Nervous system. Development. Pathways.

Aygul Shafigullina

Georgii Pevnev

Department of Morphology and General Pathology

Functions of the nervous system

1. Information analysis (CNS, PNS)
Interoception, Exteroception, Proprioception
Olfaction, Skin sense (pselaphesia), Vision, sense of Hearing, sense of Taste
Vestibular apparatus:
- Locomotion (CNS, PNS)
- Coordination

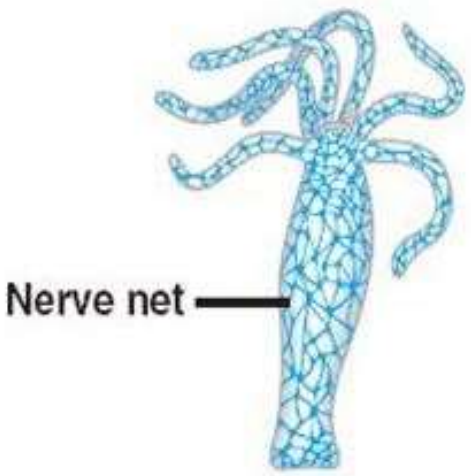
2. Regulation of organism functions
- Vegetative functions (CNS, PNS, ANS)

Breath, Digestion, Reproduction, Water Balance, Blood circulation, Homeostasis

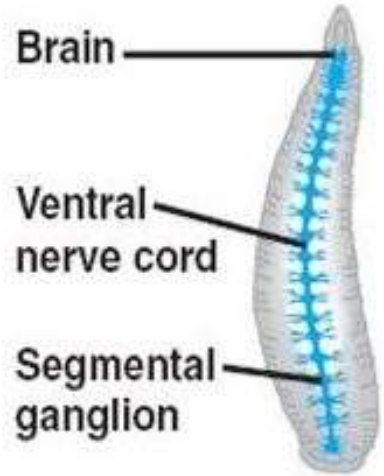
3. Higher nervous activity (CNS)
Sensation, Attention, Sleep, Adaptation, Education, Painting, Imagination, Speech, Writing, Reading, Calculation, Cognition, Awareness of ones` own, Memory, etc.

Evolution of the nervous system

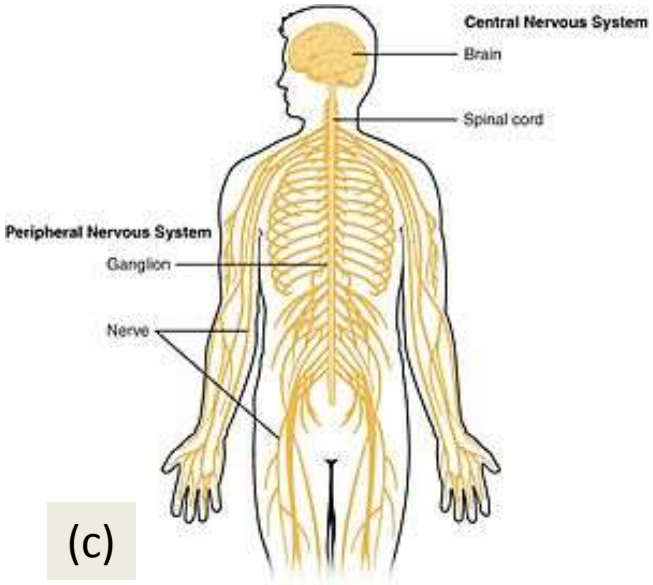
Organism	Characteristics	Presence in human body
Hydra (a)	Diffuse cells, net	- Submucose Meissner`s plexus of the intestinal wall - Myenteric Auerbach's plexus of the gut
Earthworm (b)	Ganglious system, directed transmission of the signal	Paravertebral sympathetic trunk, periphery vegetative ganglions
Human (c)	Tubular structure, segmentation, developed CNS and PNS	CNS and PNS



(a) Hydra (cnidarian)



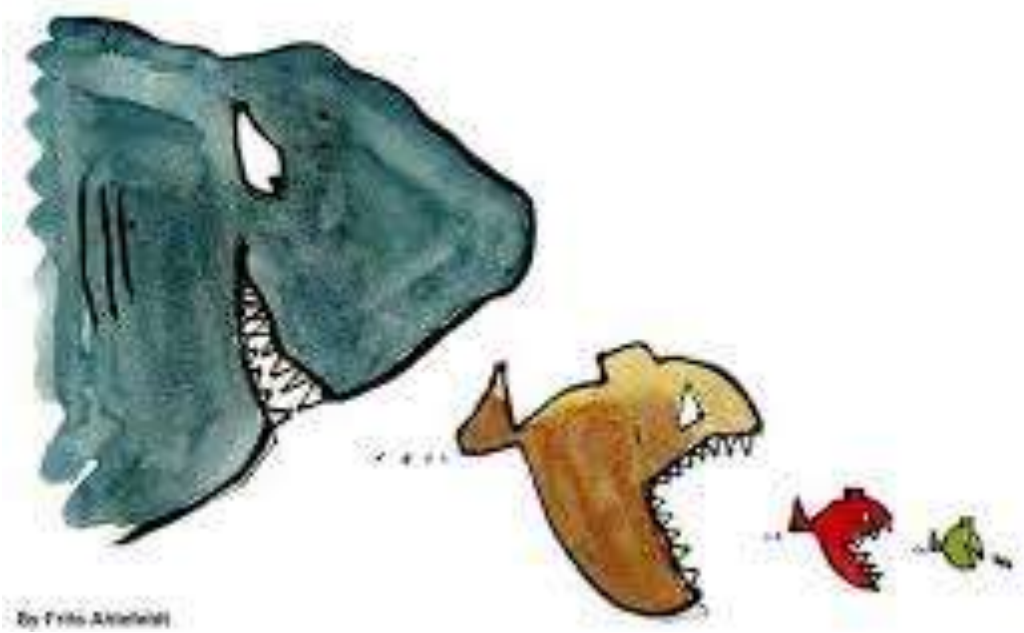
(b) Leech (annelid)



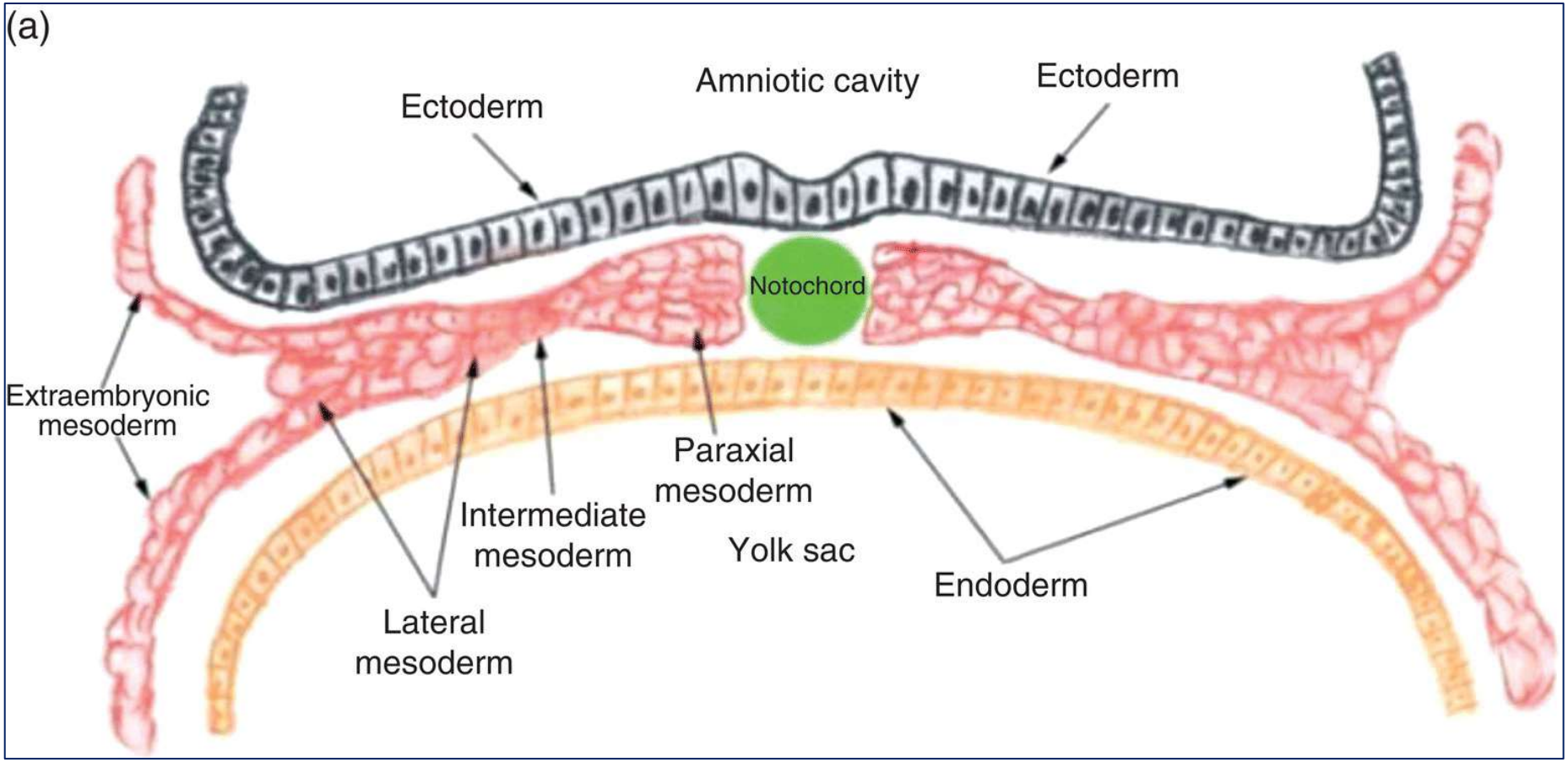
(c)

Remember:

- Development of the brain determined special functional *subordination, hierarchy* and *connections* between brain and spinal cord
- There is a hierarchy between cortex and subcortex, cervical and lumbar enlargements, etc.
- Evolutionary new structures *regulate* functions of the older ones by inhibition and excitation
- Appearance of new functions do not mean disappearance of older functions. Older functions occur, when new ones are damaged.
- *Phylogenic new structure* are more vulnerable and have lower ability to regenerate.

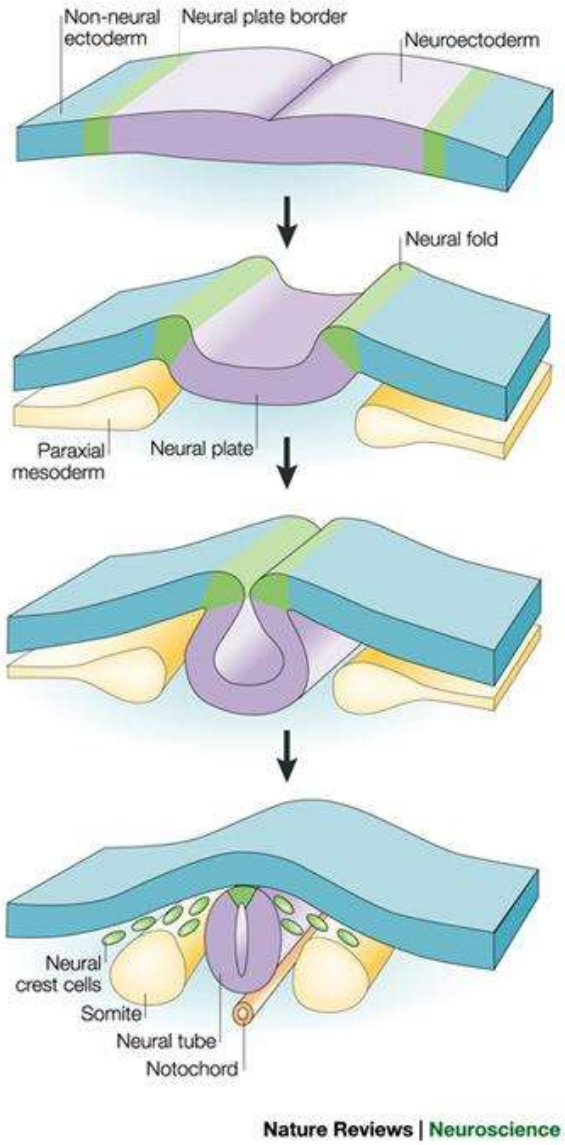


Development of the nervous system



Nervous system is developed on the base of **ectoderm**.

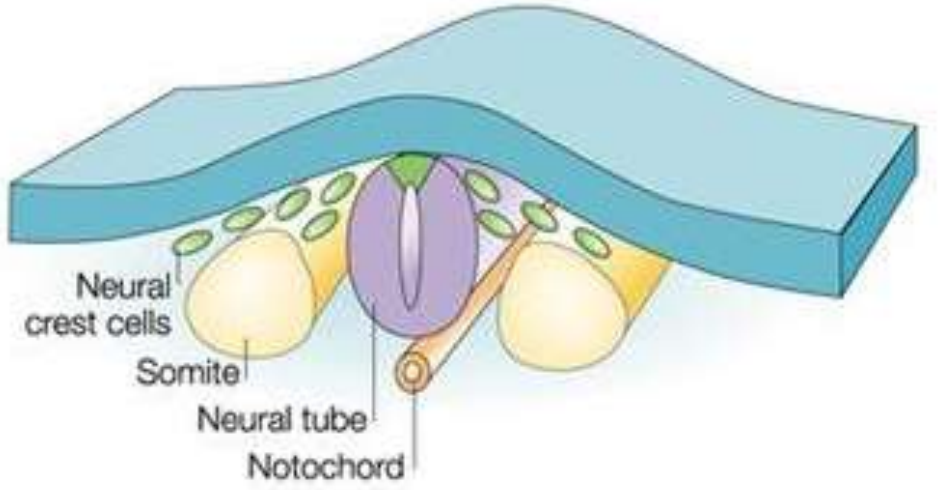
Development of the nervous system



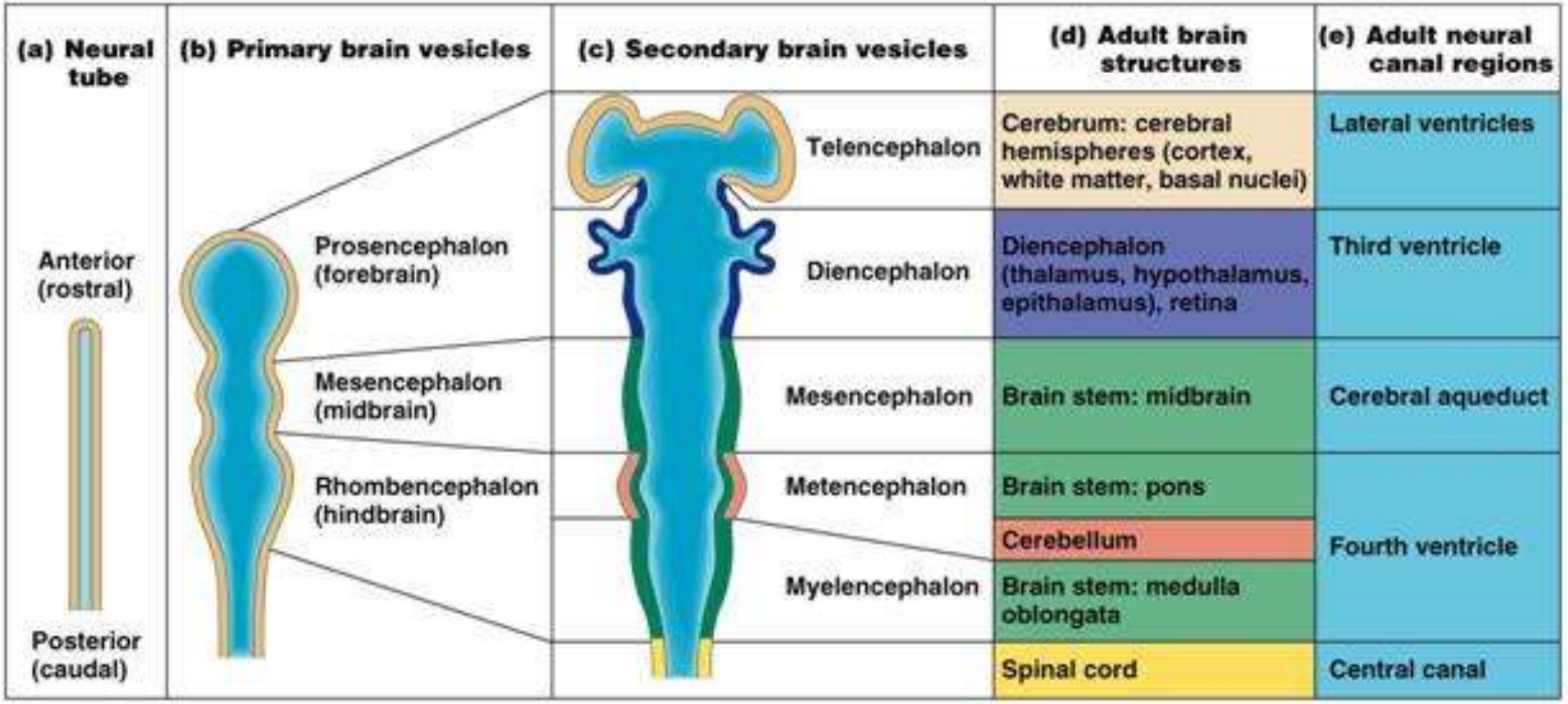
11th day

Development of the nervous system

Neural tube derivatives	Neural crest derivatives
- Brain - Spinal cord	- Neural ganglion (sensory and vegetative) - Neuroglia - Medullary part of suprarenal glands - C-cell of the thyroid gland - Skin melanocytes - Some bones, cartilage and muscles of the head



Anatomy of the Developing Brain:



Three brain vesicles
4-5th week

Five brain vesicles
6-7th week

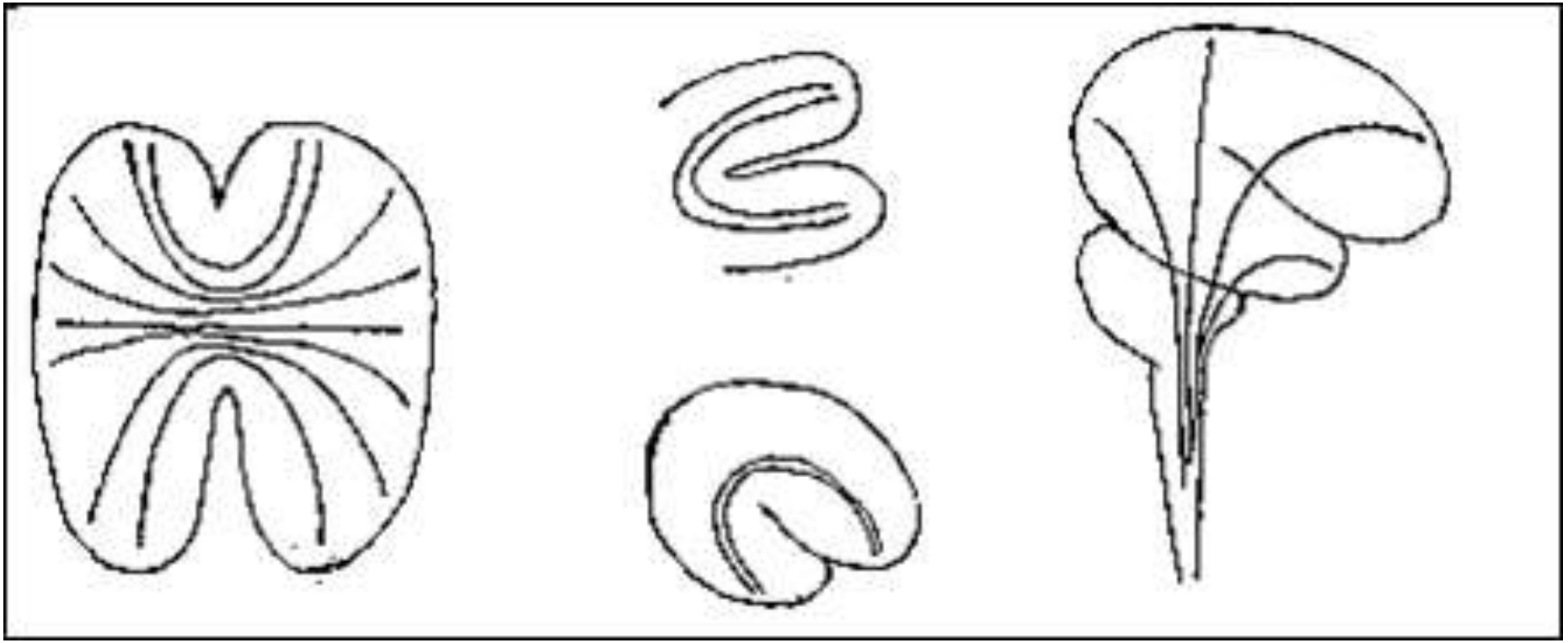
Age-related evolution of the brain:

- **Final development** of the brain cortex and all nervous system is **after birth**

- **4 years old** – sensory perception
- **20 (30) years** – maturation of the prefrontal cortex
- Formation of social behavior
- **“Adult Control”** over impulses

