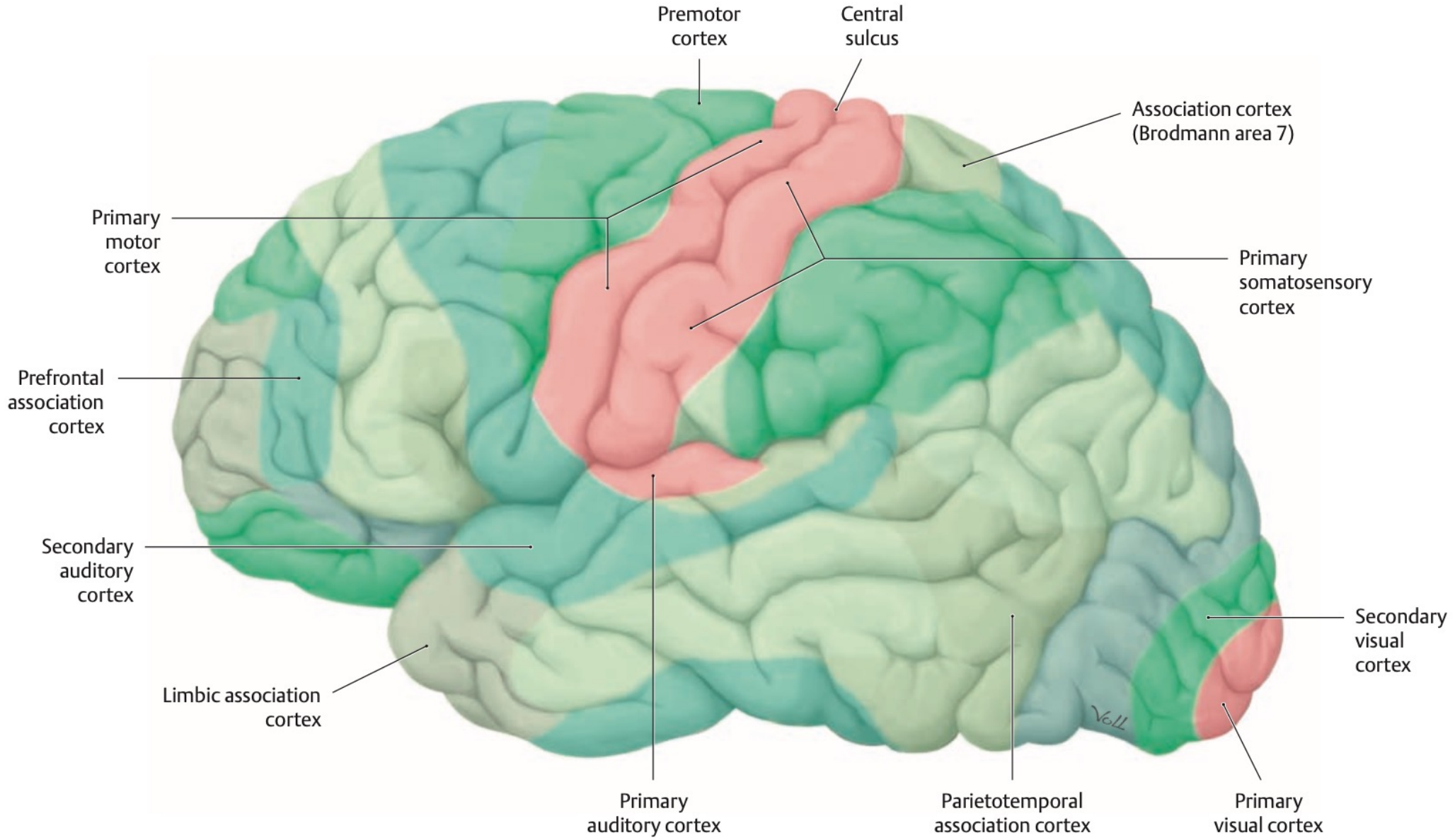
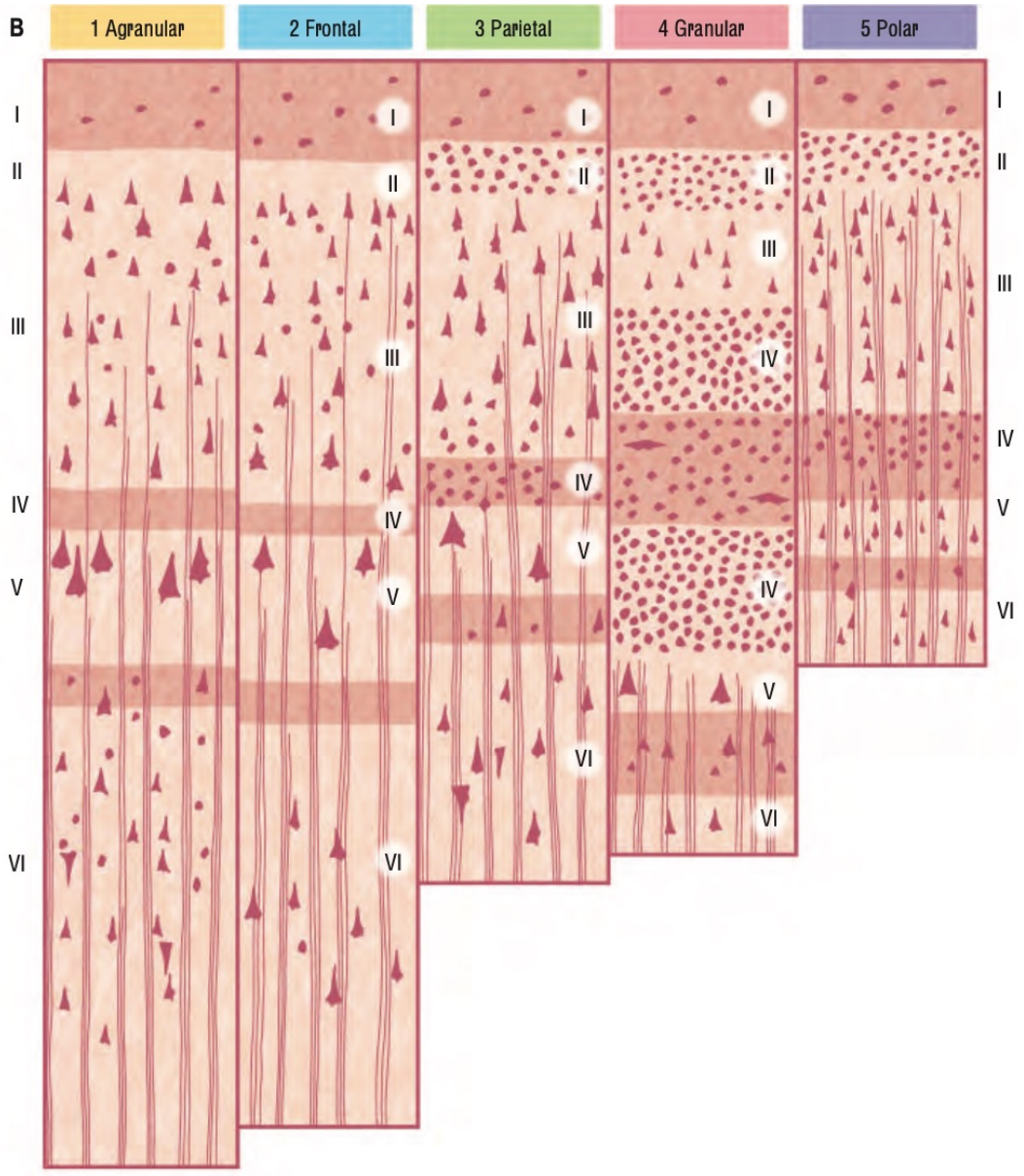
# Neuroanatomy – functional systems

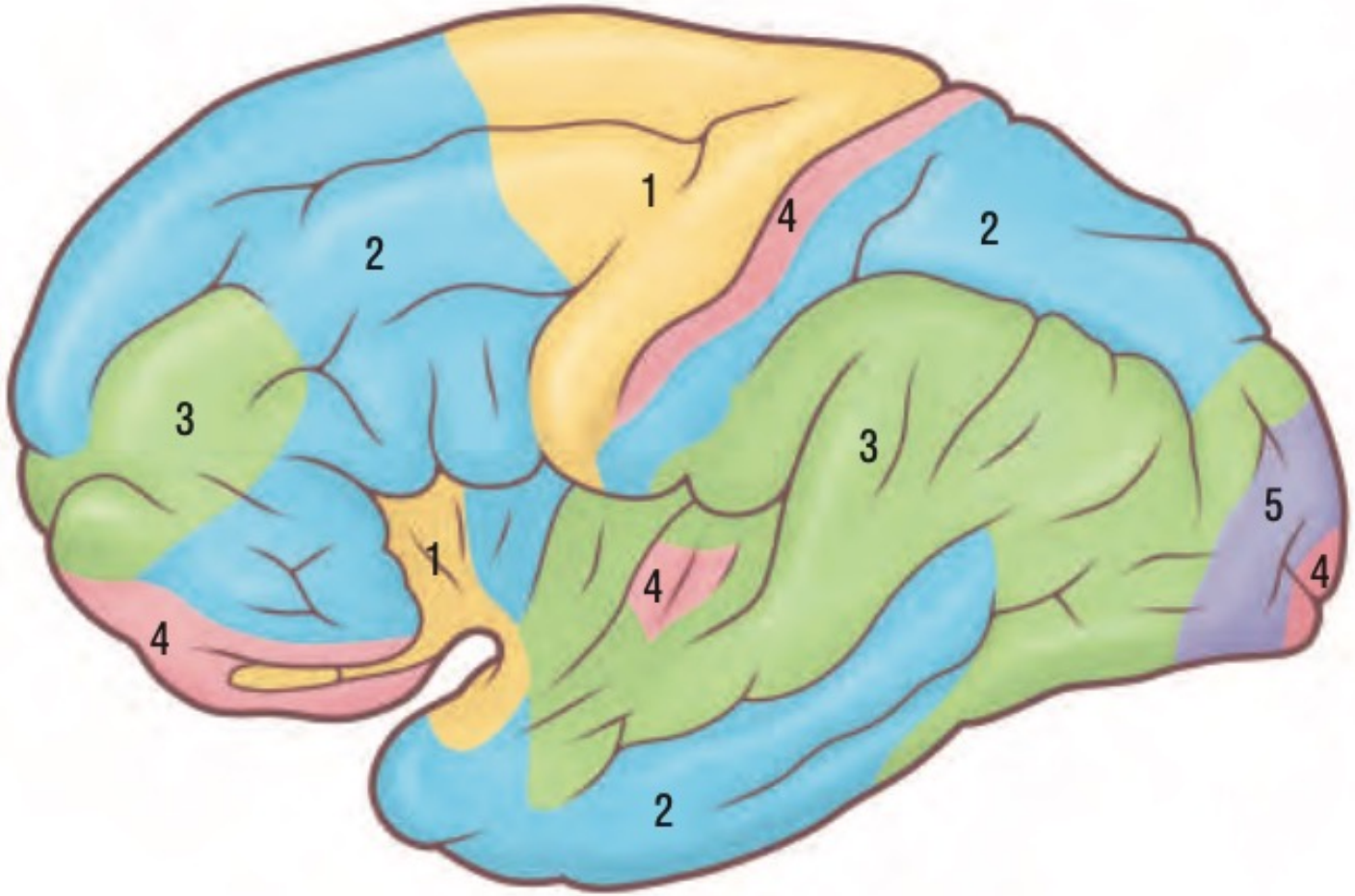


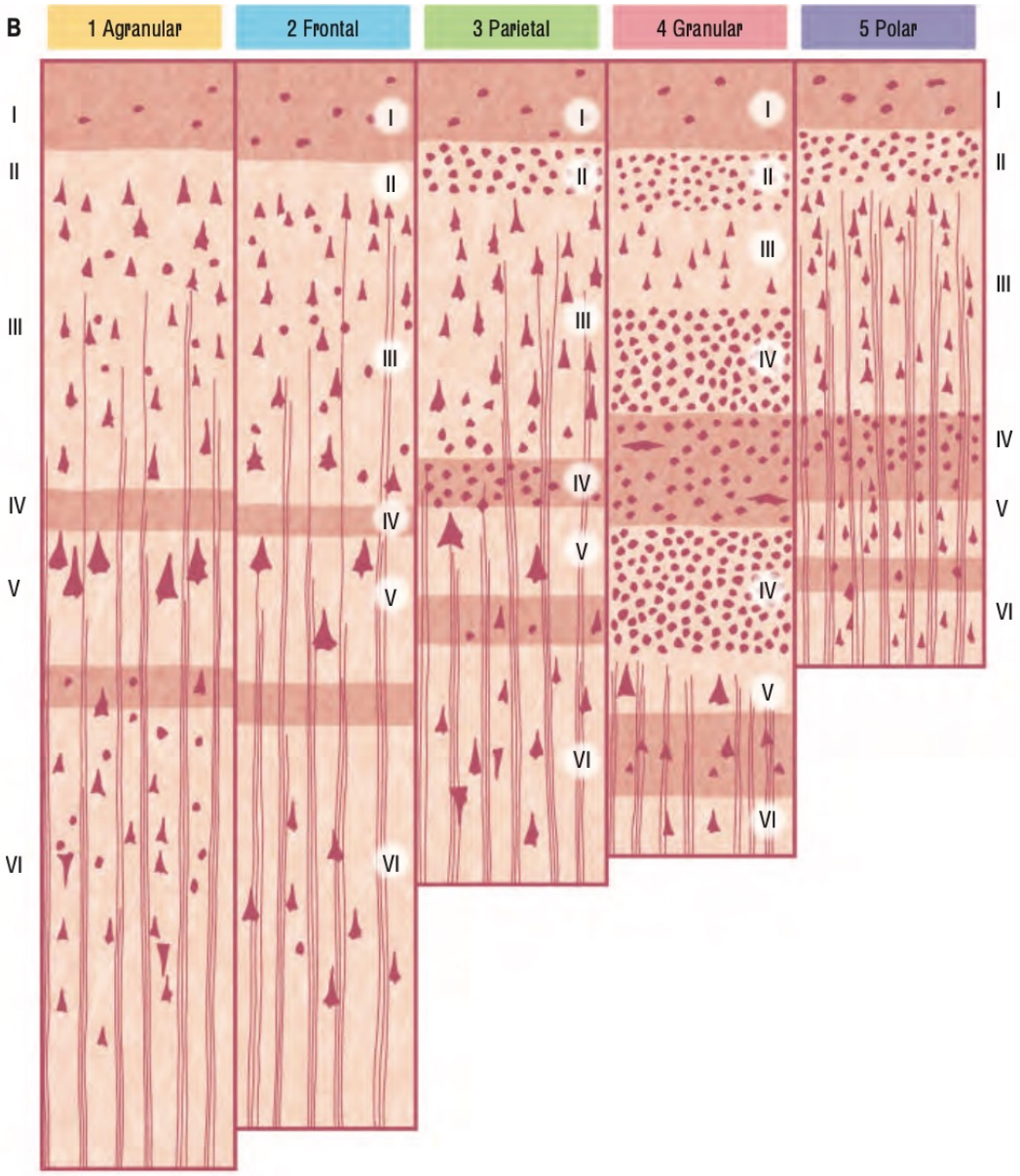
# Telencefalon – from last lecture

- **Homotypical cortex**
  - *All layers symmetric*
- **Heterotypical cortex**
  - *Some  layers augmented, other reduced*
- **Agranulary cortex**
  - *motor*
  - *Augmented layers III. + V.*
  - *Domination of pyramidal cells*
  - *Reduction of stellar neurons*
- **Granulary cortex**
  - *sensoric*
  - *Augmented II. +  IV.*
  - *Overwhelming stellar neurons*



# Architecture differences

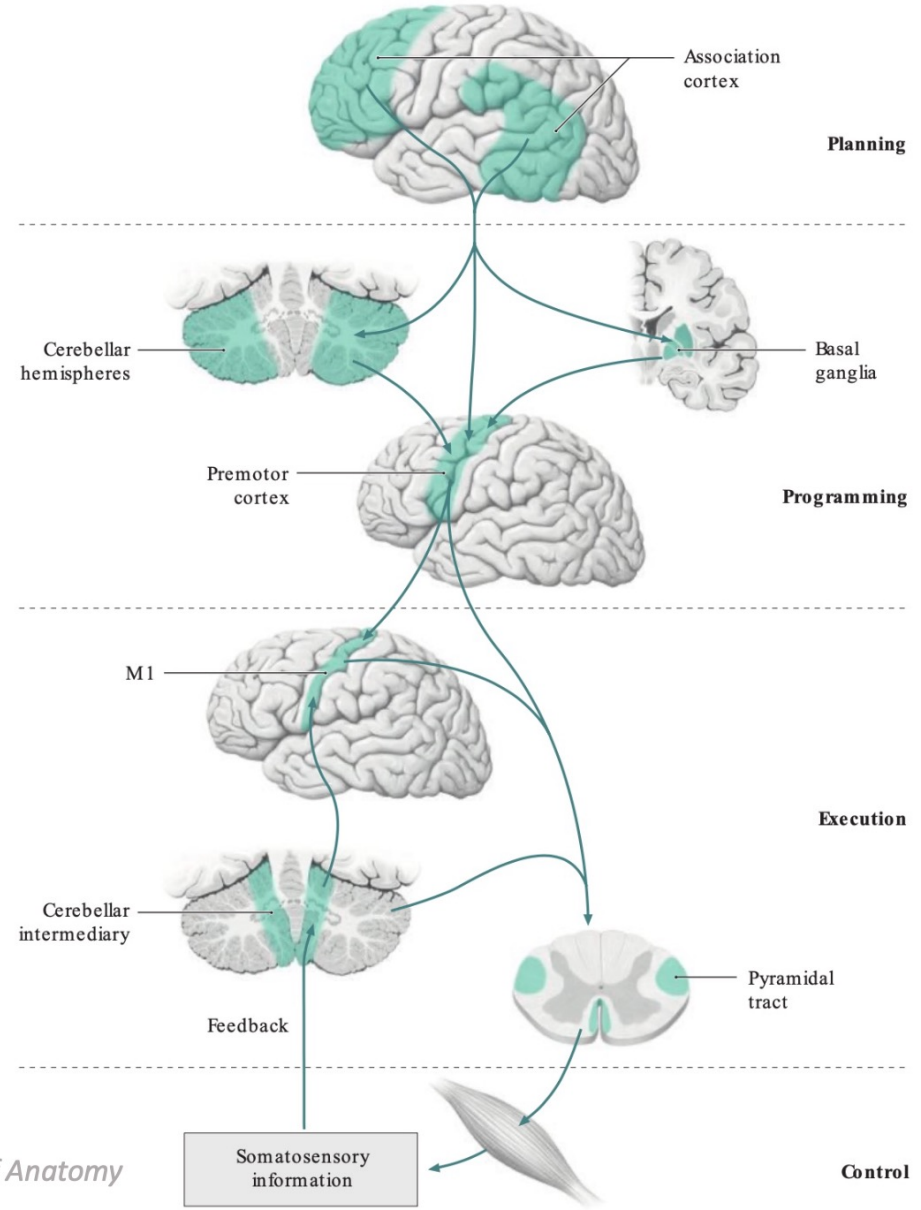


# Motion

- Planning
- Programming
- Execution
- Control

- Motor system - work
- Somatosensory system - feedback

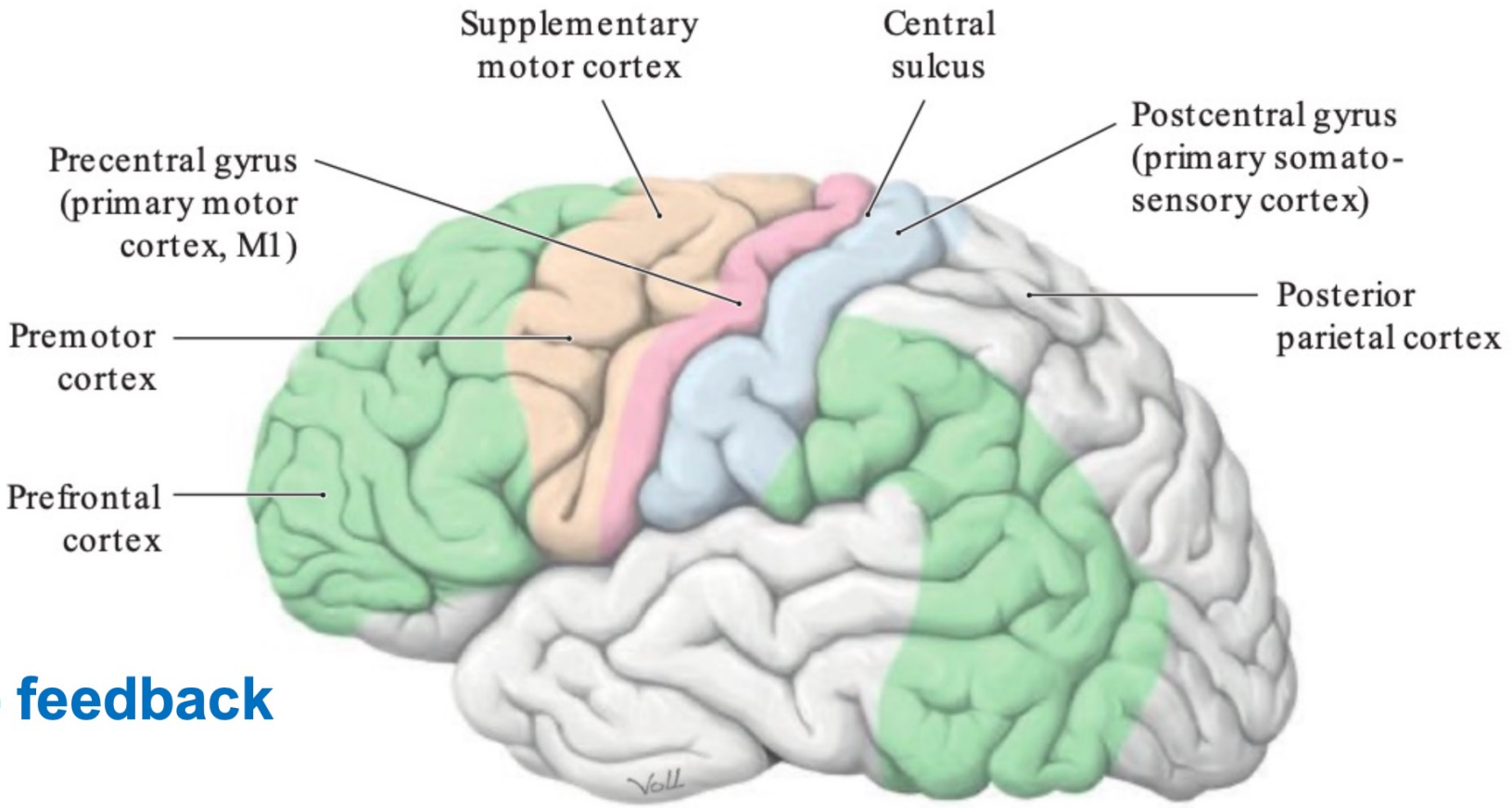


# Motion

- Planning
  - Prefrontal cortex
  - Association cortex
- Programming
- Execution
- Control

- Motor system - work
- Somatosensory system - feedback

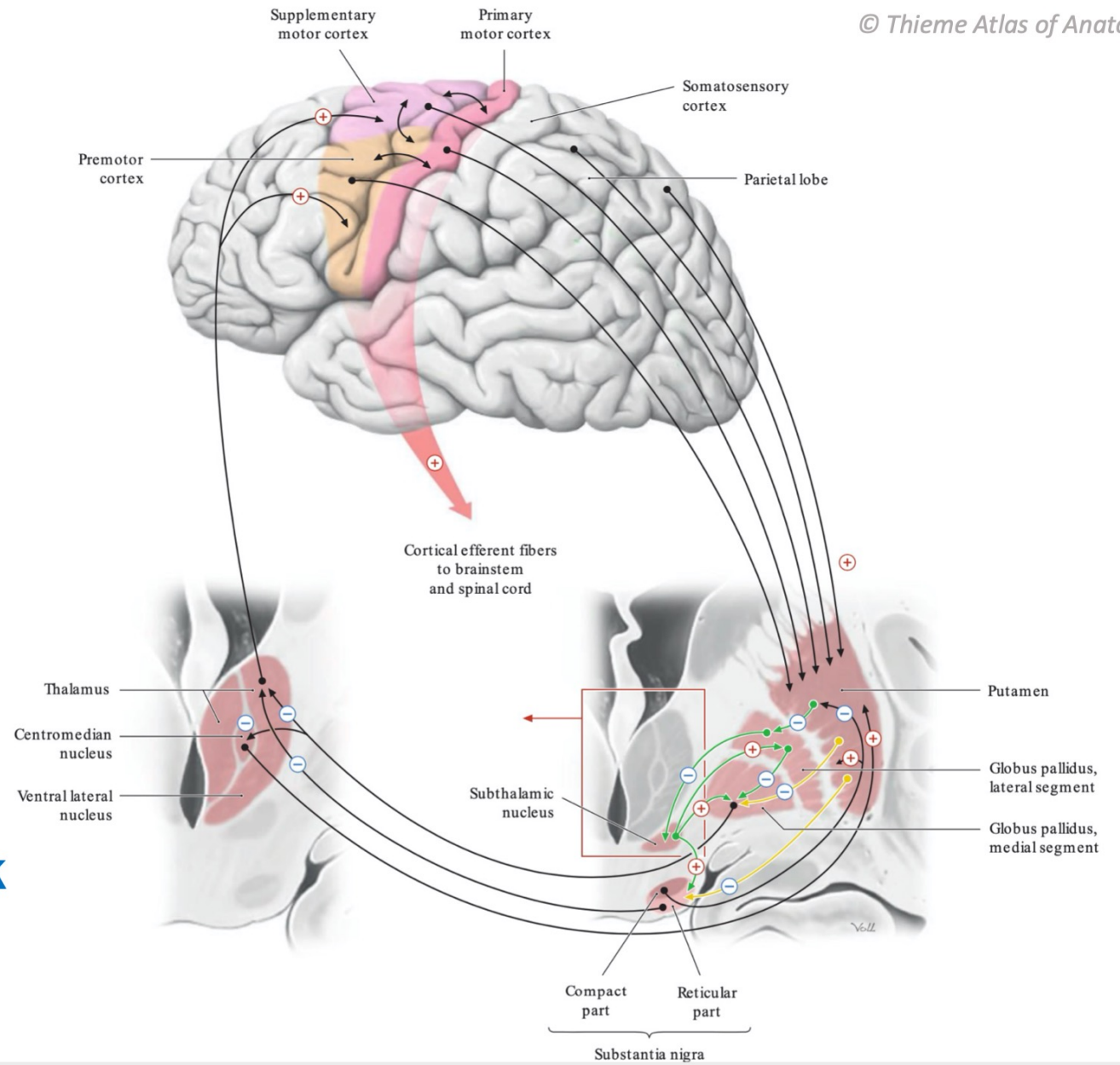




# Motion

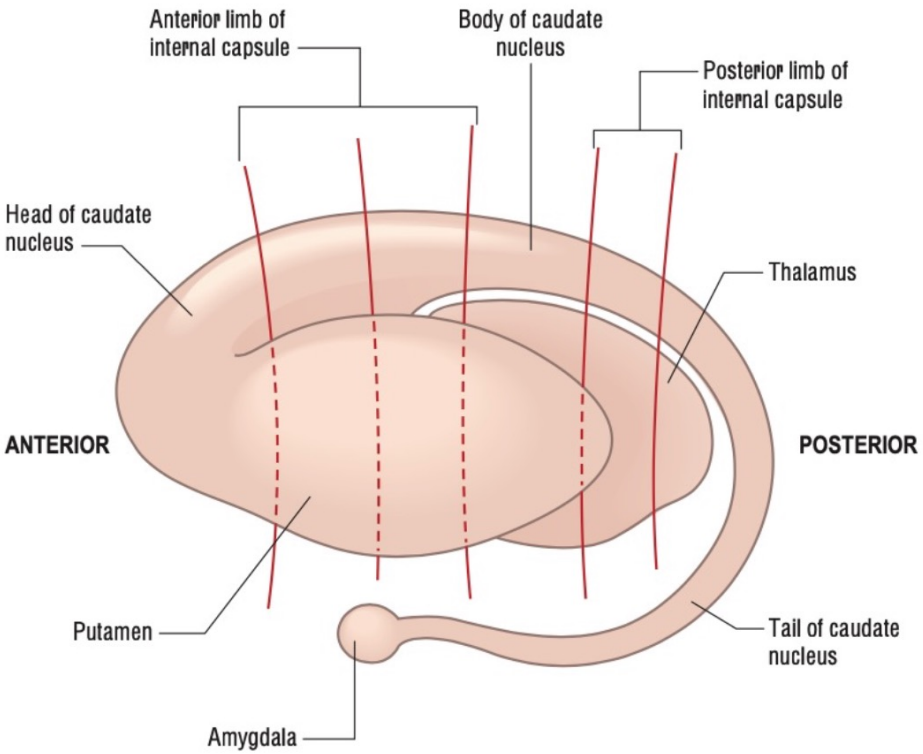
- Planning
  - Prefrontal cortex
  - Association cortex
- Programming
  - Basal ganglia
  - Thalamus
  - Cerebellum
- Execution
- Control

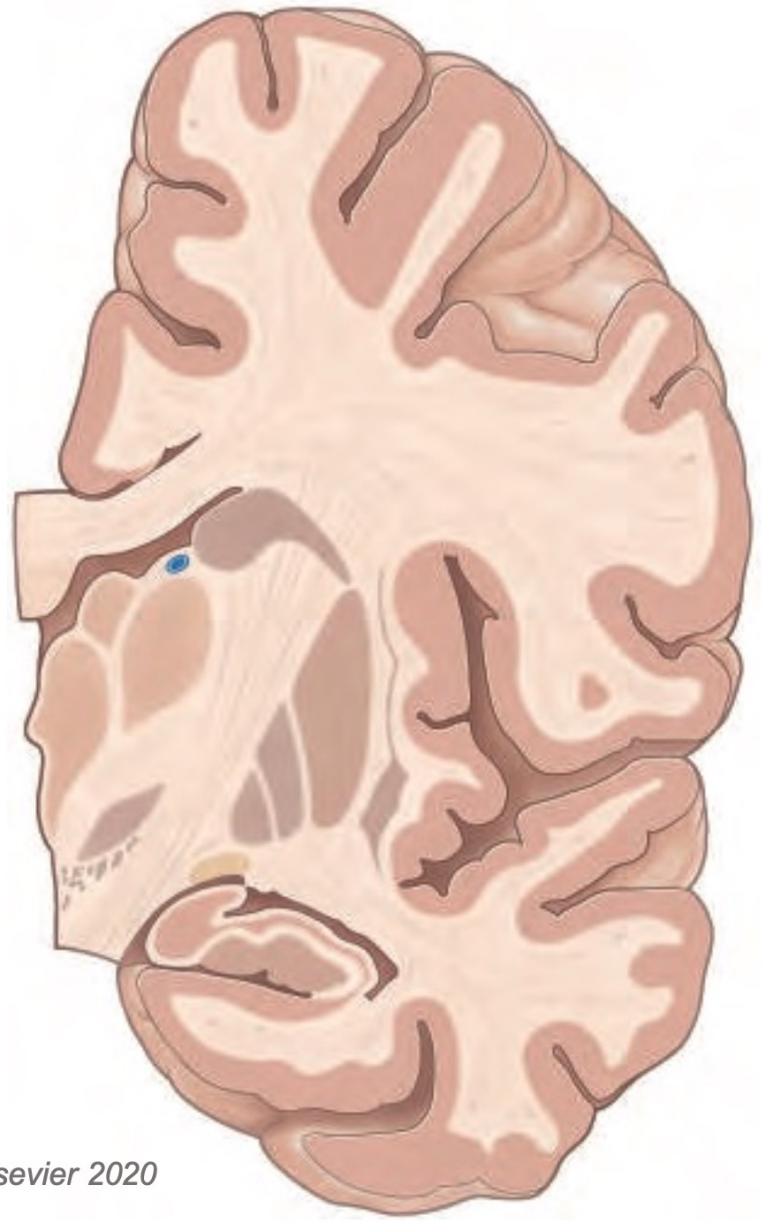
- Motor system - work
- Somatosensory system - feedback



