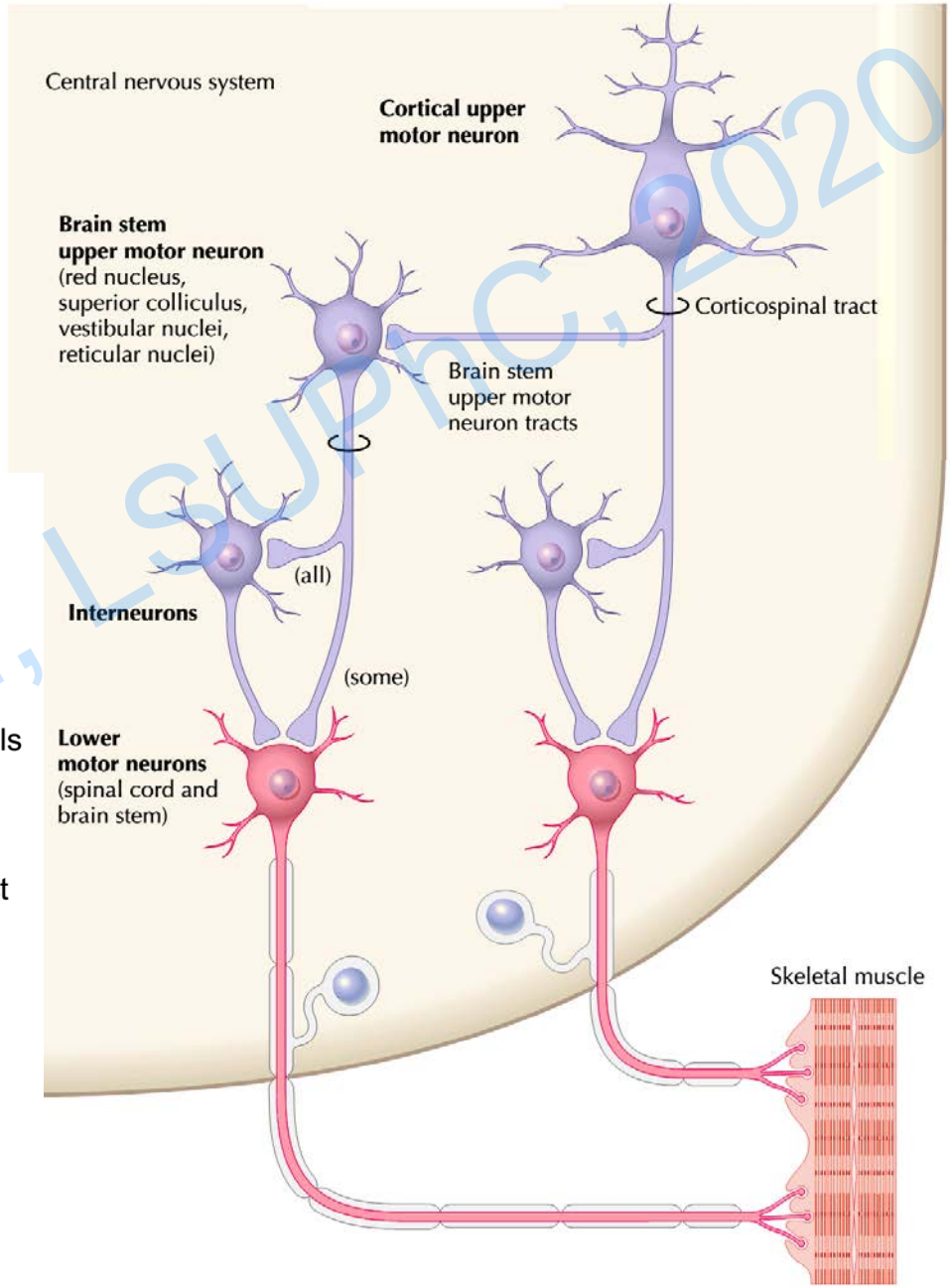
Centers	Reflexes
Oculomotor nuclei *(also visceral)*	Control eyes movement, cause constriction of pupil during light reflex, accommodation
Trochlear nucleus	Controls eyes movement
Substantia nigra	One of the components of basal ganglia
Red nucleus	Control of muscle tone, control of complex muscular movements, interaction with vestibular nuclei, part of extrapyramidal system of movements control - sends efferent fibers to various parts of brain and spinal cord

Control of eyes movement



Basic organization of motor neurons





The Diencephalon. Thalamus

On the basis of **functions and their projections**, thalamic nuclei are classified into five groups. This type of classification is also called Bondok classification. **Five groups of thalamic nuclei** are:

- **Specific sensory relay** nuclei
- **Specific motor** nuclei
- **Association** or less specific nuclei
- **Non-specific** nuclei
- **Limbic system** nuclei.