Neural pathways

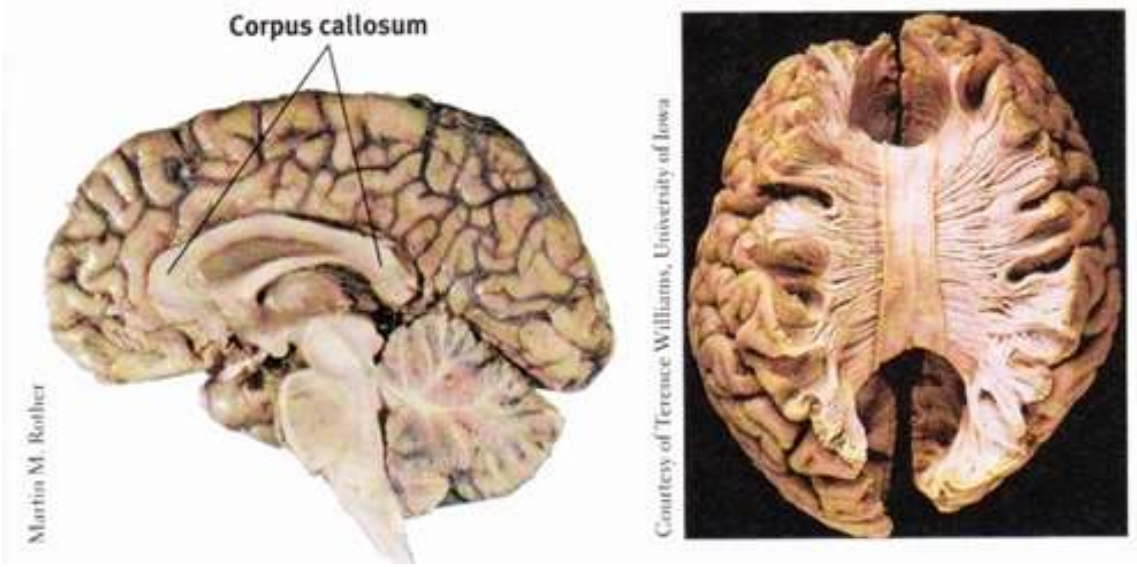
Types of nerve fibers



Comissural nerve fibers

Associative nerve fibers

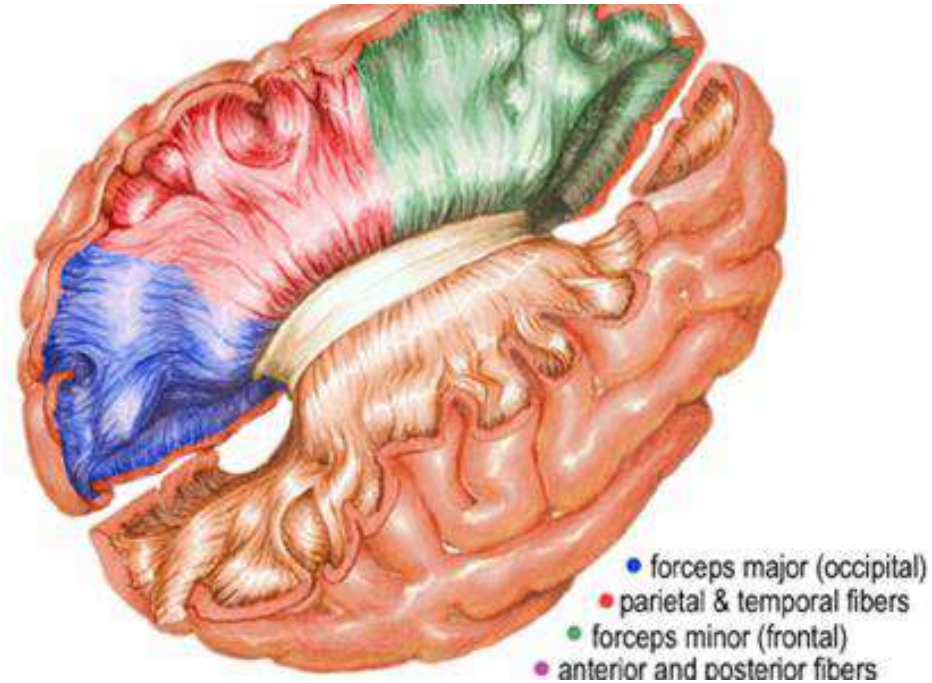
Projection nerve fibers

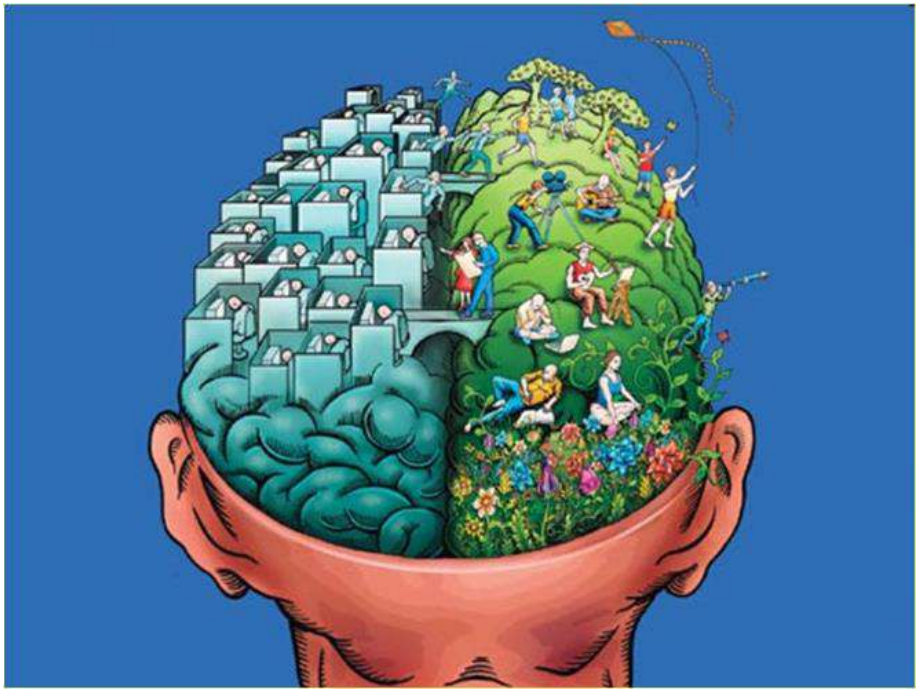


Comissural nerve fibers

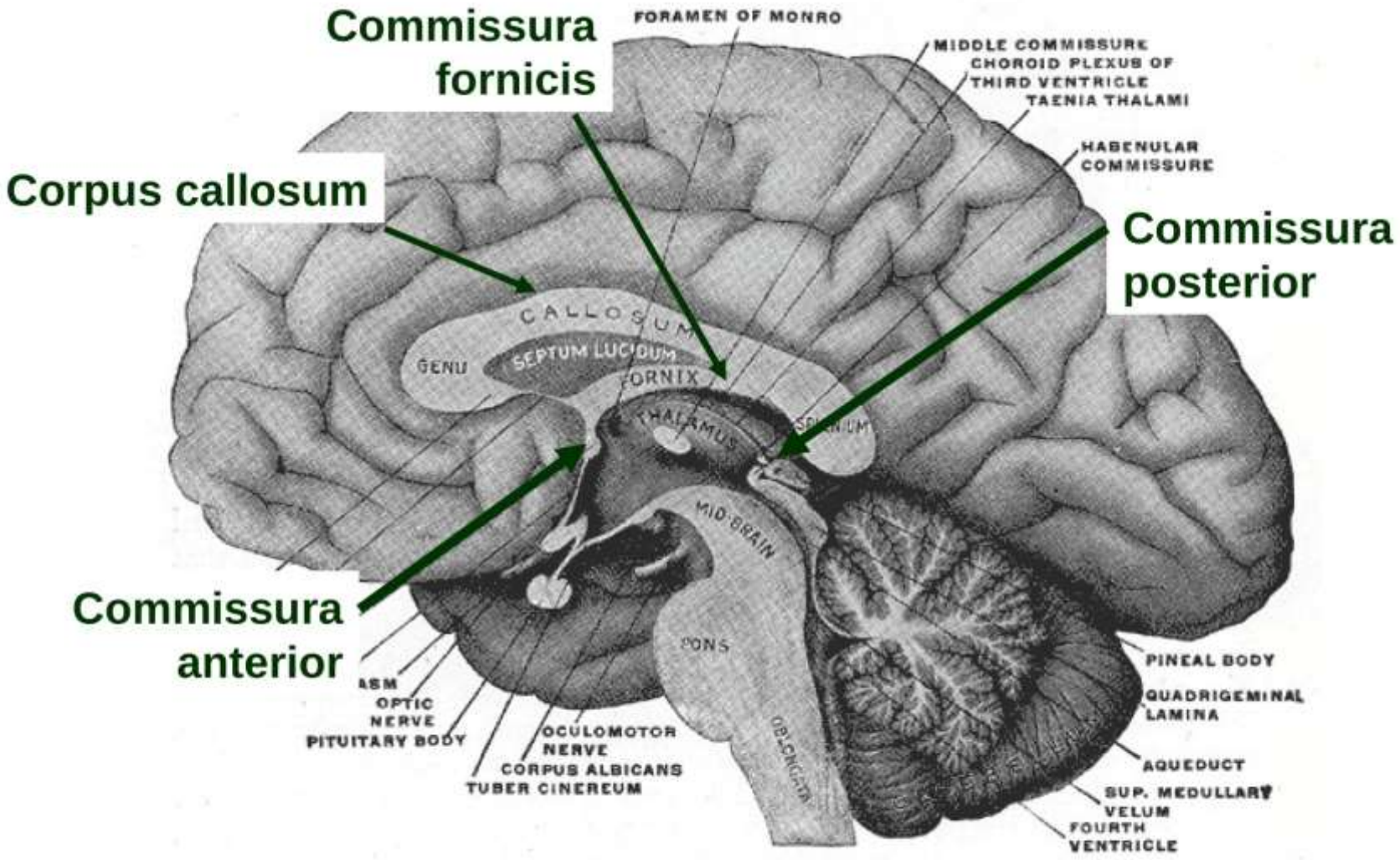
–

Corpus callosum

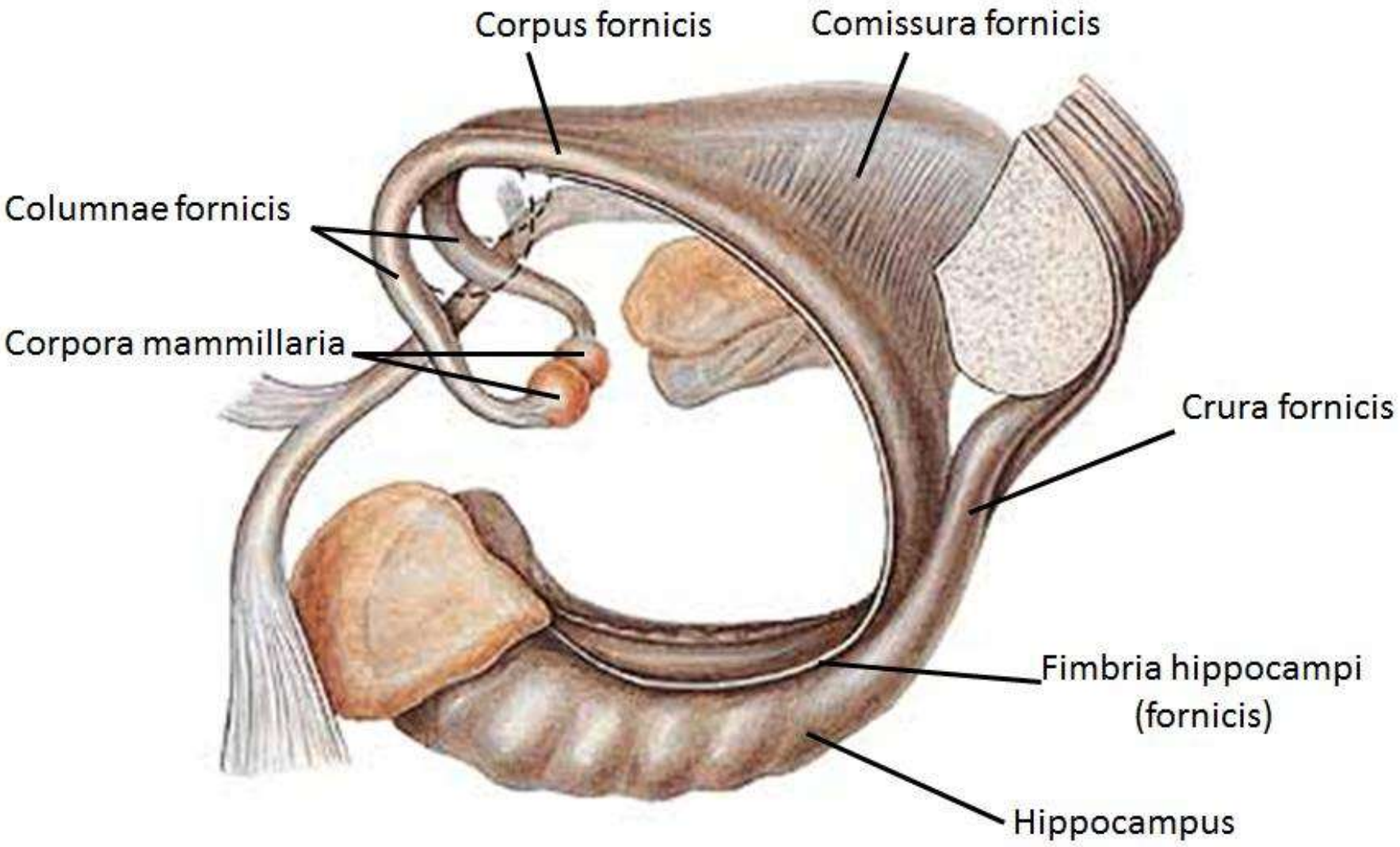




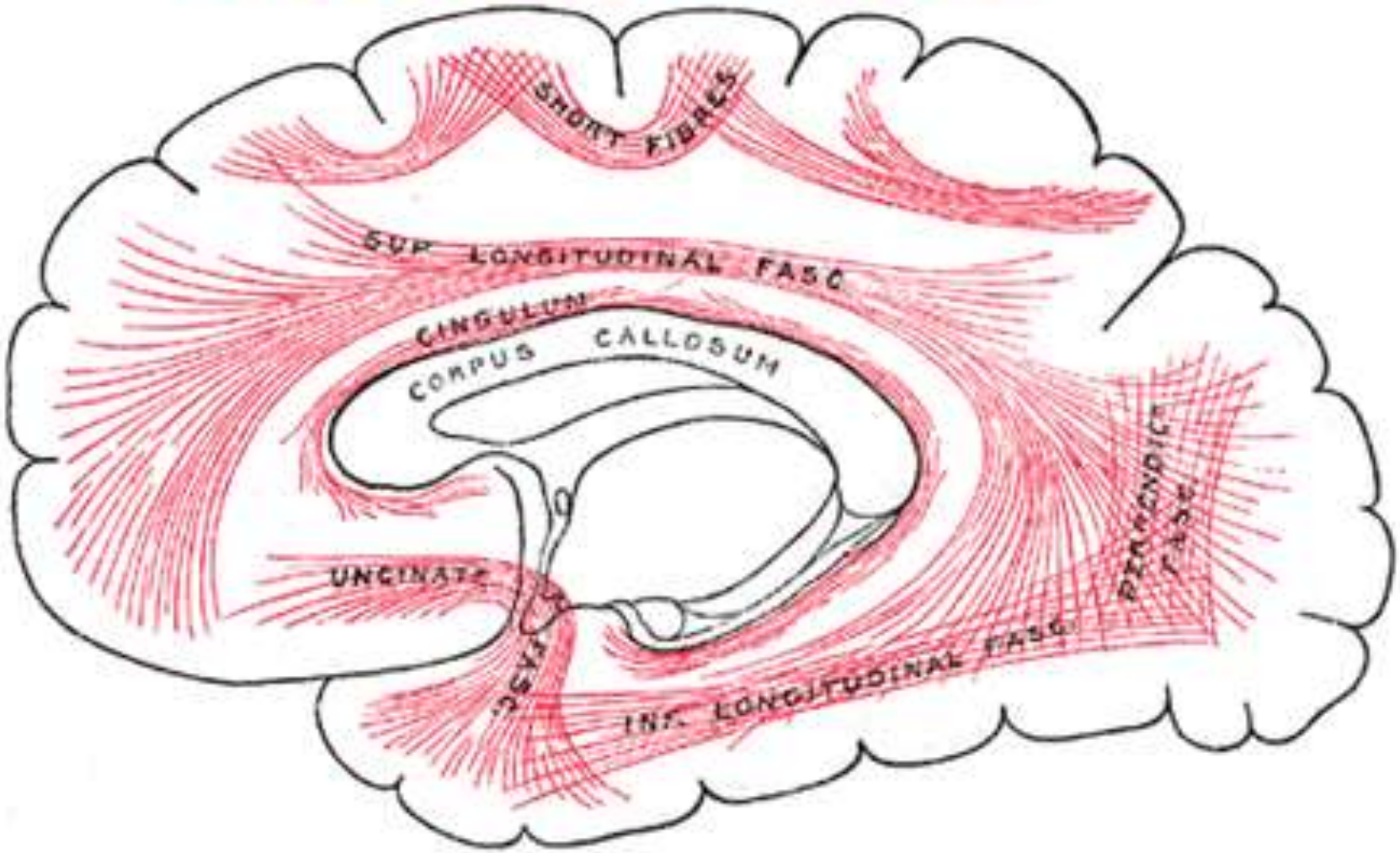
Anterior and posterior (epithalamic) comissures of the brain



Comissura fornicis



Association Fibres

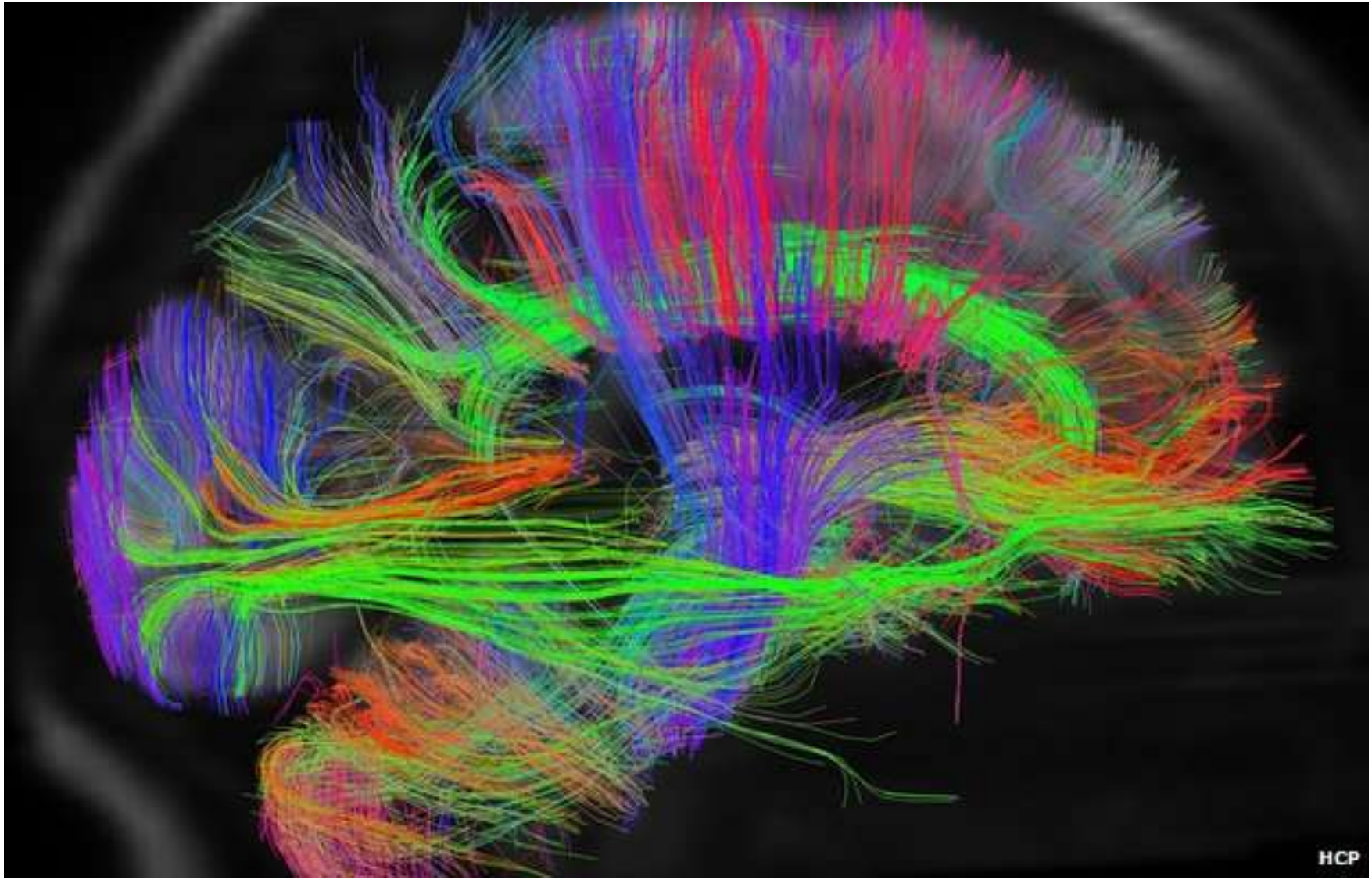


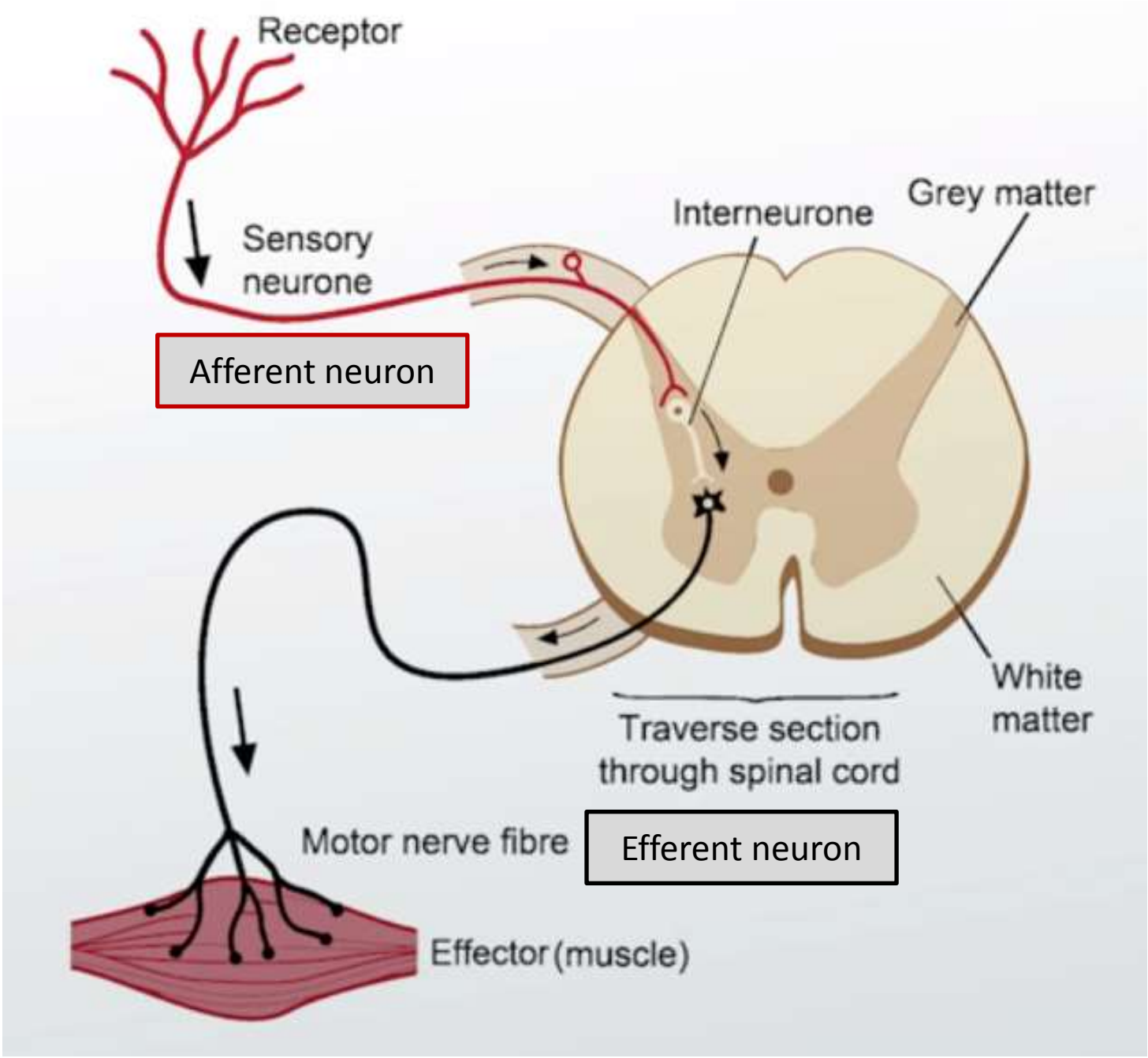
Projection pathways:

- Afferent (ascending) – transmit the impulse from receptor to the integrative center
- Efferent (descending) – transmit the impulse from integrative center to the effector

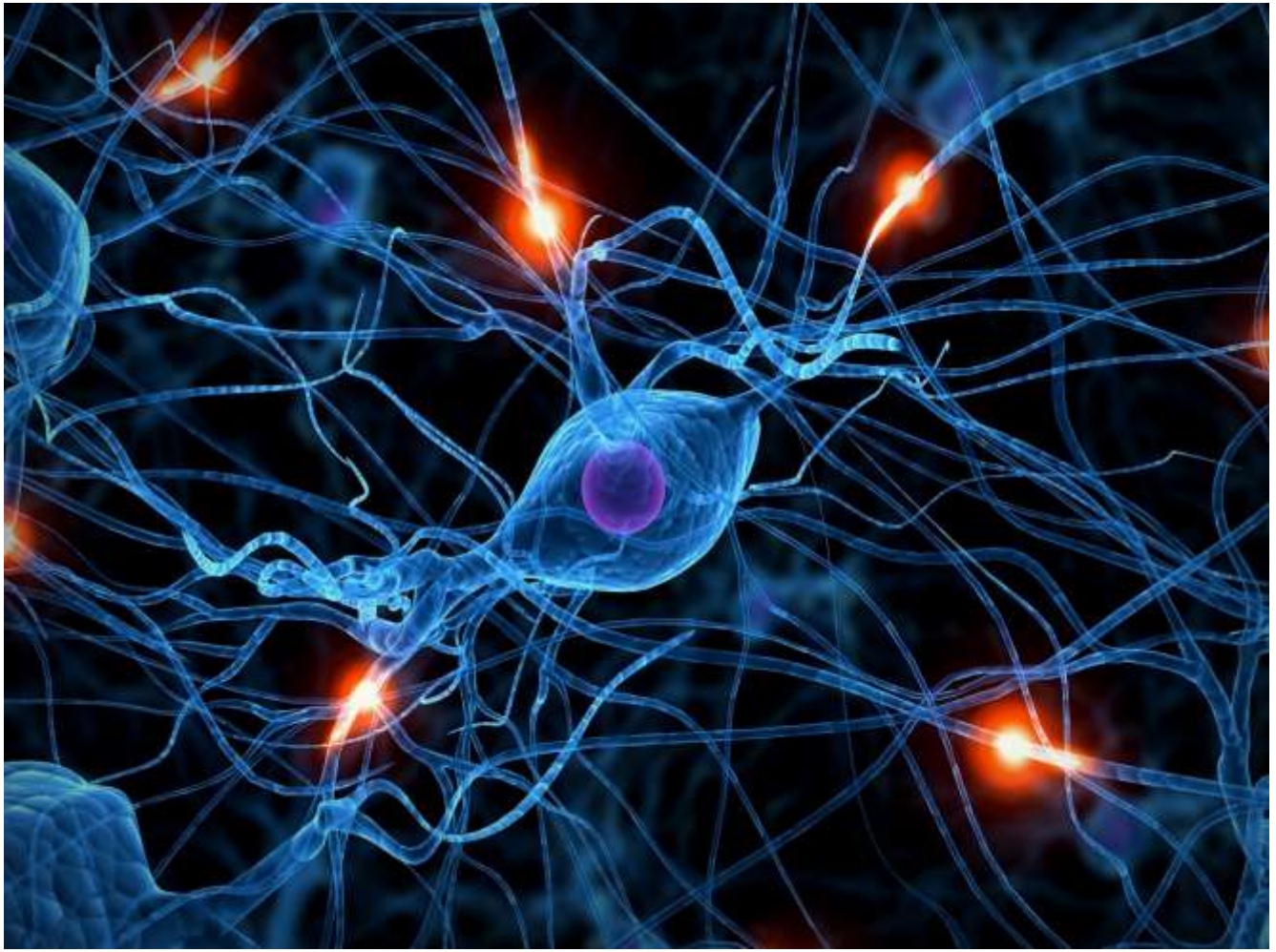
Neural pathway (neural tract)

– complex of neurons, that provides transmission of the impulse in definite direction.