# Basal ganglia

- Subcortical nuclei
- Corpus striatum
  - Nucleus caudatus
  - Putamen
  - Globus pallidus
- Claustrum
- Amygdaloid complex
- Associated centres
  - Diencephalon
  - Mezencephalon

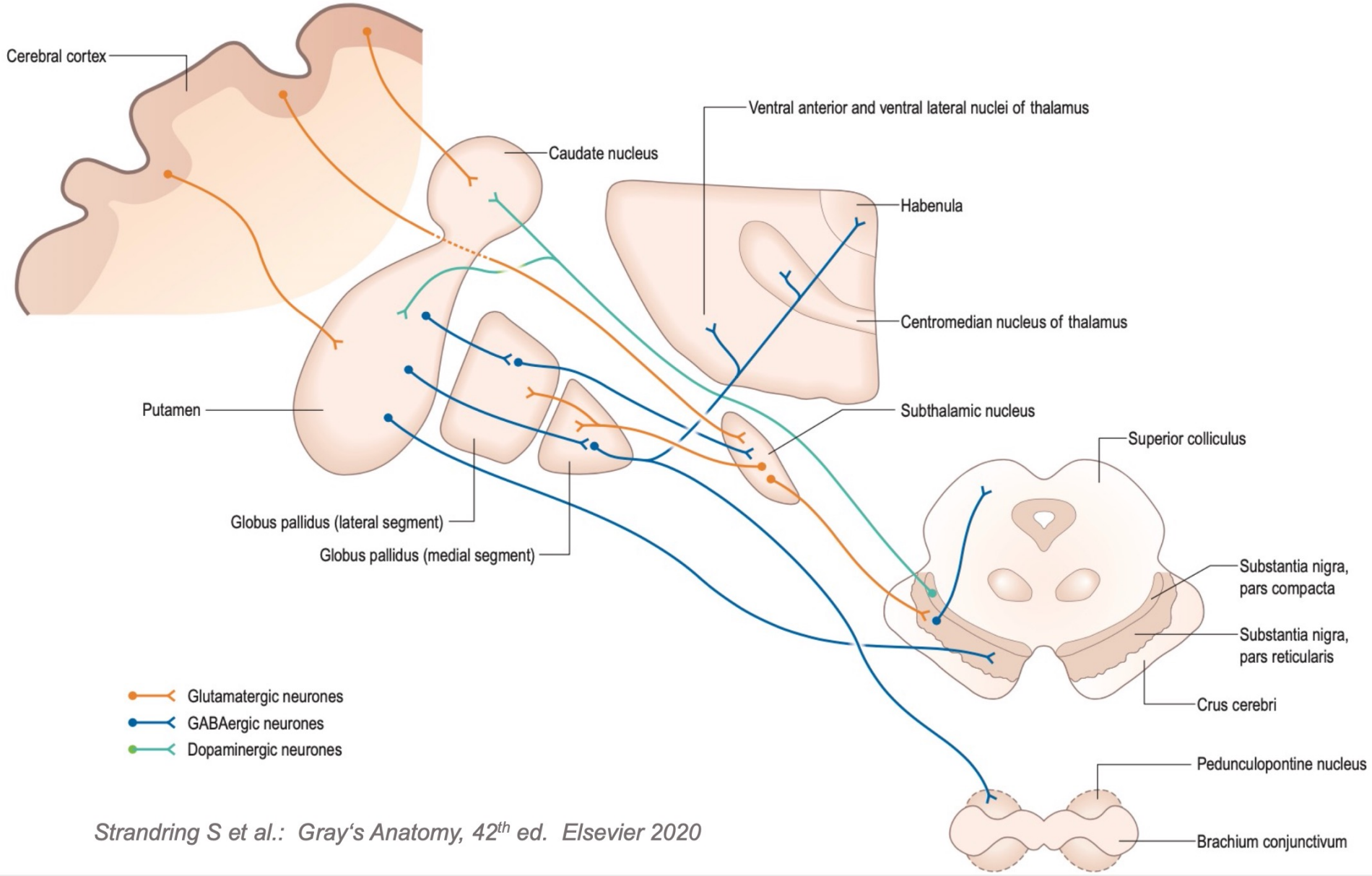


- Neostriatum = striatum = nucleus caudatus + putamen
- Paleostriatum = globus pallidus = pallidum

*Strandring S et al.: Gray's Anatomy, 42th ed. Elsevier 2020*

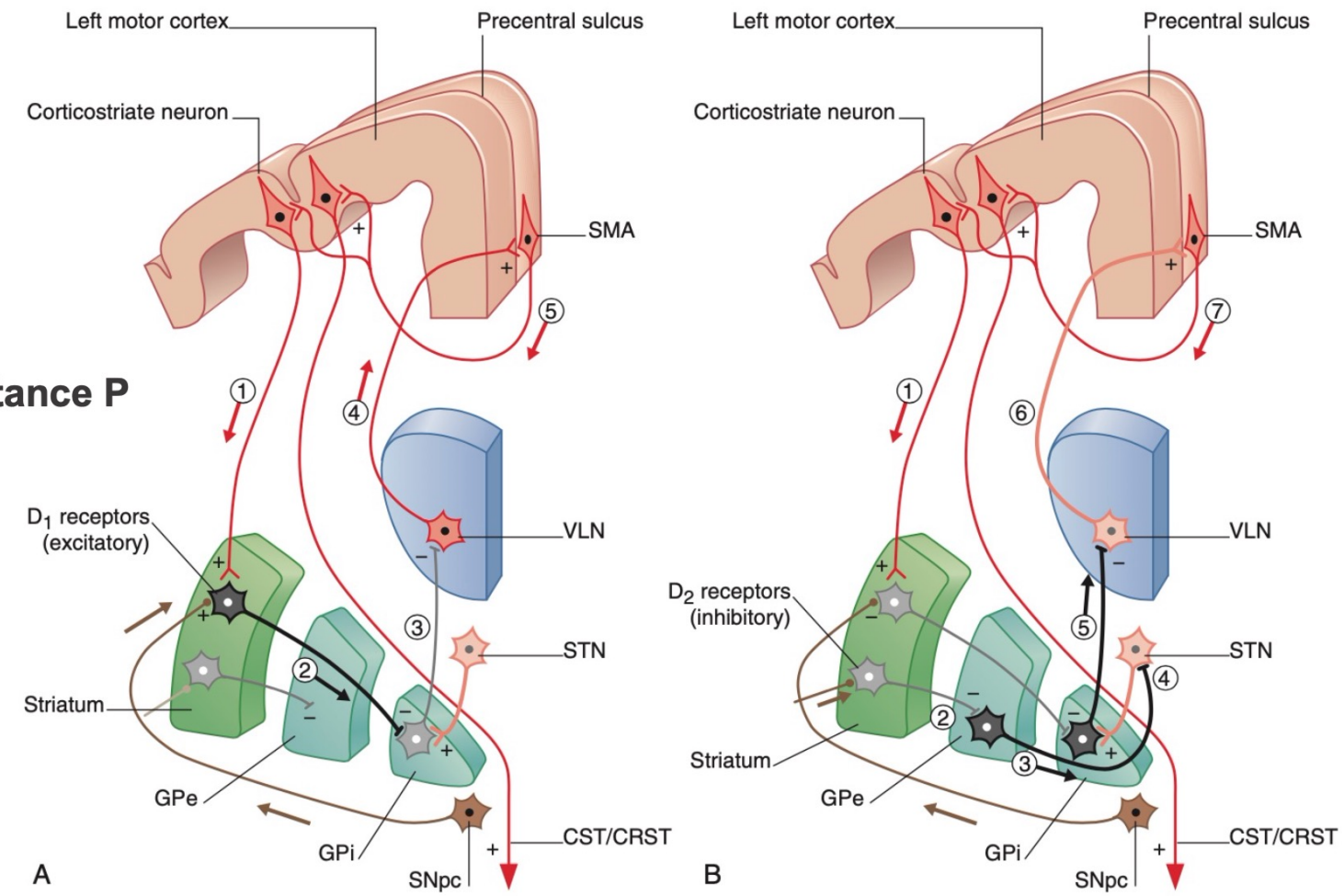
# Connections of striatum




*Strandring S et al.: Gray's Anatomy, 42th ed. Elsevier 2020*

# Globus pallidus = pallidum

- Paleostriatum = pallidum
  - 5% of cells in comparison to striatum
  - Striatopallidal connections
- Direct pathway
  - striatum
  - Globus pallidus pars medialis
    - (pallidum internum)
  - Substantia nigra pars reticulata
  - Dopamin (D1 receptor), dynorphin, substance P
- Indirect pathway
  - striatum - nc. subthalamicus
  - Globus pallidus pars lateralis
    - (pallidum externum)
  - Substantia nigra pars reticulata
  - Dopamin (D2 receptor), enkefalin
- Hyper-direct pathway
  - Frontal lobe
  - Nc. subthalamicus

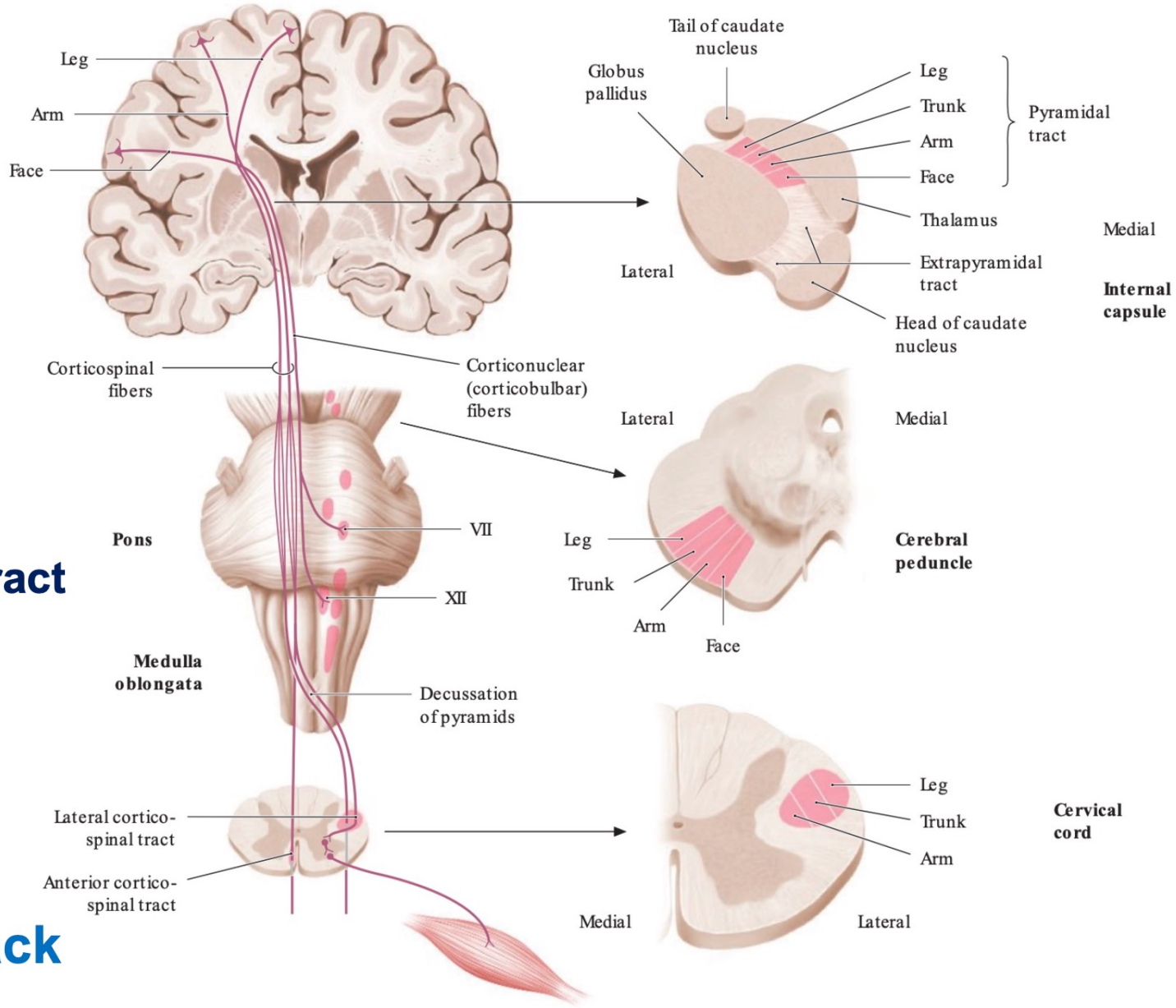



*Strandring S et al.: Gray's Anatomy, 42th ed. Elsevier 2020*

# Motion

- **Planning**
  - **Prefrontal cortex**
  - **Association cortex**
- **Programming**
  - **Basal ganglia**
  - **Thalamus**
  - **Cerebellum**
- **Execution**
  - **Corticospinal and corticonuclear tract**
  - **Extrapyramidal tracts**
- **Control**

- **Motor system - work**
- **Somatosensory system - feedback**



# Motion

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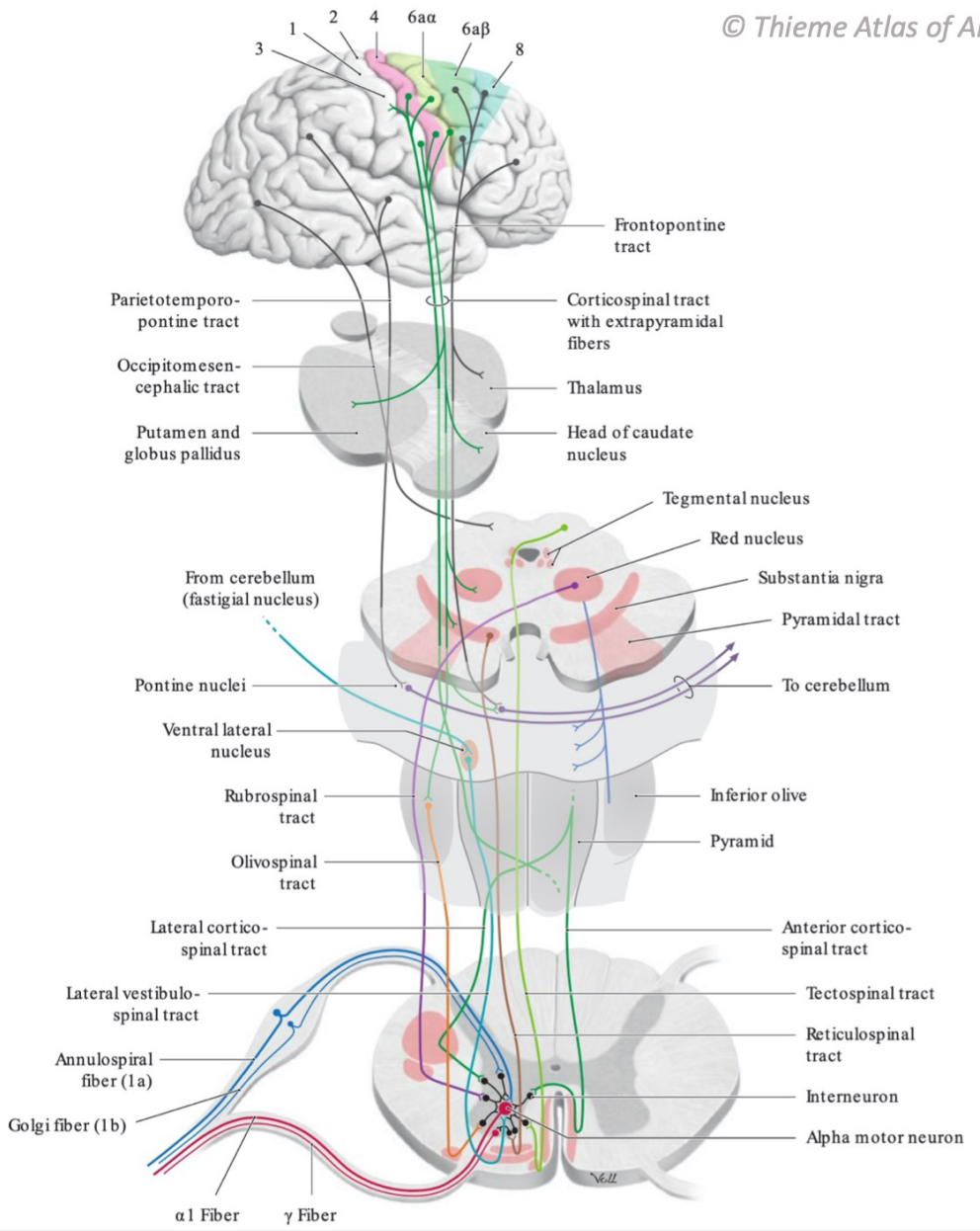
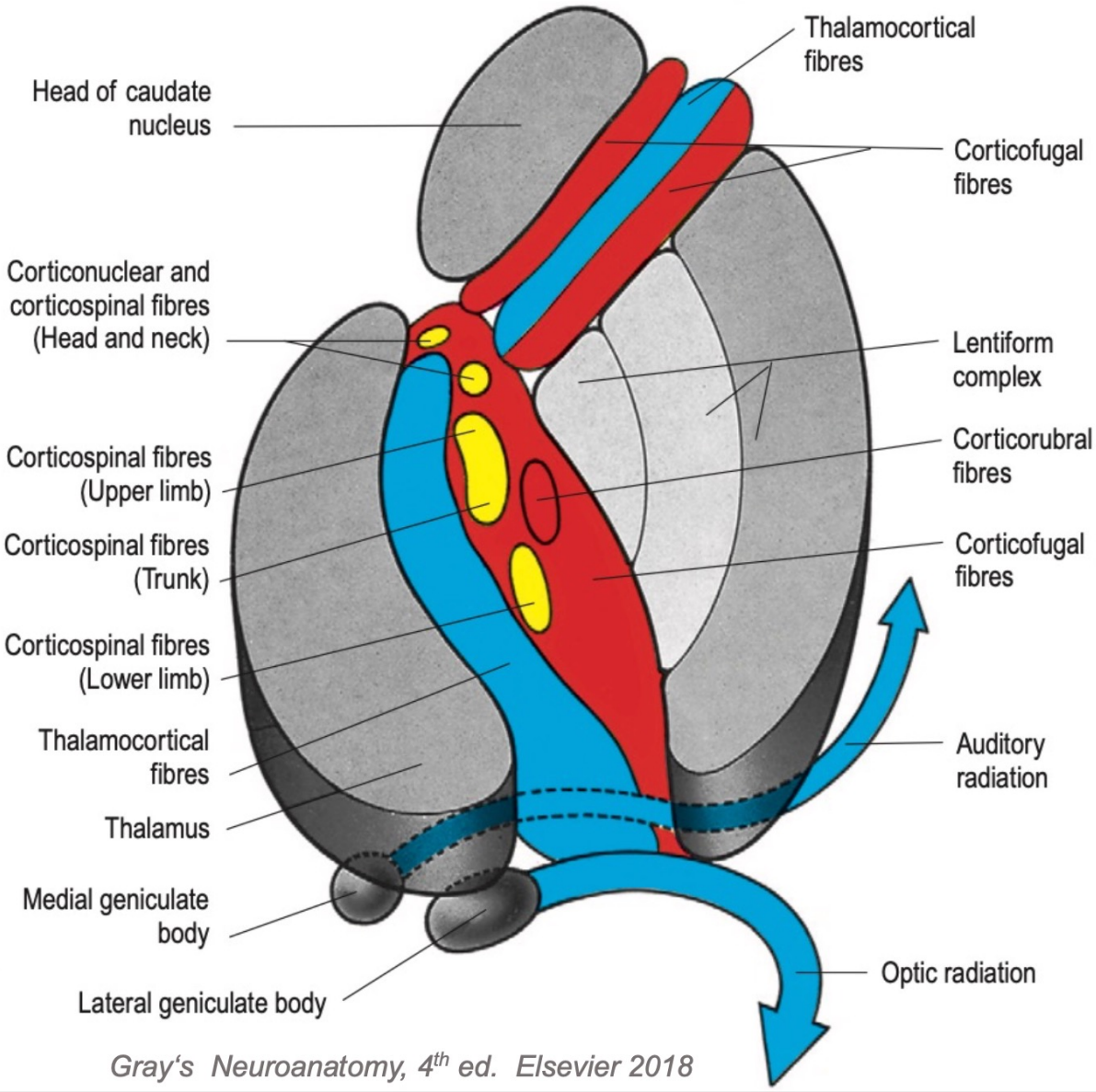


# Capsula interna

- **Motor (descending) fibers**
- **Corticonuclear tract**
- **Corticospinal tract**
  - ***Cervical***
  - ***Upper limb***
  - ***Trunk***
  - ***Lower limb***
- **Corticorubral tract**

- **Somatosensory (ascending) fibers**
- **Thalamocortical tracts**

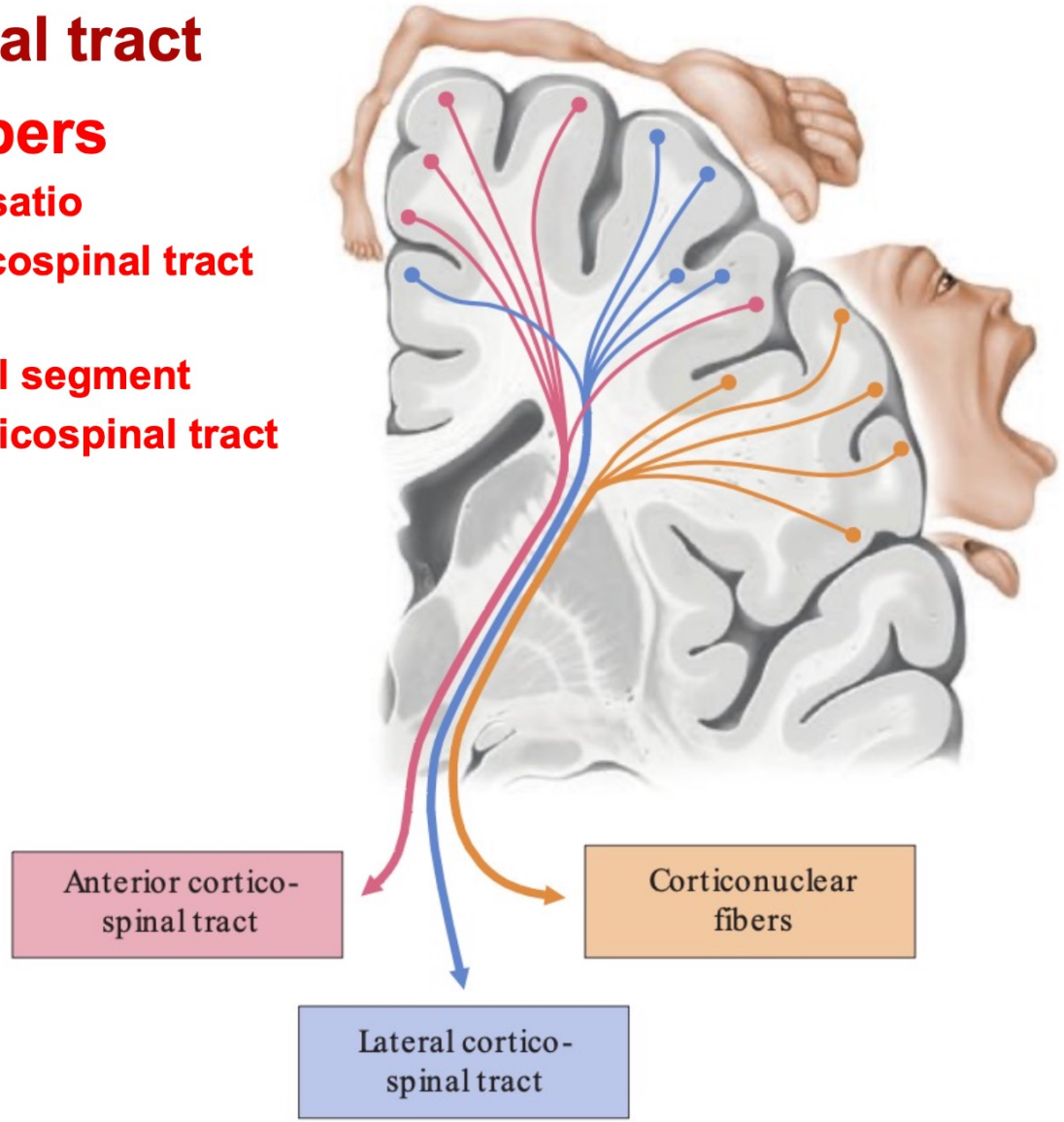


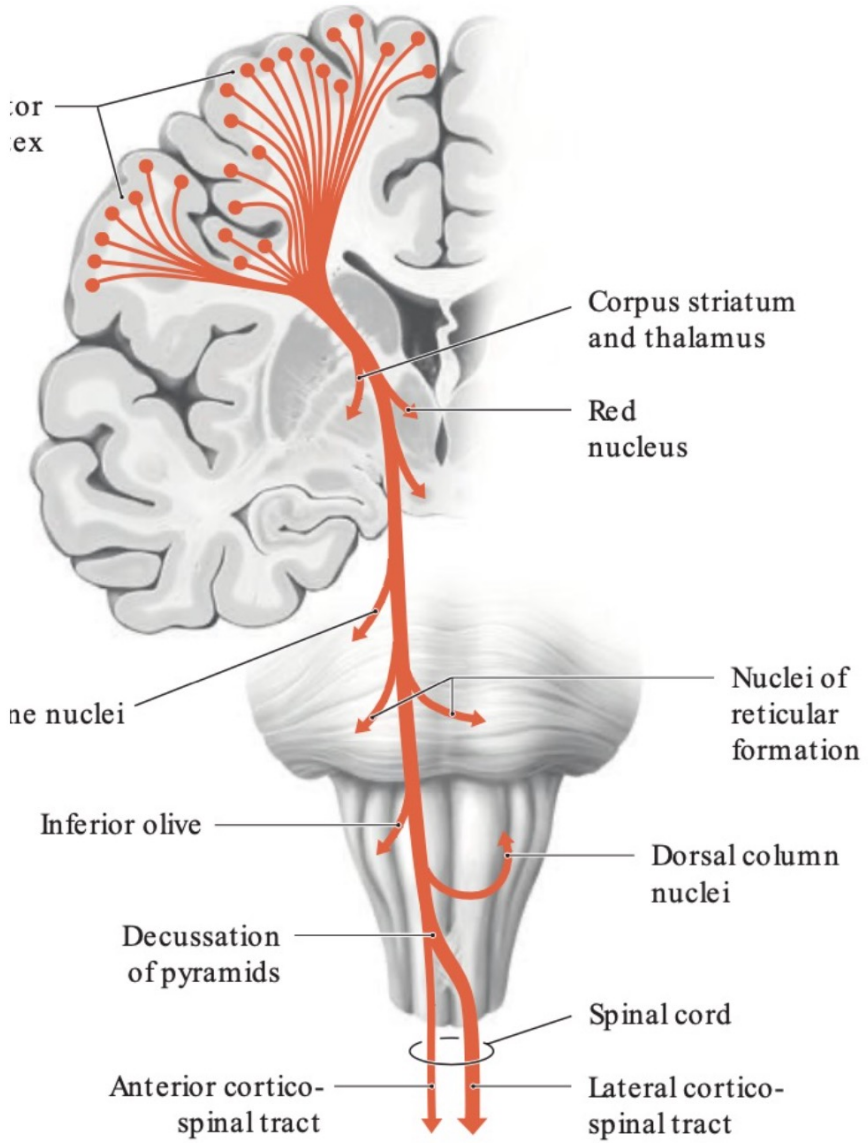

*Gray's Neuroanatomy, 4th ed. Elsevier 2018*

# Motor cortex

- **Corticospinal tract**
- **Crossing fibers**
  - **80% at decusatio**
  - **Lateral corticospinal tract**
  - **20% at spinal segment**
  - **Anterior corticospinal tract**