Bondok Classification of Thalamic Nuclei

Group	Nuclei	Functions
Specific sensory relay nuclei	Ventral posterior nucleus Medial geniculate body (auditory) Lateral geniculate body (visual)	Project sensory signals to distinct (specific) areas of cerebral cortex
Specific nuclei	Ventral anterior nucleus Ventral lateral nucleus	Receive signals controlling motor activities from cerebellum and corpus striatum and send these signals to motor areas in the cerebral cortex to complete the feedback system of motor control mechanism

Bondok Classification of Thalamic Nuclei

Group	Nuclei	Functions
Association or less specific nuclei	Dorsolateral nucleus Posterolateral nucleus Pulvinar	Send information to association areas of cerebral cortex
Non-specific nuclei	Midline nuclei Intralaminar nuclei Reticular nucleus	Project signals to diffused areas of cerebral cortex
Limbic system nuclei	Anterior nucleus Dorsolateral nucleus	Project into limbic cortex

Function of Thalamus

Relay Center

- impulses of almost all the sensations (except smell) reach the thalamic nuclei, and after being processed are carried to cerebral cortex

Center For Processing of Sensory Information

- sensory impulses reaching thalamus are integrated and modified before being sent to specific areas of cerebral cortex

Center For Determining Quality of Sensations

- determine whether a sensation is pleasant or unpleasant and agreeable or disagreeable

Center For Integration of Motor Activity

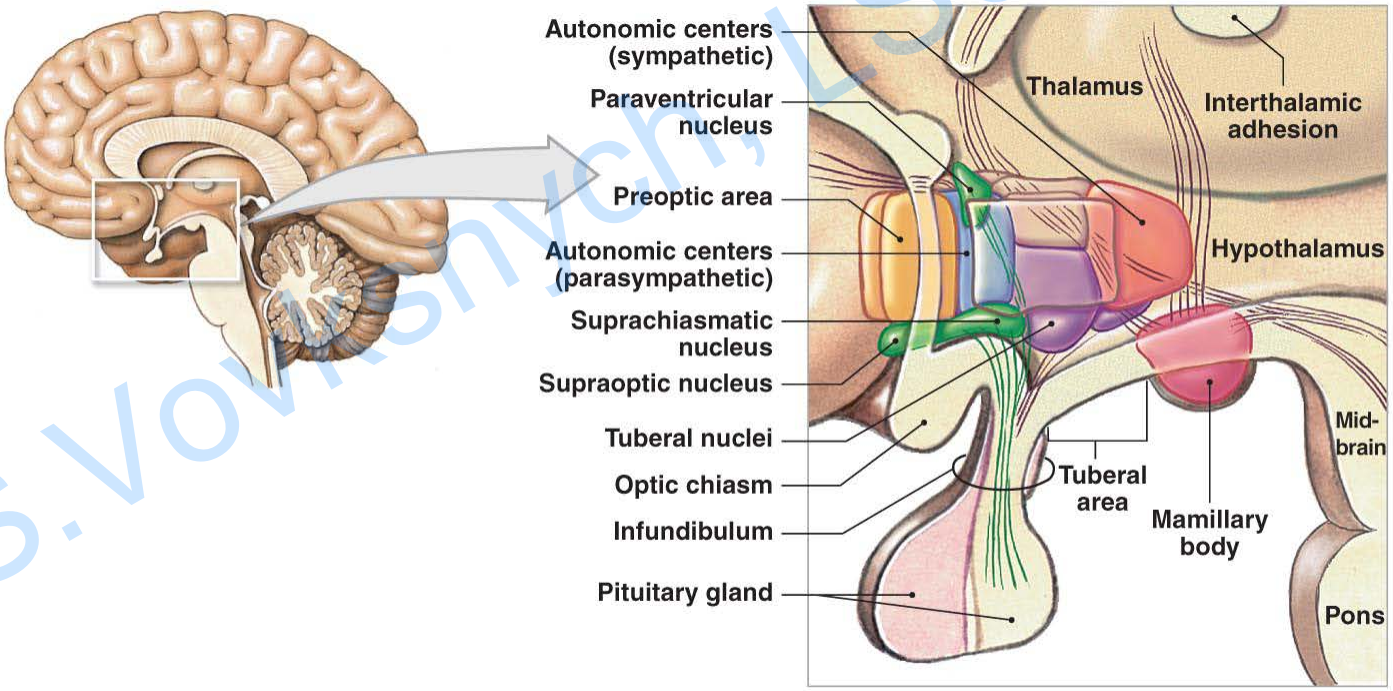
- through the connections with cerebellum and basal ganglia, halamus serves as a center for integration of motor functions

Control of The Rhythmic Activity of Cerebral Cortex

- by the system of non-specific thalamic nuclei

The Hypothalamus

- **Regulates** many **vital functions** of the body like endocrine functions, visceral functions, metabolic activities, hunger, thirst, sleep, emotion, sexual functions, etc.
- **Keeps** the **homeostasis** of the body



Functions of Hypothalamus

- **Secretion** for the **posterior pituitary hormones** (antidiuretic hormone (ADH) and oxytocin)
- **Controls** the **secretions of anterior pituitary gland** by secreting releasing hormones and inhibitory hormones
  - regulates **adrenal cortex**
  - control of **adrenal medulla**
- Hypothalamus **controls autonomic nervous system** (ANS), both sympathetic and parasympathetic divisions
  - regulates **heart rate** (by acting on the vasomotor center)
  - regulates the **blood pressure** (the same)
- Regulation of **body temperature**

Functions of Hypothalamus

- Regulation of **hunger** and **food intake**
  - feeding center
  - satiety center
- Regulation of **water balance**
  - thirst mechanism
  - antidiuretic hormone (ADH) mechanism
- Regulation of **sleep and wakefulness** (through mamillary body, part of the limbic system)

Functions of Hypothalamus

- Control of **behavior and emotional changes** (two responding systems in hypothalamus and structures of limbic system)
  - **Reward** center - pleases or satisfies the animals
  - **Punishment** center - stimulation leads to pain, fear, defense, escape reactions. May leads to rage.
  - **Rage** center - refers to violent and aggressive emotional expression, developing a defense posture.
- Regulation of **sexual function**
- Response to **smell** (include feeding activities and emotional responses like fear, excitement and pleasure)

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