Receptor
Sensory neurone
Afferent neuron
Interneurone
Grey matter
White matter
Traverse section through spinal cord
Motor nerve fibre
Efferent neuron
Effector (muscle)

Afferent (ascending) somatosensory pathways



Afferent (ascending) somatosensory pathways

Sensitivity is a conscious or unconscious awareness of external or internal stimuli.

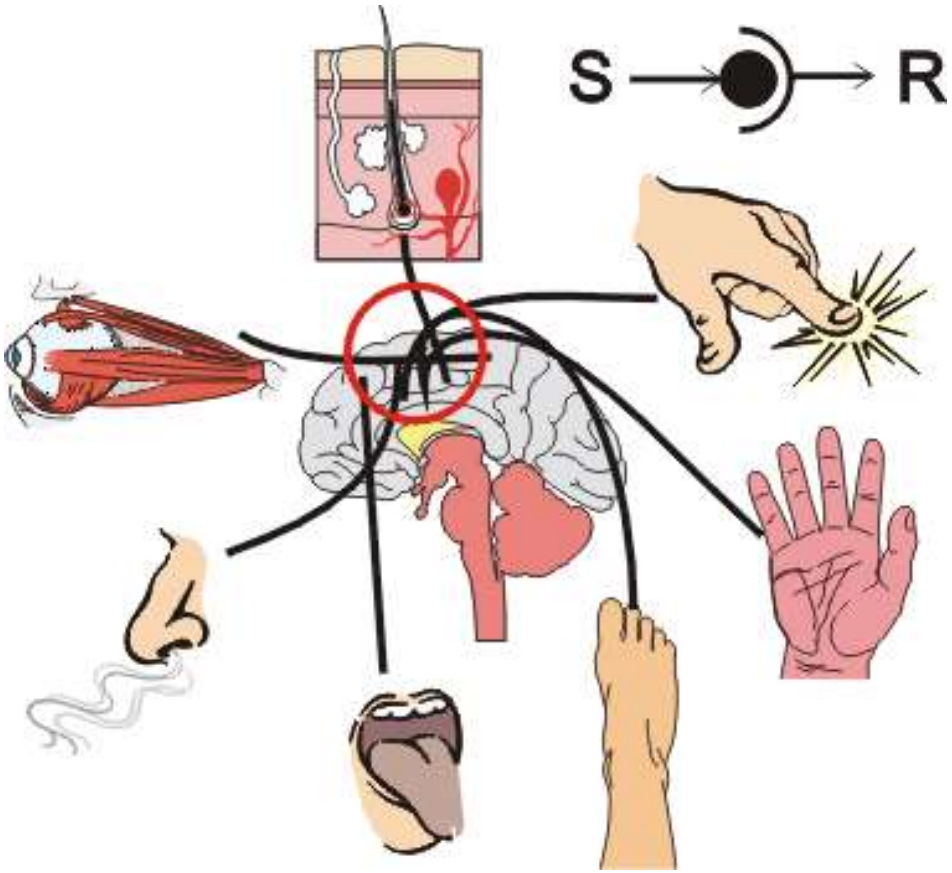
Perception is the conscious awareness and interpretation of sensations.

Sensitivity:

1) **superficial** (tactile, pain, temperature) – *exteroceptors*

2) **deep**
- musculo-articular - *proprioceptors*;
- pressure and mass sense, vibrational sense – exteroceptors

3) **complex** (stereognosis, topoesthesia, etc.) – combined work of different types of receptors and cortex centers

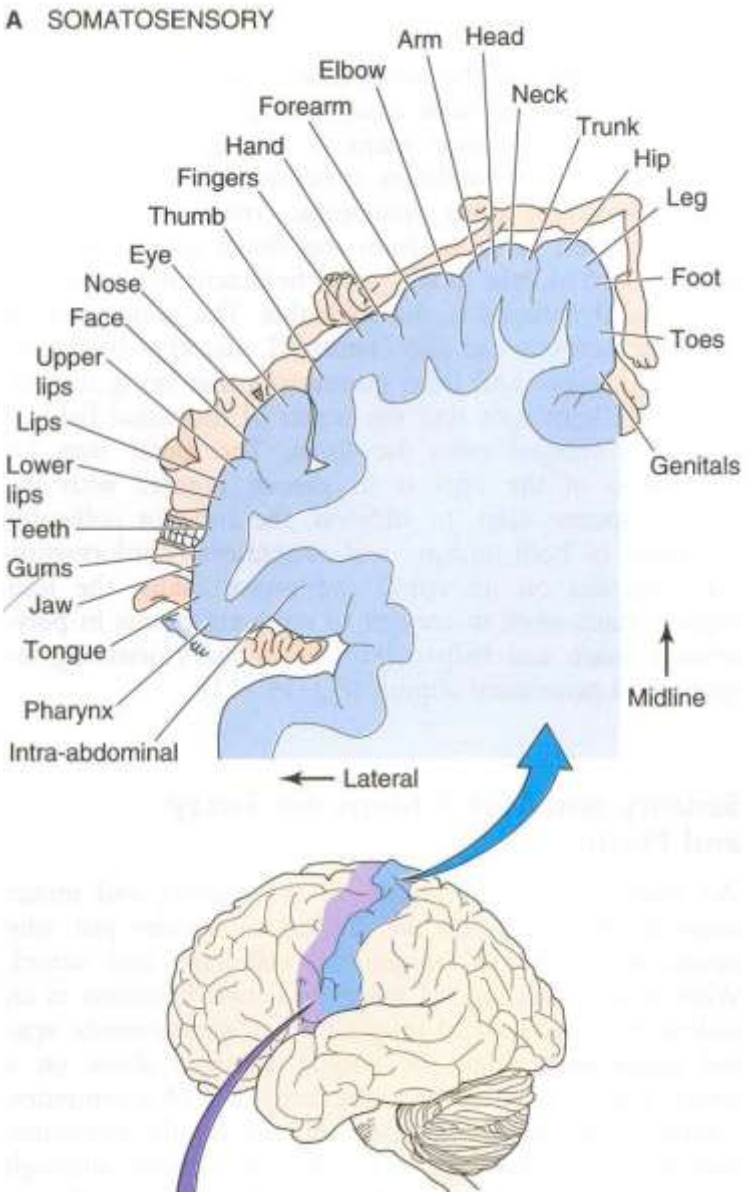


Afferent (ascending) somatosensory pathways

Function: relay information from somatic receptors to the primary somatosensory area in the cerebral cortex.

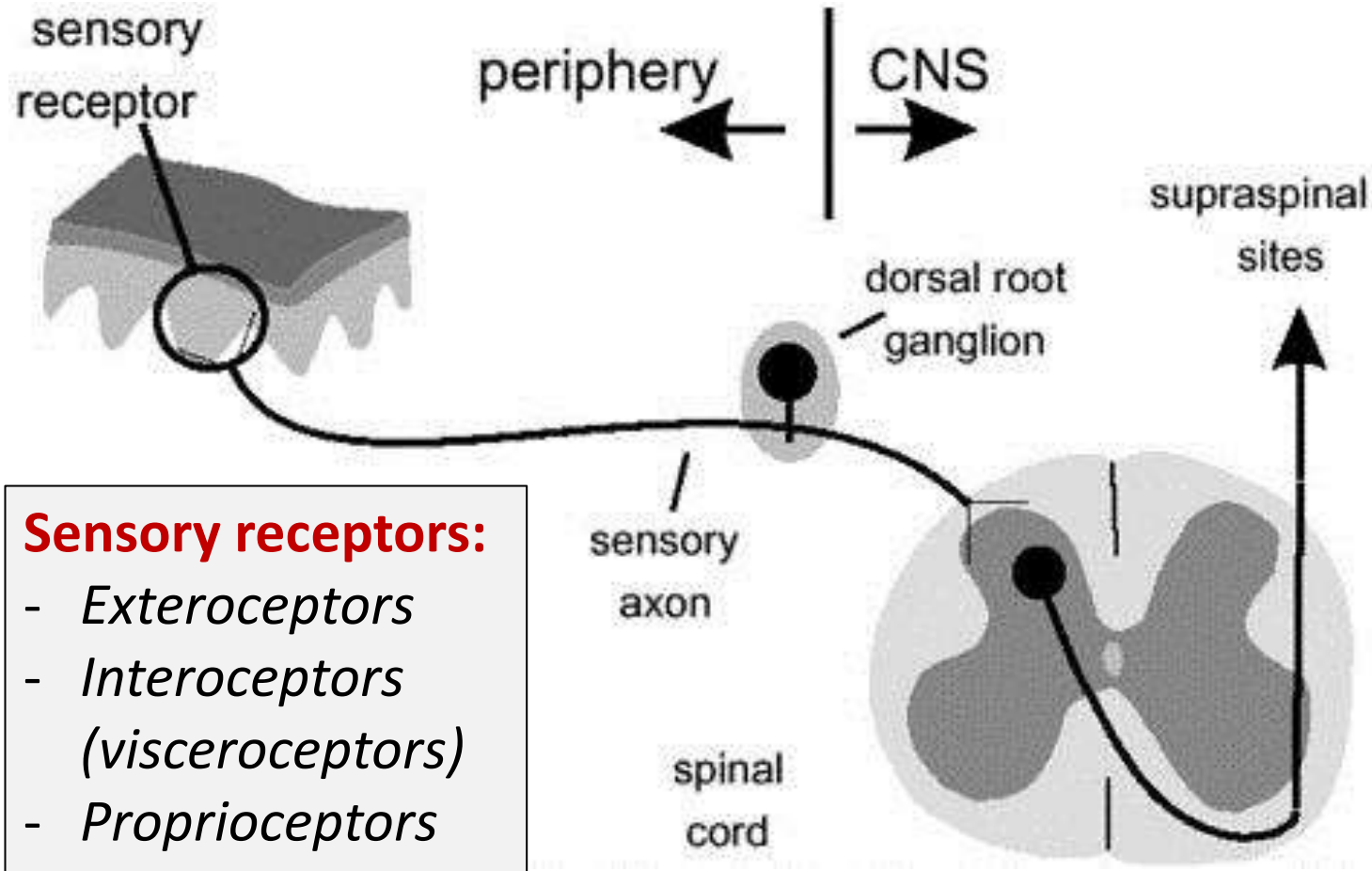
General characteristics:

- begin - receptors
- conceive the irritation, transform it into nerve impulse and transmit into CNS
- cell body of the 1st neuron is outside the CNS (in ganglions!)
- 2nd and 3rd neurons (interneurons) are within the brain
- in most of the cases 2nd neurons decussate



Afferent (ascending) somatosensory pathways

The peripheral axons arise from dorsal root ganglia and enter spinal cord through the dorsal roots.



Sensory receptors:

- *Exteroceptors*
- *Interoceptors (visceroceptors)*
- *Proprioceptors*

1.PATHWAY OF CONSCIOUS SUPERFICIAL SENSITIVITY

(*Tractus spinothalamicus*)

NB!

- tactile, temperature and pain impulses from the whole body except face and organs of the head

Tractus spinothalamicus

4th neuron – cortex of the postcentral gyrus

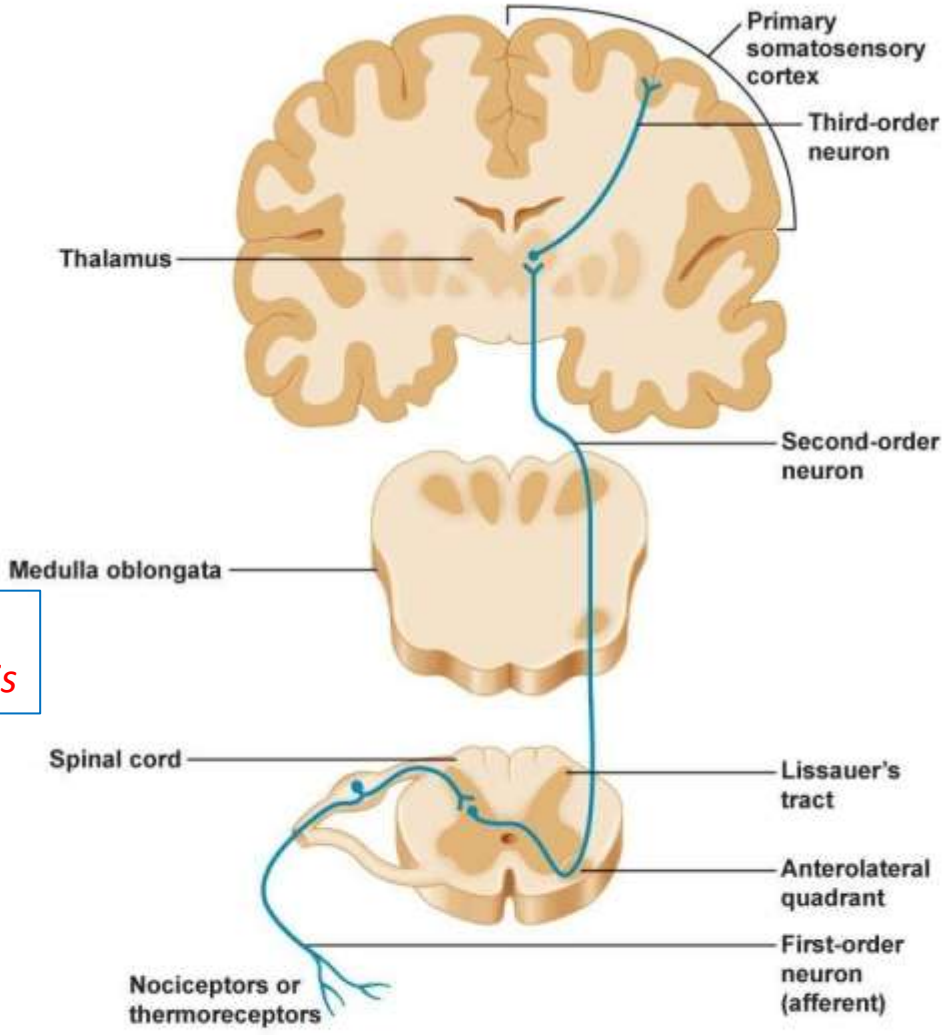
Crus posterior capsulae internae

3rd neuron – *ventrolateral nucleus* of the thalamus

100% fibers **decussate**, 2-3 segments higher, *lemniscus spinalis*

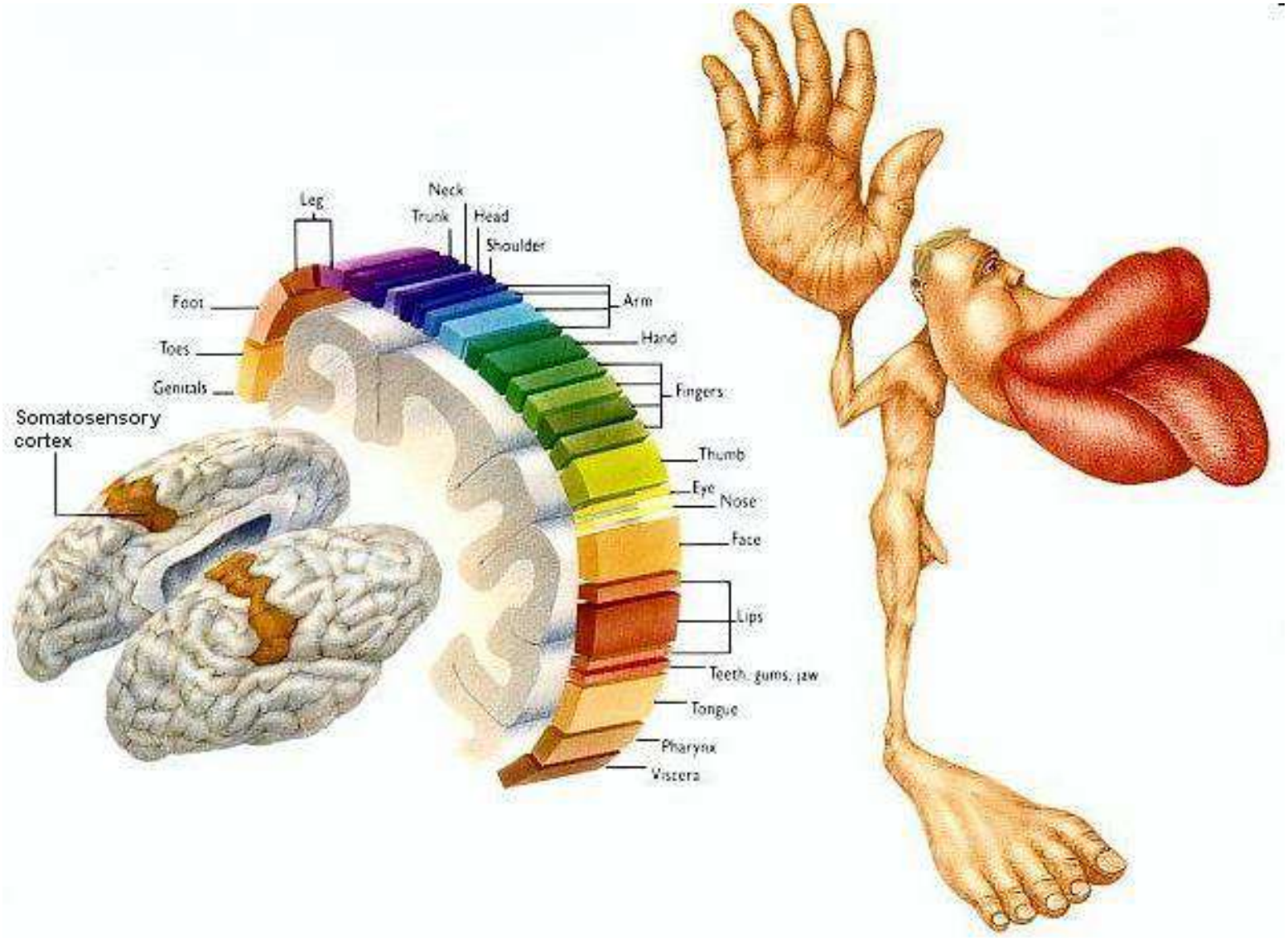
2nd neuron – *nucleus proprius* of the posterior horn

1st neuron – pseudounipolar neuron, spinal ganglion



(b) Spinothalamic tract

Somatosensory cortex – *Gyrus postcentralis*



2. PATHWAY OF THE CONSCIOUS DEEP SENSITIVITY

(Tractus ganglio-bulbo-thalamo-corticalis, Fasciculus gracilis et Fasciculus cuneatus)

NB!