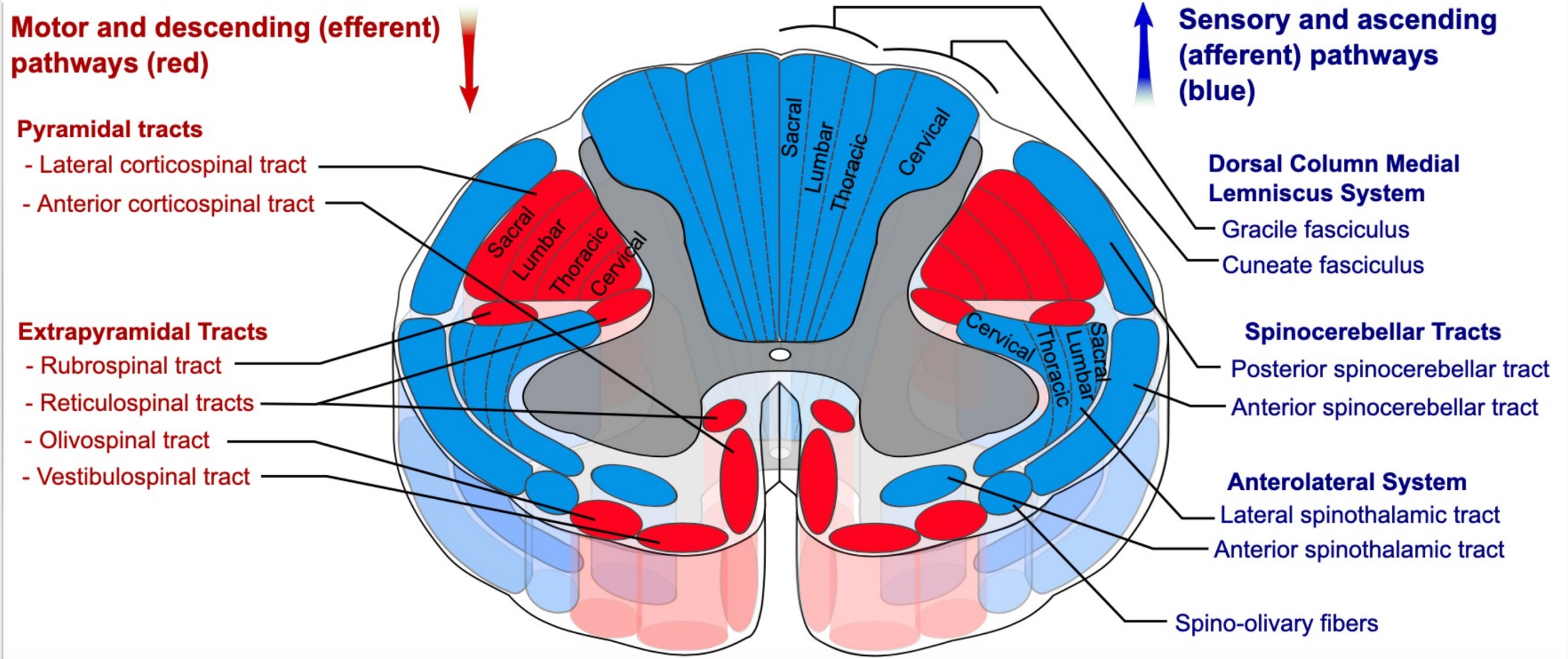




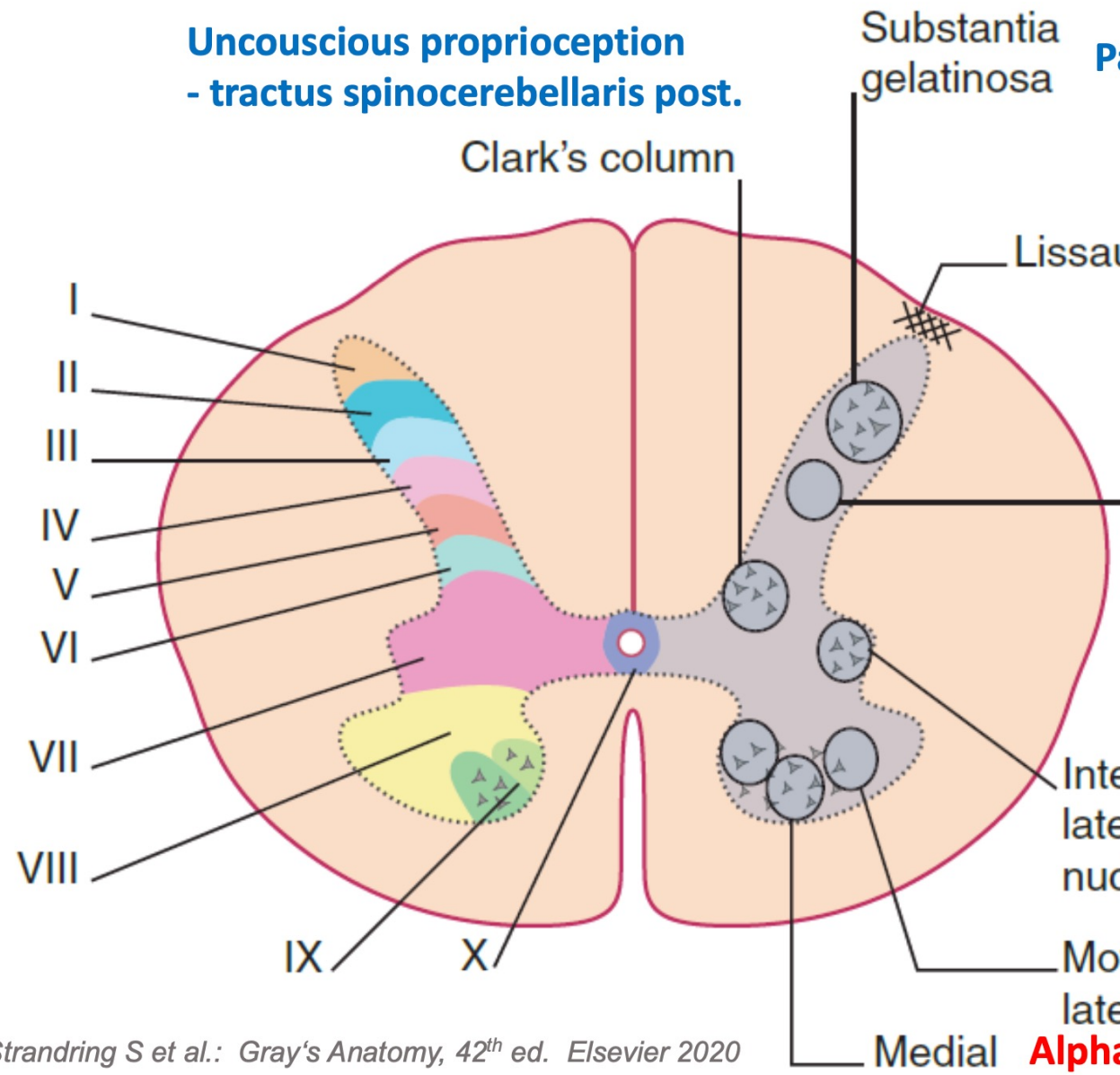



# Tractus medullae spinalis

Wikipedia



# Nuclei medullae spinalis

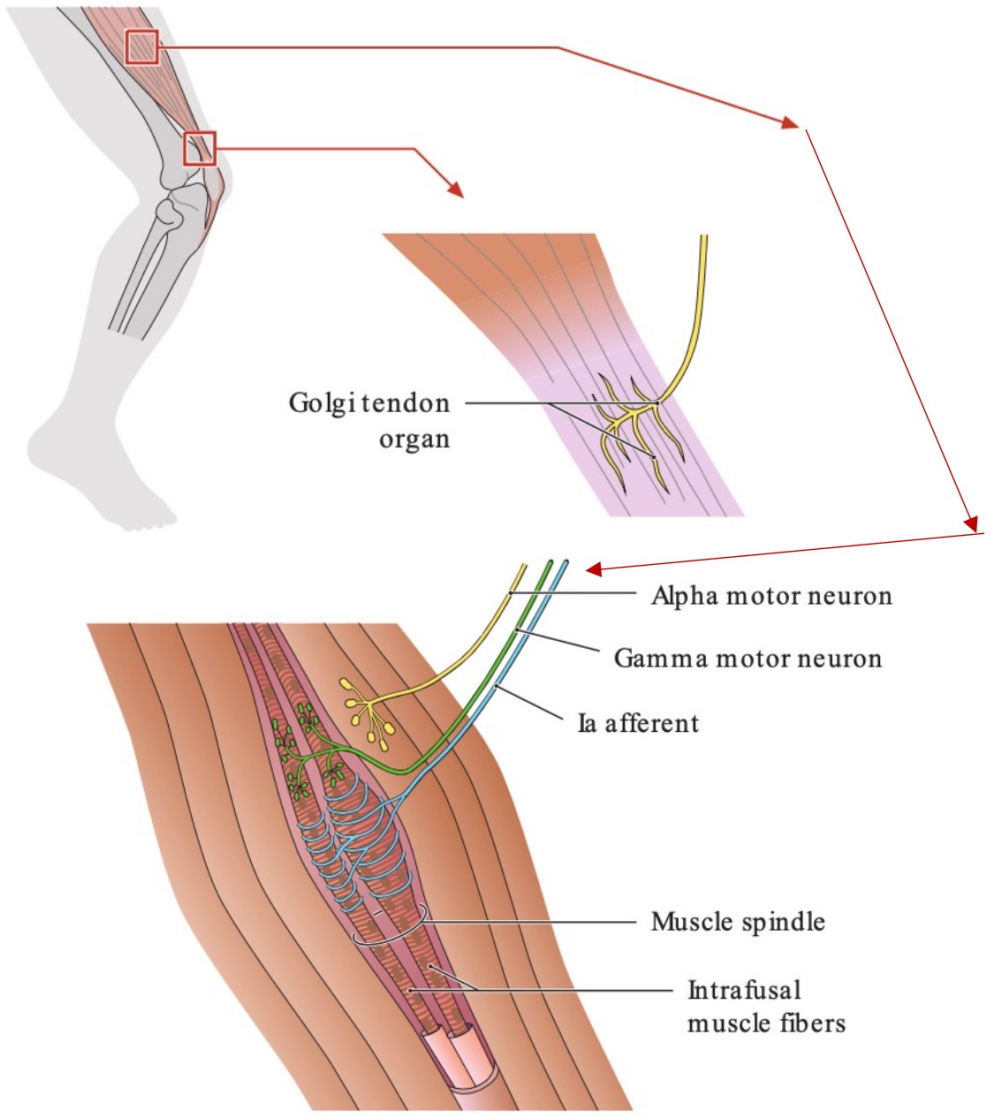



*Strandring S et al.: Gray's Anatomy, 42th ed. Elsevier 2020*

# Motion sensation

- **Proprioception conscious**
  - ***Funniculus posterior – fasciculus gracilis, cuneatus***
  - ***Relayed through  nc. gracilis et cuneatus***
  - ***And by the way by cuneo/gracillo cerebellar tract***
  - ***(from nc. cuneatus/gracilis accesorius)***
  - *Space  and position information*
  - *Tension information*
  - *How the motion was executed*

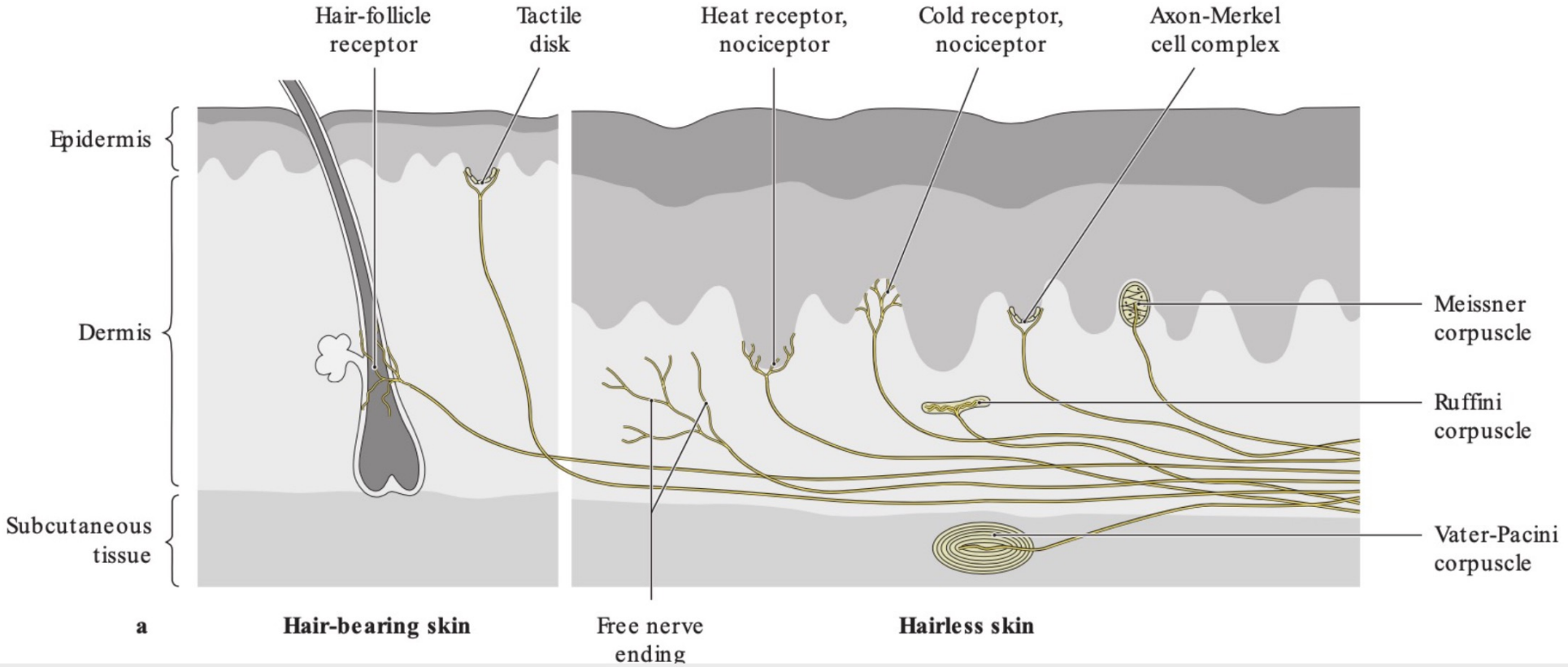
- **Proprioception uncousnious**
  - *Spinocerebellar tract*
  - *(head – n. trigeminus)*
  - *Used for an information of cyclic motions*
  - *Clim stairs*
  - *Ride a bicycle*



# Skin sensation

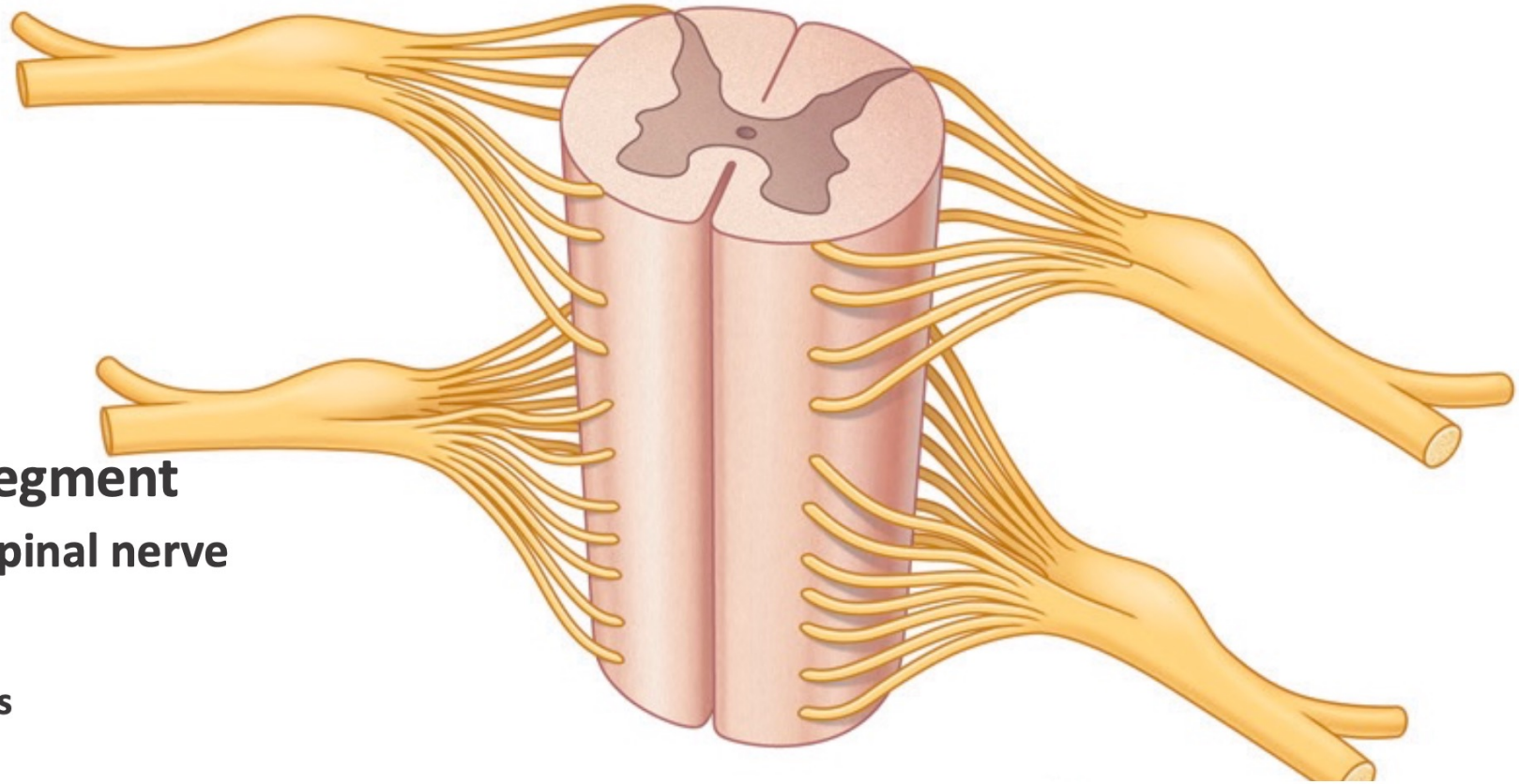
- **Fine tactile perception**
  - *Funniculus posterior – fasciculus gracilis, cuneatus - detailed skin perception*
- **Crude perception**
  - *Spinothalamic lateral tract - wide projection in spinal cord*
- **Pain and heat perception - nociception**
  - *Unmyelinzed free endings - one segment spinal cord projection*





# Nervi spinales

- radix posterior - posterior root
  - Soma in ganglion spinale ( neural crest cell)
  - Senzitive filaments
  - centripetal
- radix anterior - anterior root
  - Soma in anterior horn
  - Motoric filaments
  - centifugal
- segmentum spinalis - spinal segment
  - rootlets - roots - forming one spinal nerve
- Rami nervi spinalis
  - Ramus posterior - intrinsic mm, et cutis
  - Ramus anterior other mm, and skin
  - Rami meningeales - recurrent small branches

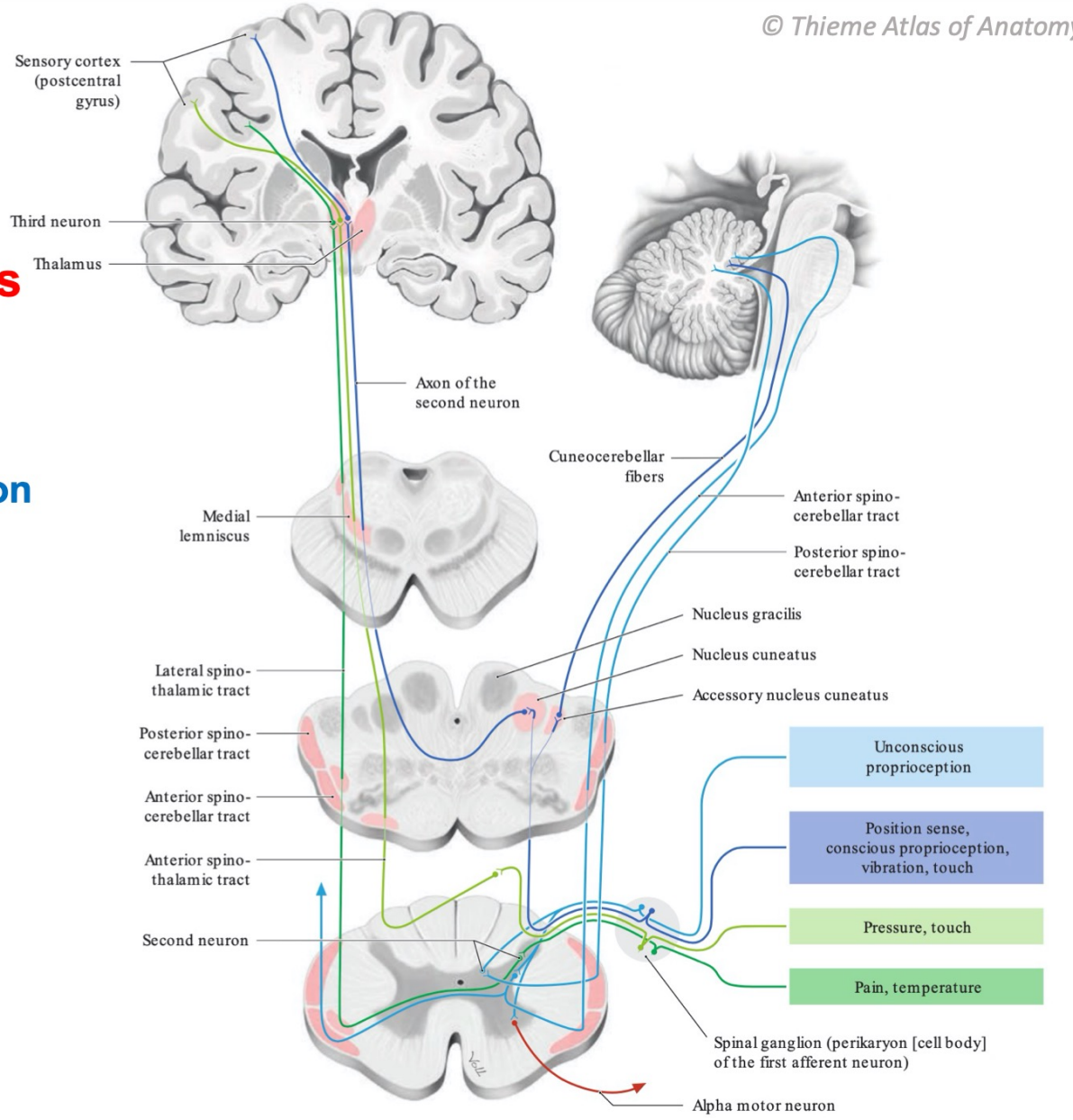


*Strandring S et al.: Gray's Anatomy, 42th ed. Elsevier 2020*

# Tractus spinothalamicus anterior

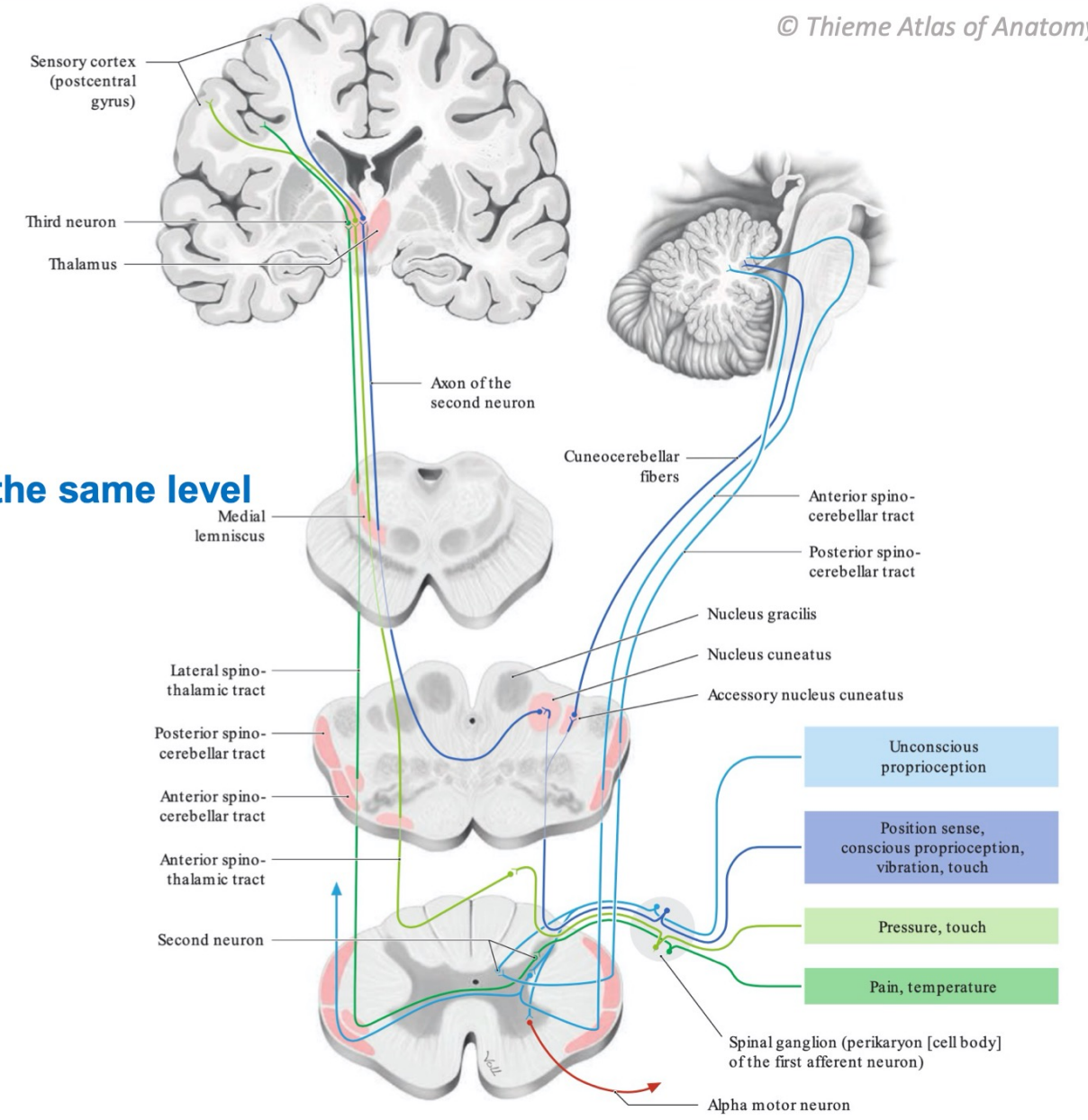
- 1st neuron
  - *Pseudounipolar in spinal ganglion*
  - Crude touch
  - Receptors in hair follicles and skin receptors
- 2nd neuron
  - in posterior horn – nucleus proprius
    - -15. to +2. segment entry os pseudounipolar neuron
  - Spinal lemniscus
  - Ventral posterolateral nucleus of thalamus
- 3rd neuron
  - projects to postcentral gyrus





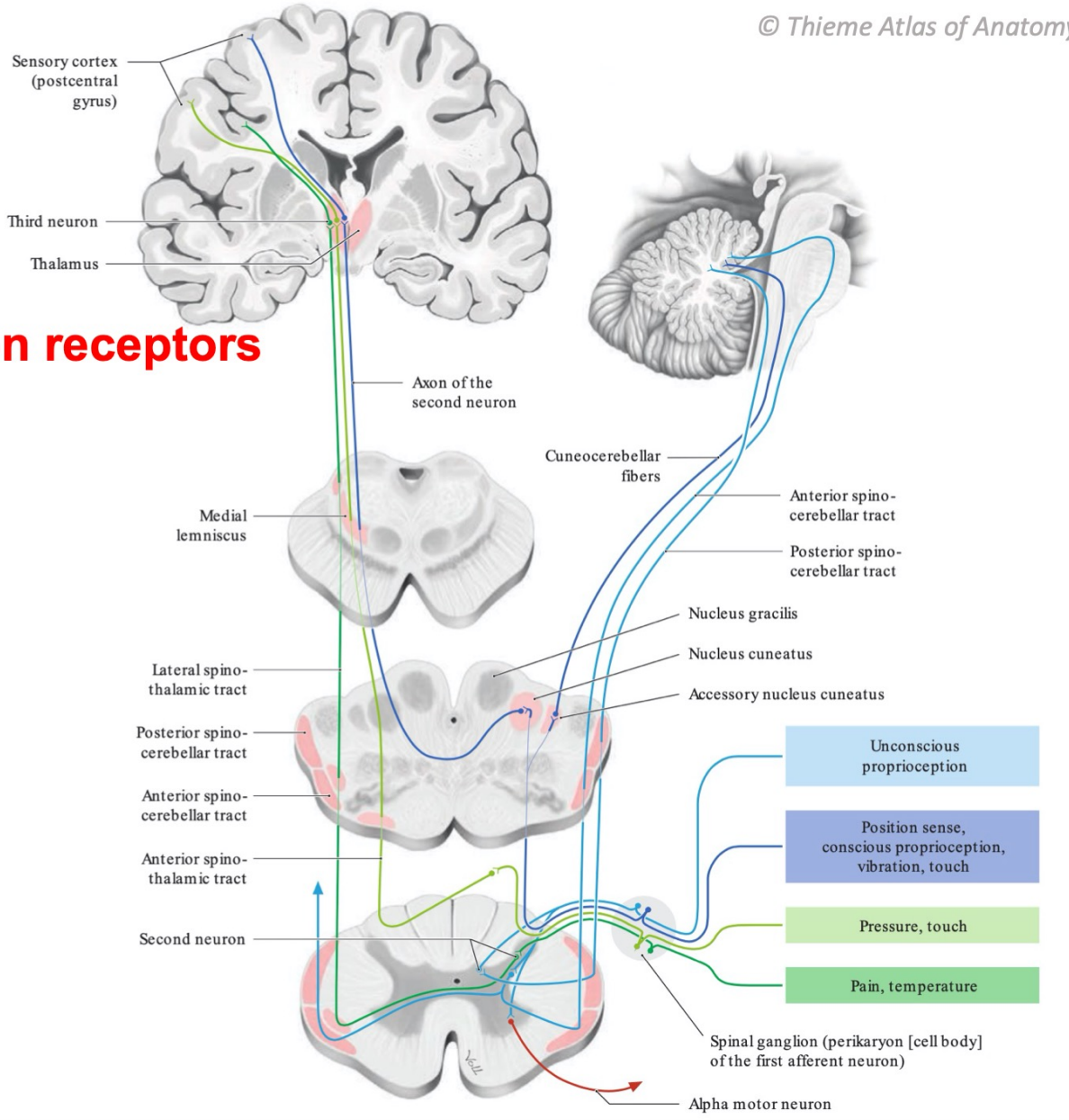
# Tractus spinothalamicus lateralis

- 1st neuron
  - *Pseudounipolar in spinal ganglion*
  - Pain and heat
  - Free nerve endings
- 2nd neuron
  - substantia gelatinosa
    - Axon crosses midline in anterior commissure at the same level
  - Spinal lemniscus
  - Ventral posterolateral nucleus of thalamus
- 3rd neuron
  - projects to postcentral gyrus



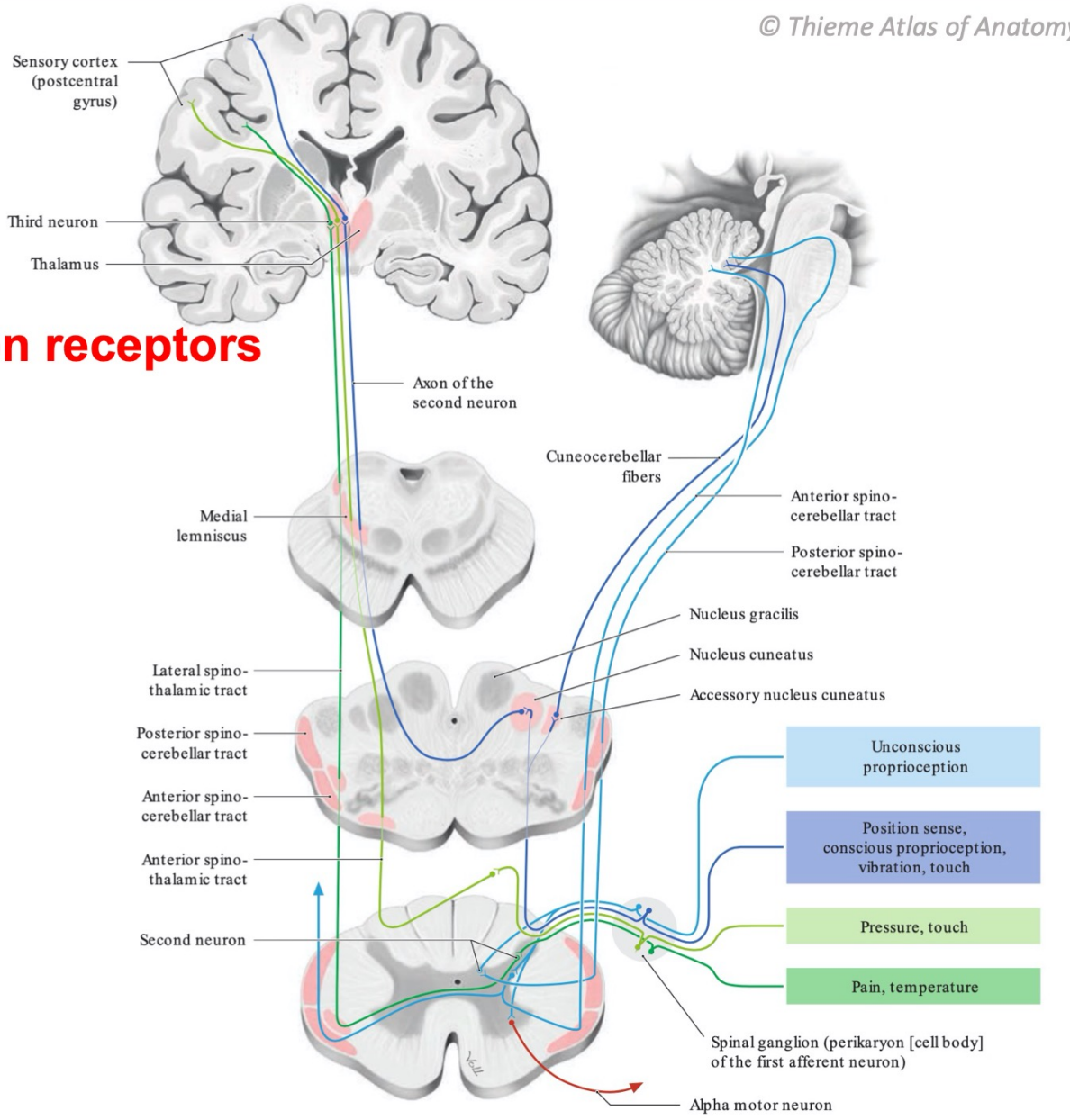
# Fasciculus gracilis

- 1st neuron
  - *Pseudounipolar in spinal ganglion*
  - Fine touch and conscious proprioception
  - lower limb
  - Vater-Paccini corpuscula, muscle and tendon receptors
- 2nd neuron
  - nucleus gracilis in medulla oblongata
    - Axon crosses midline at the level of brainstem
  - Medial lemniscus
  - Ventral posterolateral nucleus of thalamus
- 3rd neuron
  - projects to postcentral gyrus