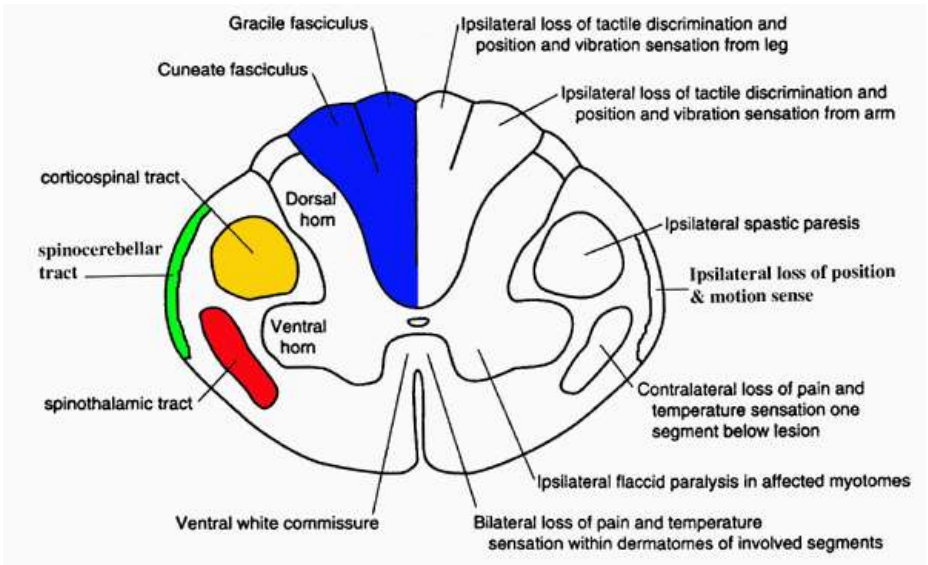
–discriminative touch,
–proprioception,
–weight discrimination,
–vibratory sensations

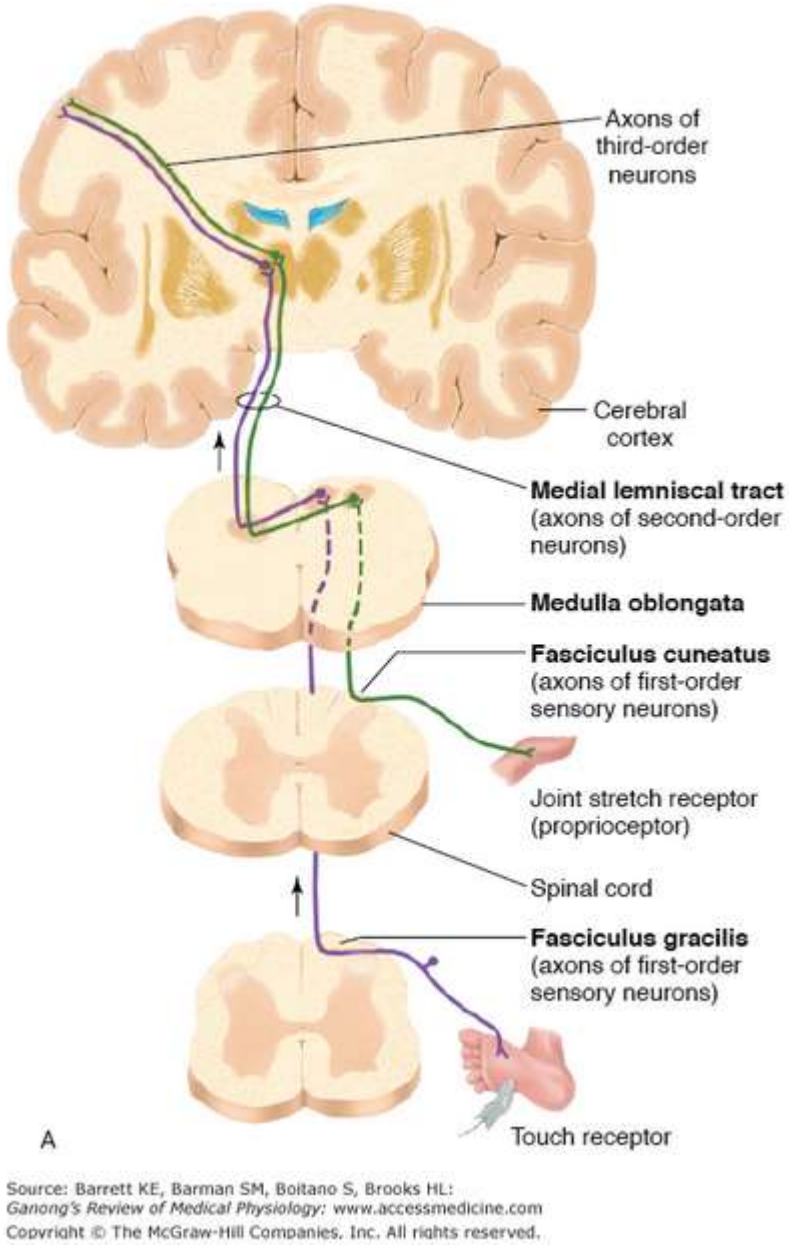
PATHWAY OF THE CONSCIOUS DEEP SENSITIVITY

1st neuron – pseudounipolar neuron (spinal ganglion), central branch runs ipsilateral dorsal column of the spinal cord

The sacral fibers, the medial-most wedge, the lumbar fibers, and the thoracic fibers 6-12 form the ***fasciculus gracilis (Goll's column)***

The arm fibers, the lateral-most wedge, and the thoracic fibers 1-6 form the ***fasciculus cuneatus (Burdach's column)***





Source: Barrett KE, Barman SM, Boitano S, Brooks HL: *Ganong's Review of Medical Physiology:* www.accessmedicine.com

Fasciculus gracilis (Goll) et Fasciculus cuneatus (Burdach)

4th neuron – cortex of the postcentral gyrus

↑

Crus posterior capsulae internae

↑

3rd neuron – *ventrolateral nucleus* of the thalamus

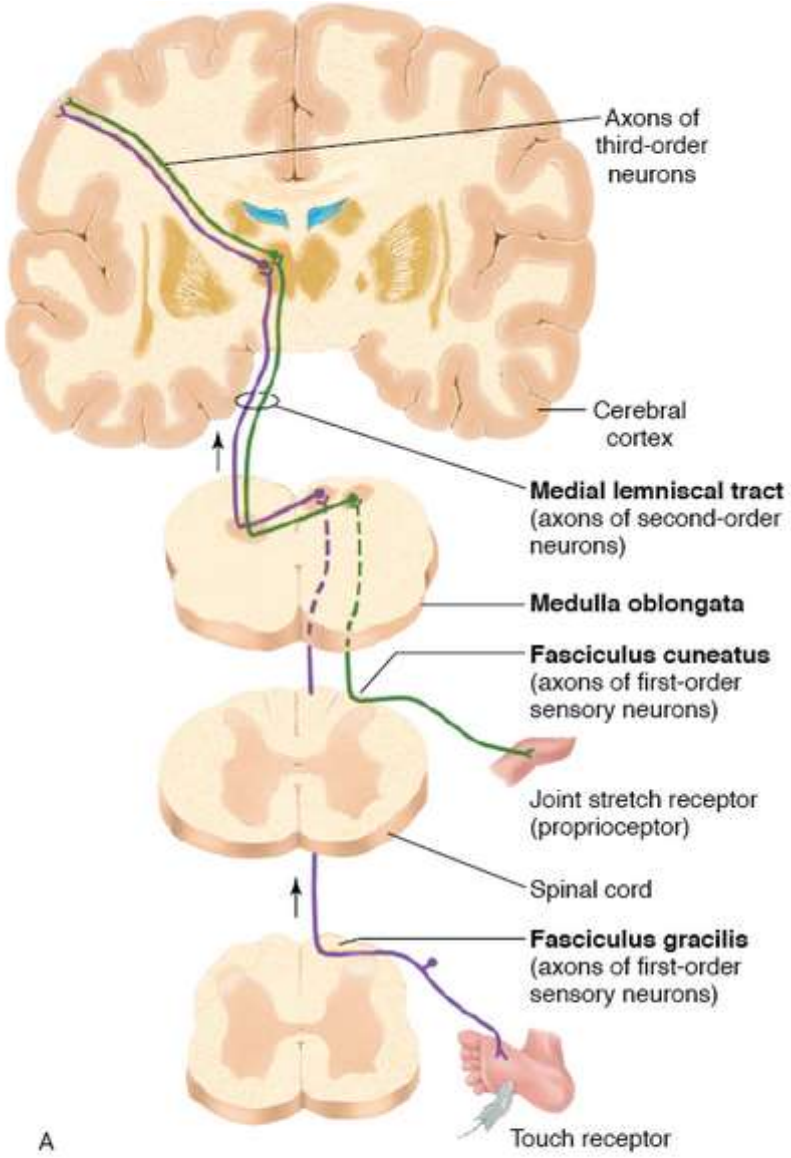
↑

100% fibers decussate, *lemniscus medialis*

2nd neuron – *nucleus gracilis (Goll fasciculus) and nucles cuneatus (Burdach`s fasciculus)* of the medulla oblongata

↑

1st neuron – pseudounipolar neuron (spinal ganglion), central branch runs ipsilateral dorsal column of the spinal cord



PATHWAYS OF THE UNCONSIOUS PROPRIOCEPTIVE SENSITIVITY

Tractus spinocerebellaris anterior (Gowers` pathway)

Tractus spinocerebellaris posterior (Flechsig`s pathway)

NB!

Transmit impulses to cerebellum:

- unconscious sensitivity pathway
- proprioceptive muscular-articular sensitivity

The receptors are the Golgi tendon organs and muscle spindles.

Tractus spinocerebellaris anterior (Gowers` pathway) - blue

- musculo-articular sense from groups of muscles

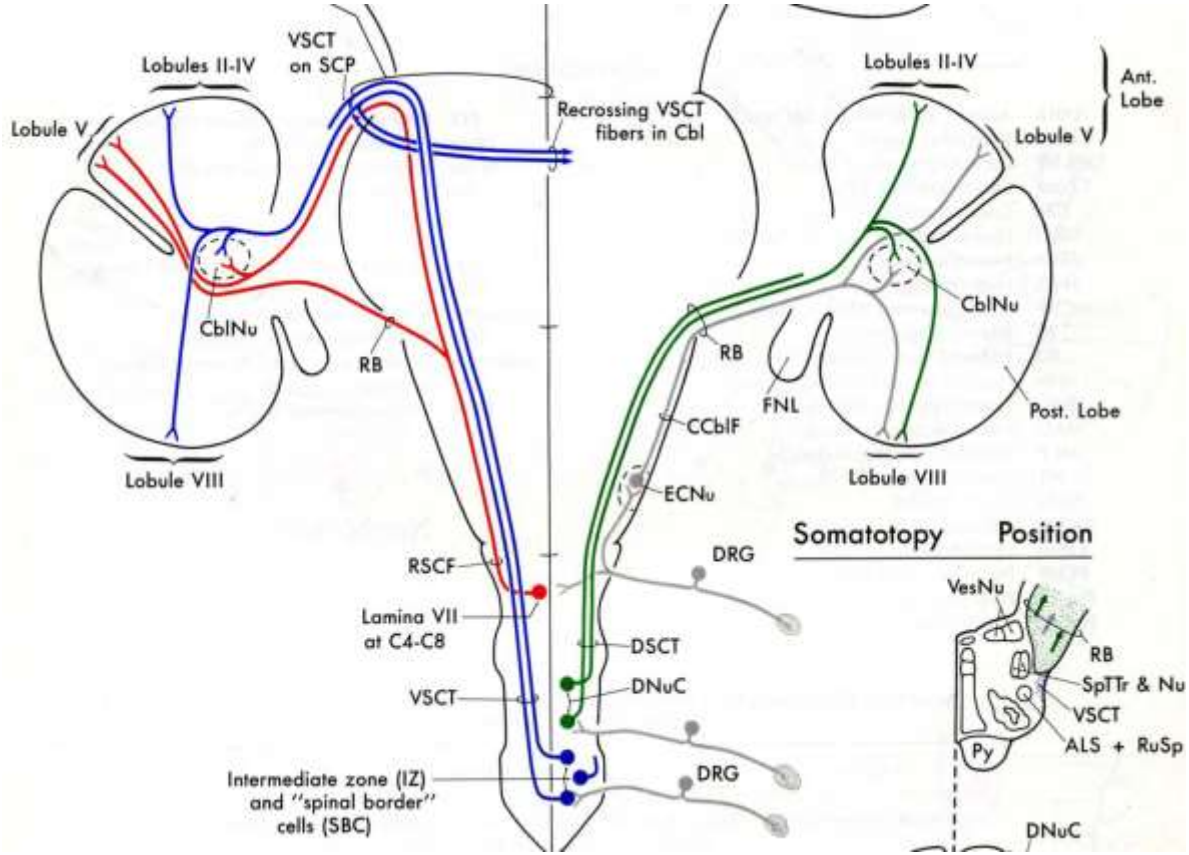
3rd neuron – nuclei and cortex of the cerebellum

Superior cerebellar peduncle

90% fibers decussate at the same segment
10% fibers decussate in superior medullary velum

2nd neuron – central intermediate substance of the spinal cord

1st neuron – pseudounipolar neuron (spinal ganglion)



Tractus spinocerebellaris posterior (Flechsig`s pathway) – green

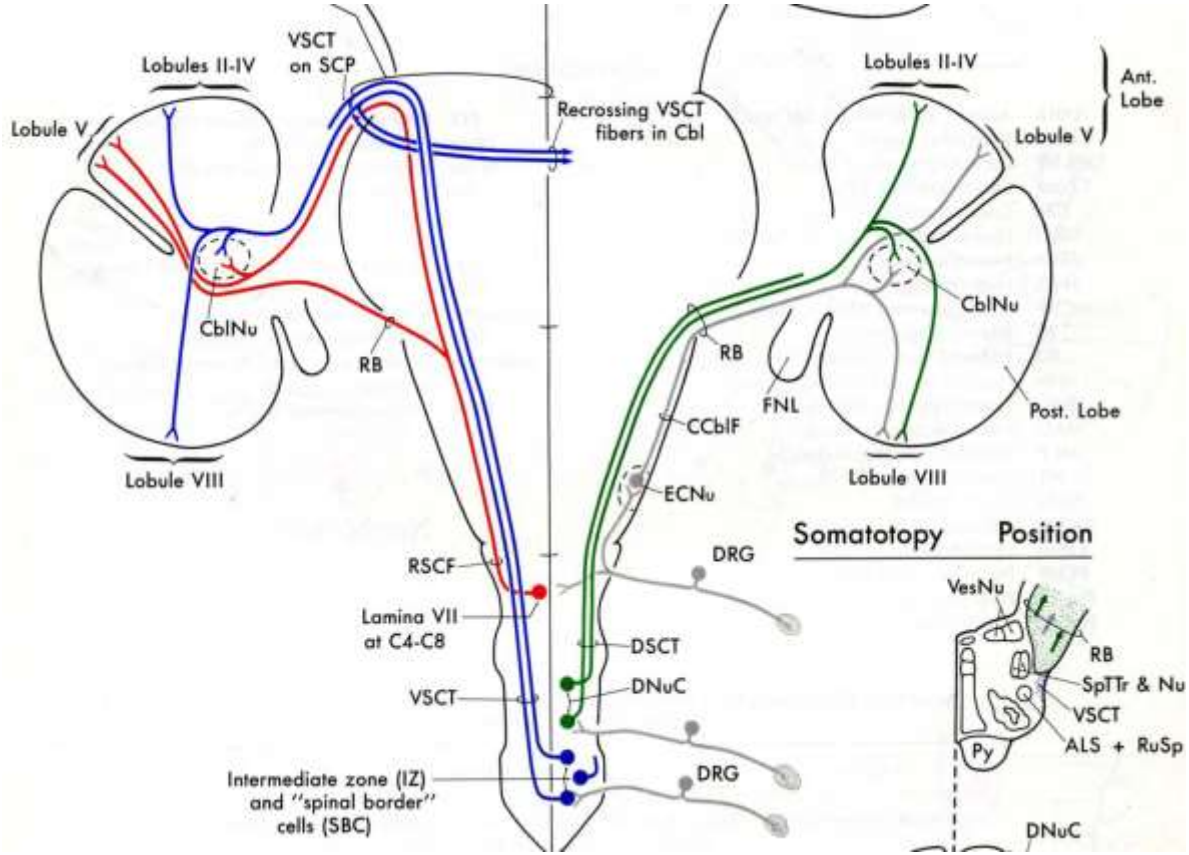
- musculo-articular sense from separate muscles
- without decussation!

3rd neuron – nuclei and cortex of the cerebellum

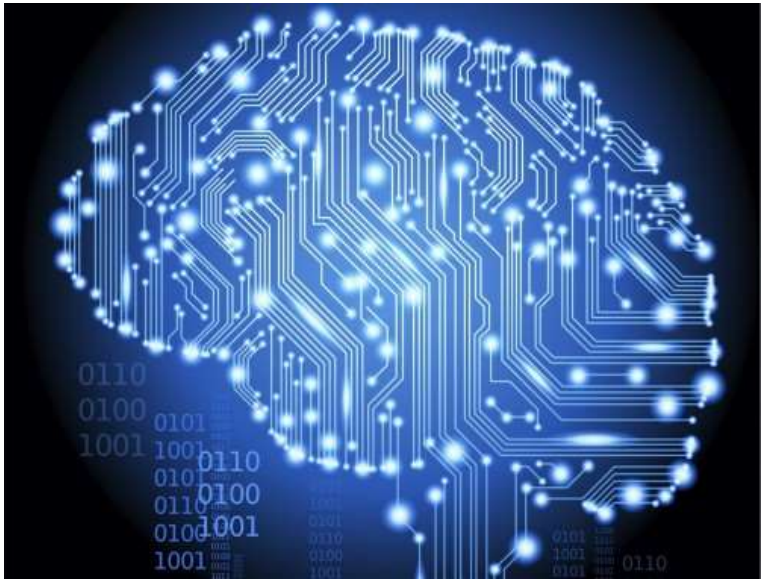
Inferior cerebellar peduncle

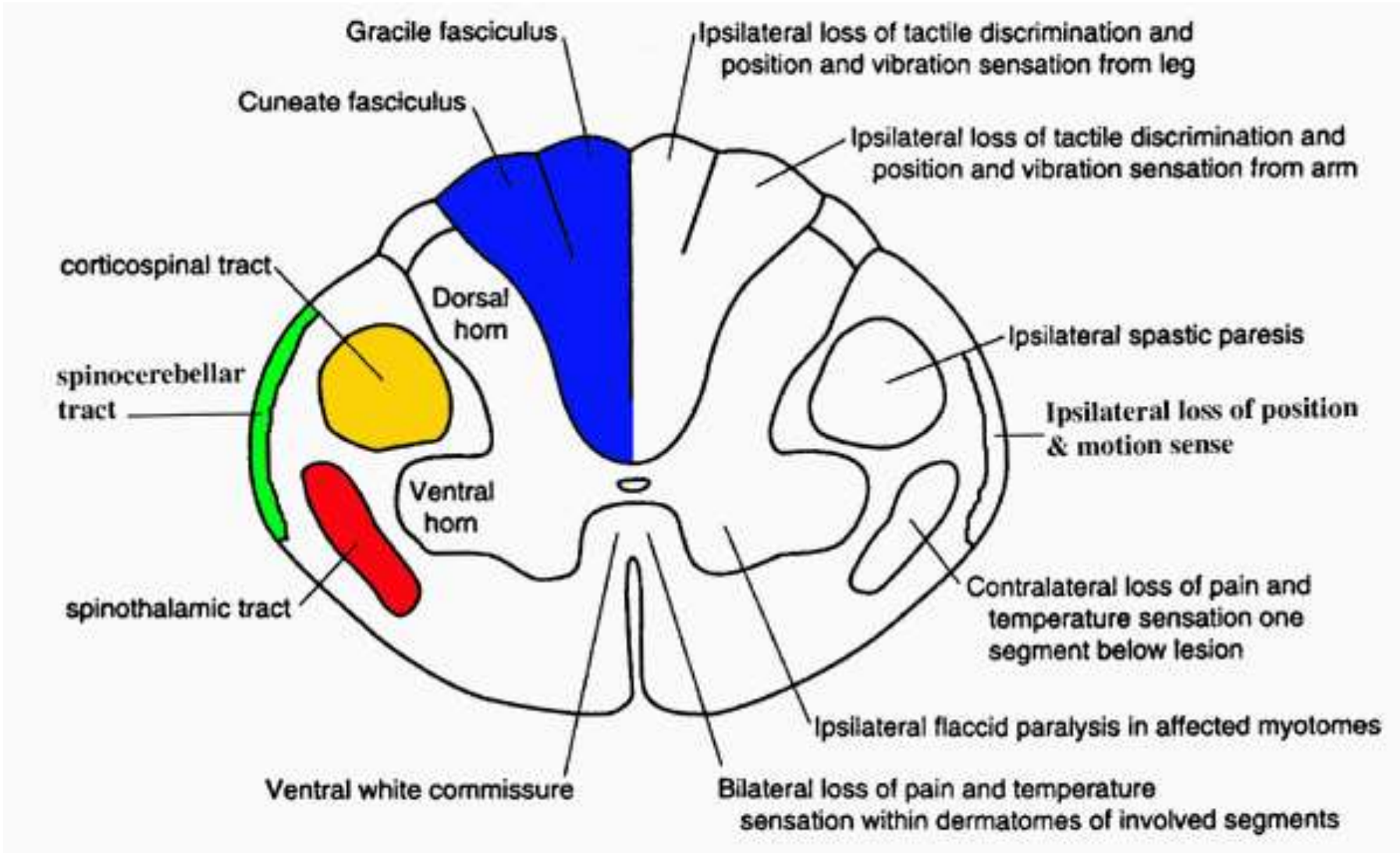
2nd neuron – nucleus dorsalis of Clarke , axons arise in ipsilateral side of lateral funiculus

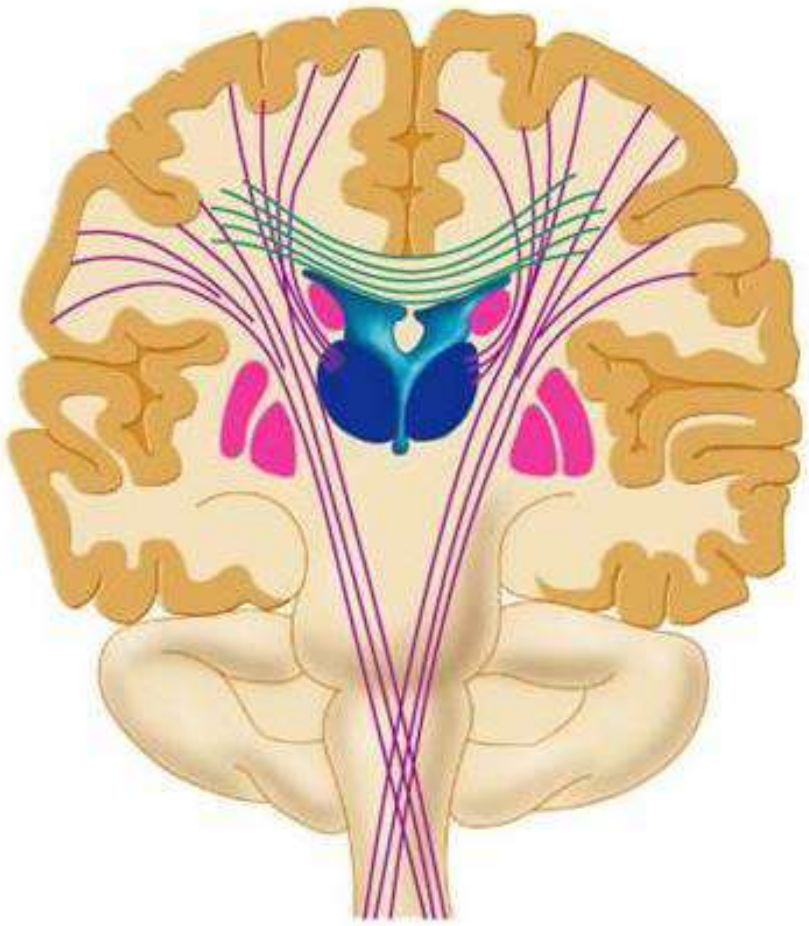
1st neuron – pseudounipolar neuron (spinal ganglion), central branch runs ipsilateral dorsal funiculus of the spinal cord



Afferent (ascending) pathways		
Superficial sensitivity	Deep sensitivity	
1. Conscious - *Tractus spinothalamicus* - exteroceptors	**2. Conscious** (*Fasciculus gracilis et Fasciculus cuneatus*) - proprioceptors - exteroceptors	**3. Unconsious** - *Tractus spinocerebellaris anterior et posterior* - prorpioceptors




Gracile fasciculus
Ipsilateral loss of tactile discrimination and position and vibration sensation from leg
Cuneate fasciculus
Ipsilateral loss of tactile discrimination and position and vibration sensation from arm
corticospinal tract
Dorsal horn
Ipsilateral spastic paresis
spinocerebellar tract
Ipsilateral loss of position & motion sense
Ventral horn
spinothalamic tract
Contralateral loss of pain and temperature sensation one segment below lesion
Ipsilateral flaccid paralysis in affected myotomes
Ventral white commissure
Bilateral loss of pain and temperature sensation within dermatomes of involved segments



SOMATIC MOTOR (DESCENDING) PATHWAYS

NB!

Always only 2 neurons!