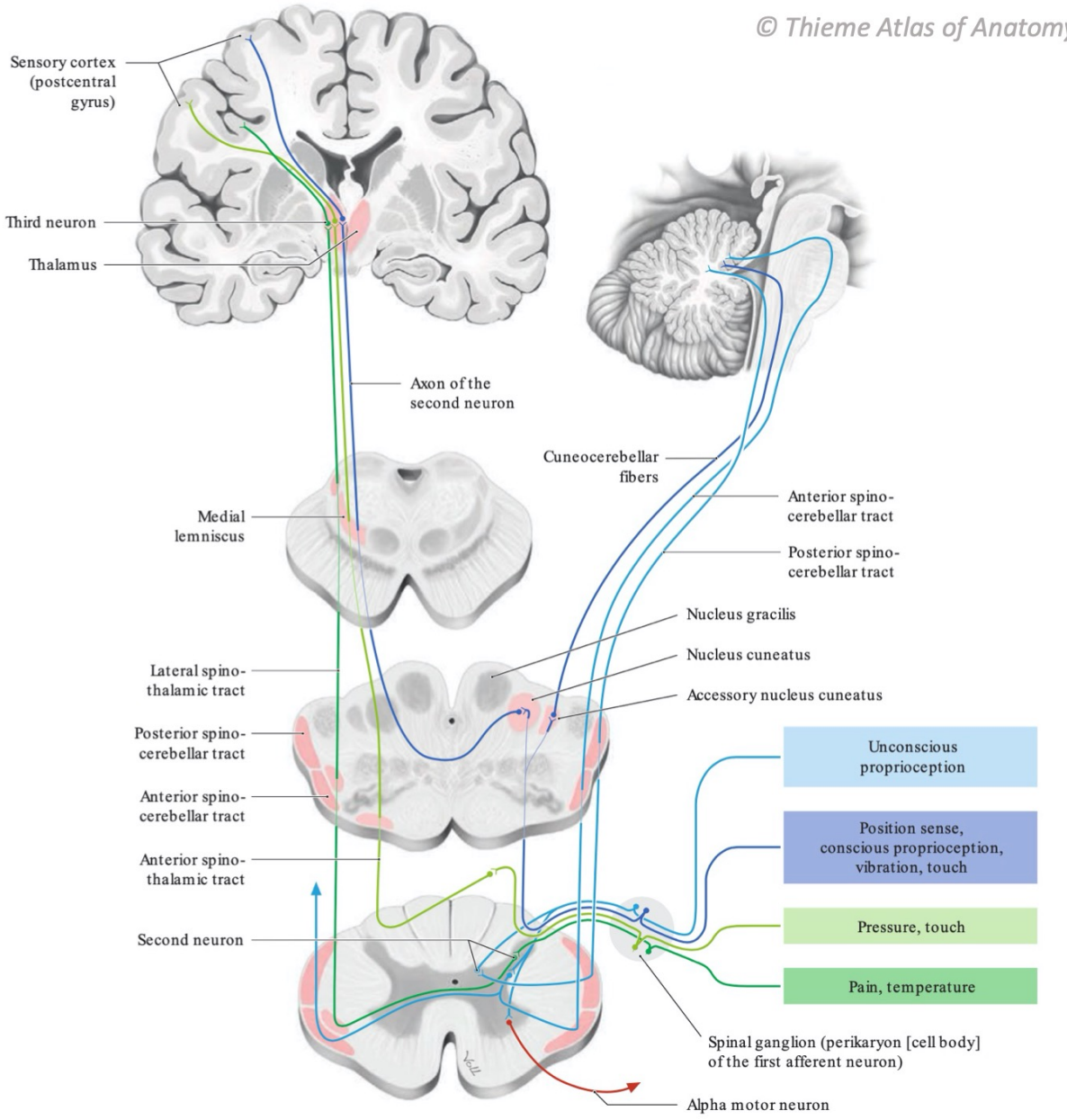
# Fasciculus cuneatus

- 1st neuron
  - *Pseudounipolar in spinal ganglion*
  - Fine touch and conscious proprioception
  - lower limb
  - Vater-Paccini corpuscula, muscle and tendon receptors
- 2nd neuron
  - nucleus cuneatus in medulla oblongata
    - Axon crosses midline at the level of brainstem
  - Medial lemniscus
  - Ventral posterolateral nucleus of thalamus
- 3rd neuron
  - projects to postcentral gyrus



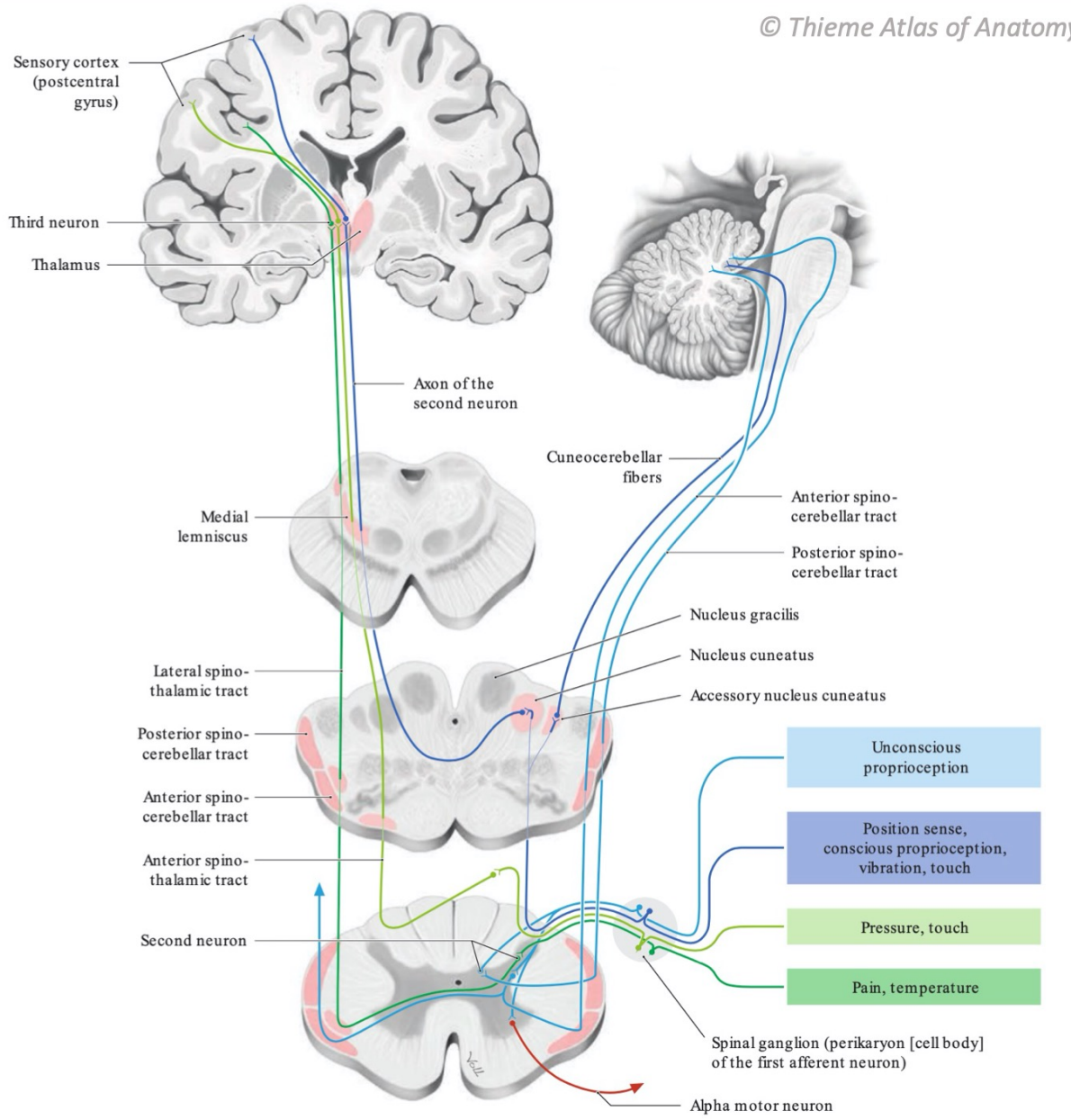
# Fasciculus spinocerebellaris anterior (Gowers)

- 1st neuron
  - *Pseudounipolar in spinal ganglion*
  - **Unconscious extero - and proprioception**
  - **crossed and uncrossed**
  - *Muscle spindles, tendon receptors*
  - *joint receptors, skin receptors*
- 2nd neuron
  - posterior horn
    - Axon crosses or does not cross midline
  - 2nd neuron projects directly to cerebellum
    - Pedunculus cerebelli superior
    - Pars vermiana spinocerebelli



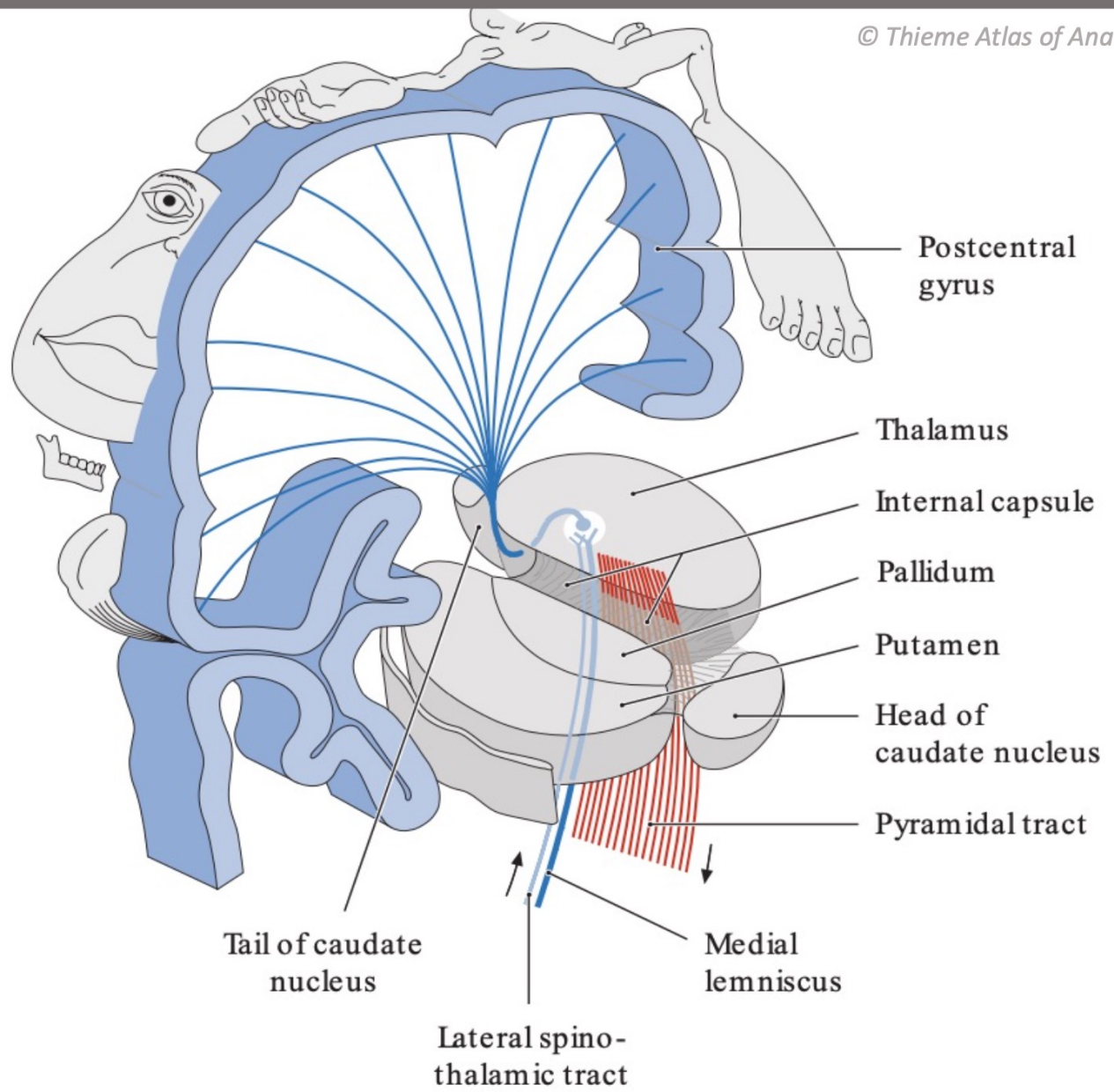
# Fasciculus spinocerebellaris posterior (Flechsig)

- 1st neuron
  - *Pseudounipolar in spinal ganglion*
  - Unconscious extero - and proprioception
  - uncrossed
  - Muscle spindles, tendon receptors
  - joint receptors, skin receptors
- 2nd neuron
  - Clarke column - Stilling nucleus
    - base of posterior horn
    - Axon does not cross midline
  - 2nd neuron projects directly to cerebellum
    - Pedunculus cerebelli inferior
    - Pars vermiana spinocerebelli



# Somatosensoric cortex

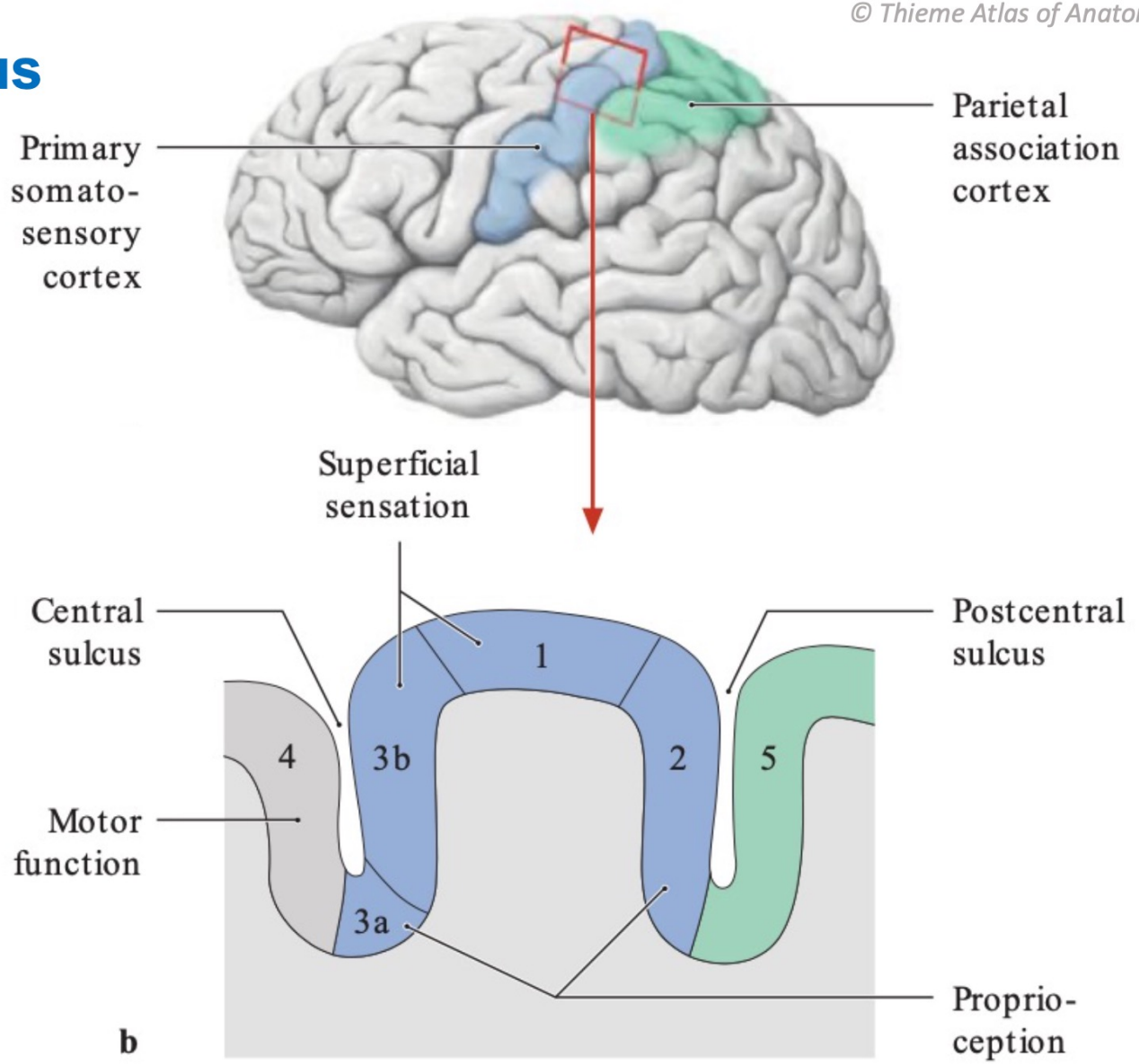
- **Postcentral gyrus**
- **Projection through thalamus**
  - **ventral posterolateral nucleus**



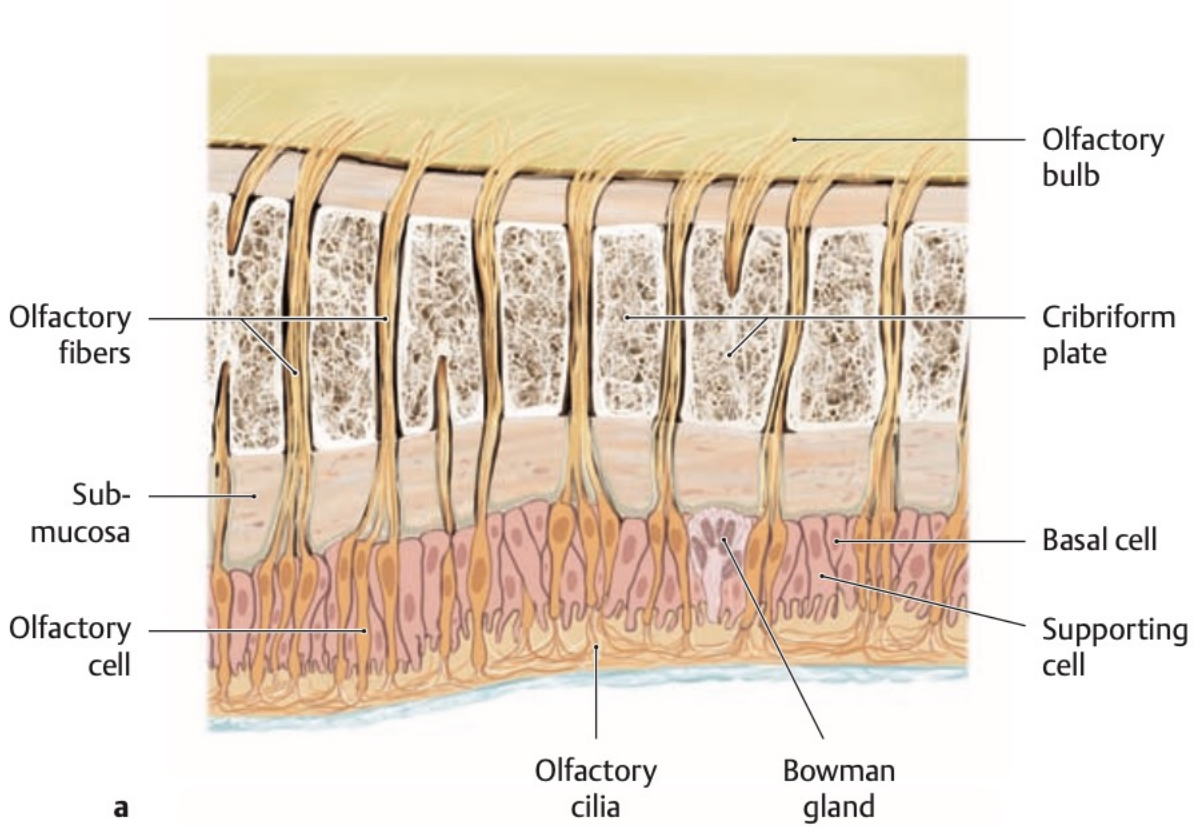
# Somatosensoric cortex

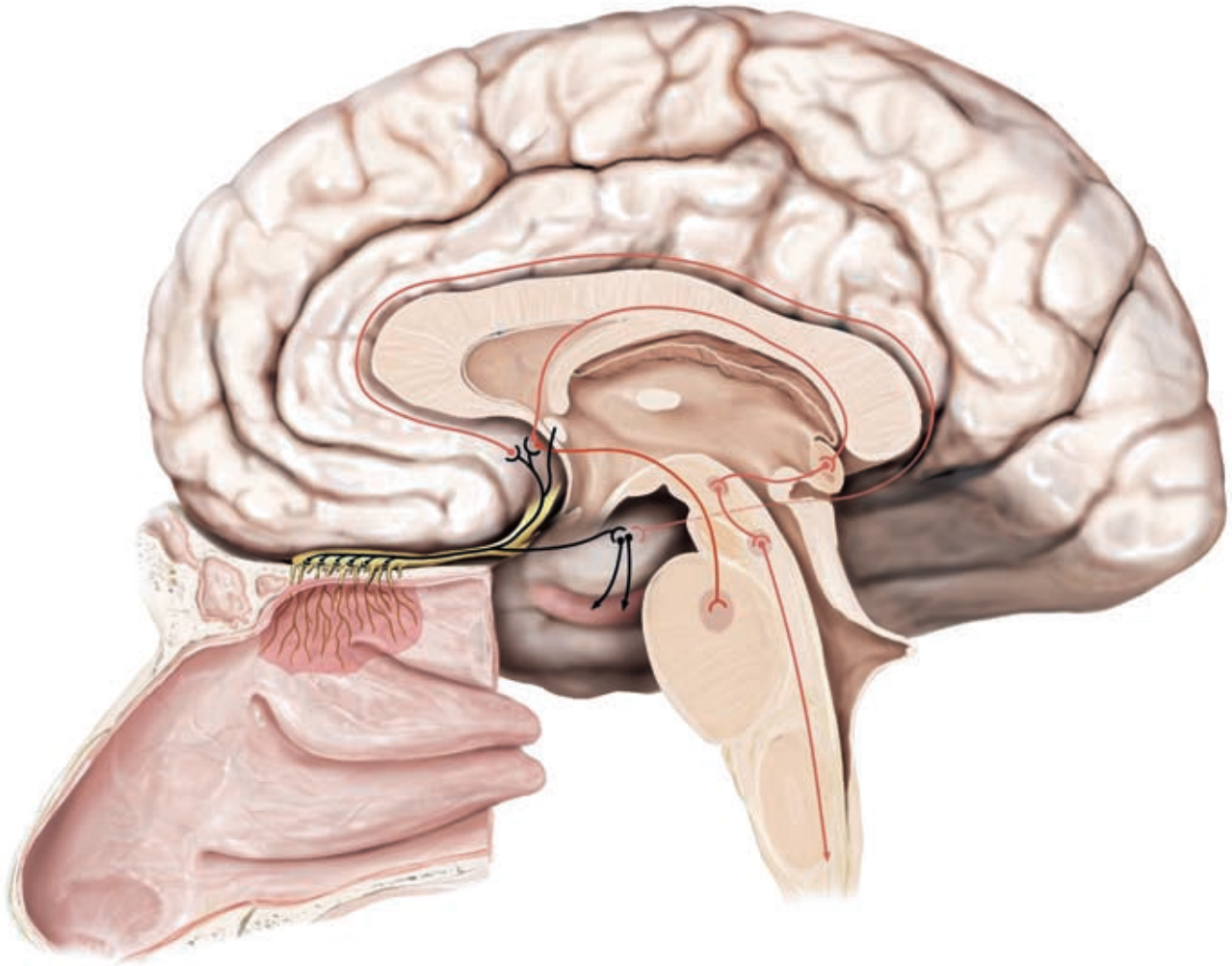
- Projection through postcentral sulcus
- Proprioception
- Superficial sensations
- Motor functions
- The spatial recognition





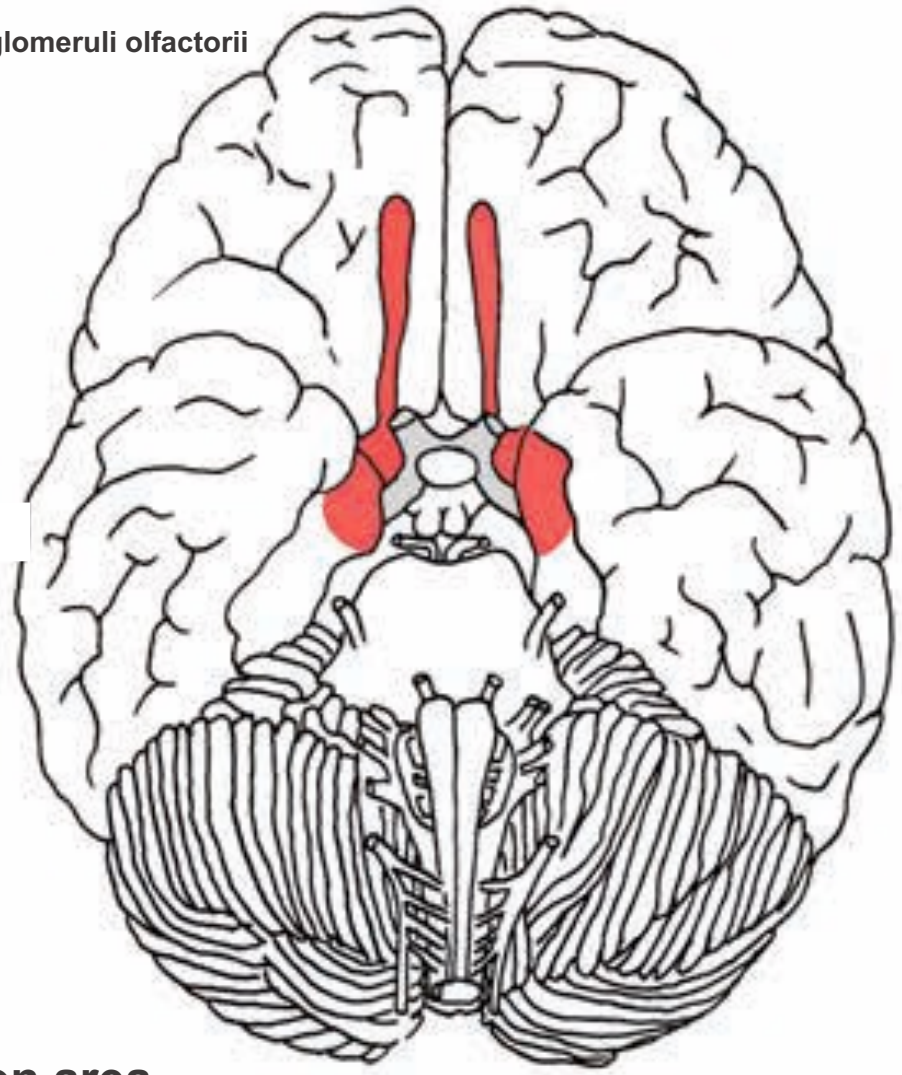
# Olfactory brain - rhinencephalon



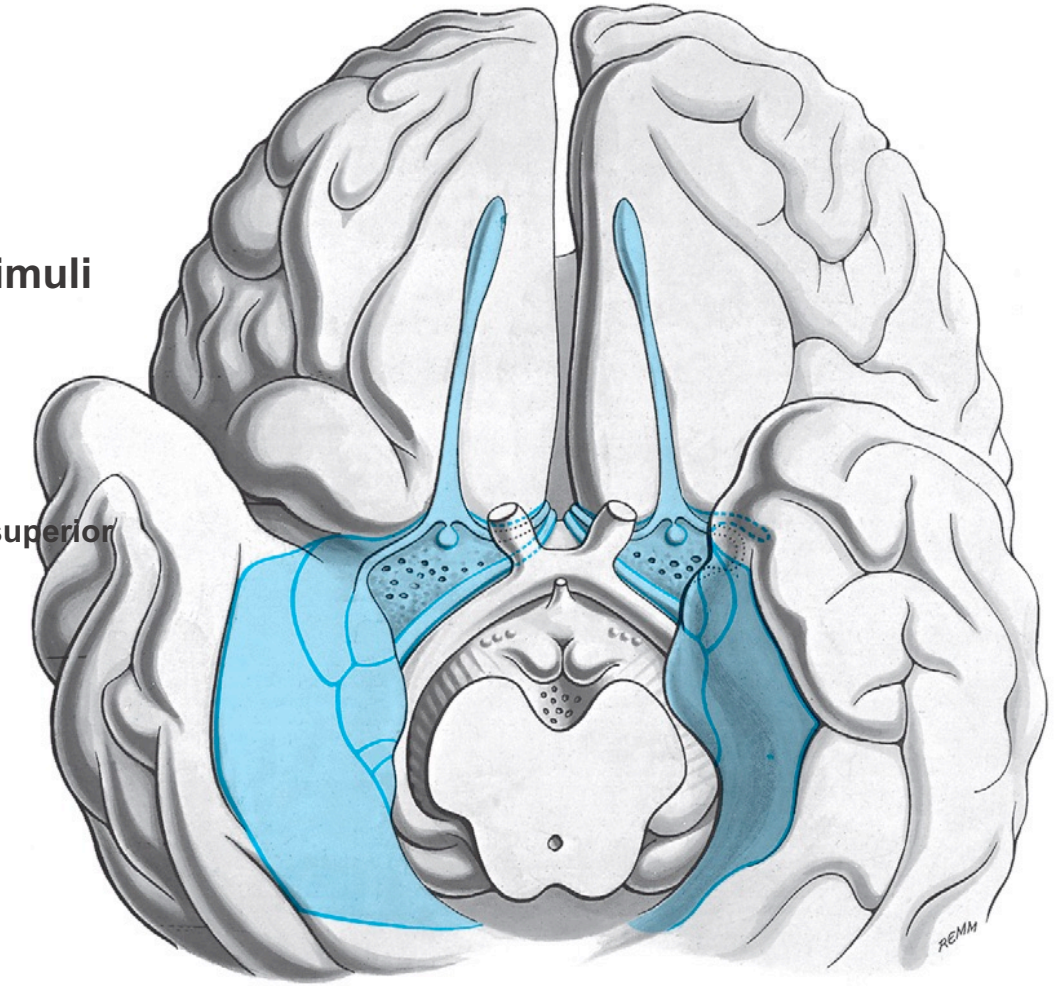
# Olfactory brain - rhinencephalon

- Bulbus olfactorius
  - Synaptic complex of special sensoric cells and mitral cells in olf. bulbs- glomeruli olfactorii
  - Endings of olfactory region fibers and from septum verum
- Tractus olfactorius
  - Substantia perforata anterior
- stria olfactoria lateralis
  - Leads to uncus gyri hippocampalis
  - To primary olfactory region
- stria olfactoria medialis
- Rhinencefalon – only where olfactory pathway
  - twoneuronal
  - Sensoric cells . Nasal mucosa
  - Mitral cells – bulbus olfactorius
- Olfactory cortical area
- Paleocortex - all
  - frontal – lateral from stria olfactoria lateralis
  - Temporal upper surface odf – uncus gyri hippocampalis
- Anterior part of entorhinal region
- Medial and cortical nukleus of amygdala
- Primary olfactory area only bulbus
- rest of rhinencefalon – a som signs of association area