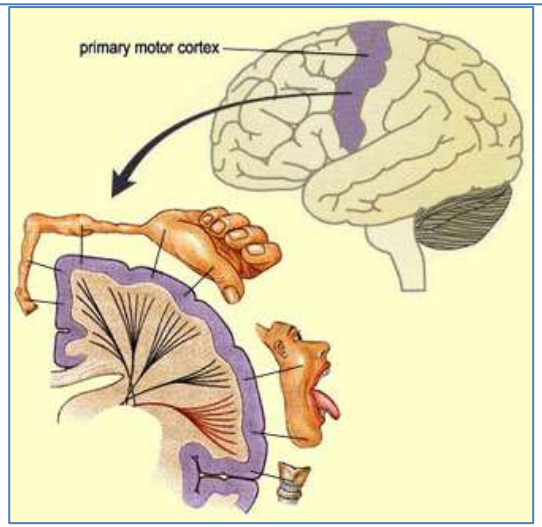
- Most of the pathways decussate
- Decussate always the 1st neuron

Somatic motor pathways (1st neuron):

Pyramidal somatic motor pathways

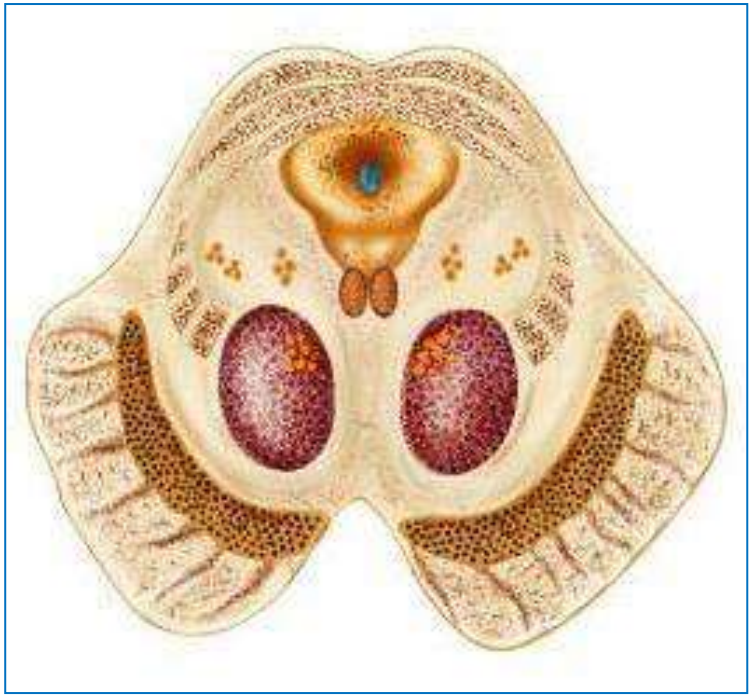
- **1st neuron** – motocortex (Gyrus precentralis) – Pyramidal cells (**Betz cells**)
- Direct link to the lower motoneurons

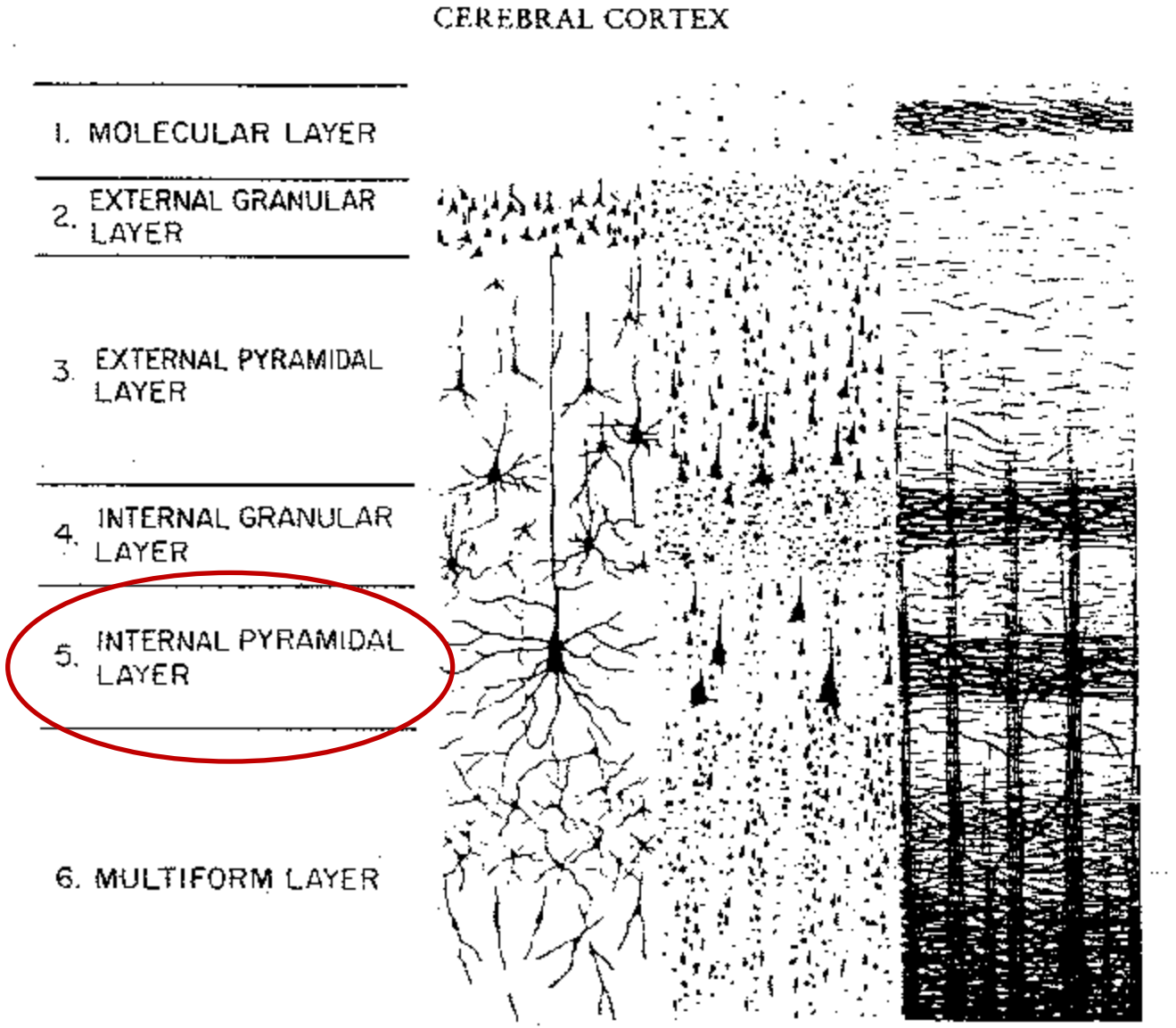
- initiation of **voluntary movements** of **skeletal muscles**



Extrapyramidal somatic motor pathways

- **1st neuron** – subcortical nuclei
- Indirect link to the lower motoneurons

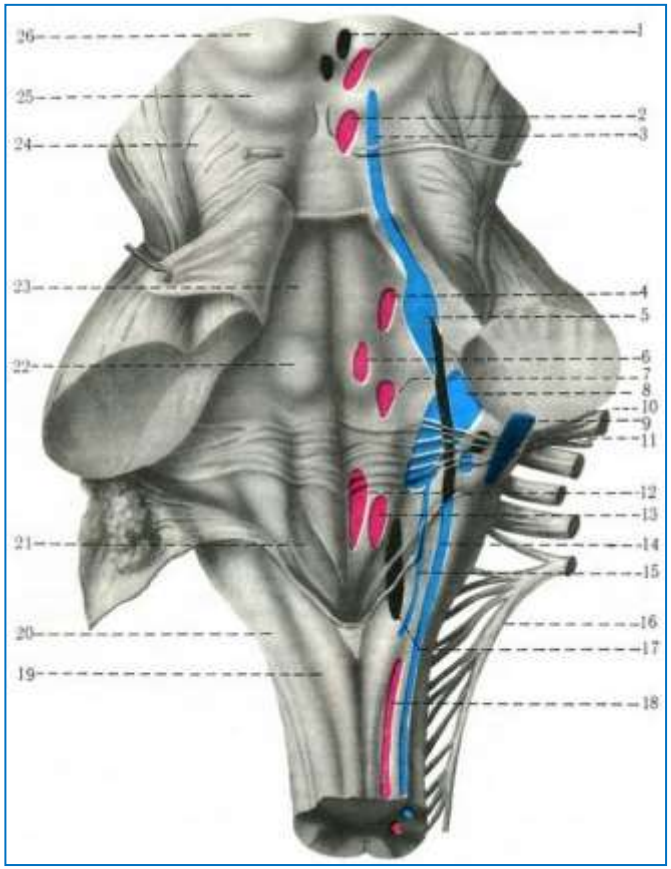



CEREBRAL CORTEX
1. MOLECULAR LAYER
2. EXTERNAL GRANULAR LAYER
3. EXTERNAL PYRAMIDAL LAYER
4. INTERNAL GRANULAR LAYER
5. INTERNAL PYRAMIDAL LAYER
6. MULTIFORM LAYER
Betz cells

Somatic motor pathways (2nd neuron):

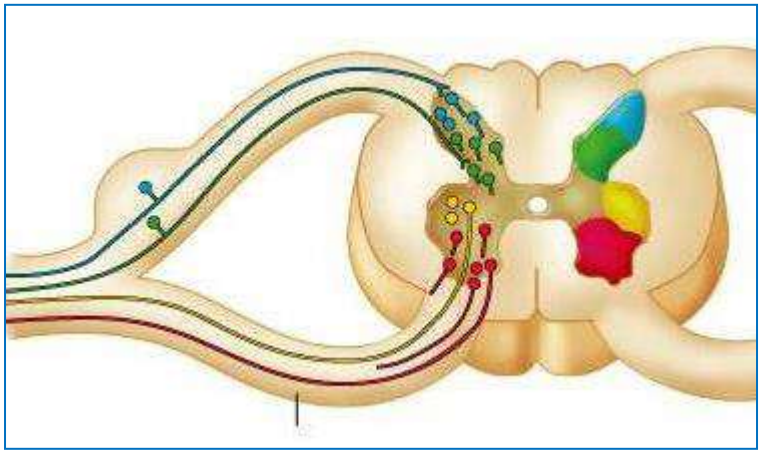
Motoneurons of the cranial nerves

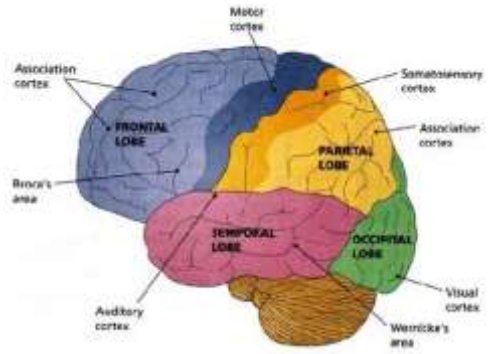
- *Tractus corticobulbaris*



Motoneurons of the spinal cord (anterior horn)

- *Tractus corticospinalis anterior*
- *Tractus corticospinalis lateralis*





Pyramidal somatic motor pathways – *Tractus corticobulbaris*

- **1st neuron** – pyramidal neurons (Betz cells, the V layer of the cortex) of **gyrus precentralis**

↓

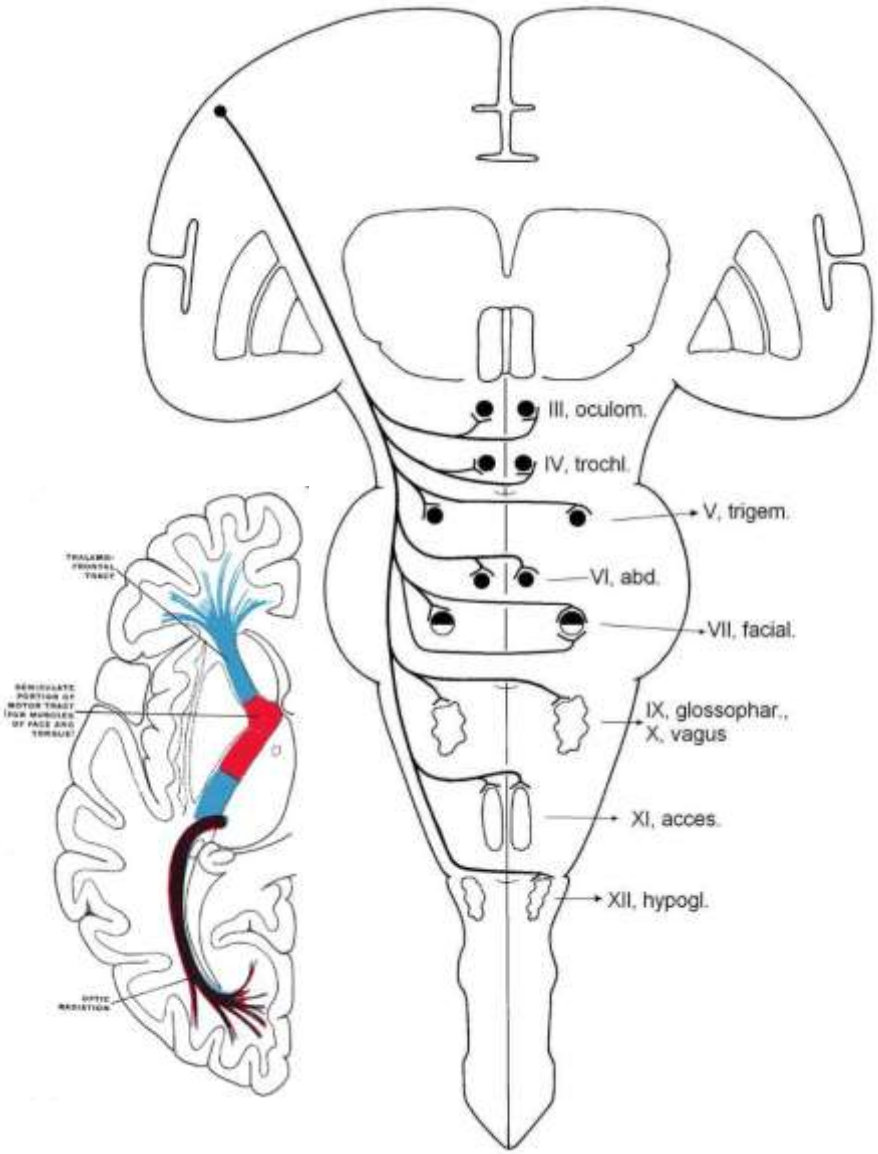
Genus of the internal capsule

↓

Partial decussation
(part – ipsilaterally, part – contralaterally)
Exceptions! Total decussation:
- lower part of facial nerve (VII)
- hypoglossus nerve (XII)

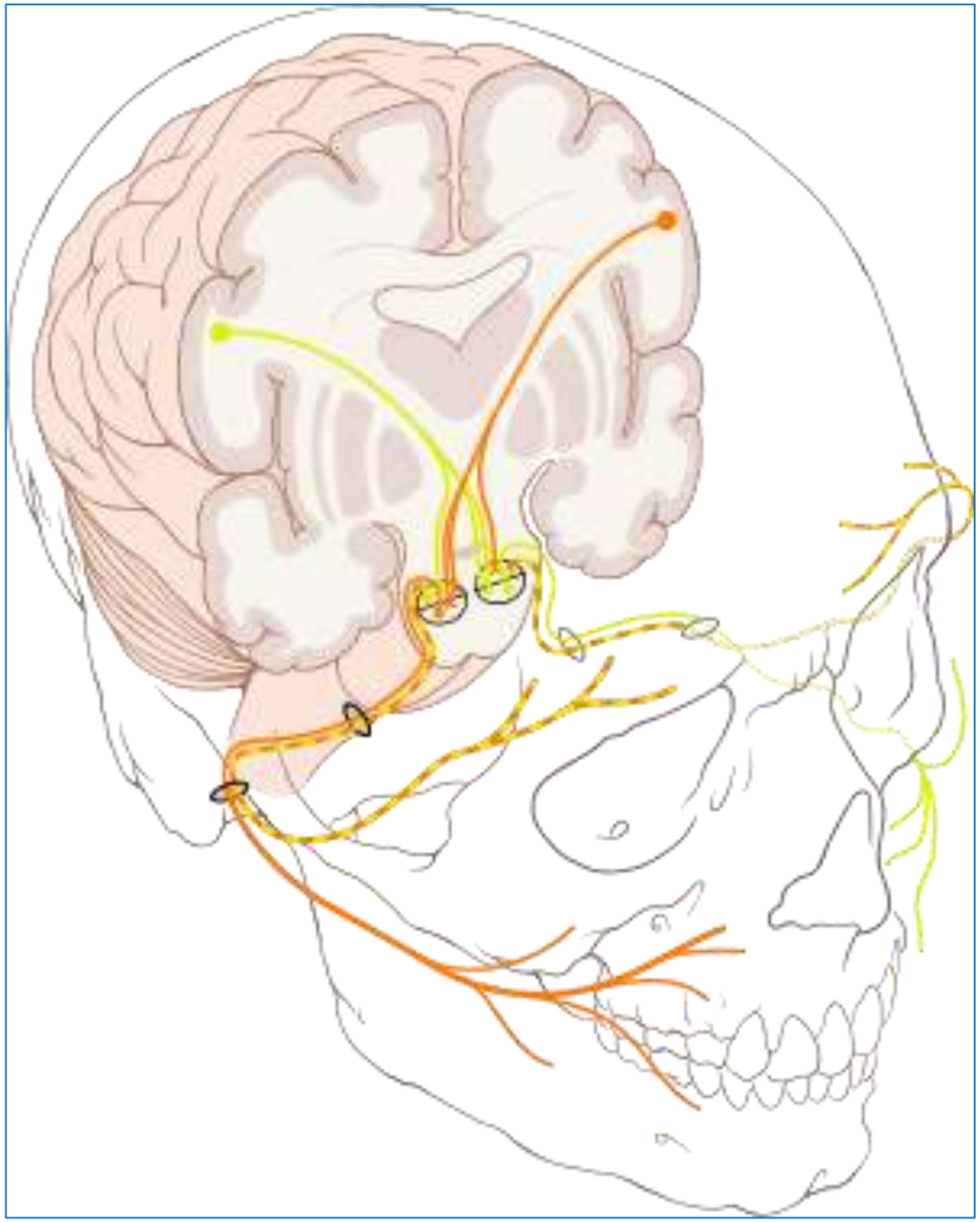
↓

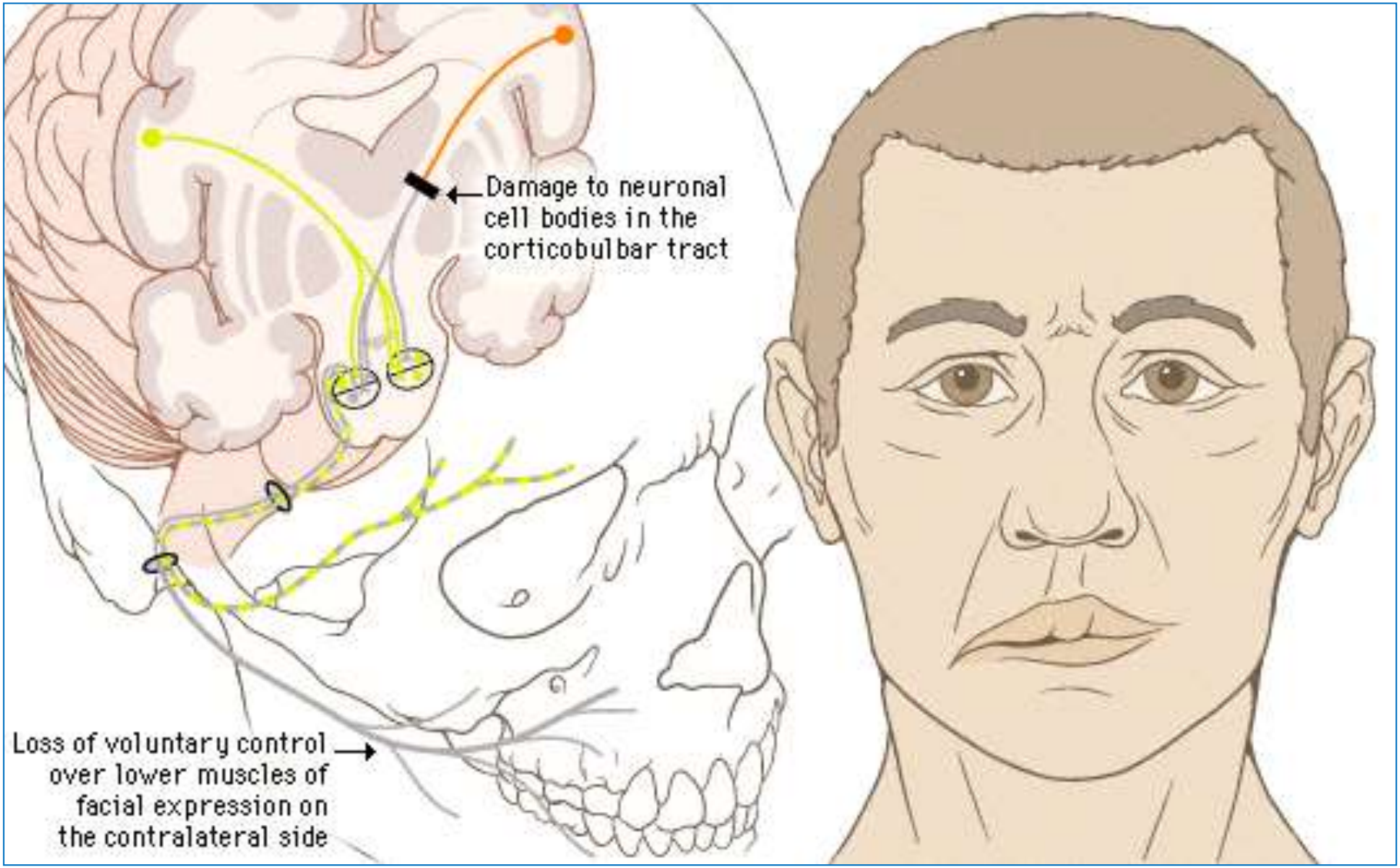
- **2nd neuron** – motor nuclei of the cranial nerves (except I, II, VIII)



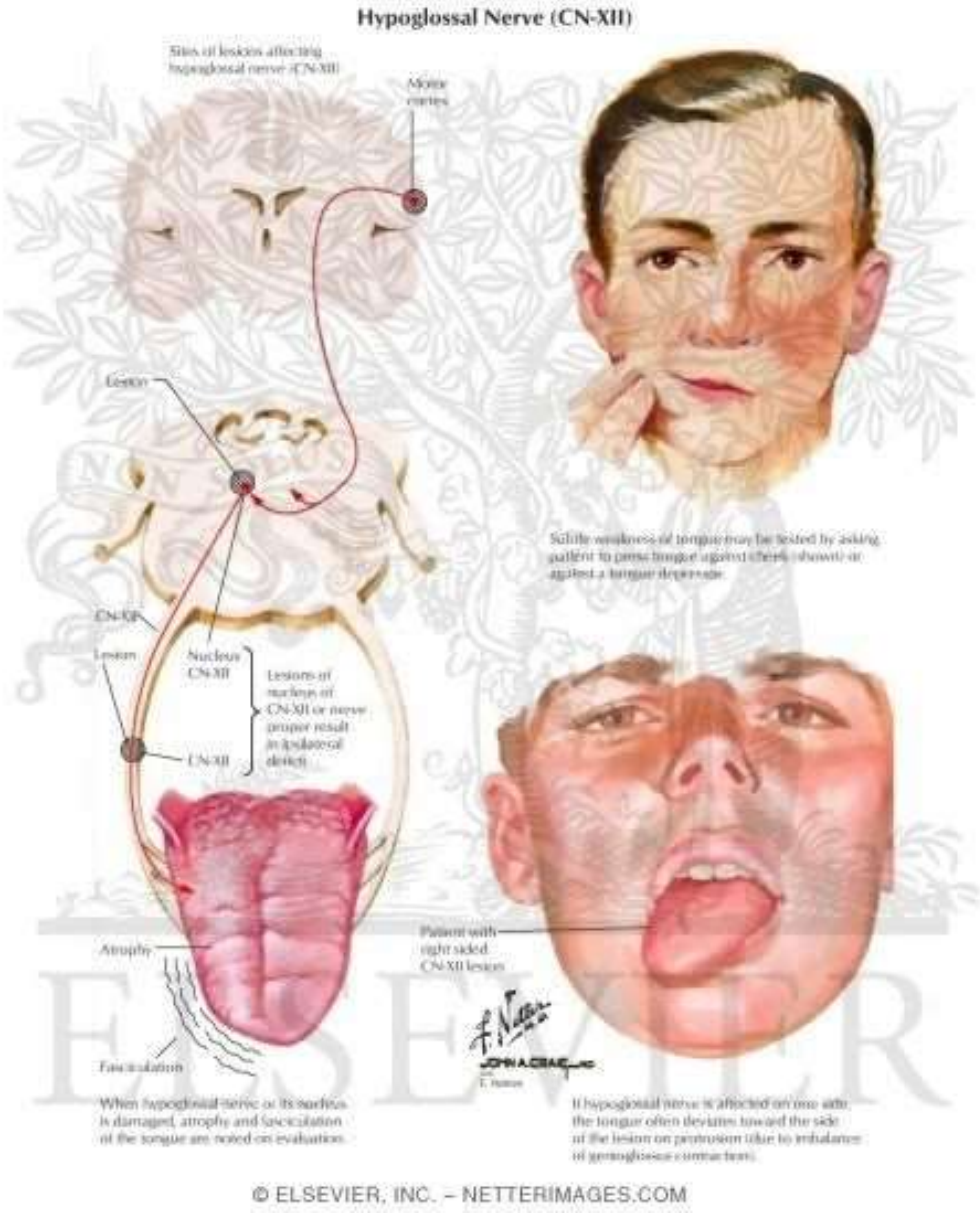
Facial nerve (VII cranial nerve):

- superior part of the face – signals from both sides hemispheres
- inferior part of the face – only contralateral hemisphere signals!!!




Damage to neuronal cell bodies in the corticobulbar tract
Loss of voluntary control over lower muscles of facial expression on the contralateral side

Hypoglossal nerve (XII) – only contralateral side (total decussation)

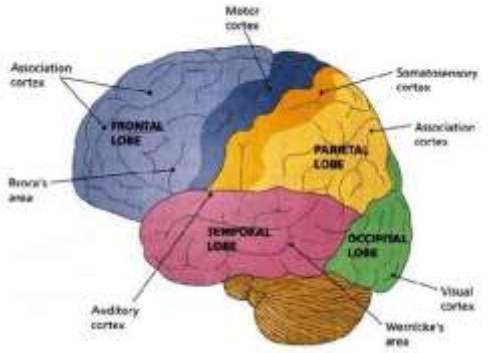


Normal

Contralateral damage

Pyramidal somatic motor pathways – *Tractus corticospinalis anterior et lateralis*

•1st neuron – pyramidal neurons (**Betz cells**, the V layer of the cortex) of **gyrus precentralis**



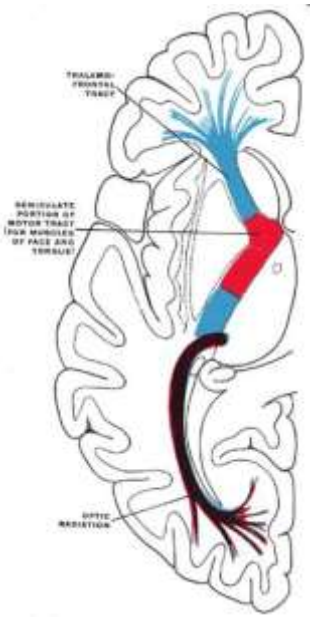
Crus posterior (anterior part) of the internal capsule

Without decussation (15% fibers)

Partial decussation:
- 85% fibers - in medulla oblongata (Decussatio pyramidum)

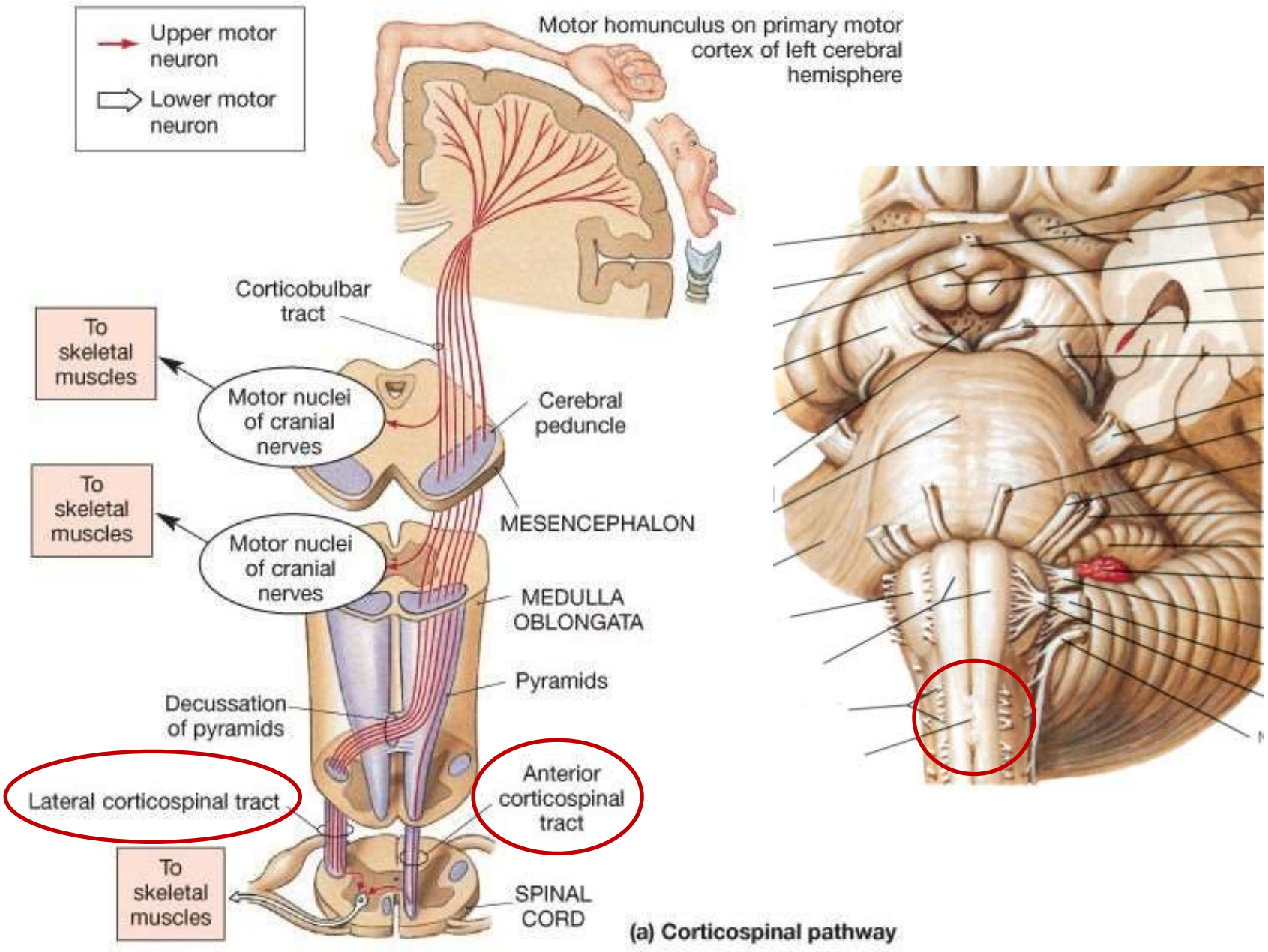
Anterior funiculus of the spinal cord (ipsilateral side) – *Tractus corticospinalis anterior*

Lateral funiculus of the spinal cord (contralateral side) – *Tractus corticospinalis lateralis*



•**2nd neuron** – motor neuron of the spinal cord (anterior horn)

Pyramidal somatic motor pathways – *Tractus corticospinalis anterior et lateralis*



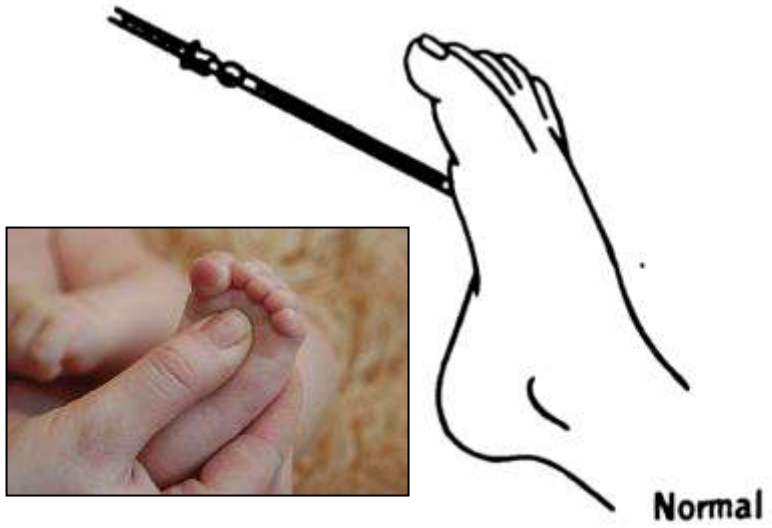
Affect of pyramidal tracts

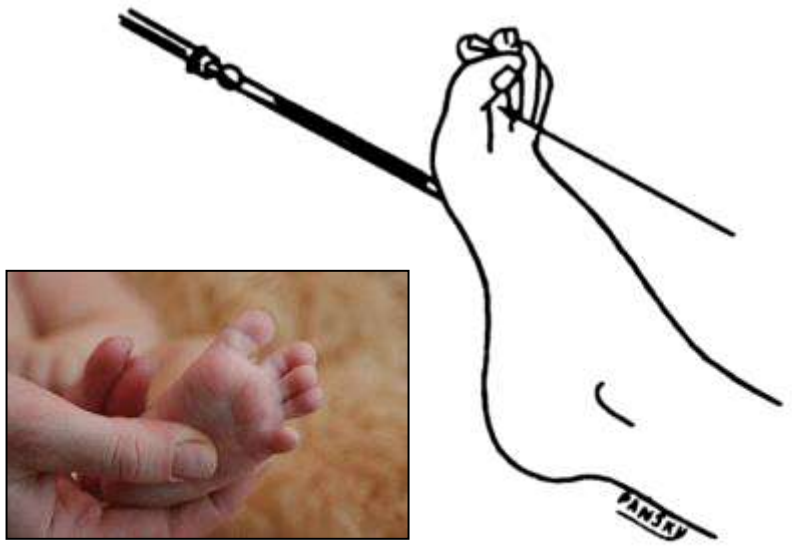
- **paralysis** – total loss of voluntary movements
- **paresis** - weakness of voluntary movement, or partial loss of voluntary movement.

Central (spastic) paralysis/paresis:

- Impairment of the 1st neuron
- Pyramidal tracts stop to suppress segmental apparatus of the spinal cord - enhancement of the unconditioned reflexes of the spinal cord:

- Increased muscle tonus
- Enhanced tendon reflexes
- Pathological reflexes

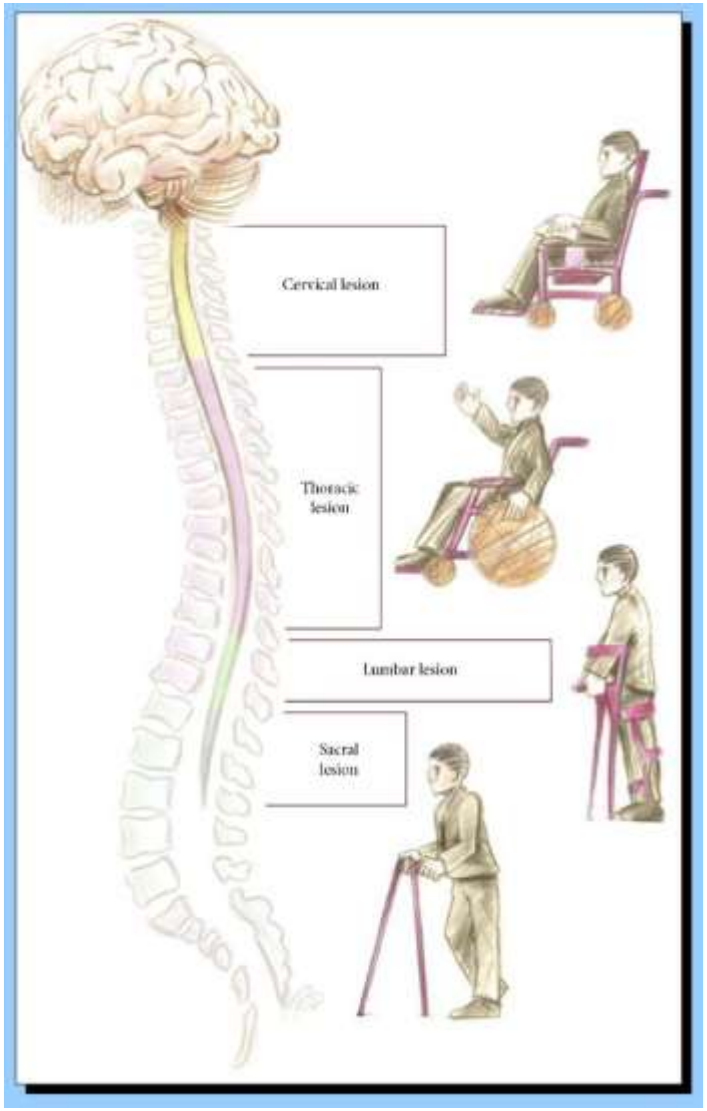




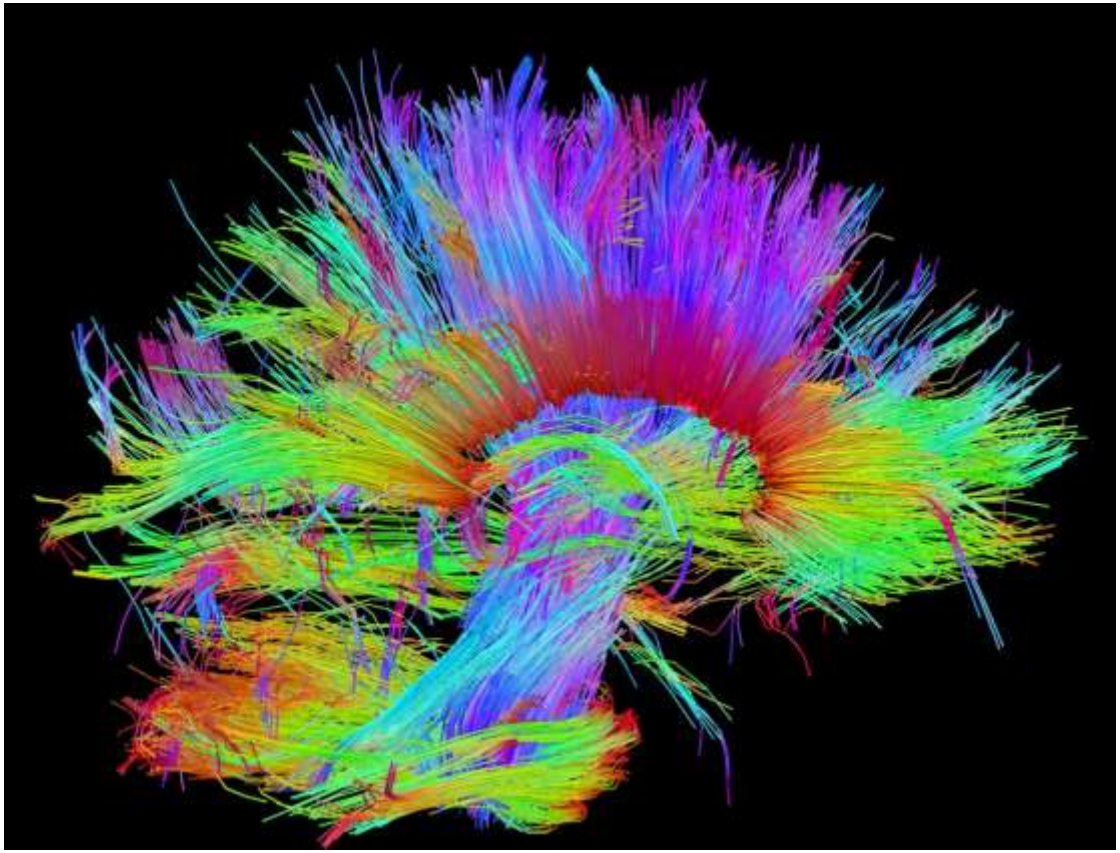
Positive (+) Babinski sign
(dorsiflexion of big toe)

Peripheral (hyposthenic) paralysis/paresis

- Impairment of the second neuron
- **4 “ A”:**
- Areflexia
- Atony of the muscles
- Adynamia
- Atrophy of the muscles



EXTRAPYRAMIDAL SYSTEM

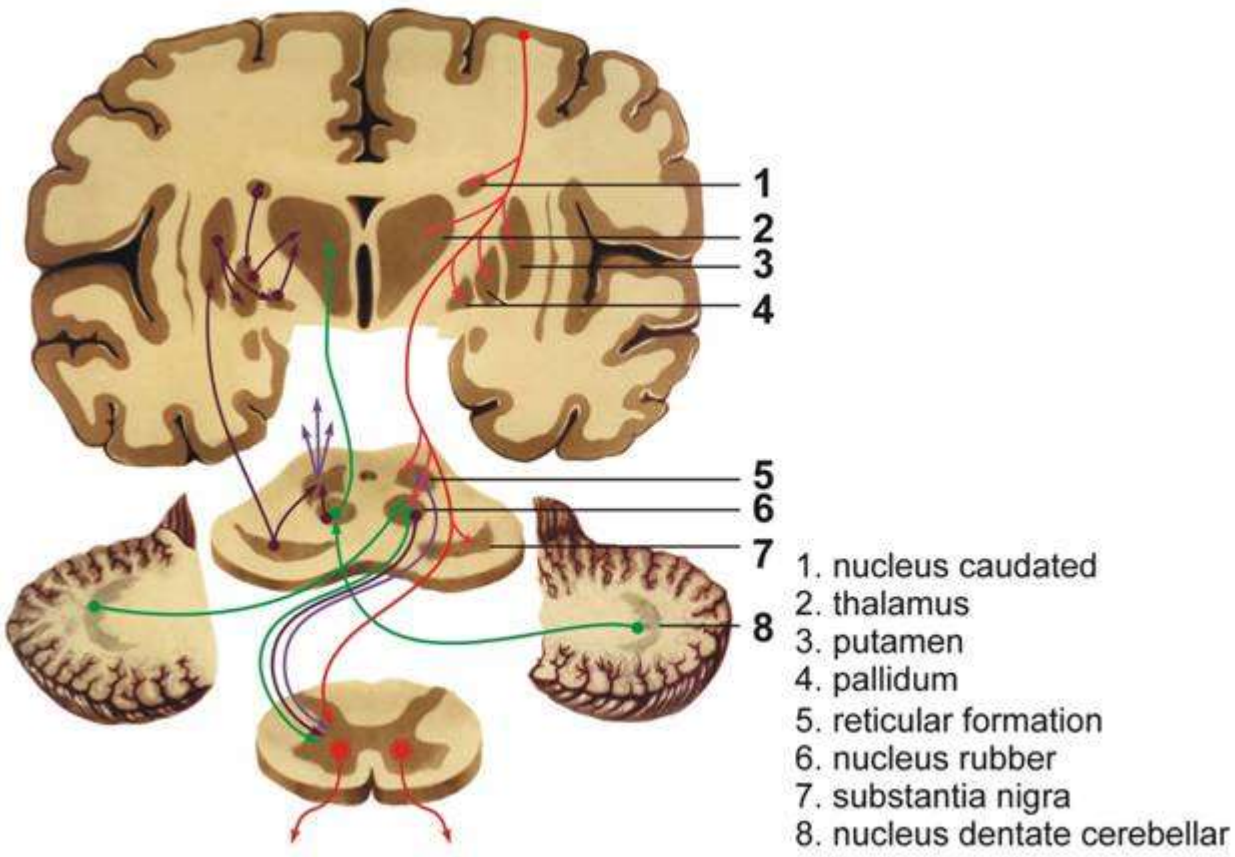


NB!