# Olfactory brain - rhinencephalon

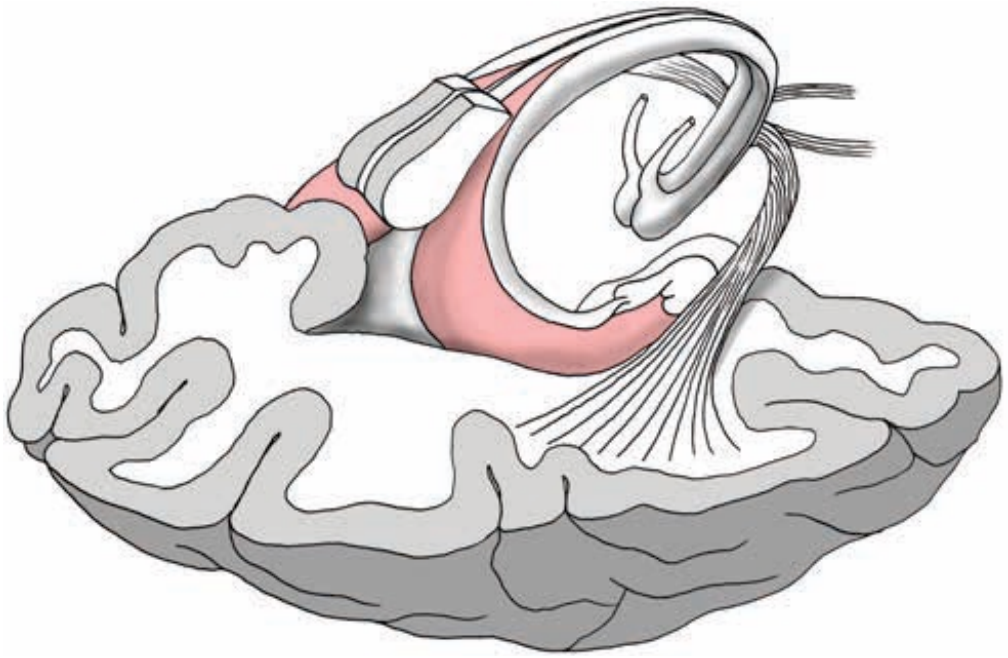
- Afferent connections
  - Axons of mitaral cells in  bulbus olfactorius
- Efferent connections
- cortical – entorhinal area
  - To hippocampal formation – archicortex of limbic cortex
  - Anterior part of olfactory cortex activated by the positive stimuli
- subcortical
  - Amygdala – activated by negative stimuli
  - Thalamus – nc. mediodorsalis
    - Orbitofrontal cortex – association cortex in insuly and gyrus temporalis superior
    - Emmltions and behaviour
  - Hypothalamus – area hypothalamica lateralis
    - Vegetative and brainsem functions
- Association connection
  - With rest of paleokortex
- Commisural connections
  - Left/right connection of paleocortex
  - Crossed projection to olfactory bulb

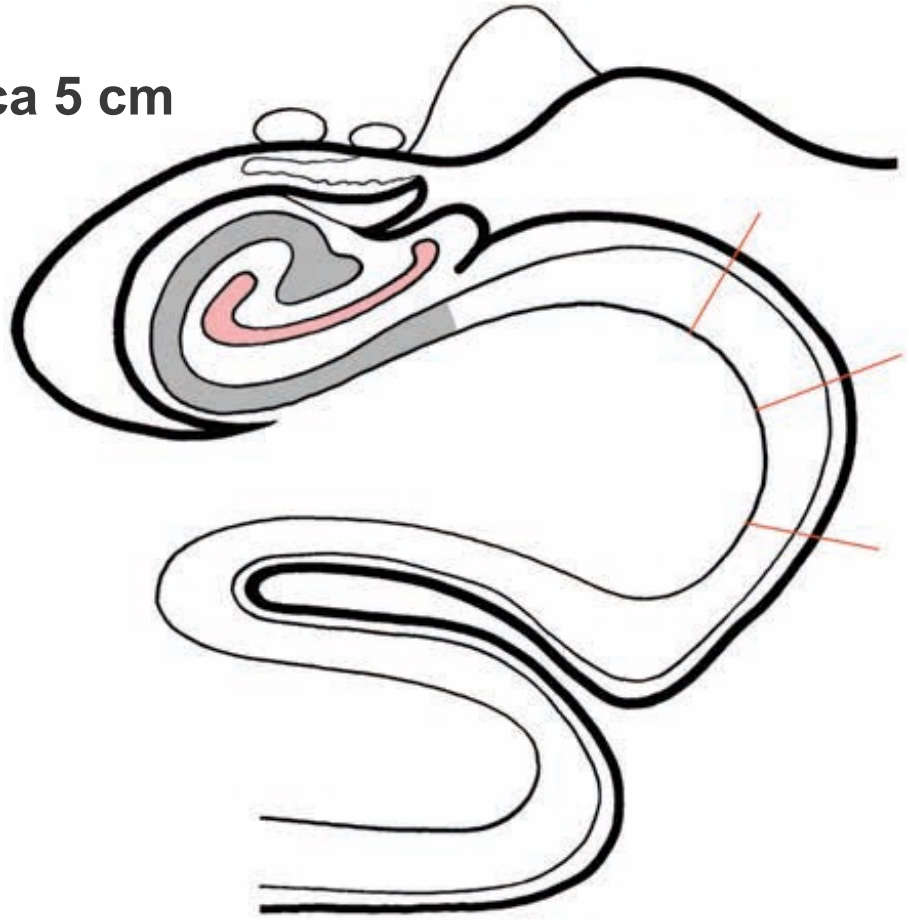


# Archaecortex

- In fissura chorioidea at the base of temporal horn of lateral ventrikle
- Thre layers
- Three bands of  gaey matter – hippocampal formation

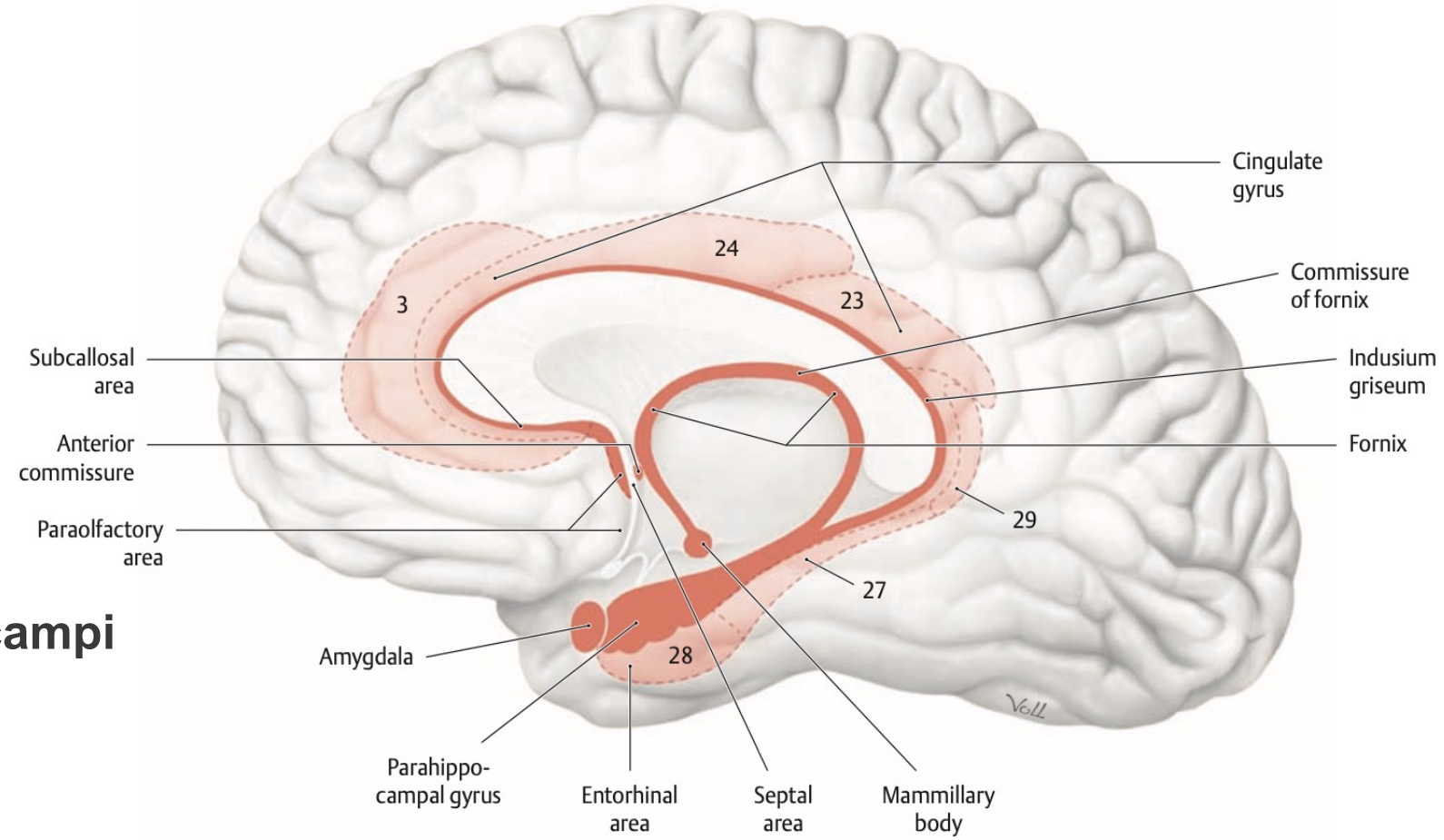
- **Subiculum – uper surface of parahippocampal gyrus**
- **Hippocampus – bank facing into lateral ventrikle  – cca 5 cm**
- **Gyrus dentatus – medial to hippocampus**





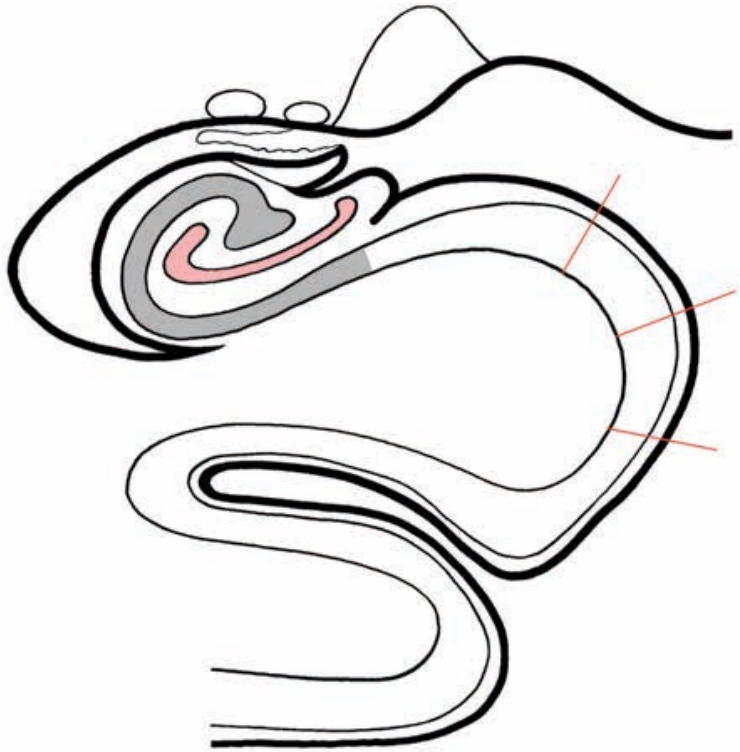
# Lobus limbicus

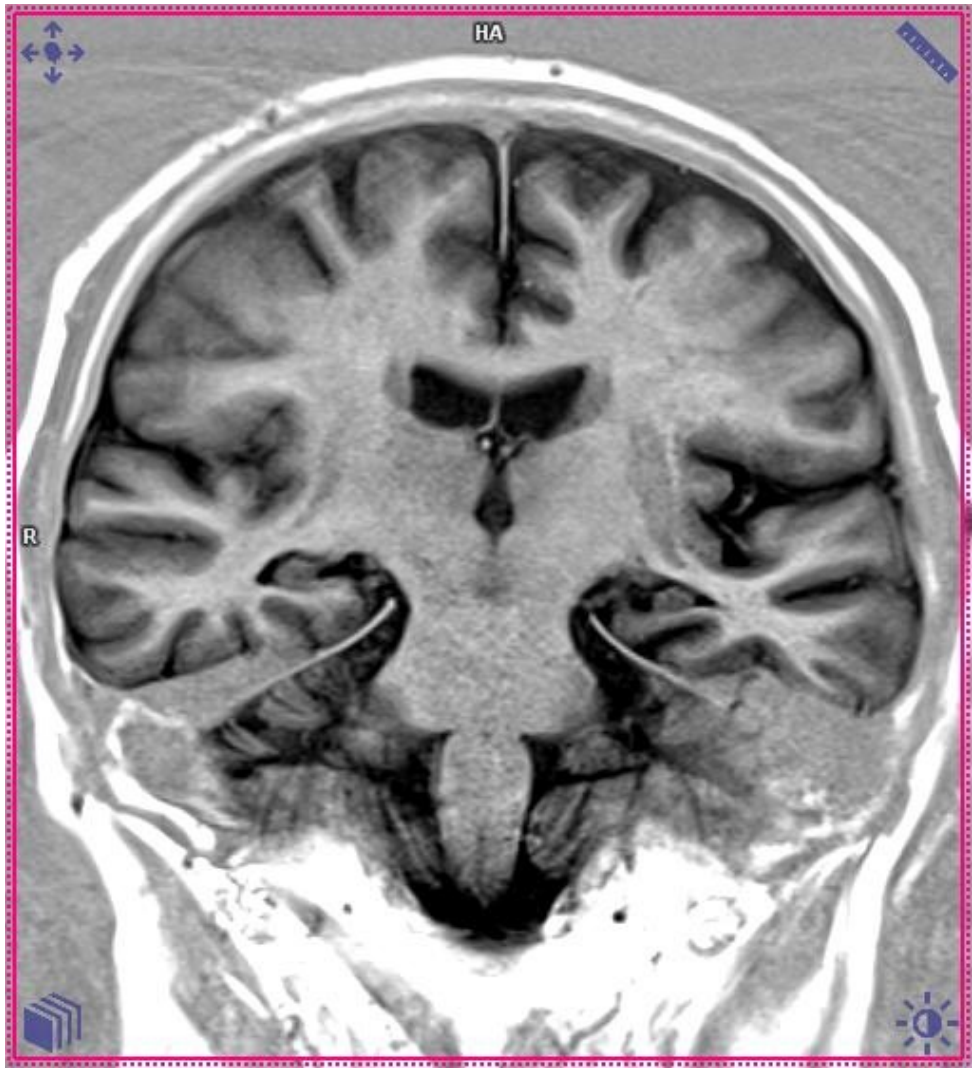
- Gyrus cinguli
- Gyrus parahipocampalis
- Uncus gyri parahipocampalis
- Sulcus hipocampi
- Subiculum
- Gyrus dentatus
- Taenia Giacomini
- Fimbria hipocampi
- Anterior broad part - pes hipocampi



# Subiculum

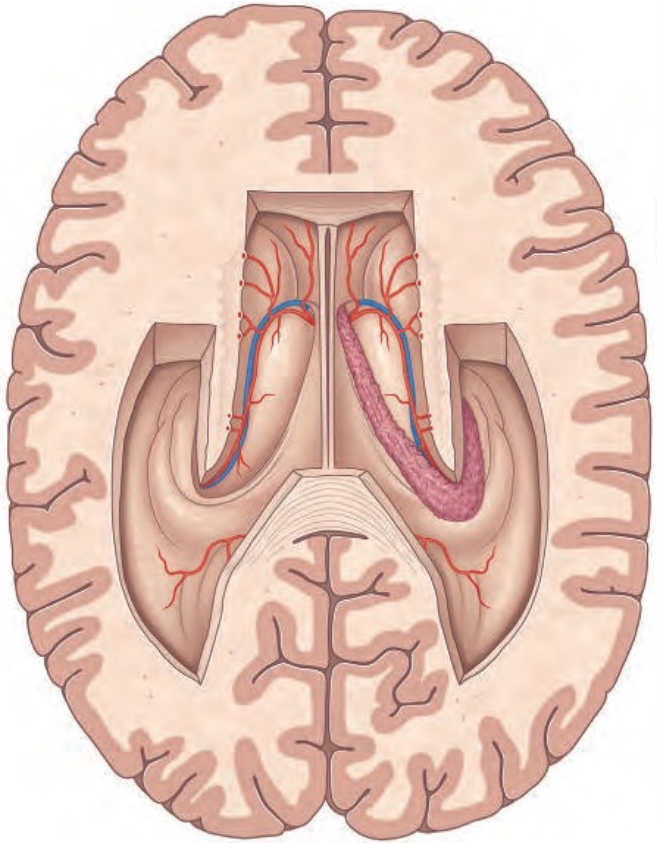
- Upper surface of gyrus hippocampi (parahippocampalis)
- Laterally continues to hipocampus
- Layers
- Surface - stratum moleculare
- Superficial pyramidal layer
- Deeper pyramidallayer
- Neghboring to mesocortex
  - Entorhinal area
  - Praesubiculum

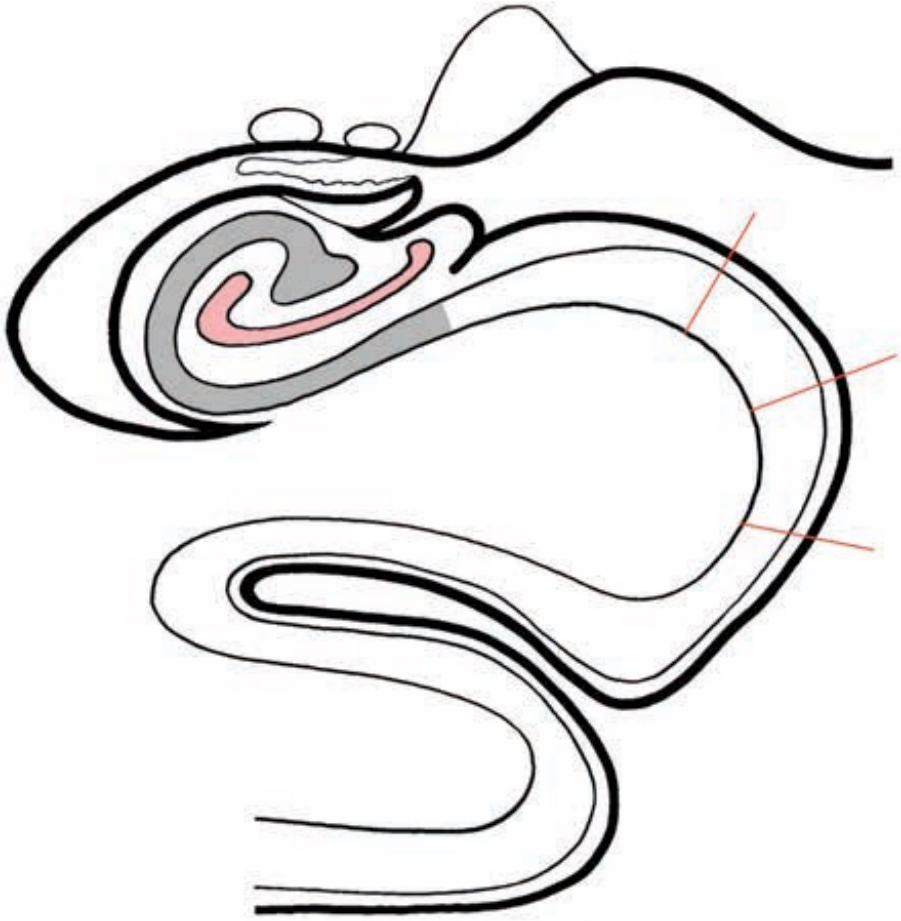




# Hippocampus

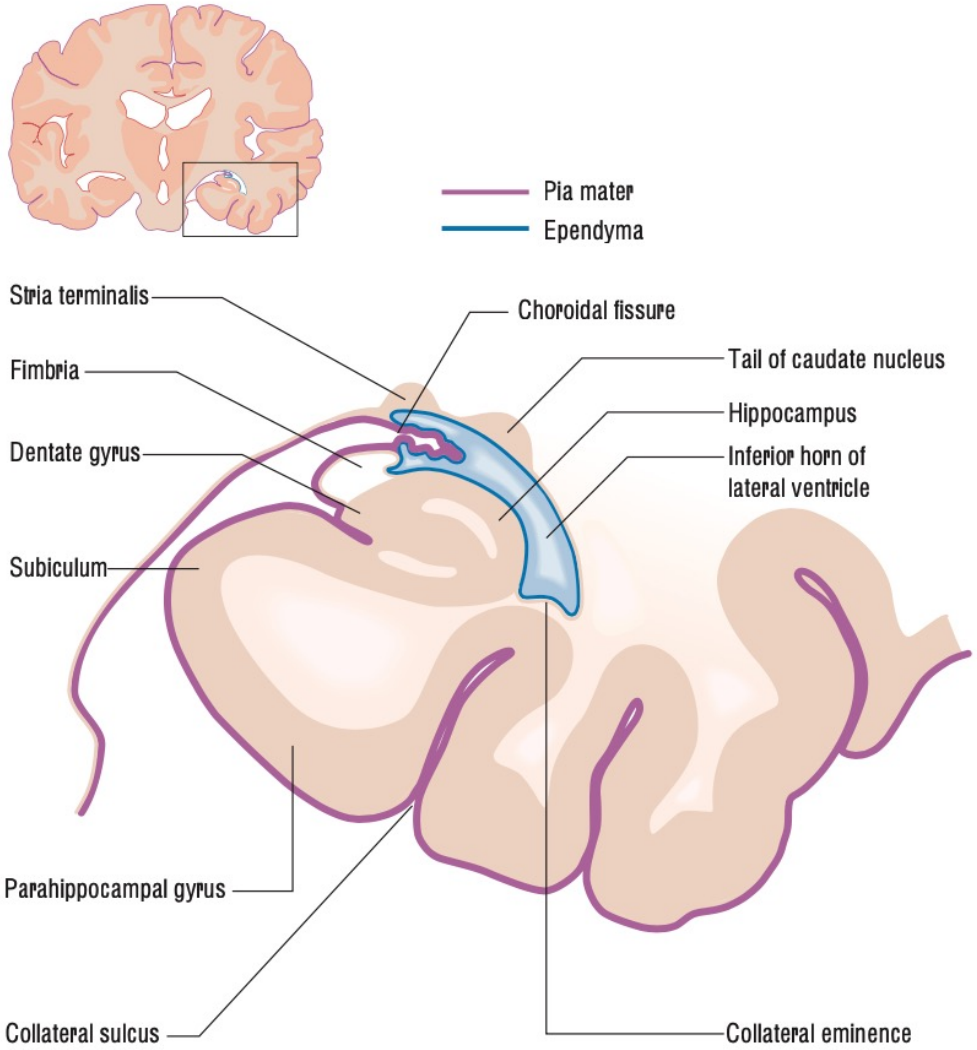
- Hippocampus (cornu Ammonis)
- Anteriorly widens to pes hippocampi (foot)
- Upper ridge – fimbria fornicis – continues like fornix
- surface  of hippocampus – ependyma
- Subependymal layer - alveus
  - Fibers converging to fimbria
- Foru fields of hippocampus
- CA1-4
- layers
  - Stratum oriens
    - Small number of neurons
  - Stratum pyramidale
    - Pyramidal projection neurons
  - Stratum radiatum
    - Small number of interneurons



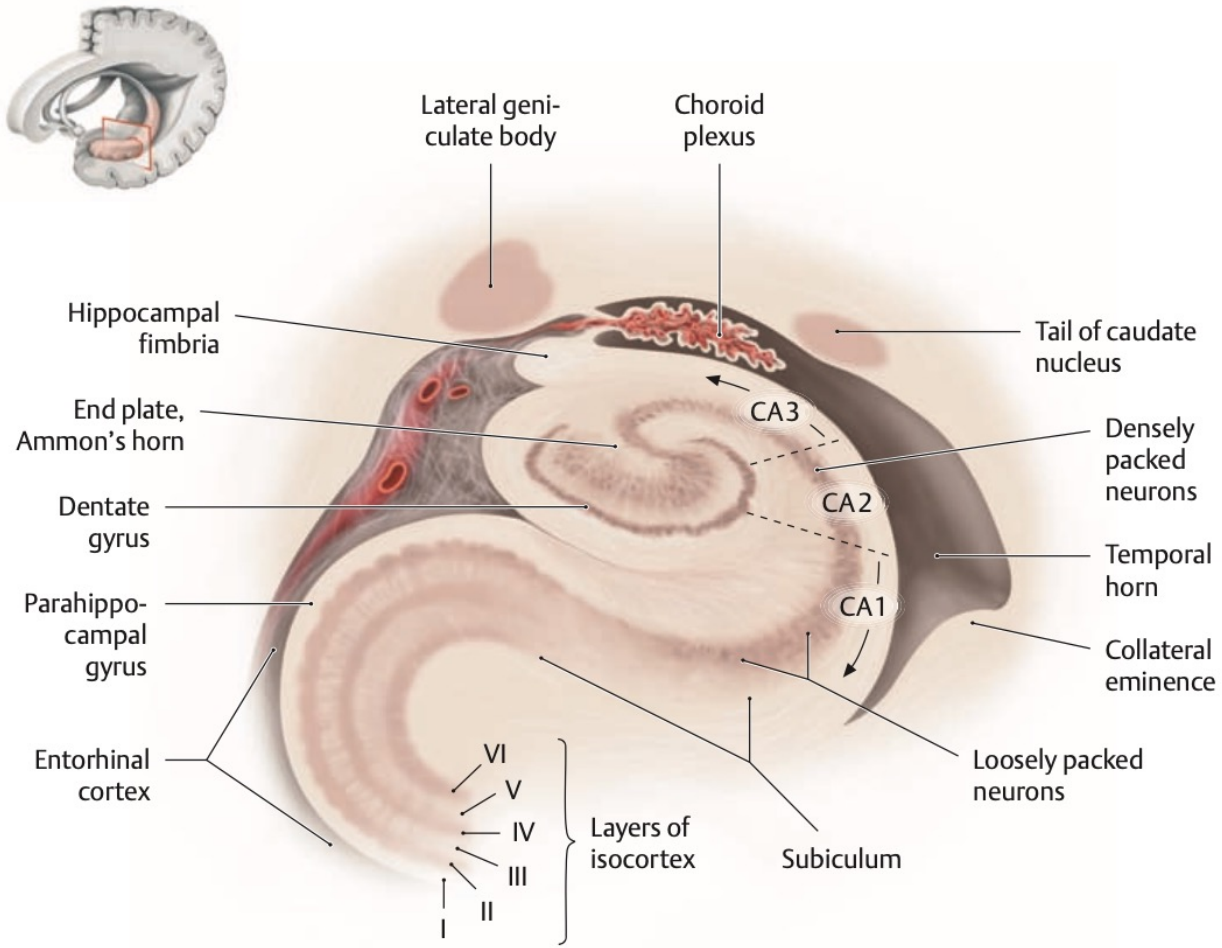


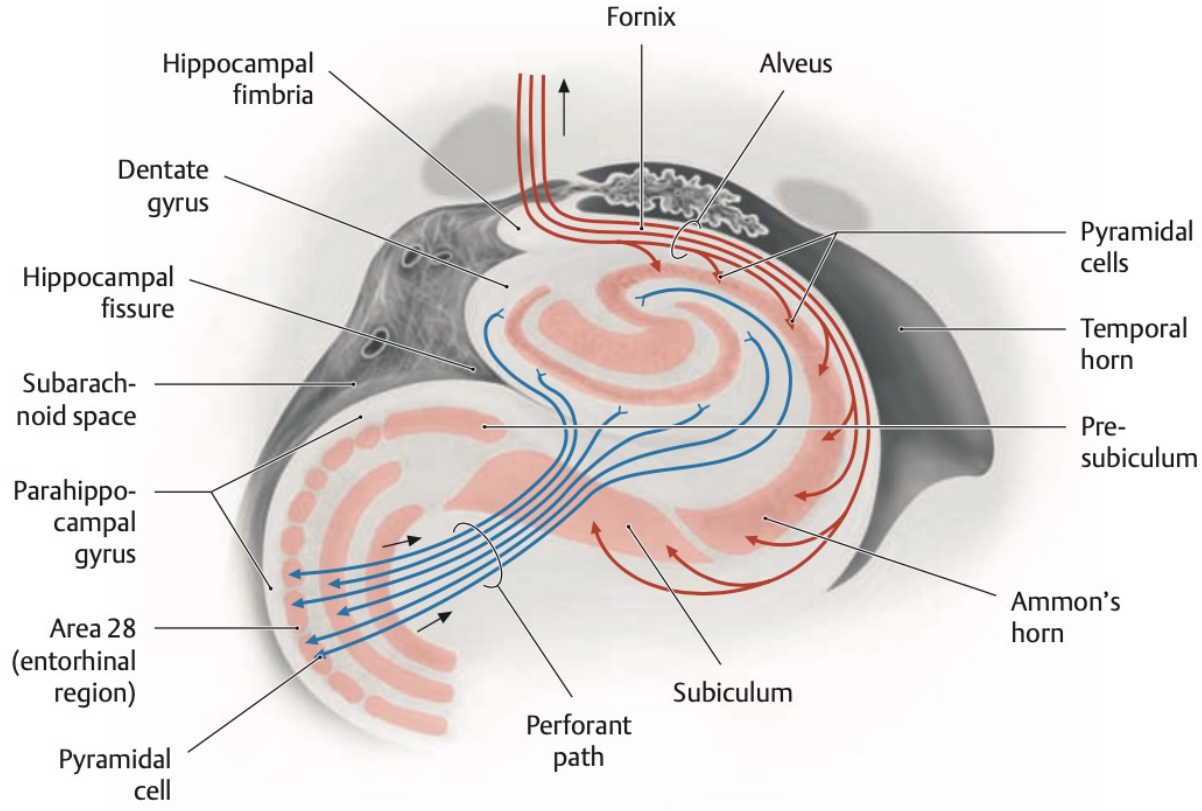
# Gyrus dentatus

- **Dentate surface**
  - Medially to hippocampus
  - Dorsally falttennig nad shrinkening
  - Giancomini belt to splenium corp. callosi
- **Stratum moleculare**
  - Rareky settled by interneurons
- **Stratum granulare**
  - High density of granular (stellar) cells
- **Stratum multiforme**
  - interneurons
- rudiments
- Upper surface of CORPUS CALLOSUM
- INDUSEUM GRISSEUM + STRIAE LONGITUDINALES