Function: provides coordinated work of the muscles in performing complicated automatic (unconscious) movements and muscle tonus

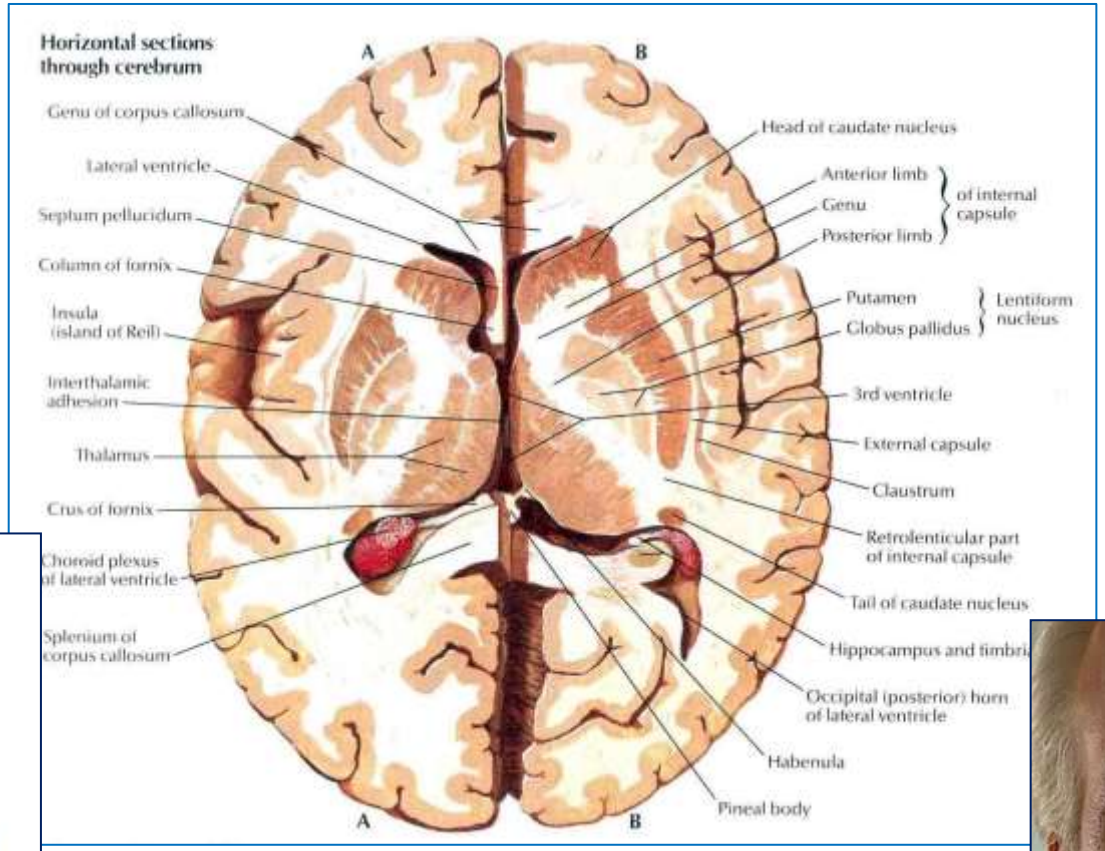
Extrapyramidal system:

- Basal nuclei (caudate nucleus, lentiform nucleus and claustrum)
- Red nucleus and black substance of the midbrain
- Cerebellum
- Reticular formation
- Vestibular nuclei

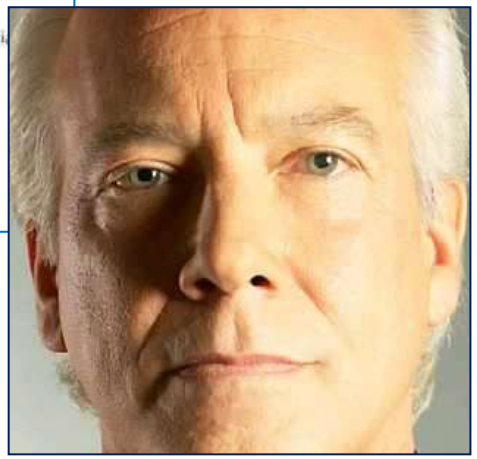


Basal nuclei

Striatum
- Nucleus caudatus
- Putamen

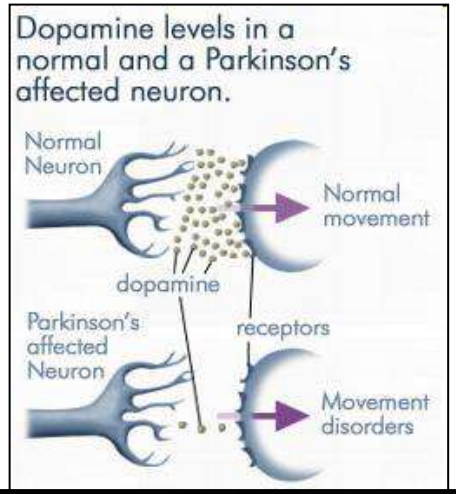


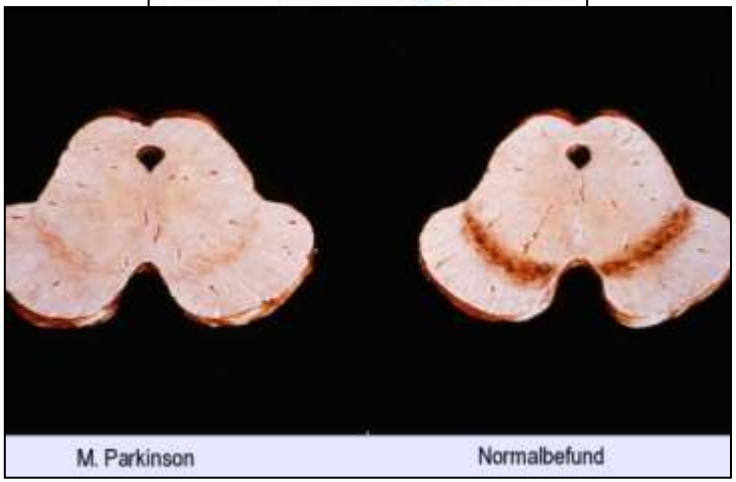
Pallidum
- Globus pallidus
- Nucleus ruber
- Substantia nigra

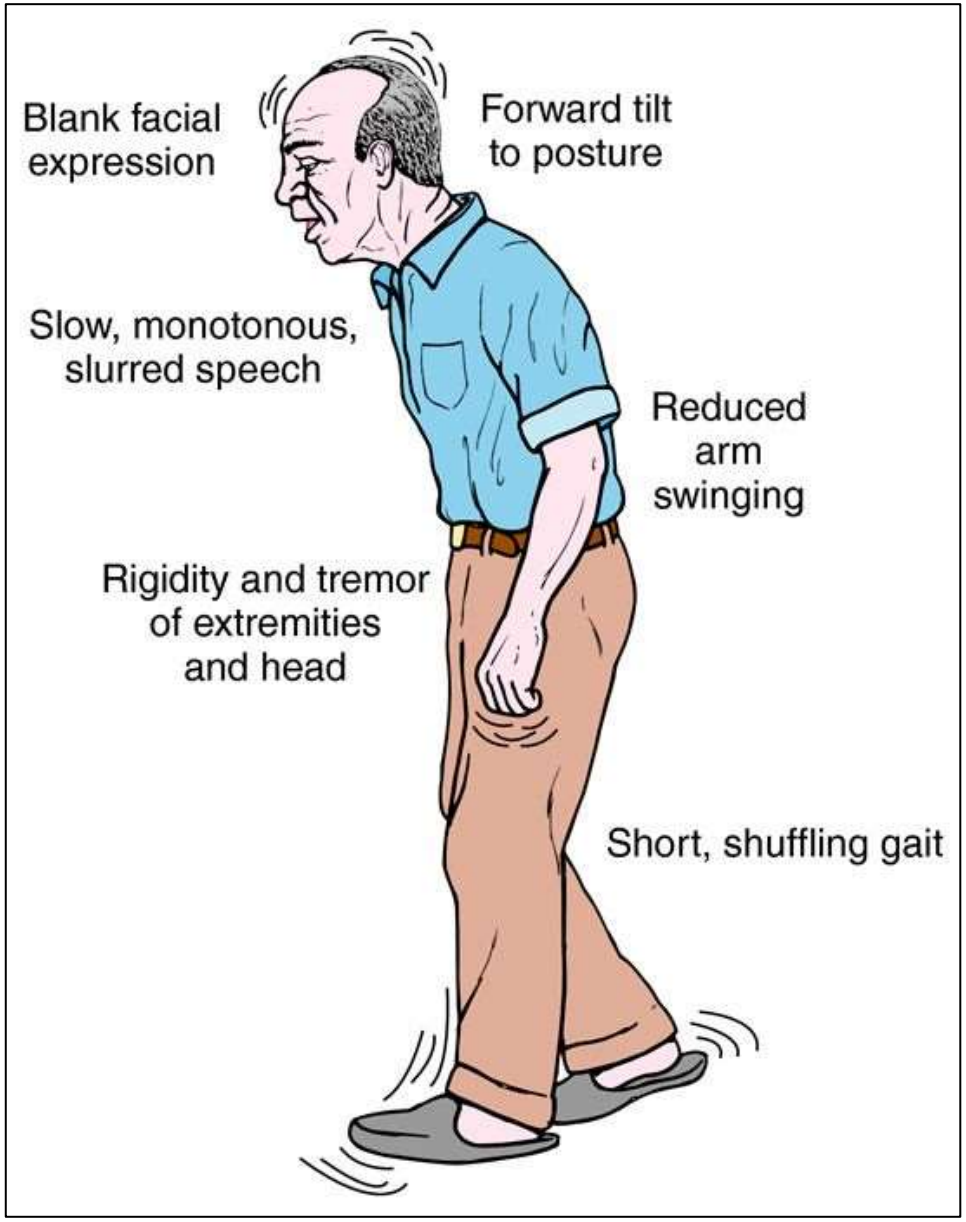


Parkinson disease
(Pallidum syndrom)

- Muscle hypertonia
- Hypokinesia – retarded, monotonous and inexpressive movements

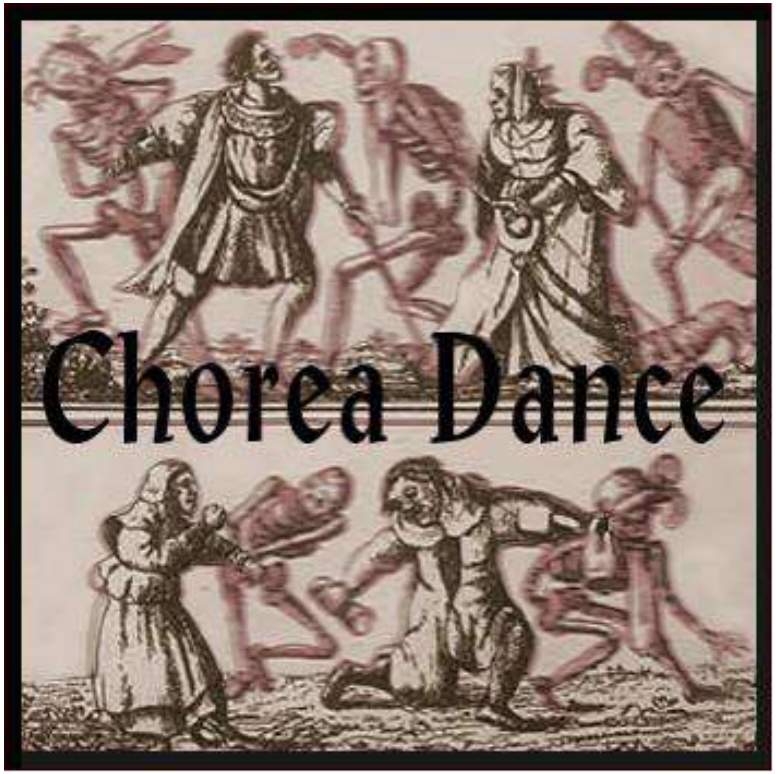






Striatic syndrom

- hypotonia of the muscles
- hyperkinesis – hypernormal movements



Extrapyramidal somatic motor pathways:

Lateral fasciculus:

- 1. Tractus rubrospinalis (X)

Anterior fasciculus:

- 2. Tractus tectospinalis (X)
- 3. Fasciculus longitudinalis medialis
- 4. Tractus reticulospinalis
- 5. Tractus vestibulospinalis

Tractus rubrospinalis (Monakow`s tract)

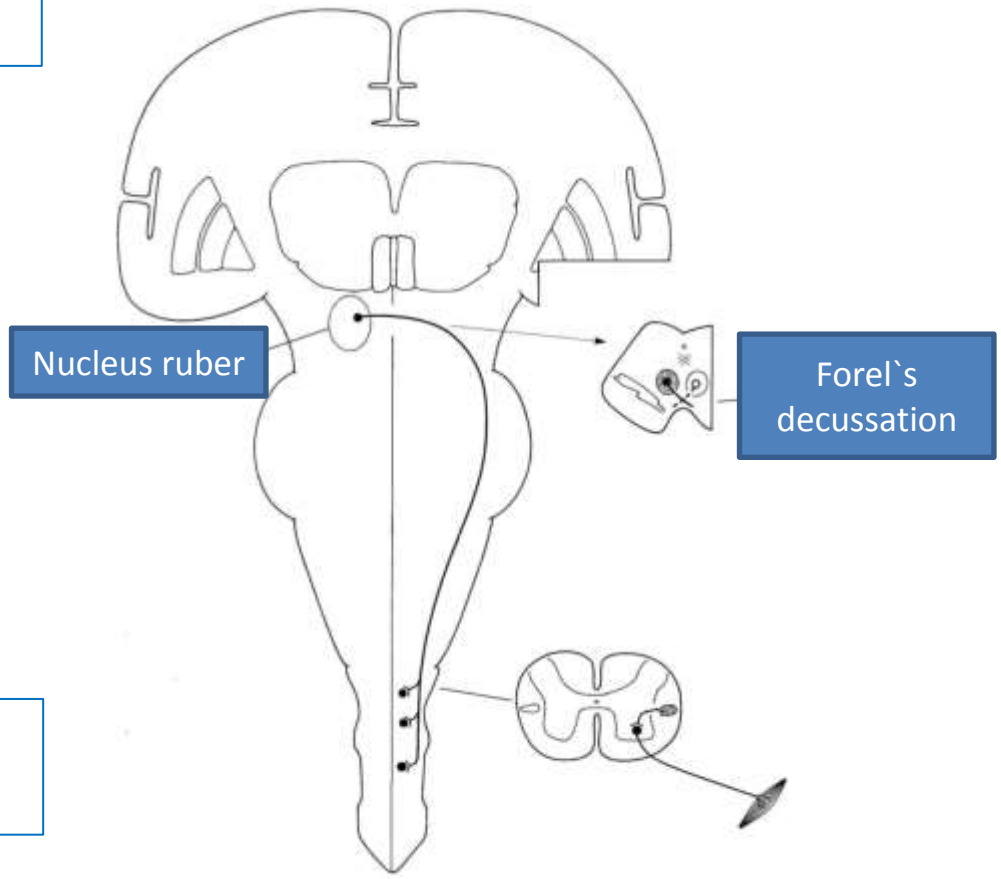
Function:
1) provides **complicated regular habitual** movements of the skeletal muscles (running, walking, etc.)
2) provides tonus of all skeletal muscles
3) suppress unconscious movements of muscles (teak, habit chorea)

- **1st neuron** – nucleus ruber (midbrain)

Forel`s decussation (ventral)

Lateral funiculus of the spinal cord (contralateral side)

- **2nd neuron** – motor neuron of the spinal cord (anterior horn)



Tractus tectospinalis

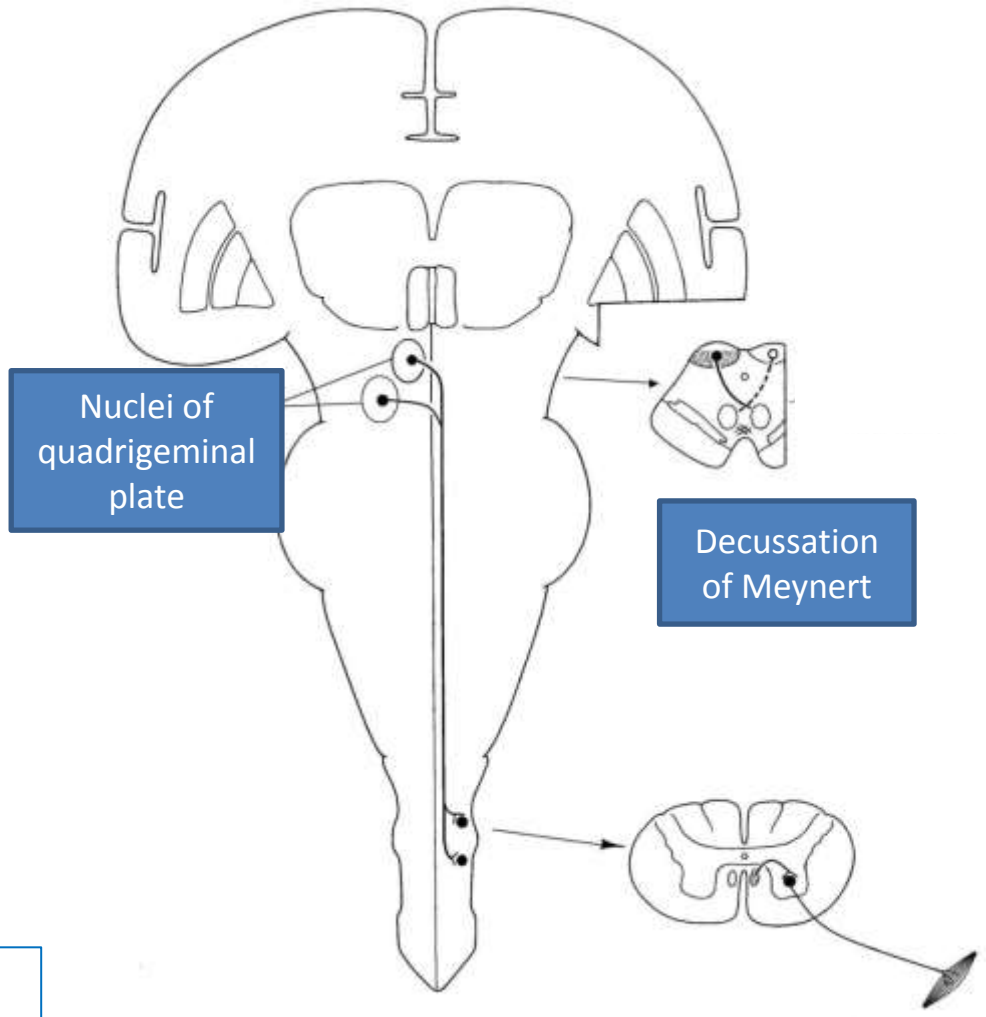
Function: provides unconditioned reflexes in response to sudden and strong auditory and visual signals ("warning reflex")

- **1st neuron** – nuclei of the quadrigeminal plate (midbrain)

Decussation of Meynert (tectum of the midbrain, dorsal)

Anterior funiculus of the spinal cord (contralateral side)

- **2nd neuron** – motor neuron of the spinal cord (anterior horn)



Fasciculus longitudinalis medialis

- without decussation:

Function:

1) connects nuclei of the reticular formation with nuclei of the cranial nerves, that innervate muscles of the eyes (III, IV and VI) and motor neurons of the spinal cord

2) Provides coordinated movements of the eyes and head

- **1st neuron** – interstitial nucleus of Kajal, Darkshevich`s nucleus of reticular formation (midbrain)

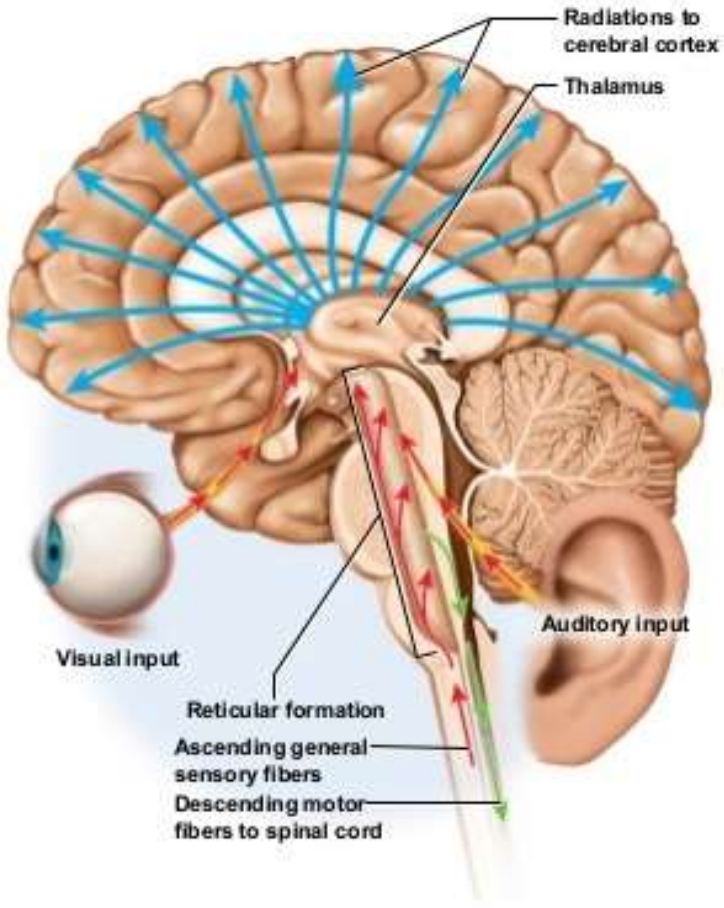
↓

Anterior funiculus of the spinal cord (ipsilateral side)

↓

- **2nd neuron** – motor nuclei of the III, IV and VI cranial nerves and motor neurons of anterior horn of the spinal cord

The Reticular Formation



- Loosely organized web of gray matter that runs vertically through all levels of the brainstem
- Clusters of gray matter scattered throughout pons, midbrain, and medulla
- Occupies space between white fiber tracts and brainstem nuclei
- Has connections with many areas of cerebrum
  - More than 100 small neural networks without distinct boundaries

NB! Reticular formation is under hypothalamic control!

- Determines tonus of the skeletal muscles.
- Connected with vegetative nervous system (cardiovascular and breathing centers, swallowing, sneezing and tussis centers)

Tractus reticulospinalis

- without decussation
Function: unconditioned reflexes with contemporary participation of muscles of different groups (griping, breathing, etc.)

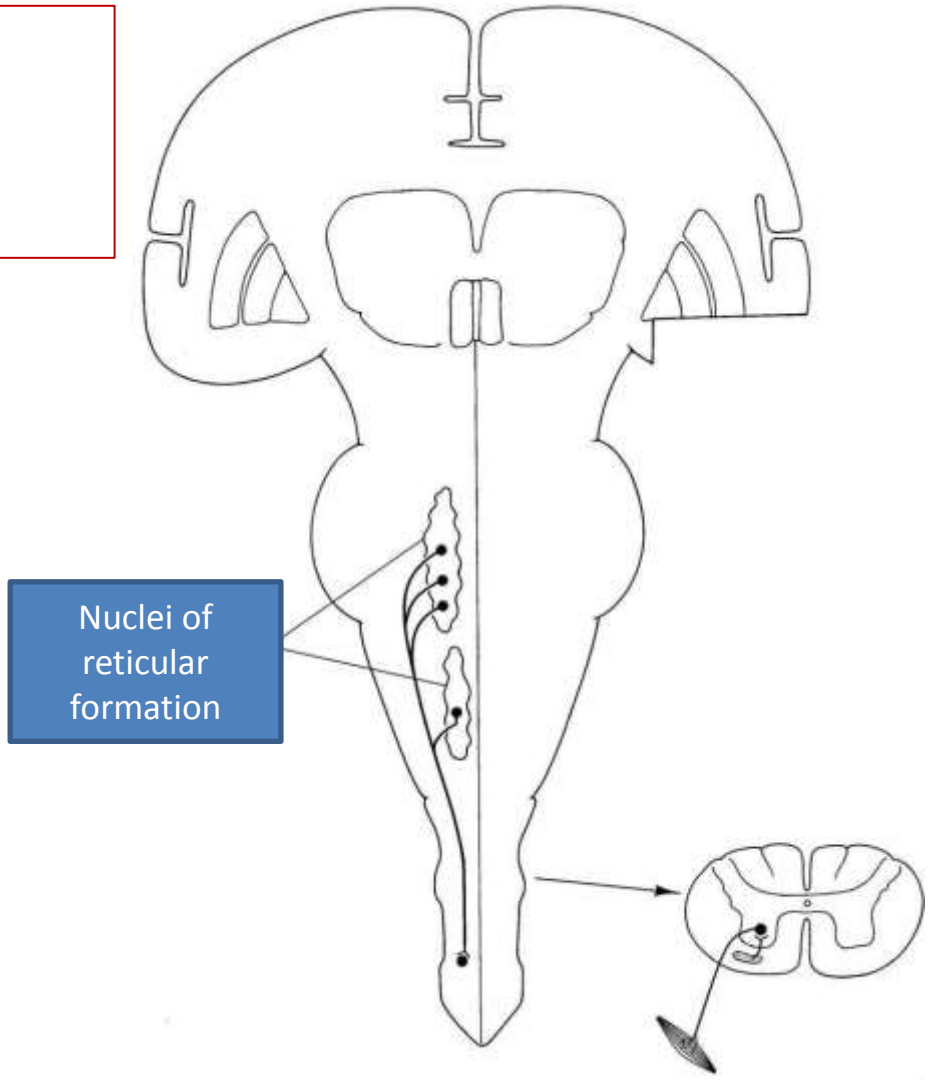
- **1st neuron** – reticular formation of the brainstem

↓

Anterior funiculus of the spinal cord (ipsilateral side)