# Mesial temporal lobe

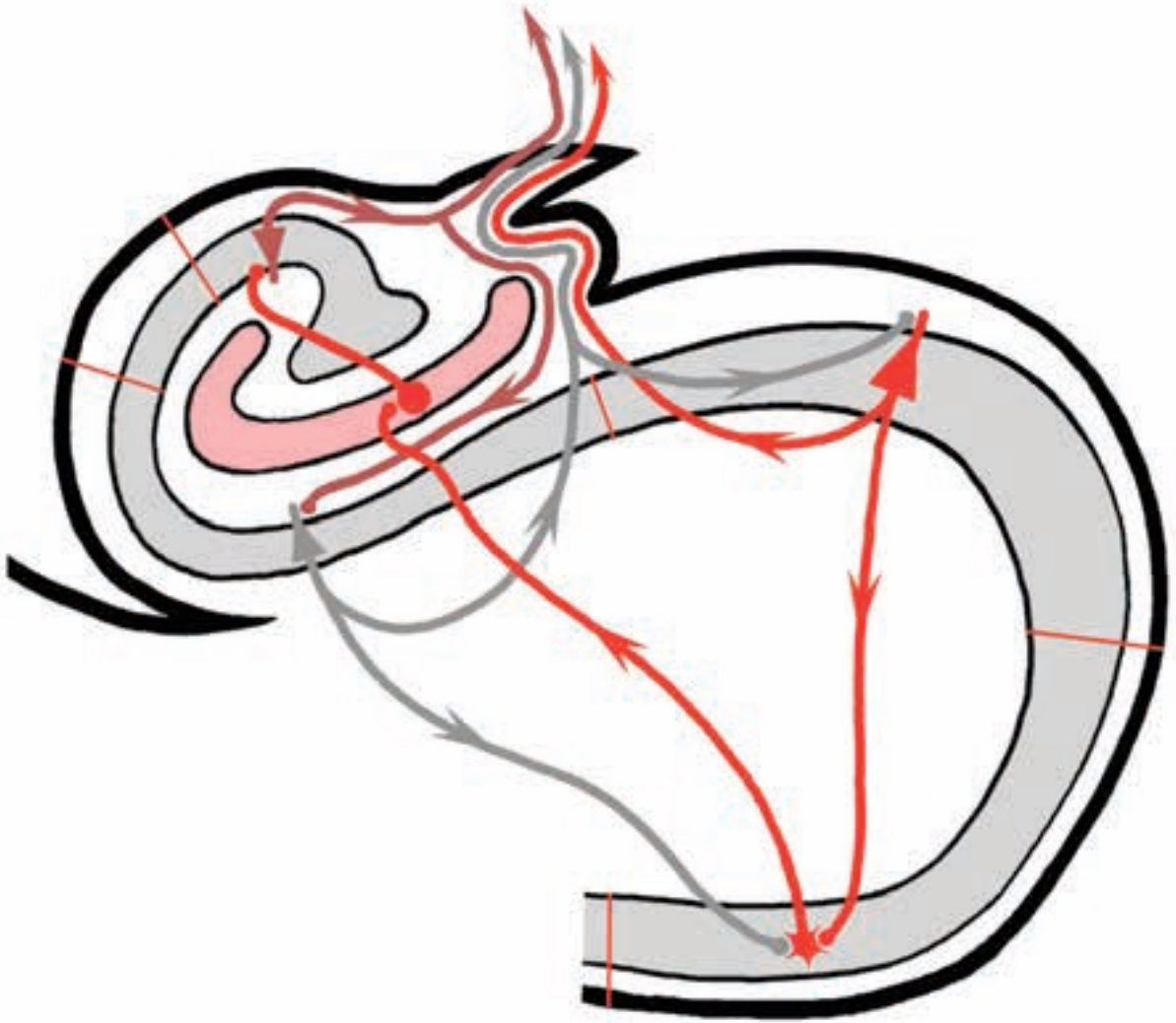


# Internal relay of hipocampal formation

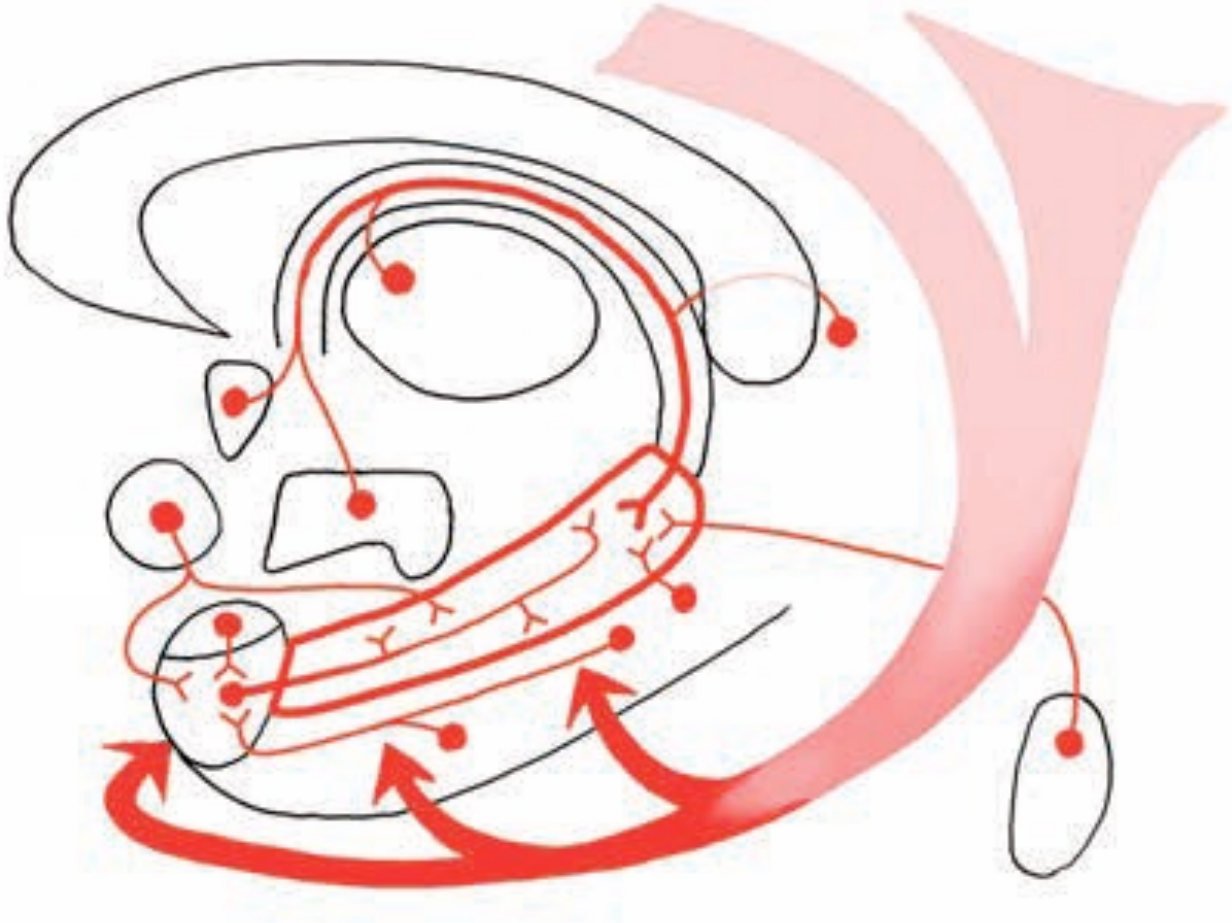
- Andersen circle
- Entorhinal cortex
- Gyrus dentatus
- CA3 hippocampus
- CA1 hippocampus
- Subiculum
- Entorhinalcortex

- Glutamate
  - Outer output – fimbria fornicis



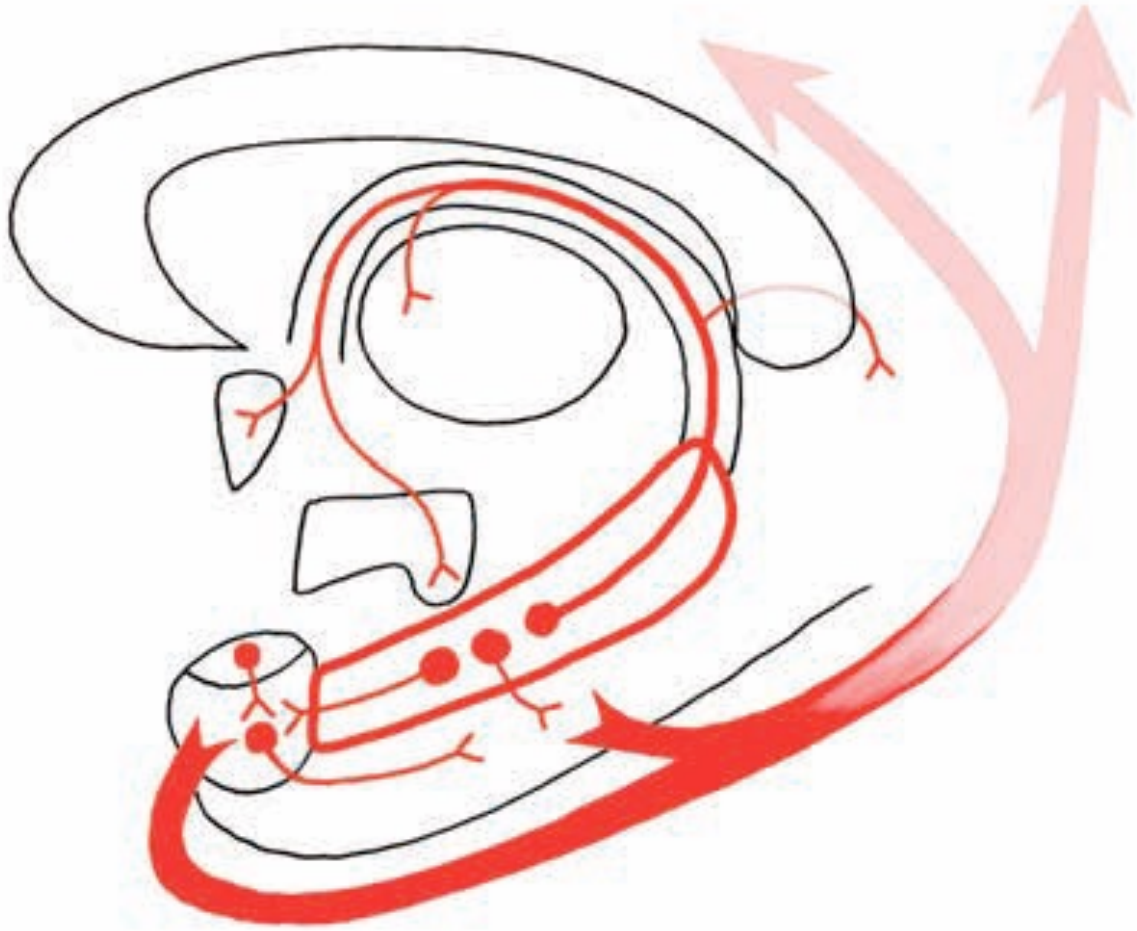
# Hipocampal formation

- **afferentation**
  - Association neocortex
  - Gyrus cinguli
  - Septum verum – cholinergic
    - Increasing excitatability
  - Amygdala
  - Thalamus
  - Hypothalamus
  - Olfactory cortex (piriform– area 51)
  - Entorhinal area (area 28)
  - Gyrus parahippocampalis
  - Commissura hippocampi
  - Reticular formation – rapheal nuclei
  - Locus coeruleus – noradrenergic
    - modulation



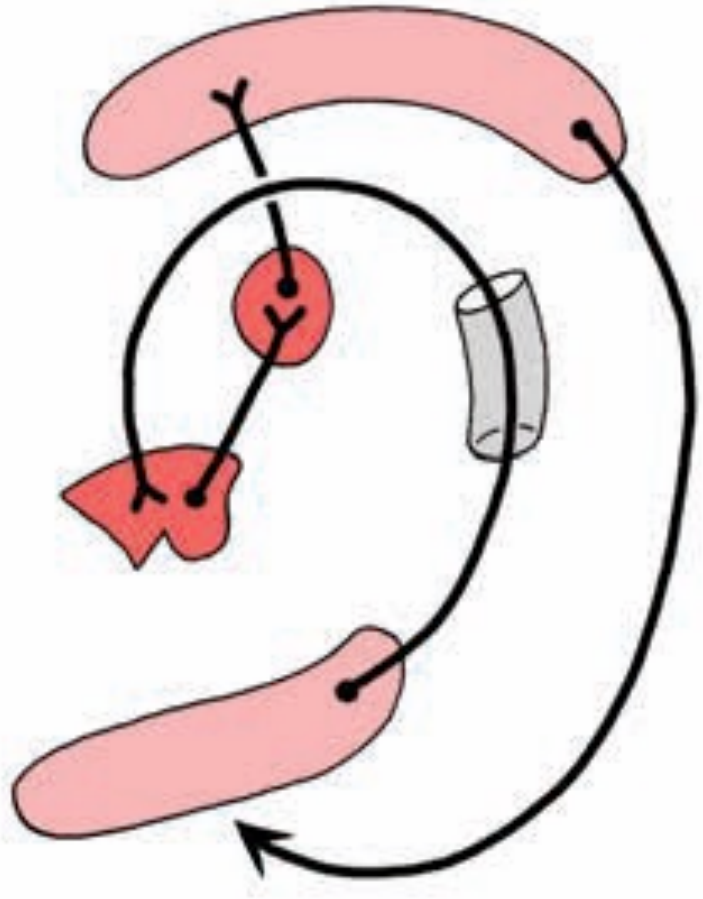
# Hippocampal formation

- **Efferent connection**
  - Via fornix
  - To subcortical centers
  - From subiculum
  - Postcommisural part of fornix
  - Hypothalamus
    - nc. mamilare
    - Nc. ventromedialis hypothalami
  - Thalamus – nuclei anteriores
  - To entorhinal cortex
  - To association center  in frontal and parietal lobi
  - From hipocampus
  - *field CA1*
  - *To precommisural part of fornix*
  - *endings in septum verum,*
  - *anterior hypothalamus*
  - *nc. accumbens – striatum ventrale*



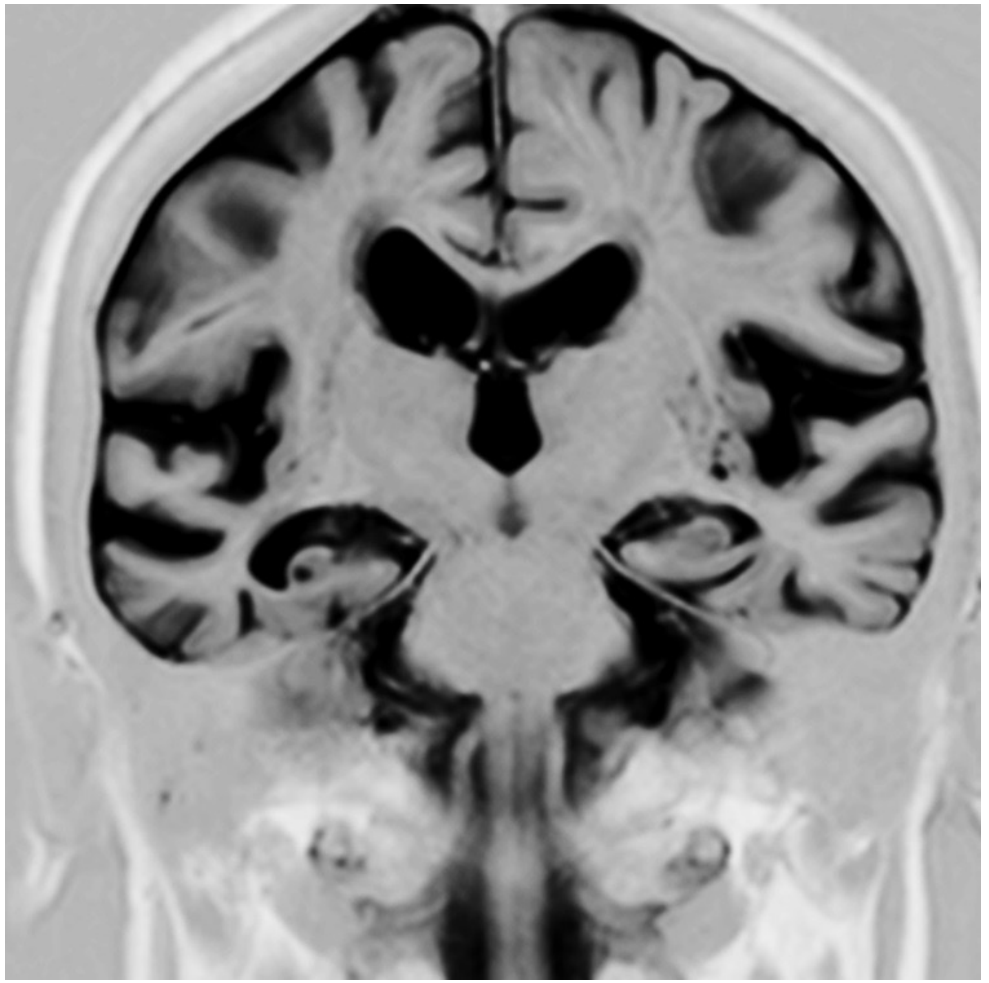
# Papez circle

- Hipocampal formation
- Fornix
- Hypothalamus – corpora mamilaria
- Tractus mamilothalamicus
- Nuclei anteriores thalami
- Thalamokortikální projekce
- Gyrus cinguli
- Cingulum (asociační vlákna)
- Gyrus parahippocampalis
- Entorhinal area
- Hippocampal formation



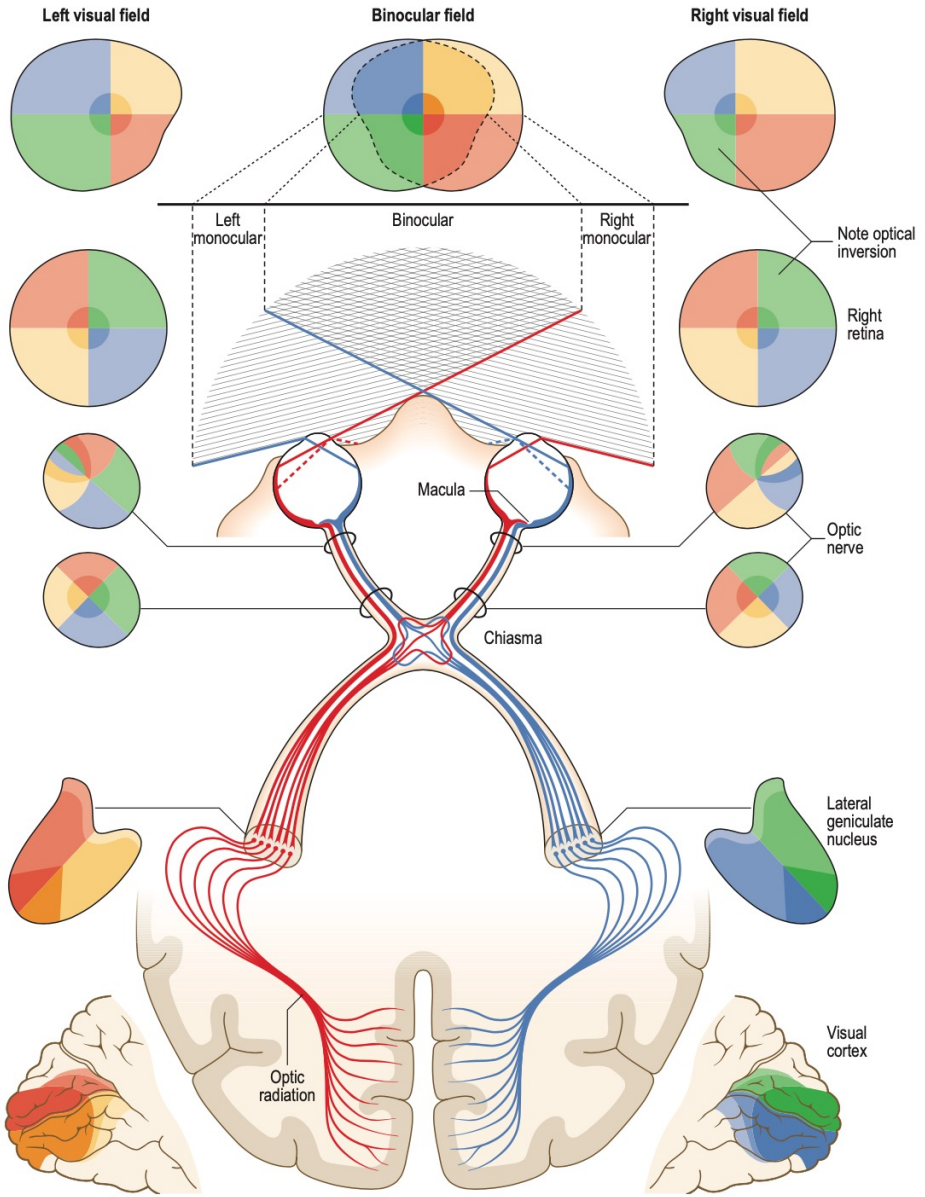
# Hippocampal formation

- function
  - Informtion transfer to diencefalon and septum verum
  - Vice versa  from hippokampus to neokortex
  - Consolidation of memory trace
  - Transformation of shortterm and midterm memory to longterm
- Mechanism of function - longterm potentiation
- Impaired  hippocampal formation
  - Impaired short-term memory
  - Also the related cortical areas
    - A lso ways of information transfer
  - entorhinal area and gyrus parahipocampalis
- Alzheimer disease
- Korsakoff syndrome
- Epileptic foci – temporal mesial sclerosis
- Spatial congnition

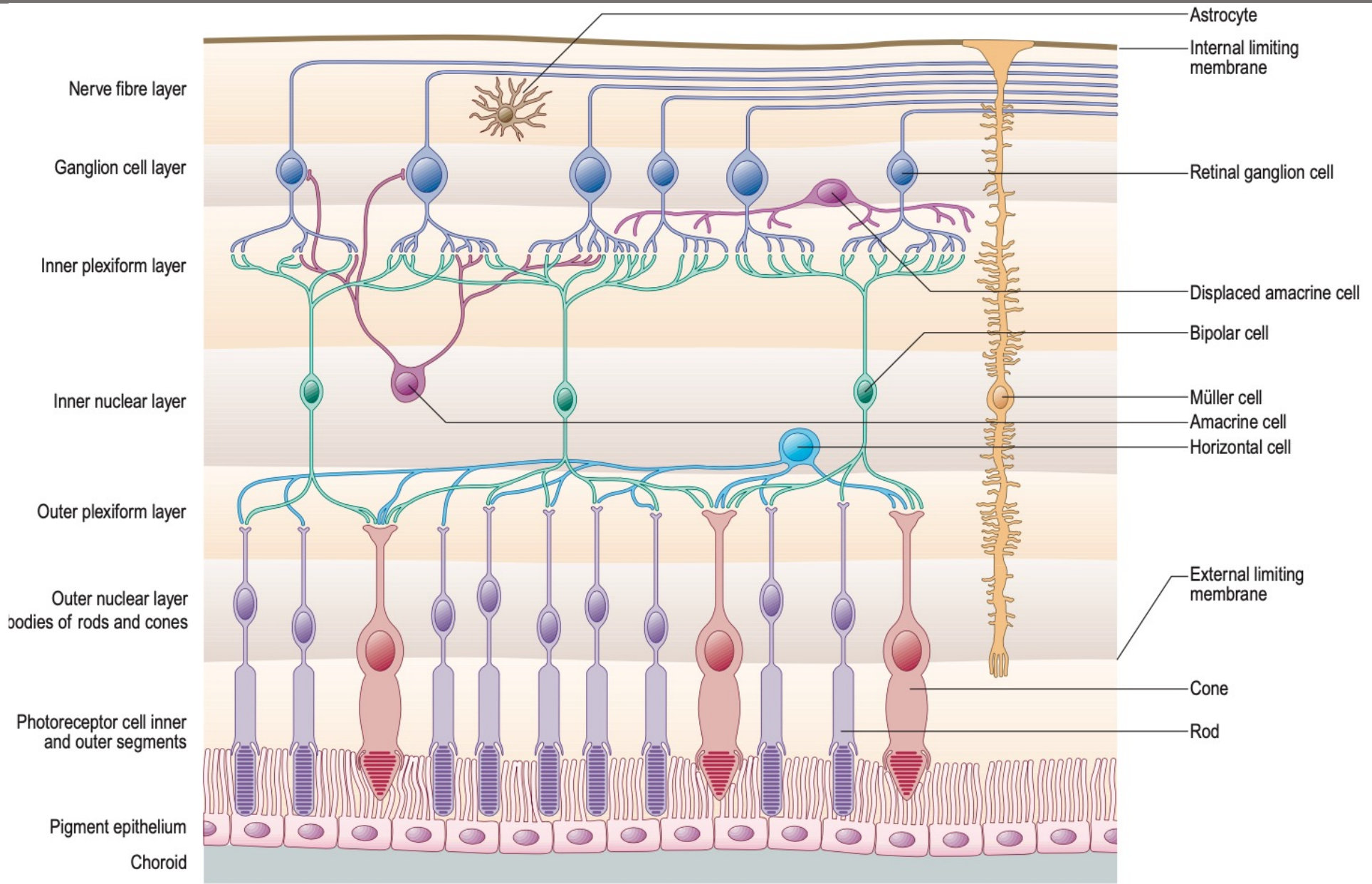


# Visual pathway

- Light-sensory cell (rod or cone)
- 1/ interneuron of retina
- 2/ retinal ganglion cell
  - axon
    - Nervus opticus (II)
    - Chiasma opticum (křížení nasálních polovin retiny)
    - Tractus opticus
- 3/ neuron corp. geniculatum laterale
  - Radiatio optica
- 4/ neuron in primary cortex

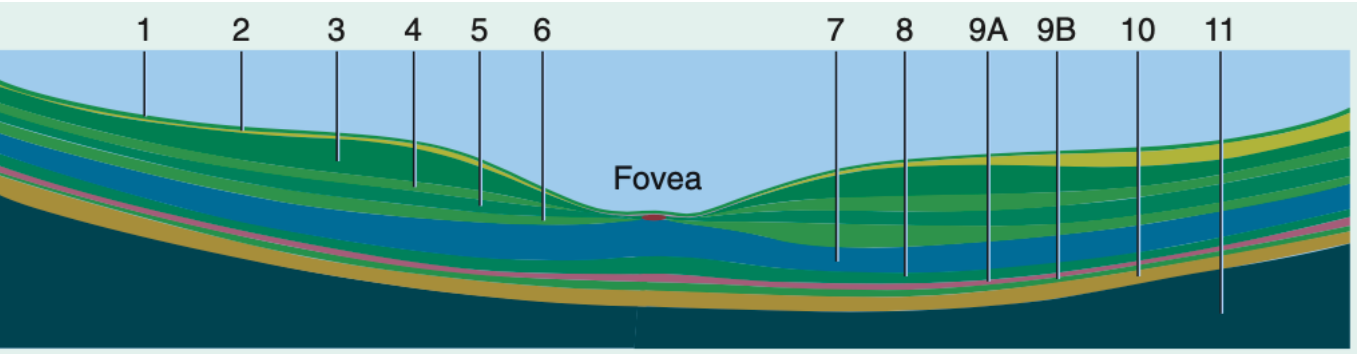


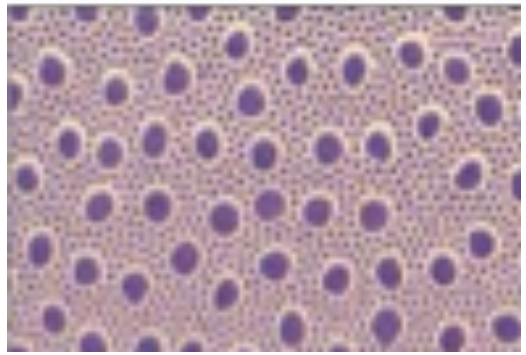
# Retina

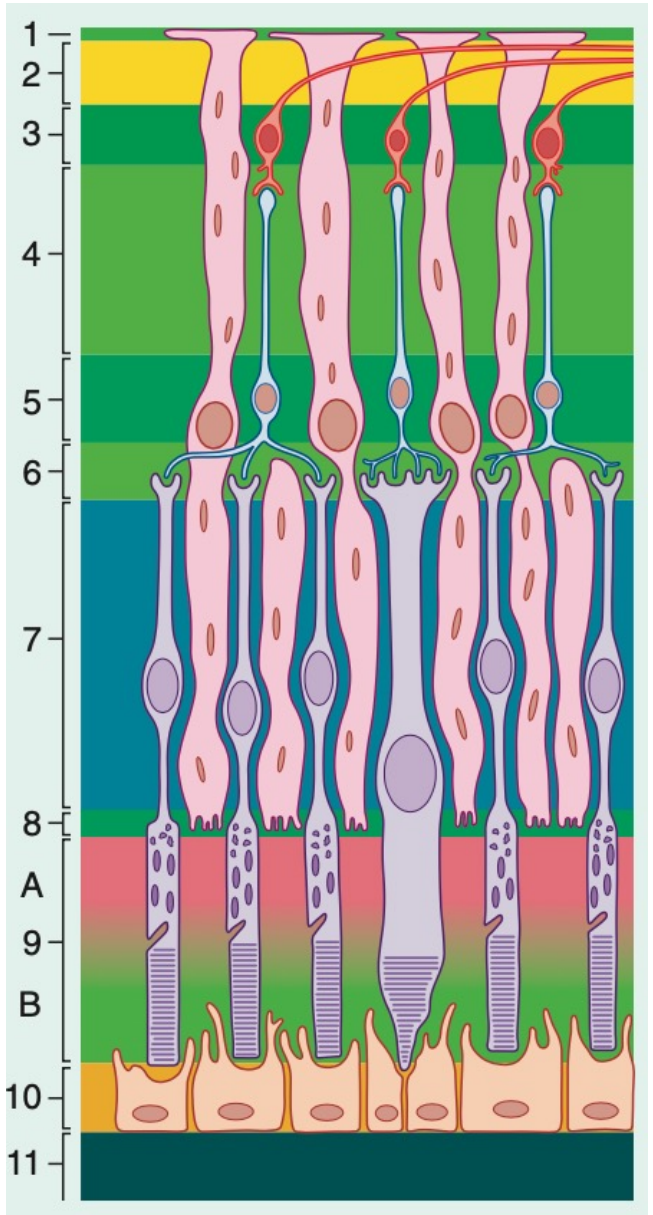

Nerve fibre layer
Ganglion cell layer
Inner plexiform layer
Inner nuclear layer
Outer plexiform layer
Outer nuclear layer
bodies of rods and cones
Photoreceptor cell inner
and outer segments
Pigment epithelium
Choroid
Astrocyte
Internal limiting
membrane
Retinal ganglion cell
Displaced amacrine cell
Bipolar cell
Müller cell
Amacrine cell
Horizontal cell
External limiting
membrane
Cone
Rod

# Rods - Cones

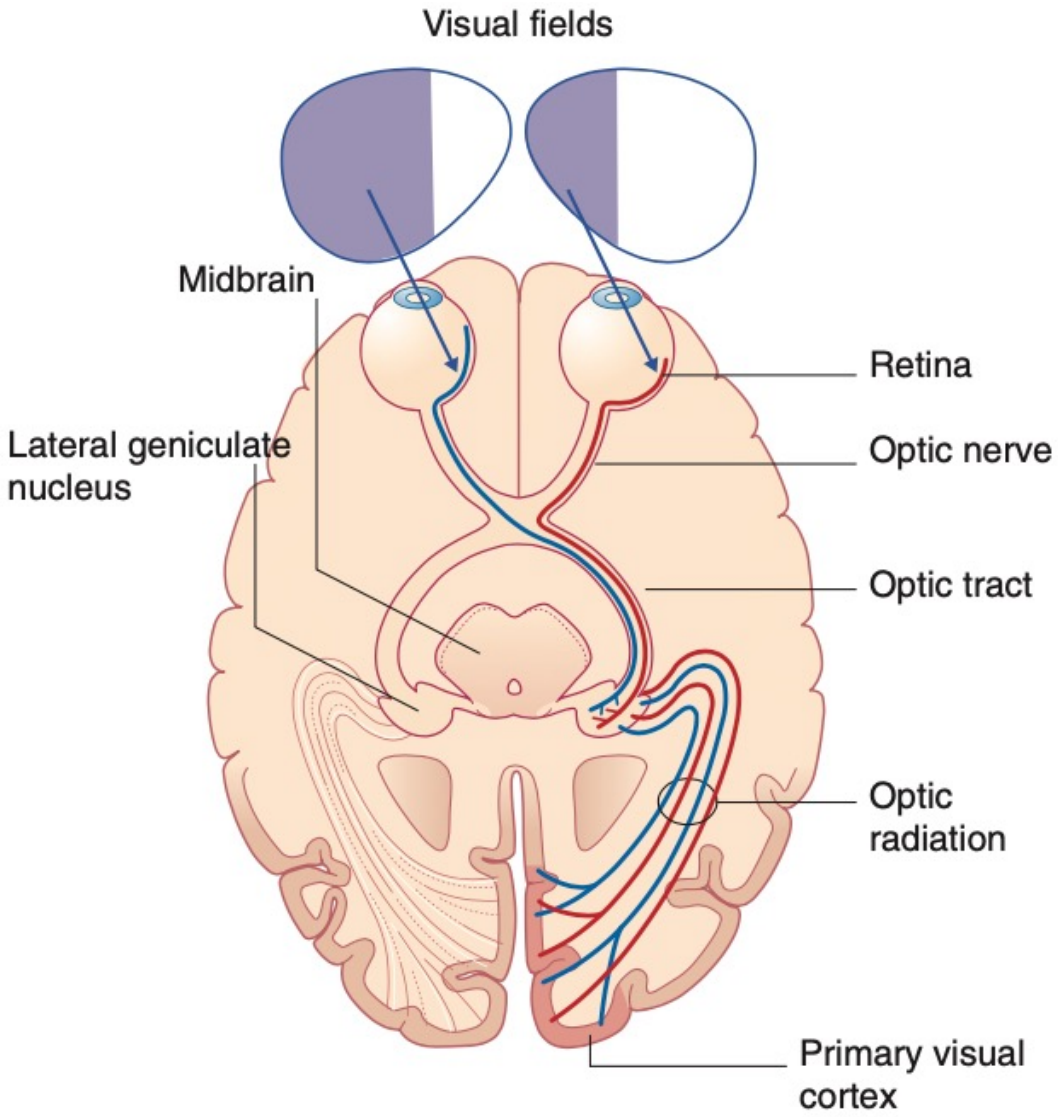
- **Cones - - conical ending**
  - 6 – 7 millions
  - Iodopsin
  - Three variants
  - Sharper visus – oen cone – bipolar cell – ganglionic cell
  - detailes
  - When light
- **Rods**
  - 120 millions
  - Rodopsin
  - More sensitive pigmentum, limited light (darkness)
  - less detailed – severtal rods – bipolar cell – ganglionic cell
  - More associative sonnections and relays

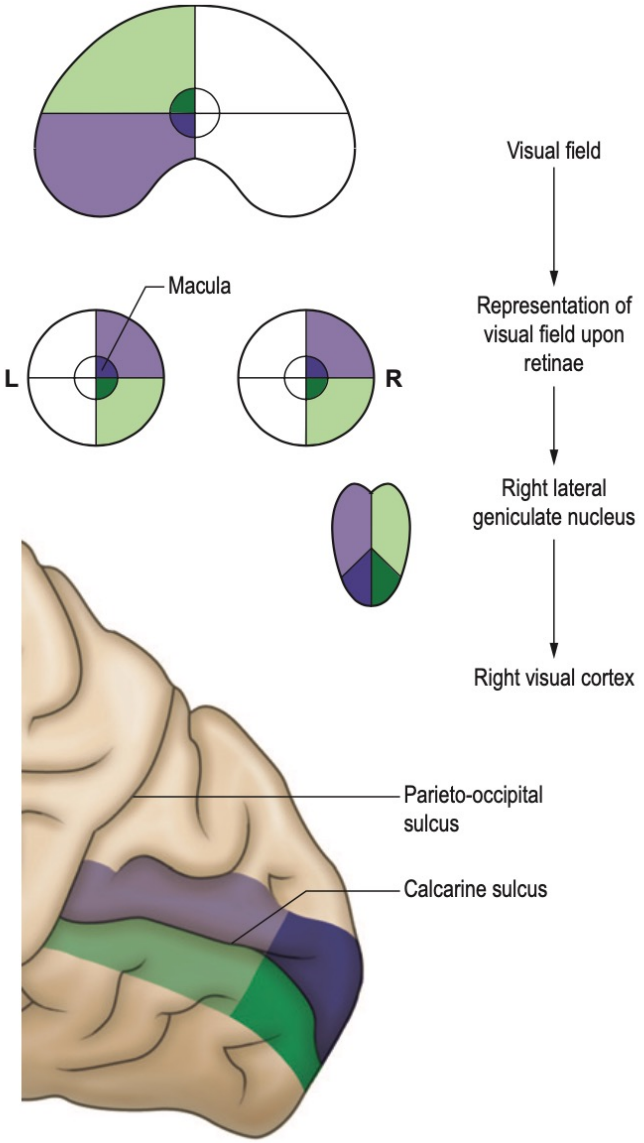




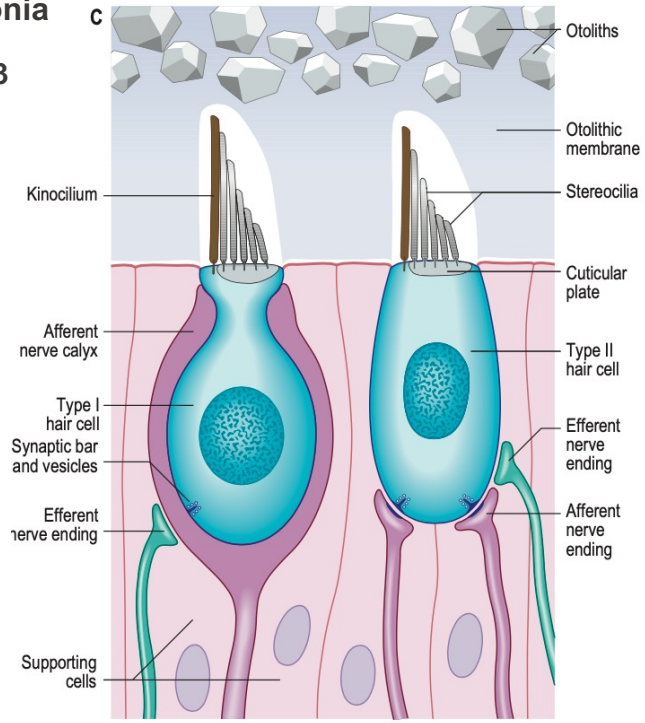
# Optic pathway



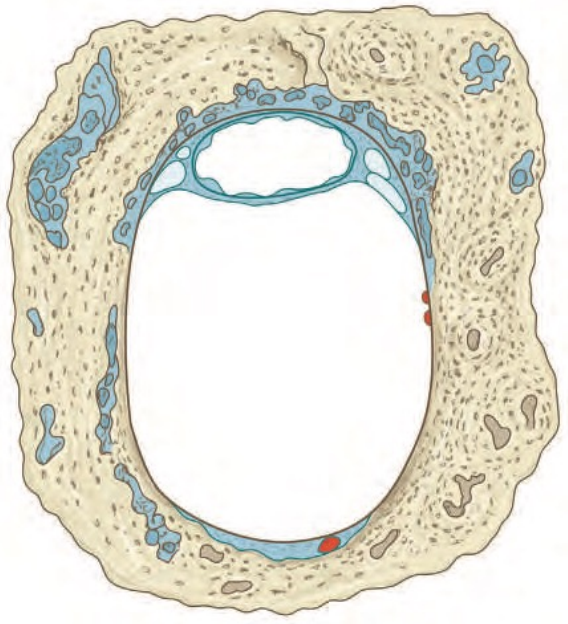



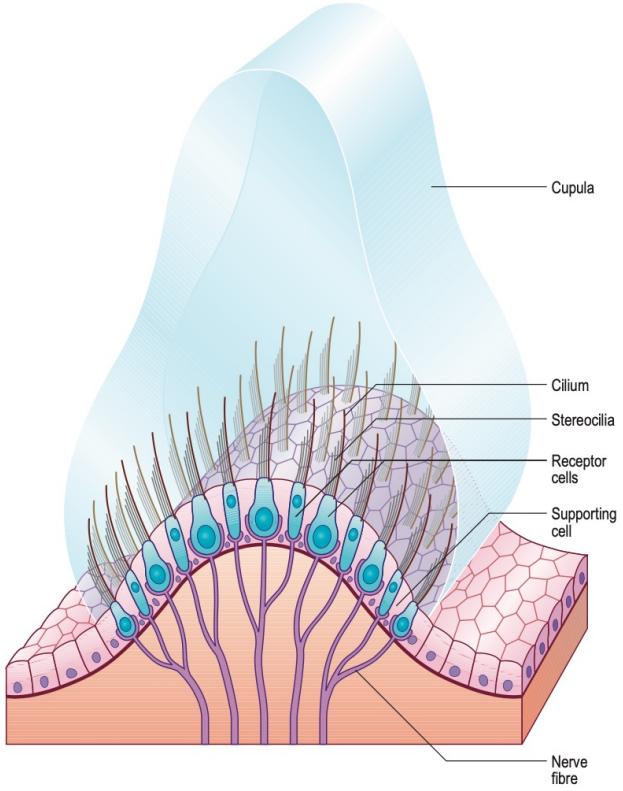
# Labyrinthus vestibularis

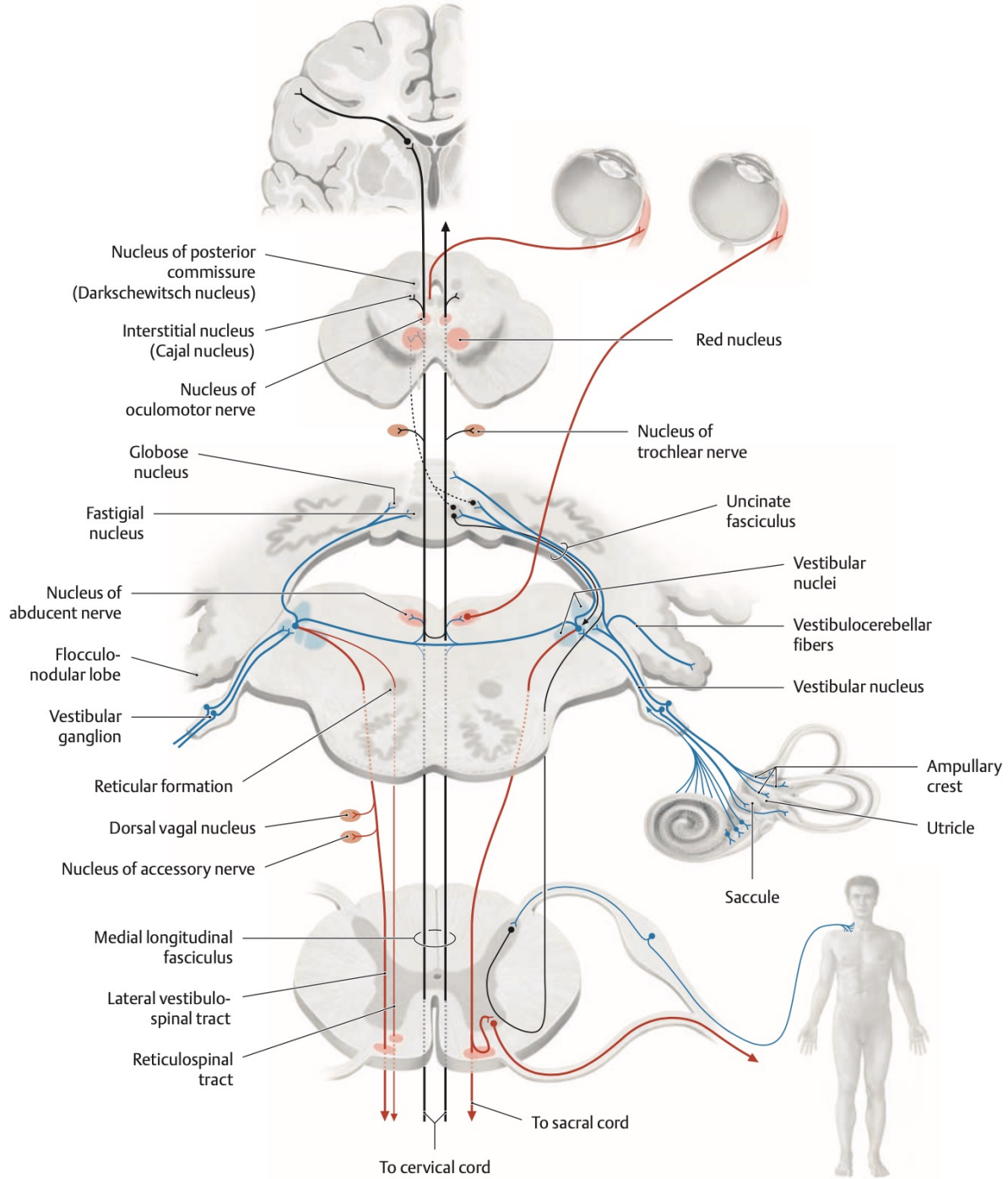
- Macula statica utriculi
- Macula statica sacculi
- Hairy cells
  - Sterocilia
  - Cillium – one long
  - Glycoprotein gelatinous surface
  - Otoliths
    - otoconia, statoconia
  - Crystals of $CaCO_3$




- Canalis semicircularis
- Ductus semicircularis
- Ampulae - cristae ampulares – hairy cells
  - One long cilia
  - gelatinous cupula
  - angular acceleration

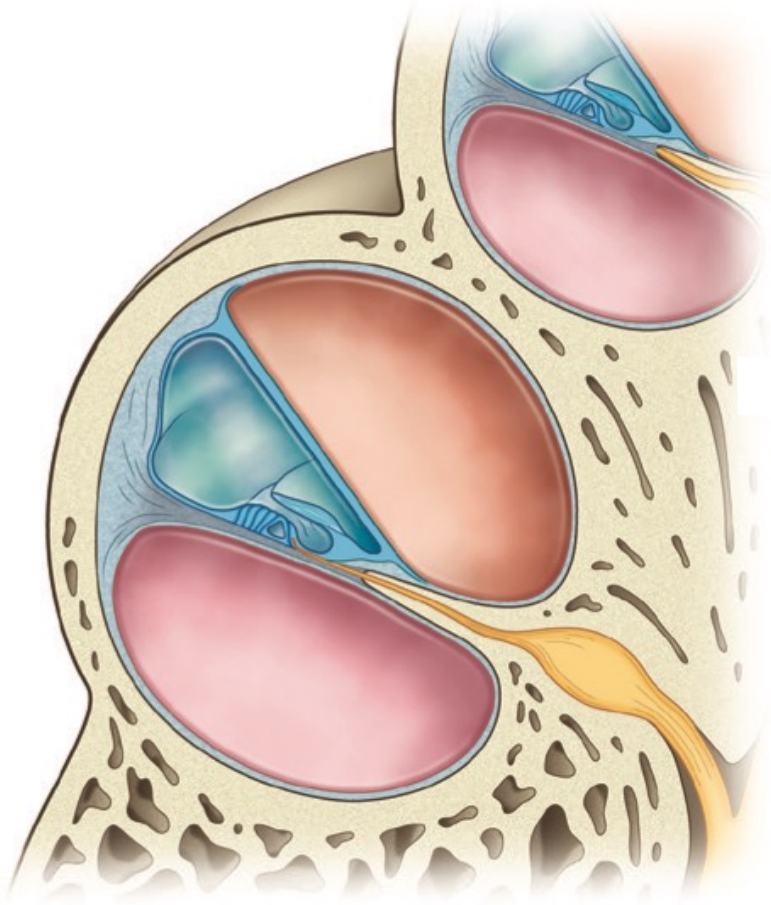


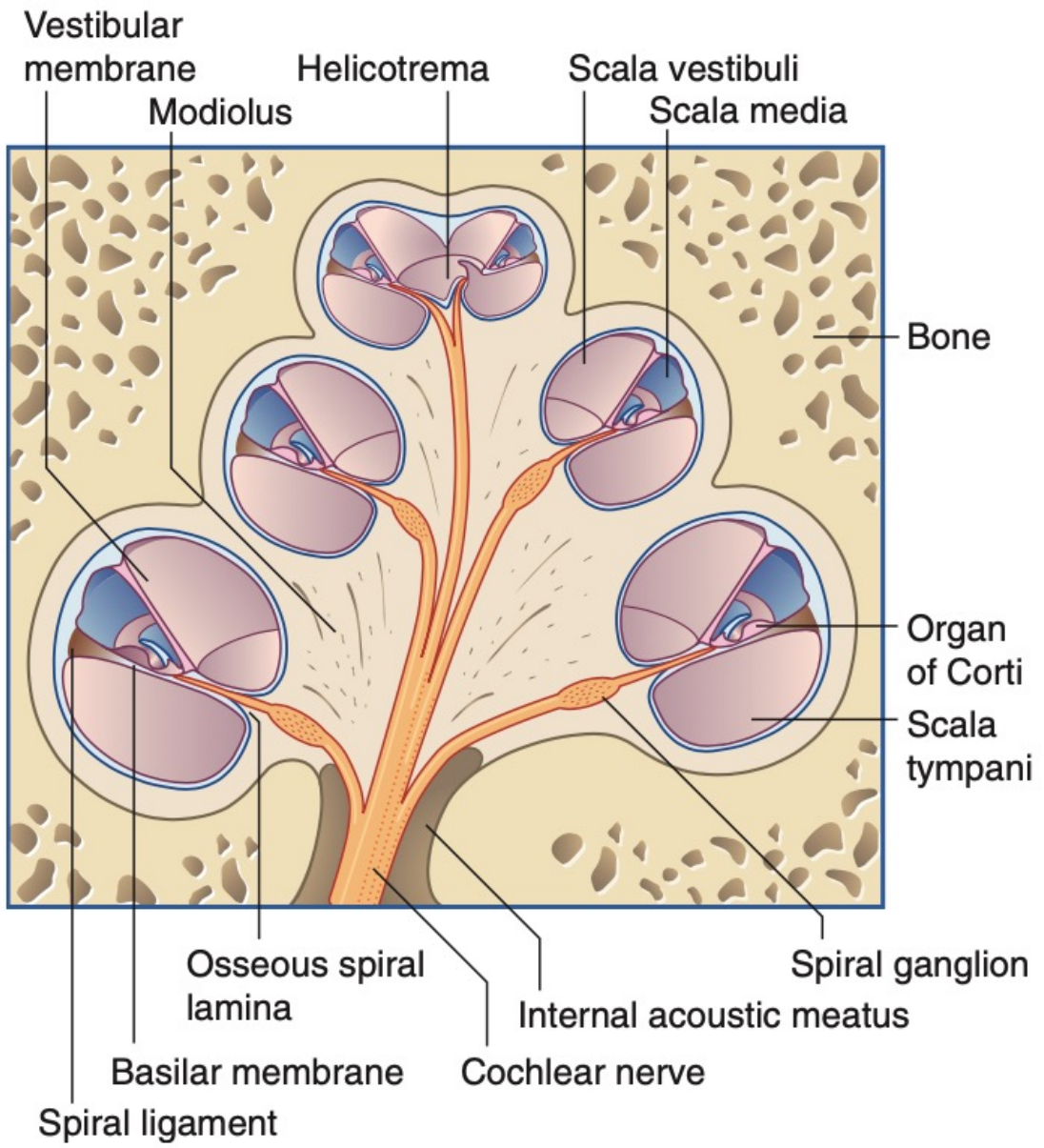



Nucleus of posterior commissure (Darkschewitsch nucleus)
Interstitial nucleus (Cajal nucleus)
Nucleus of oculomotor nerve
Red nucleus
Nucleus of trochlear nerve
Globose nucleus
Fastigial nucleus
Uncinate fasciculus
Vestibular nuclei
Nucleus of abducent nerve
Vestibulocerebellar fibers
Flocculo-nodular lobe
Vestibular nucleus
Vestibular ganglion
Ampullary crest
Reticular formation
Utricle
Dorsal vagal nucleus
Saccule
Nucleus of accessory nerve
Medial longitudinal fasciculus
Lateral vestibulo-spinal tract
Reticulospinal tract
To sacral cord
To cervical cord

# Auditoty system

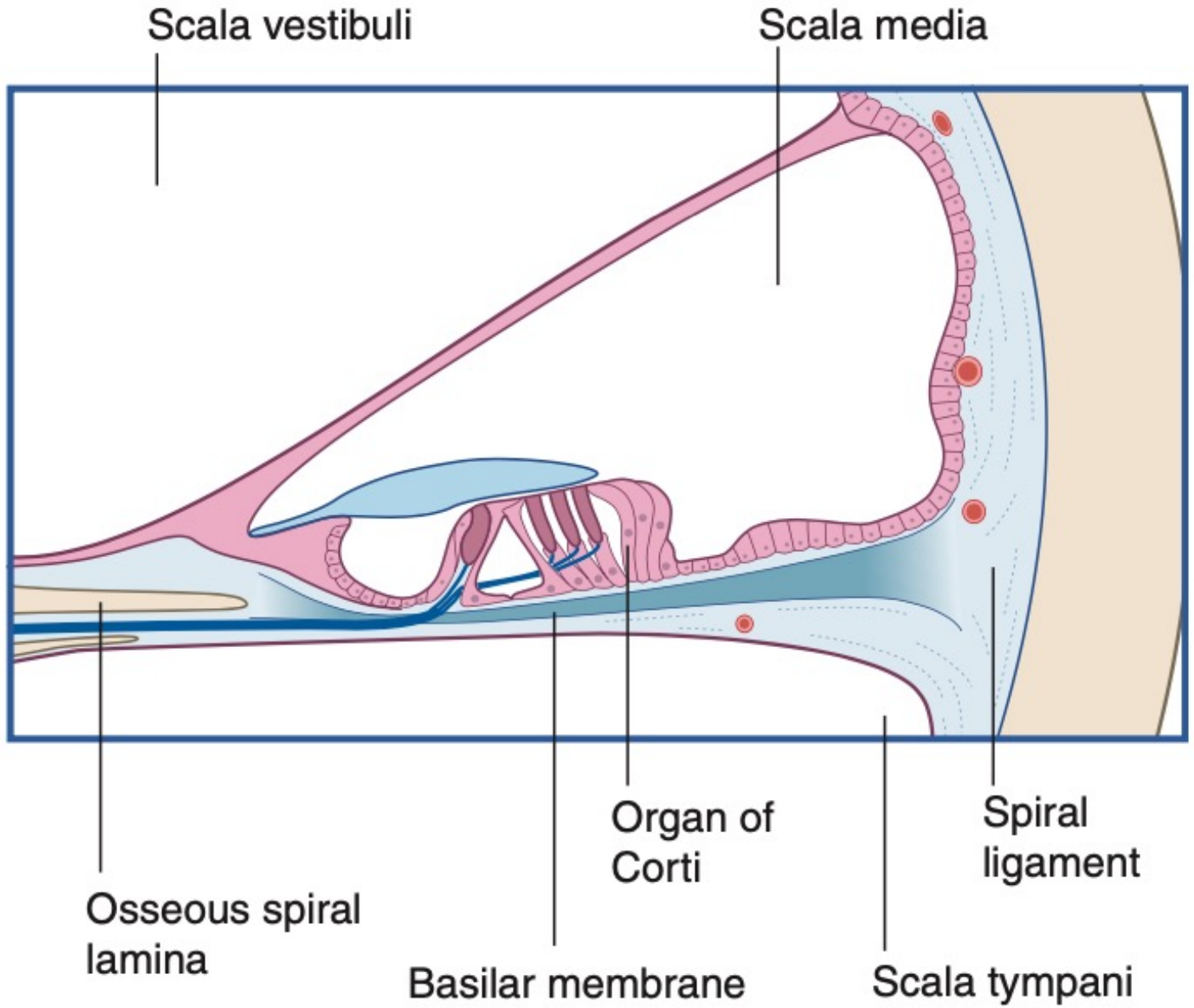
- Scala vestibuli
- Scala media – ductus cochelaris
- Scala tympani
- Helicotrema





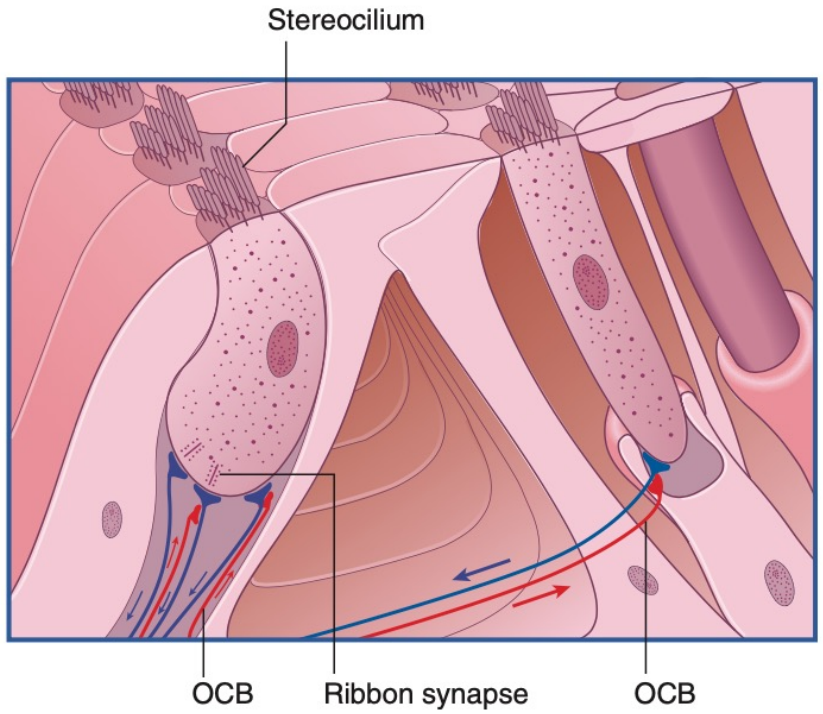
# Labyrinthus cochlearis

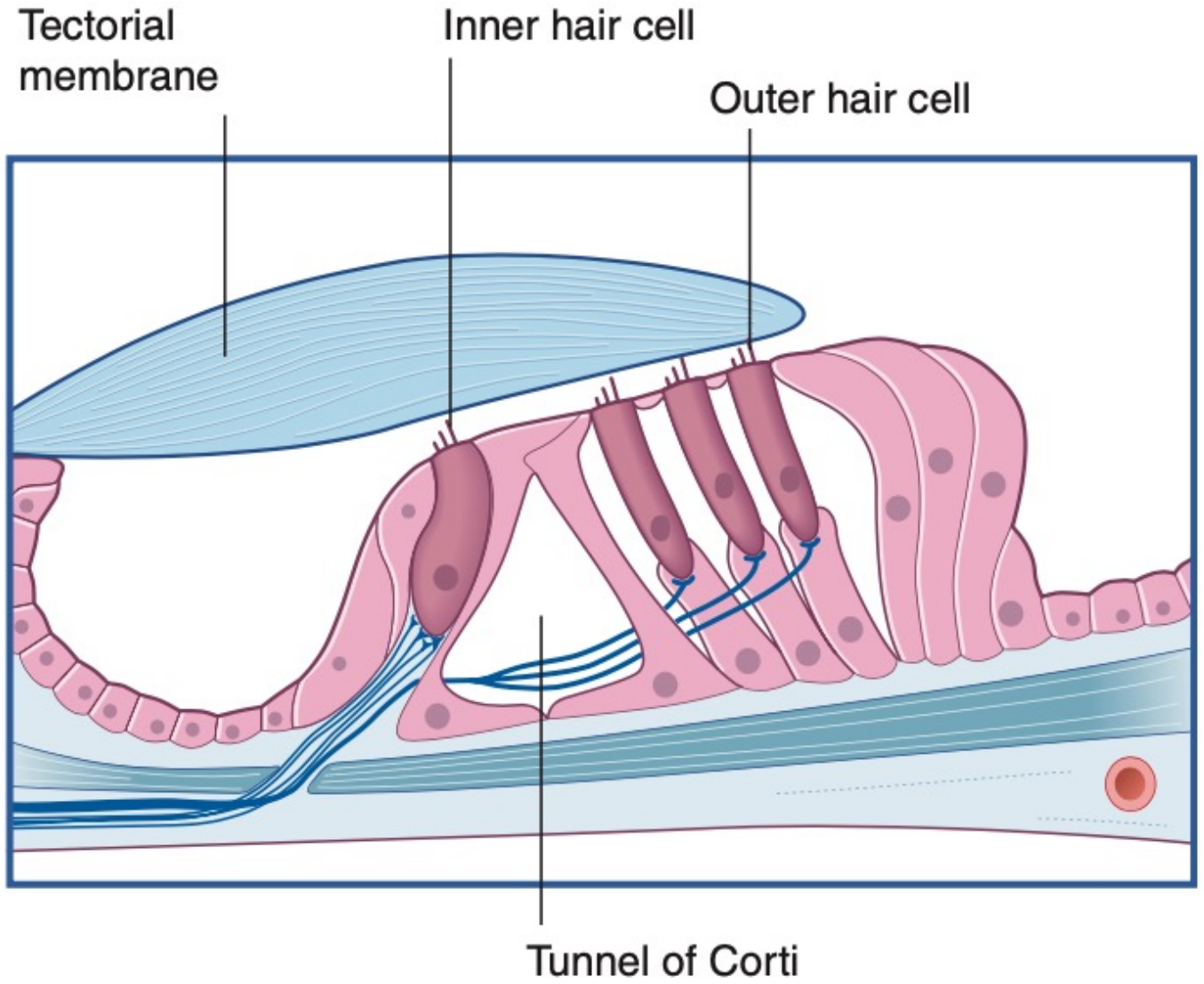
- Scala media
- **Ductus cochlearis**
  - Caecum vestibulare
  - Caecum cupulare
  - Ductus reuniens
- **Organum spirale Corti**
  - Smyslové bb. - vláskové
  - Podpůrné bb
- **Prominentia spiralis**
  - Vas prominens
  - Stria vascularis – endolymph



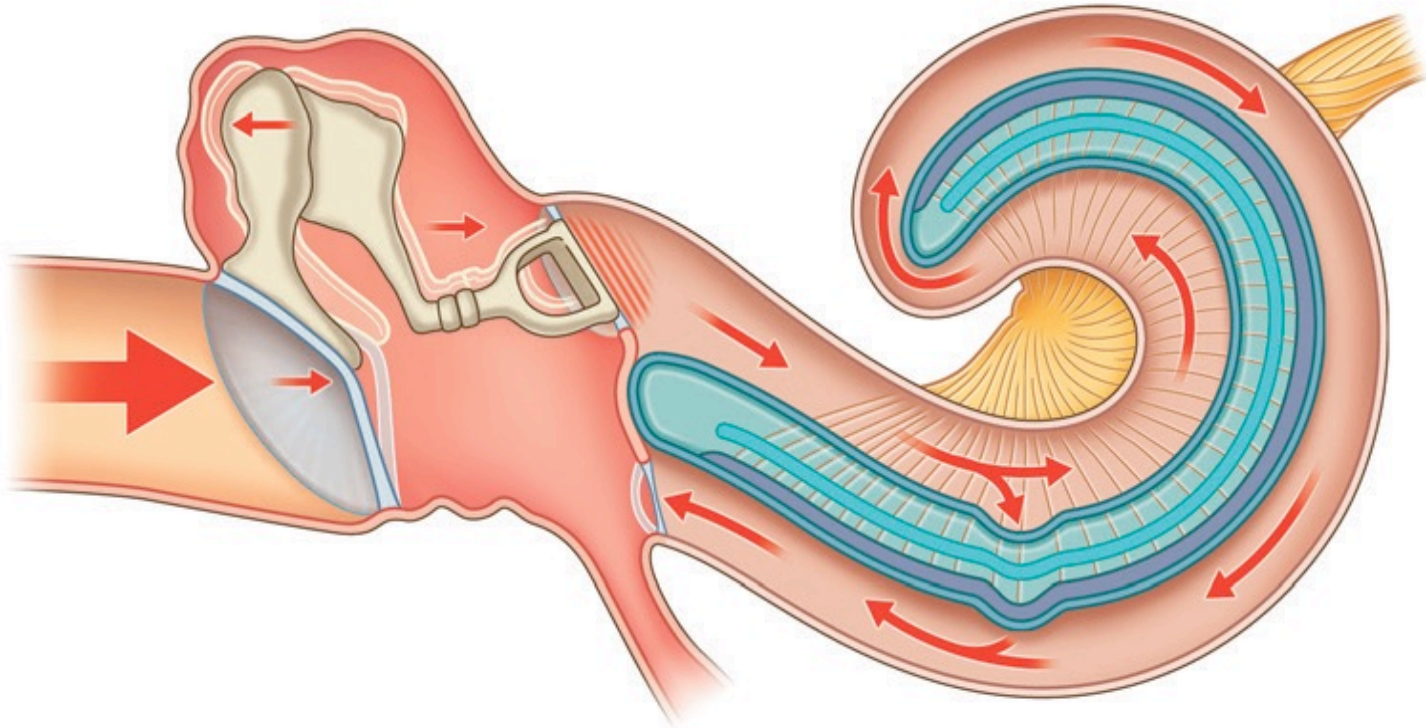
# Organum corti

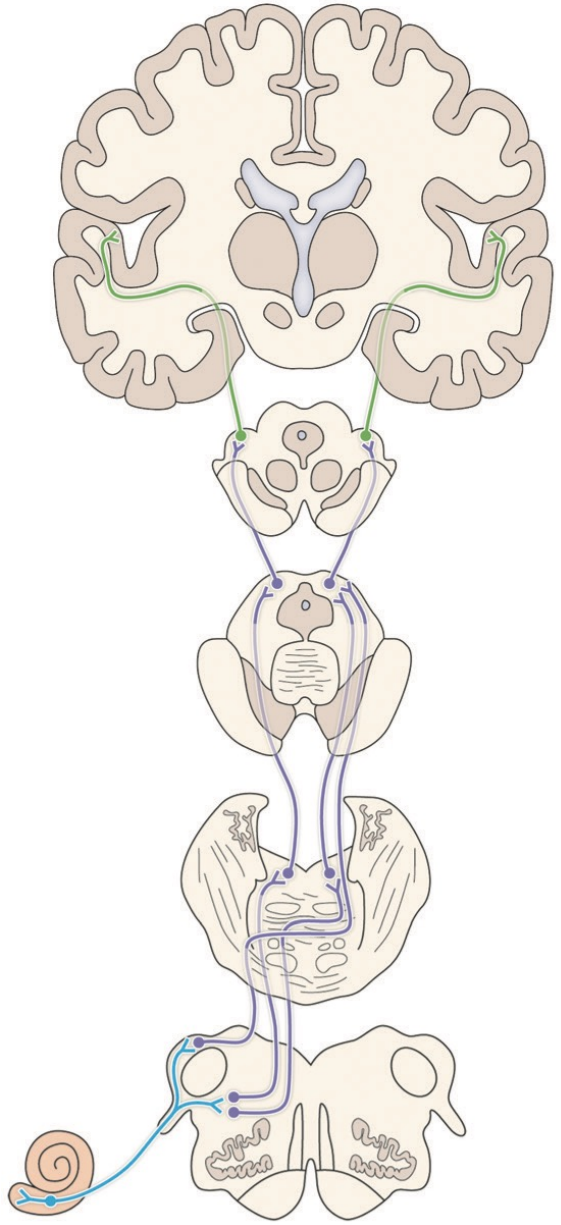
- Cortiho tunel
- Membrana tectoria
  - Cellless
- Hairy cells
  - Outer and inner
  - 40 – 50 stereocillia in 3 – 4 rows