↓

- **2nd neuron** –motor neurons of anterior horn of the spinal cord



Tractus vestibulospinalis

Function: provides unconditioned reflexes in response to postual disequilibrium

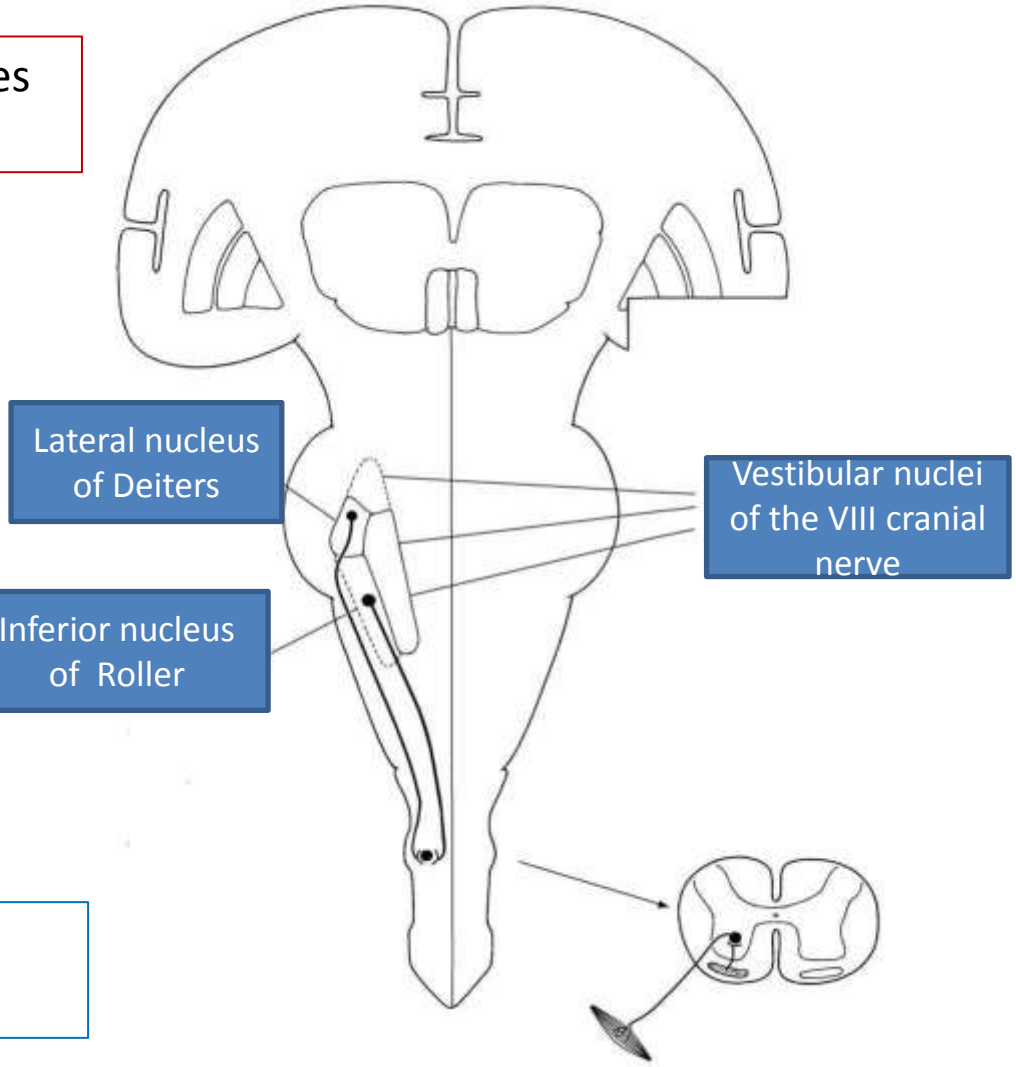
- **1st neuron** – vestibular nuclei (nucleus of Deiters, nucleus of Roller) in the pons

⬇

Anterior funiculus of the spinal cord (ipsilateral side)

⬇

- **2nd neuron** –motor neurons of anterior horn of the spinal cord



Cerebellum receives impulses from:

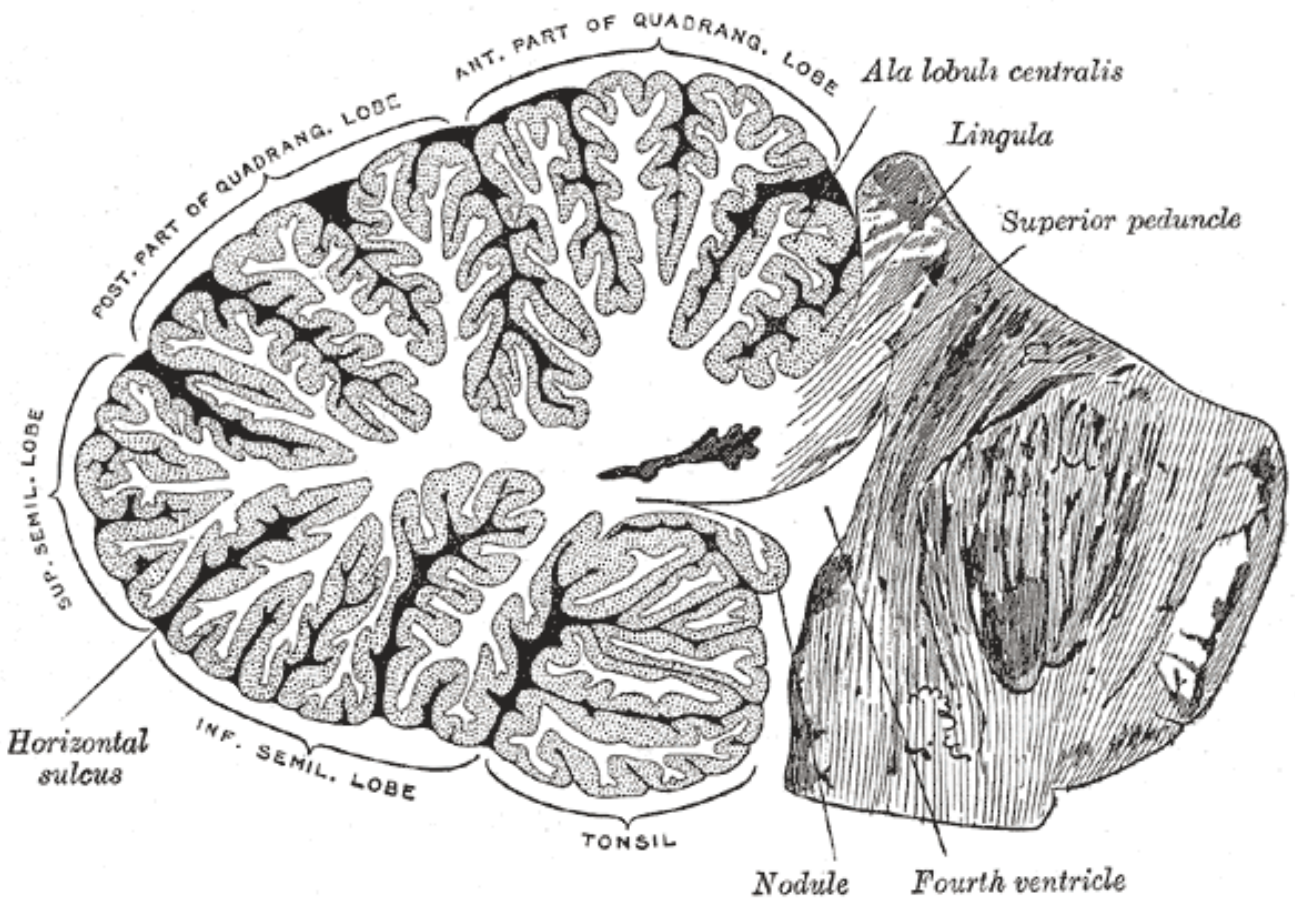
- below:

– tract of Gowers and Flechsig (deep sensitivity)

– vestibular nuclei, olives and reticular formation

- above:

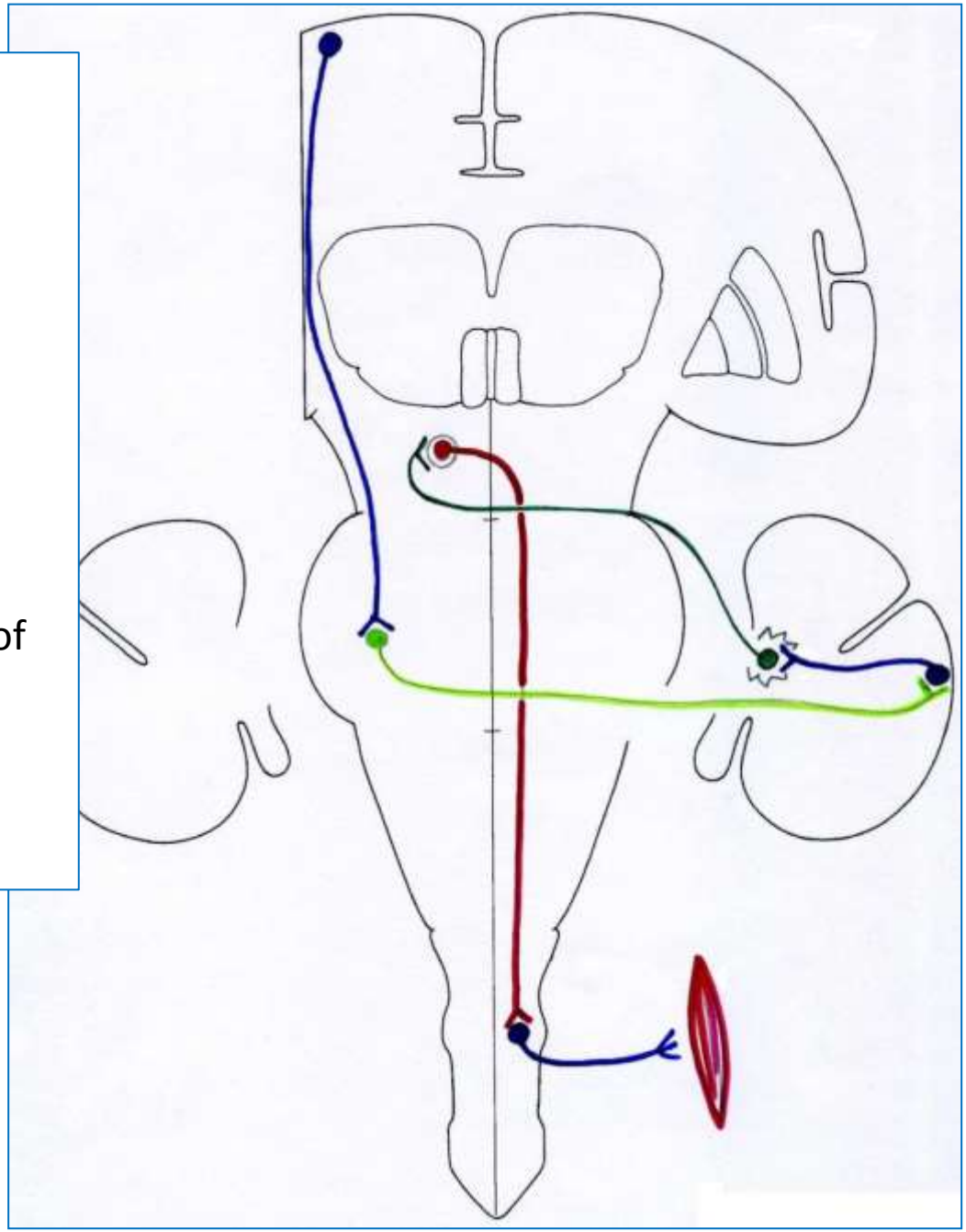
–cortex

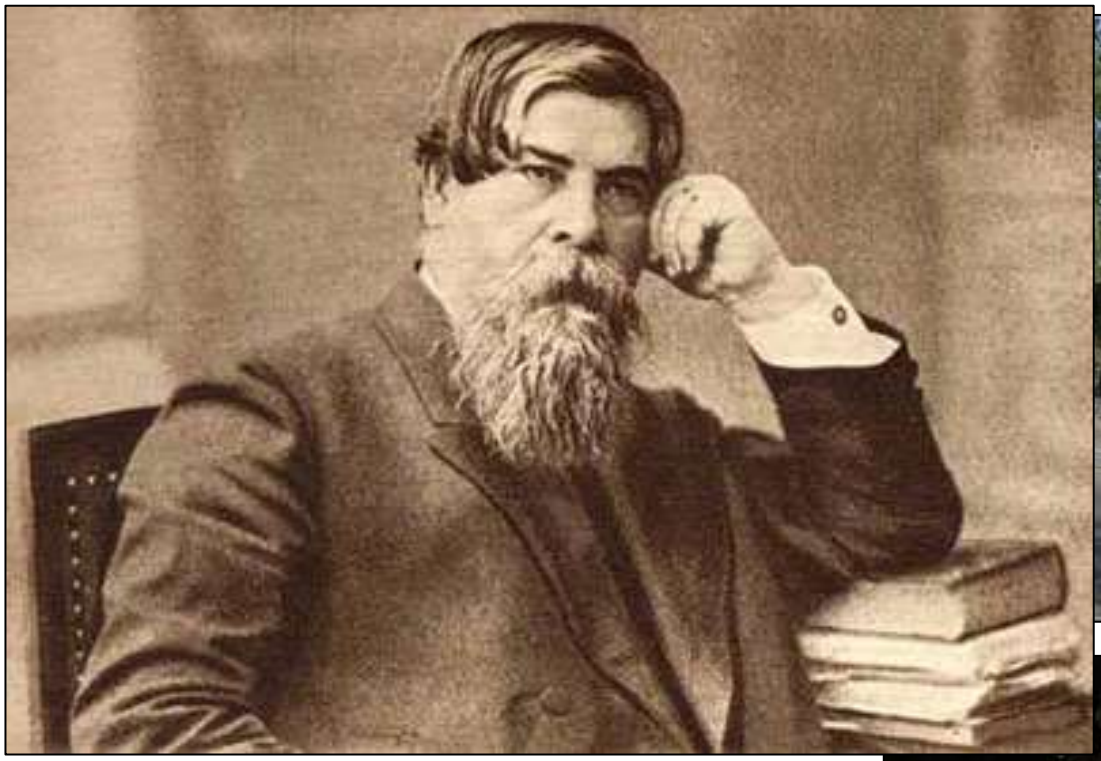


Projection pathways of the cerebellum

Tractus cortico-ponto-x-cerebello-dentato-x-rubro-x-spinalis

1. Cortex
2. Pons (nuclei) X
3. Cortex of the cerebellum
4. Nucleus dentatus (cerebellum) – decussation of Werneking (decussation of superior cerebellar peduncles)
5. Nucleus ruber (midbrain) X
6. Motor neurons of the anterior horn (spinal cord)

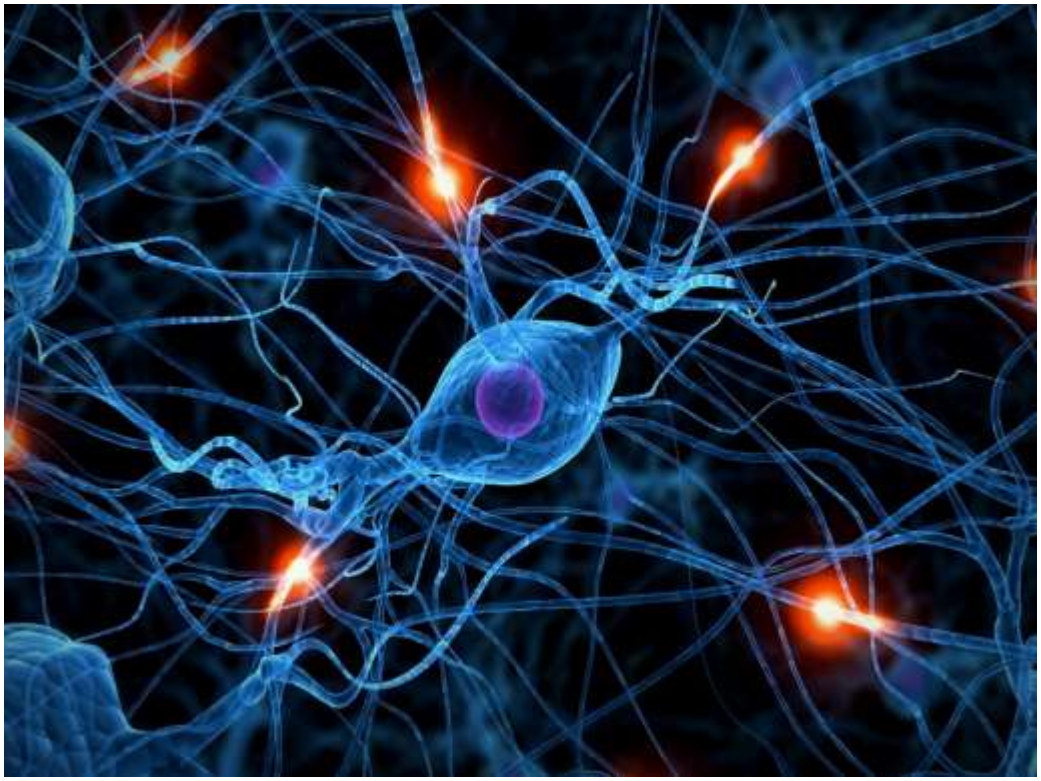




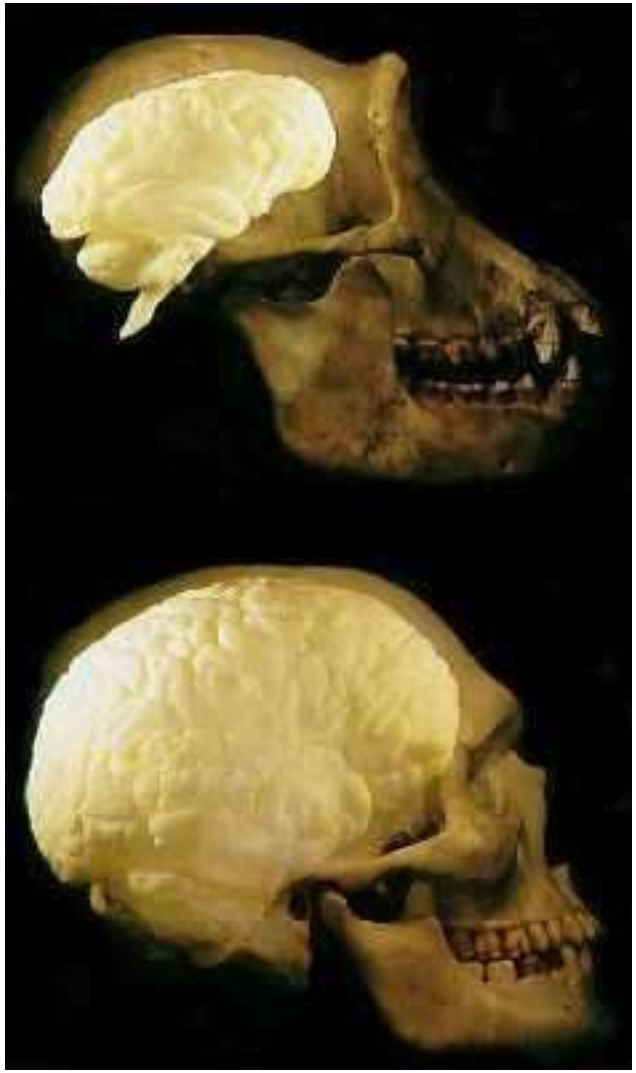
Vladimir Mikhailovich Bekhterev
(1857-1927)

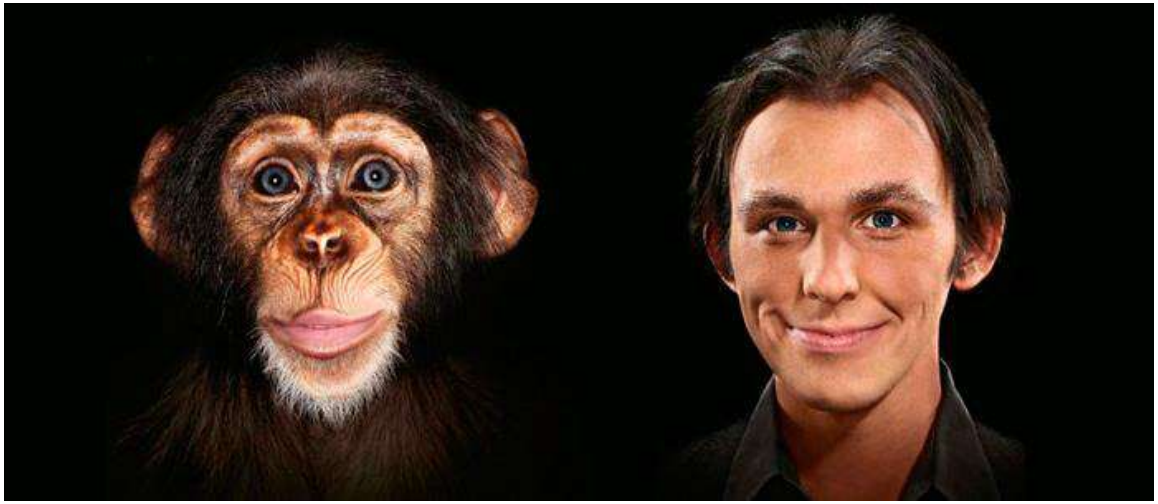
How many primary sensory neurons are within the CNS?

- 2 millions
- 10 millions
- No one
- 40 millions

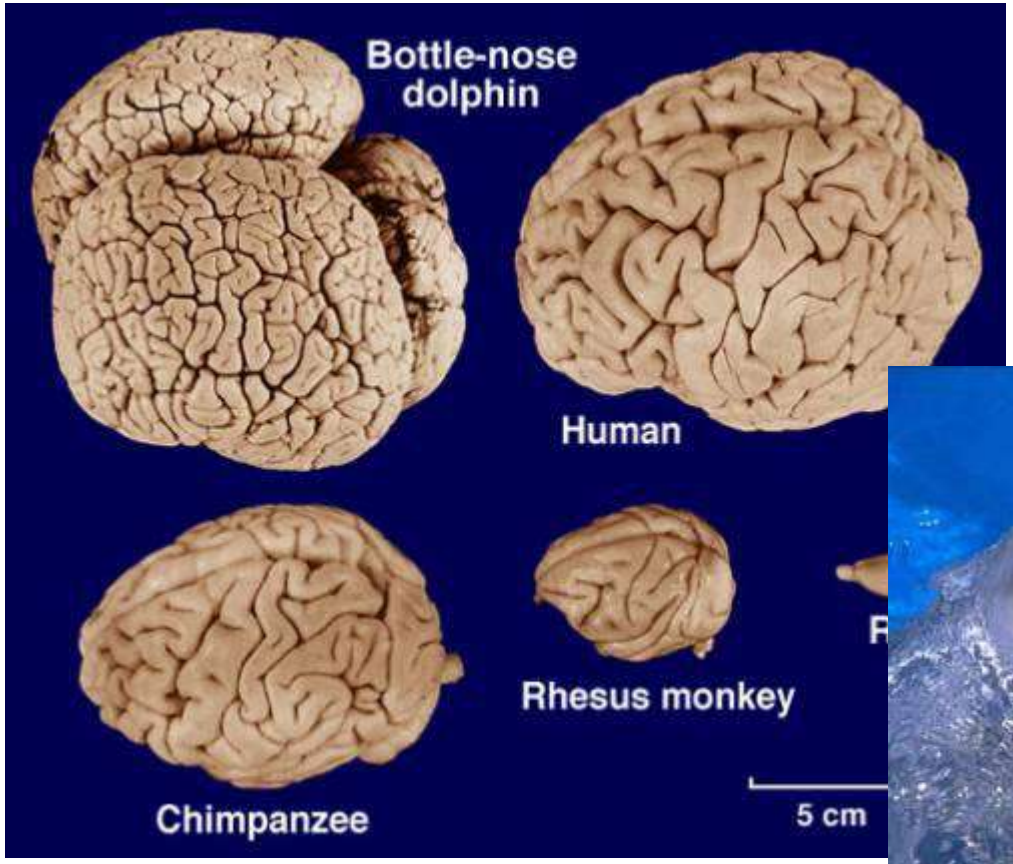


Characteristics of human brain





- Larger area (sulcuses + gyruses)
- More connection between different parts of the brain
- Great frontal lobe allow to think abstractly and logically
- 370g
- 1350g



Human use around 800-1000 words

Vocabulary of the dolphins – 1012 and over 14000 signals