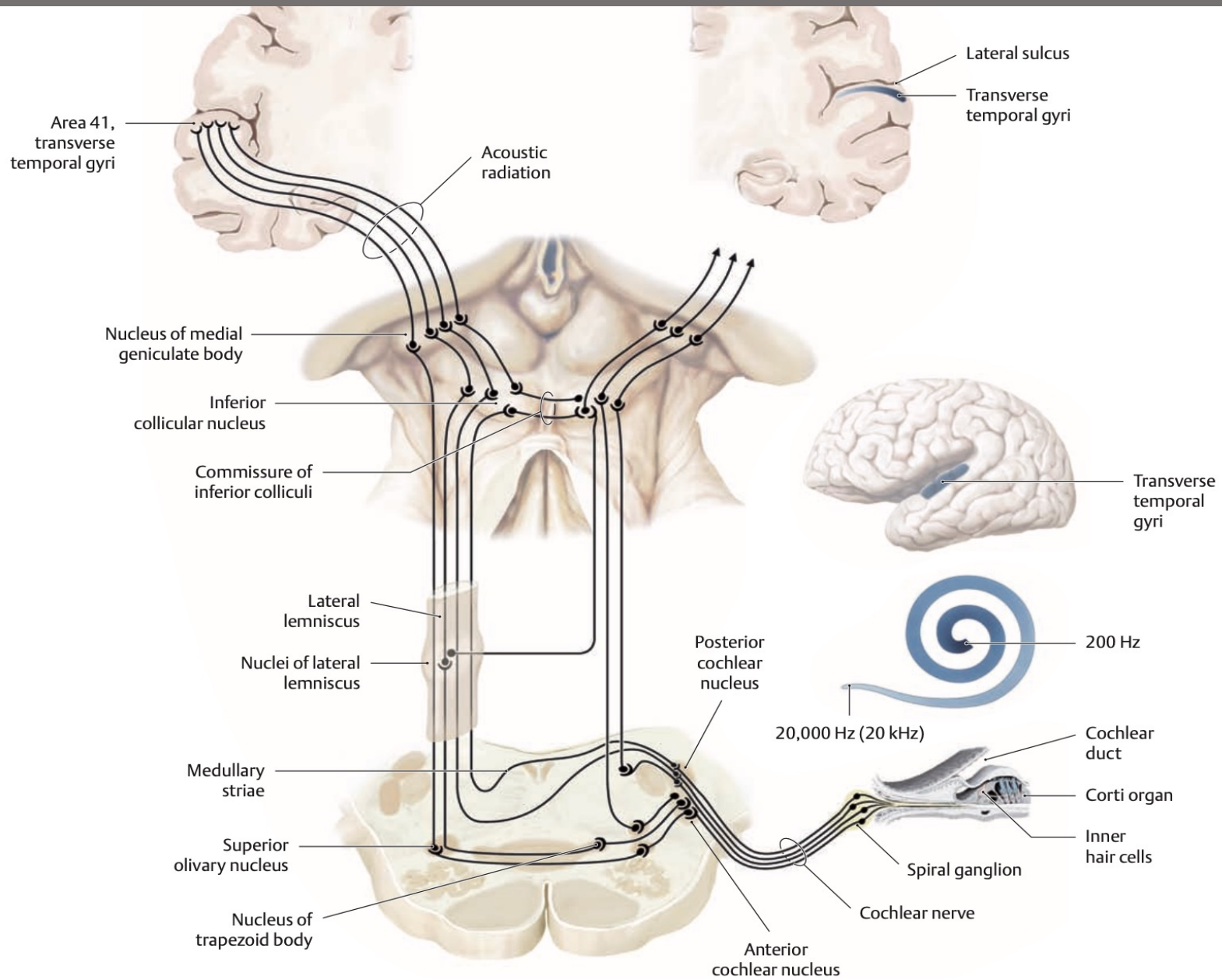



# Auditory pathway

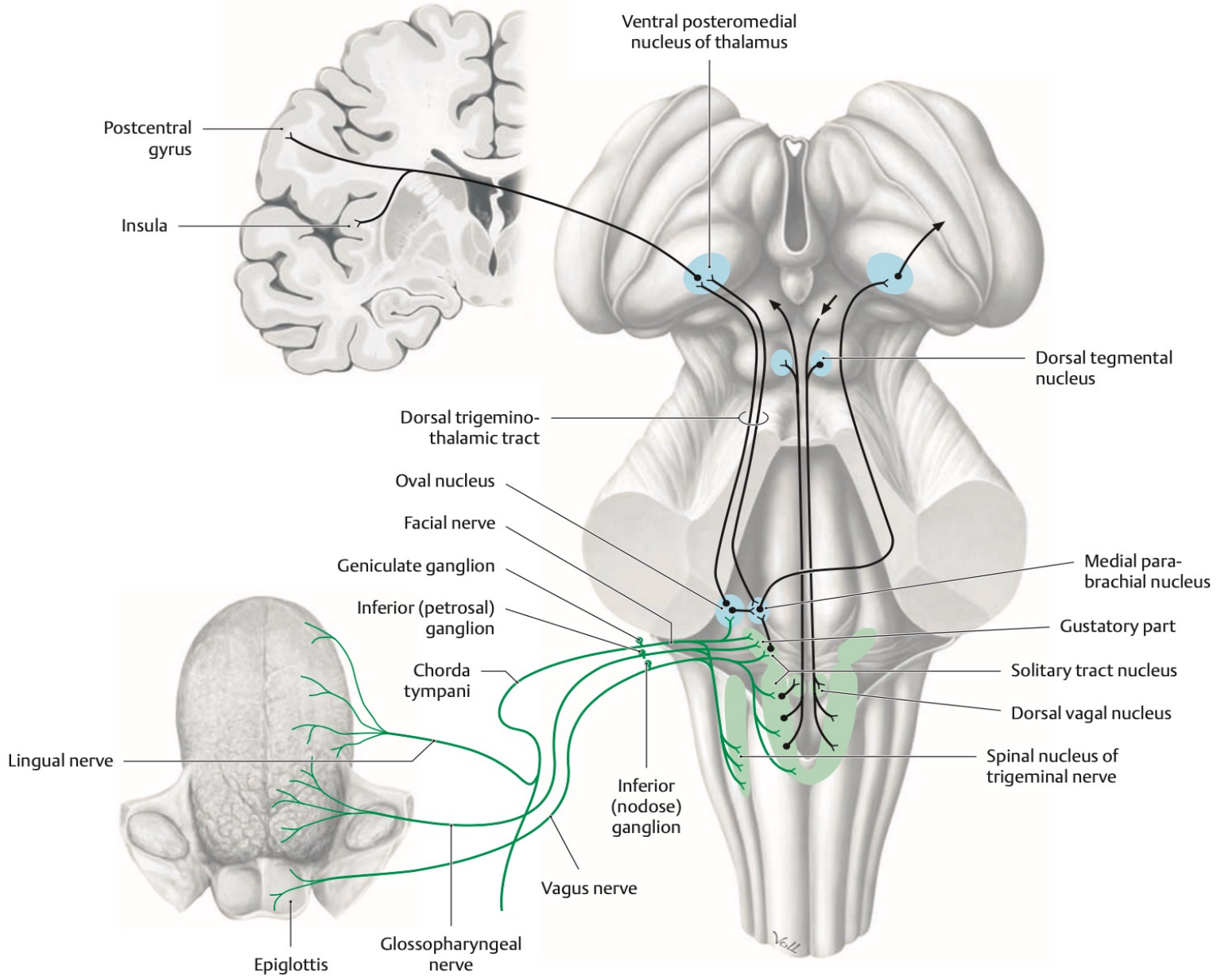




# Auditory pathway

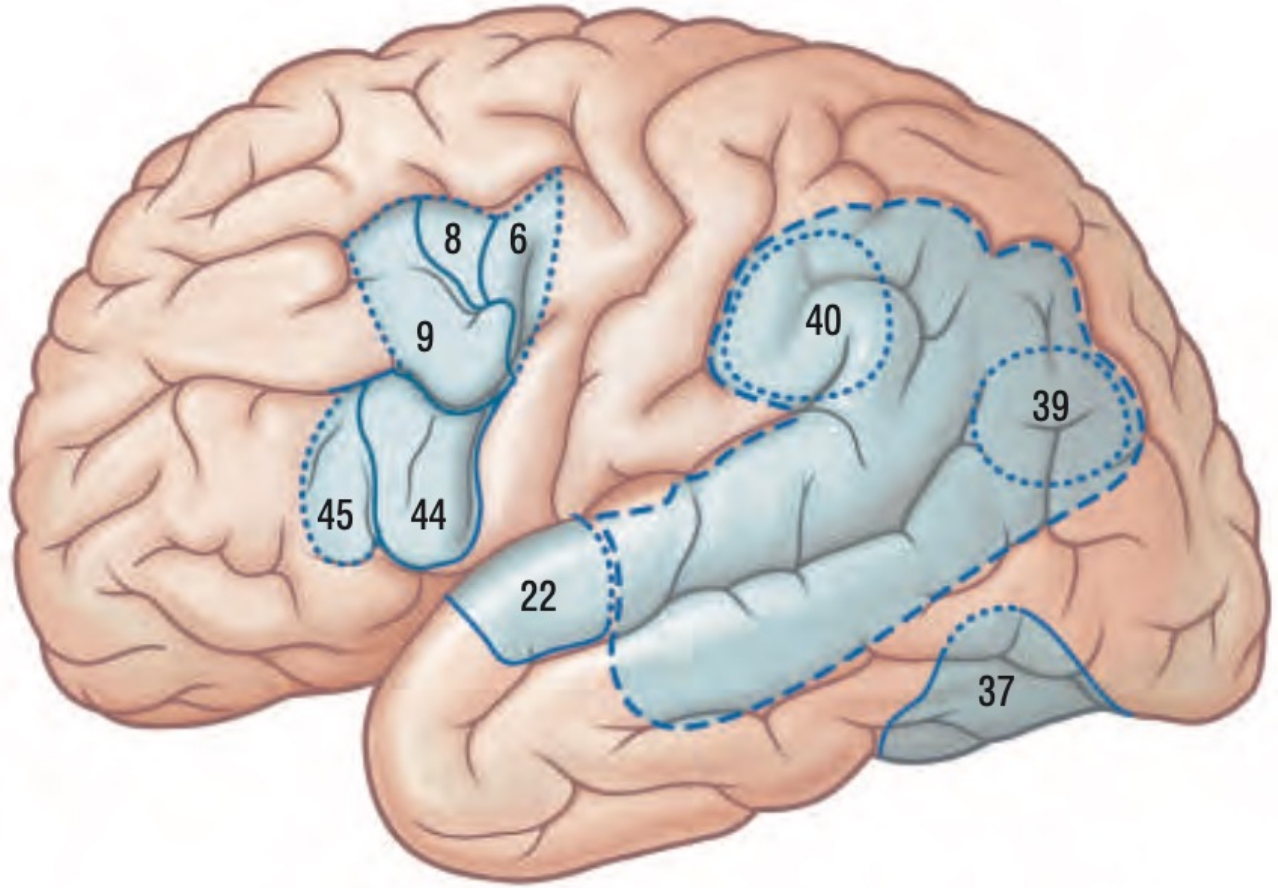


# taste pathway

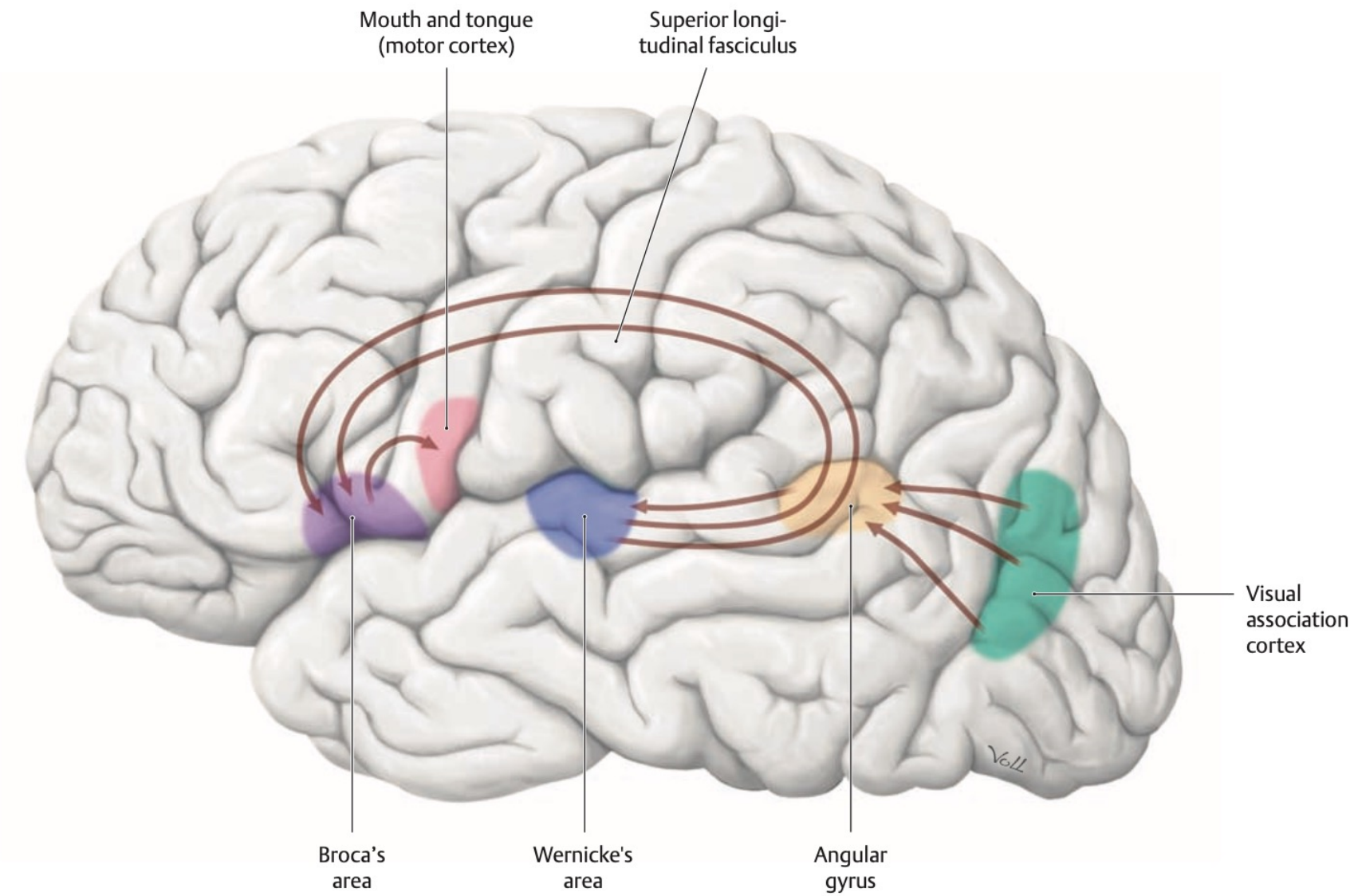


# speech

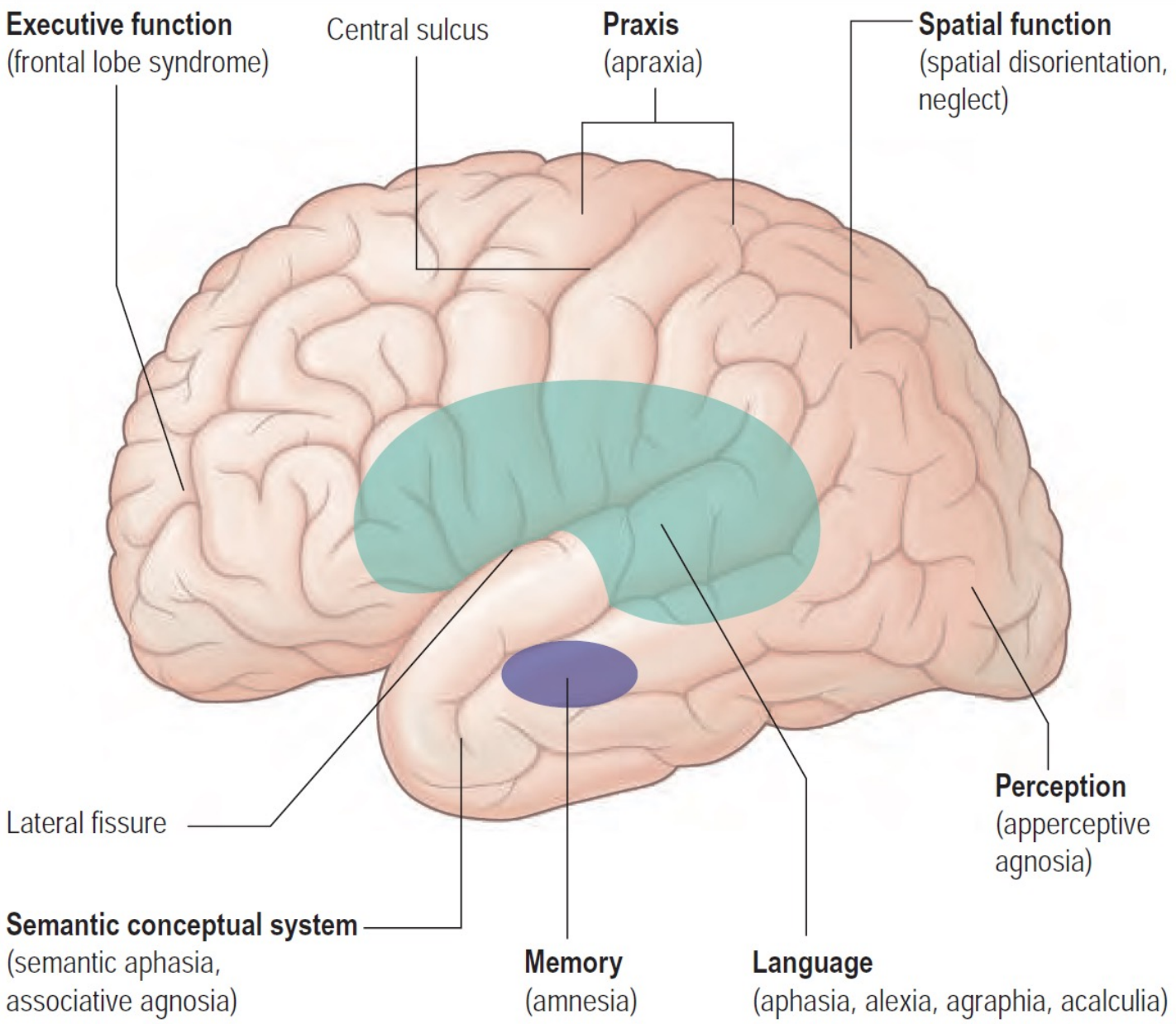
- **Broca**
  - **area 44 a 45 – gyrus frontalis inferior**
  - **Injury -motoric / expresive aphasia**
- **Wernicke**
  - **Area 39 + 40**
  - **injury – senzoric / receptive aphasia**
- ***Assiciation ceters***
  - ***auditory***
    - ***Area 22***
  - ***visual***
    - ***Area 37***
- ***Primary sensoric cortex***
  - ***visual***
    - ***Area 17 –sulcus calcarinus***
  - ***auditory***
    - ***Area 42 – gyrus temporalis superior***



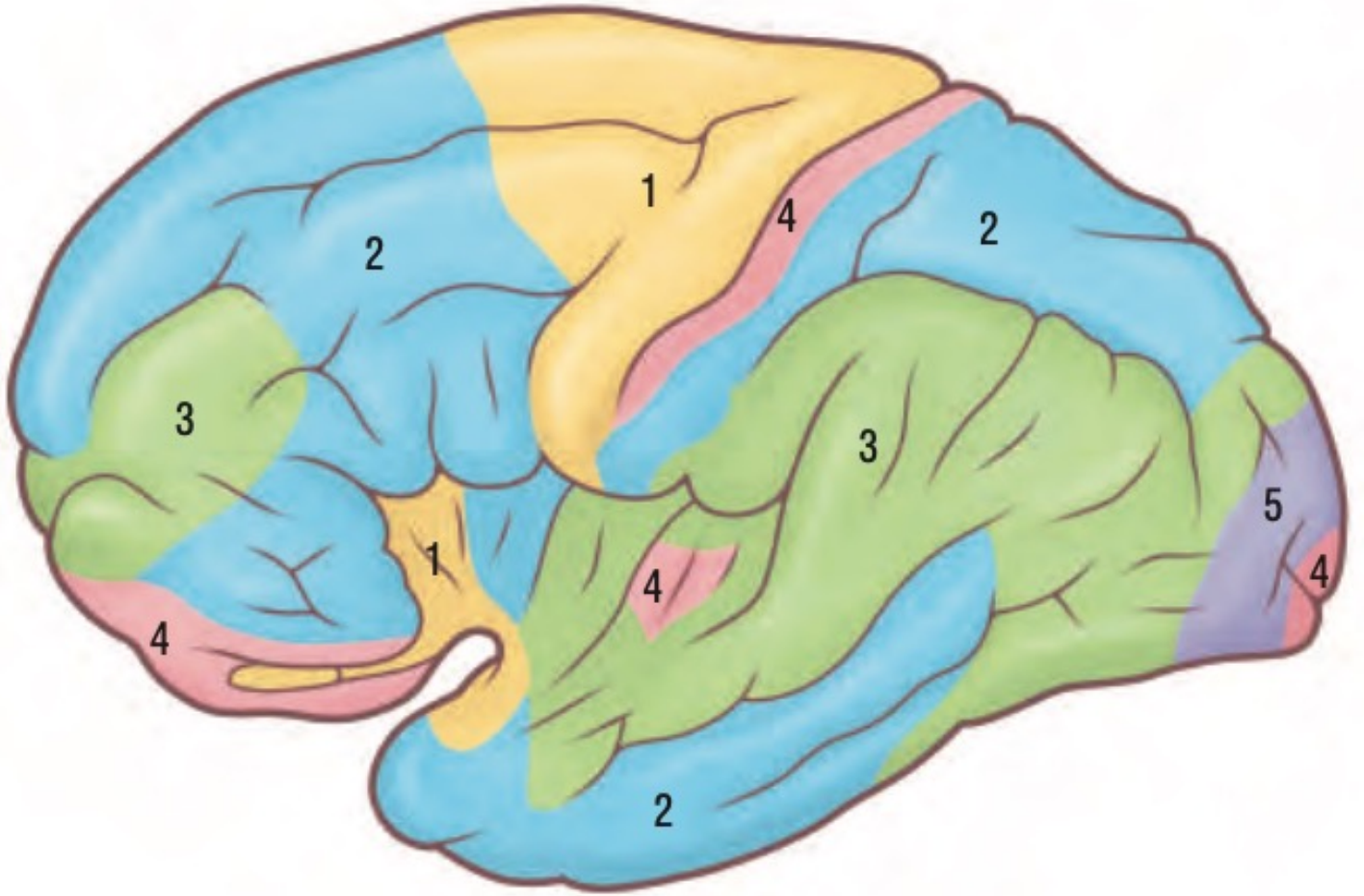
# speech


Mouth and tongue
(motor cortex)
Superior longi-
tudinal fasciculus
Visual
association
cortex
Broca's
area
Wernicke's
area
Angular
gyrus

# Behavior, thinking



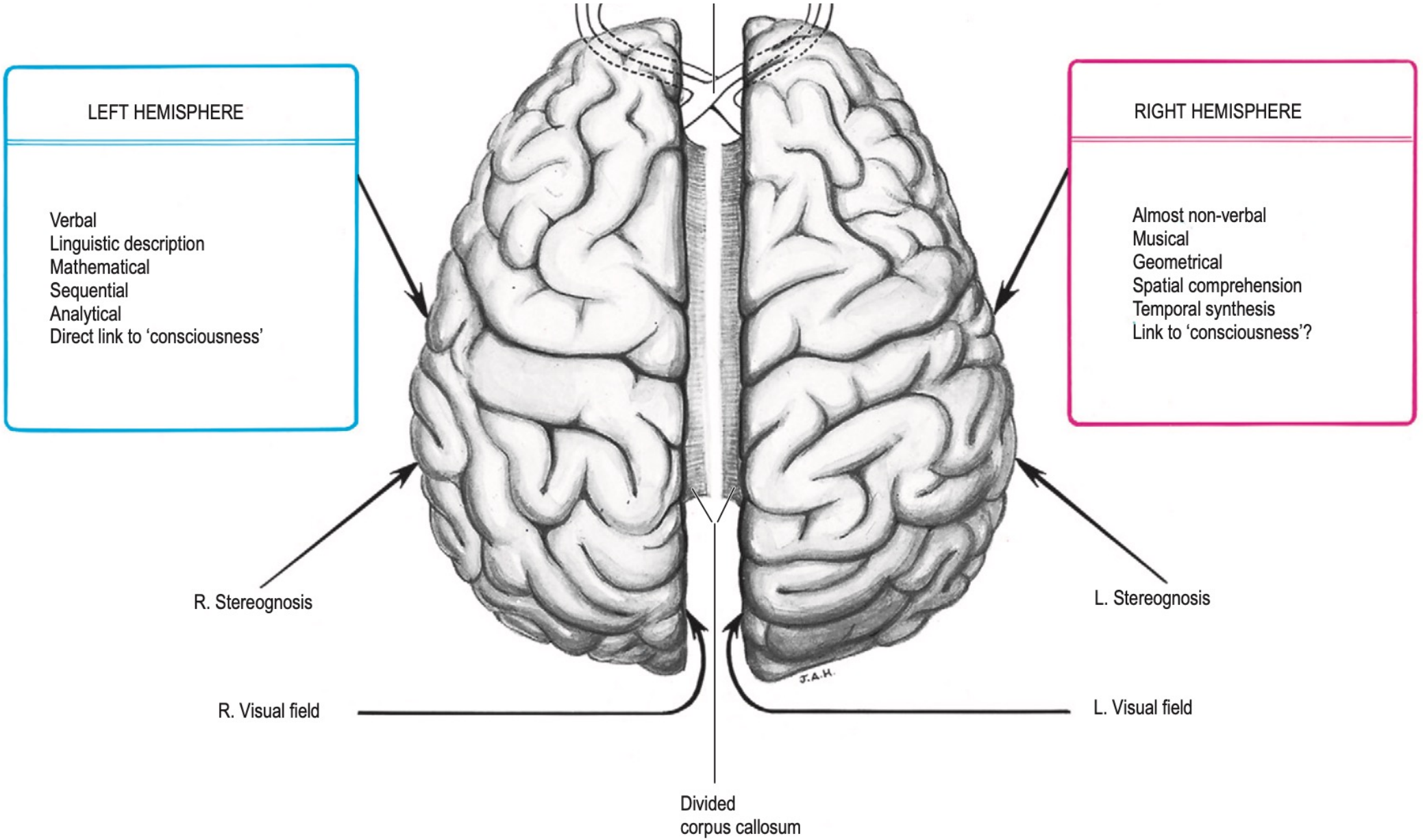
# Functional cortical regions



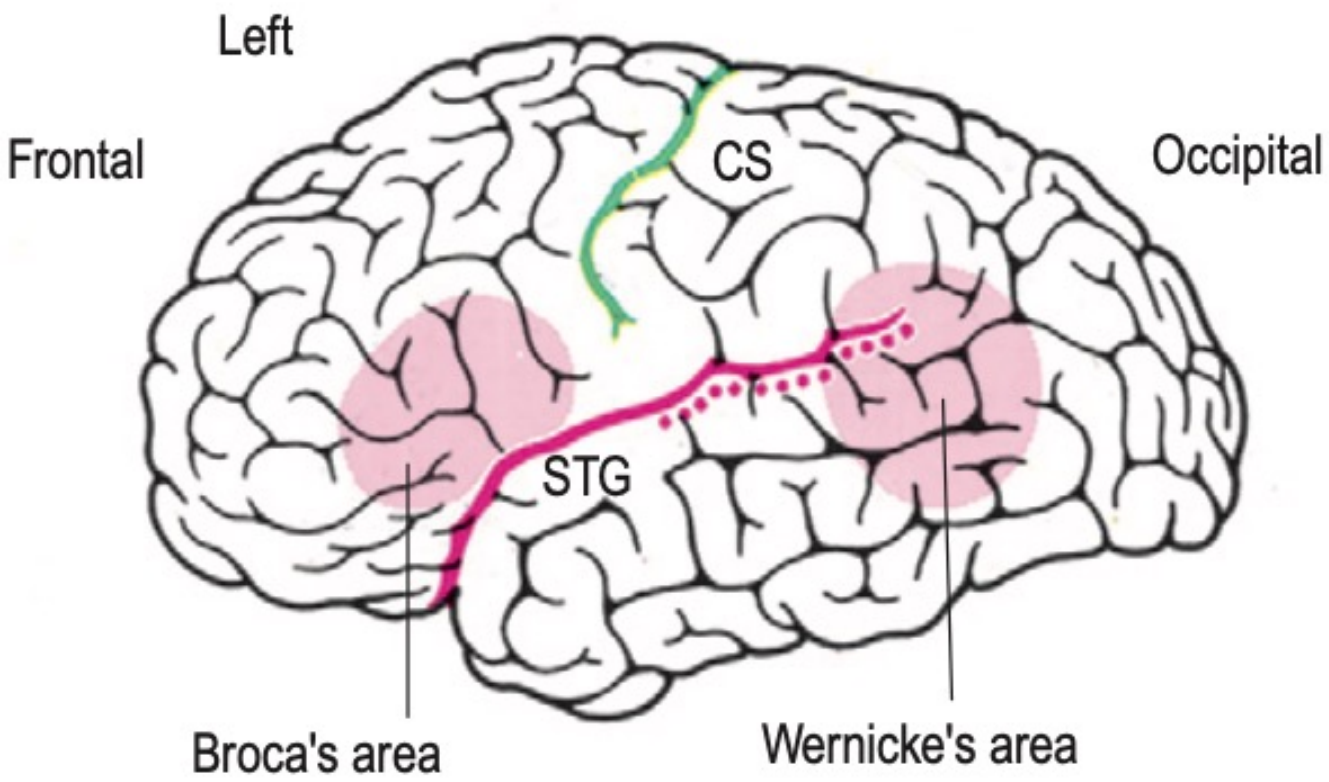

- primary (projection) cortical regions
- Secondary cortical regions
- Supplementary regions
- Terciary (association) regions

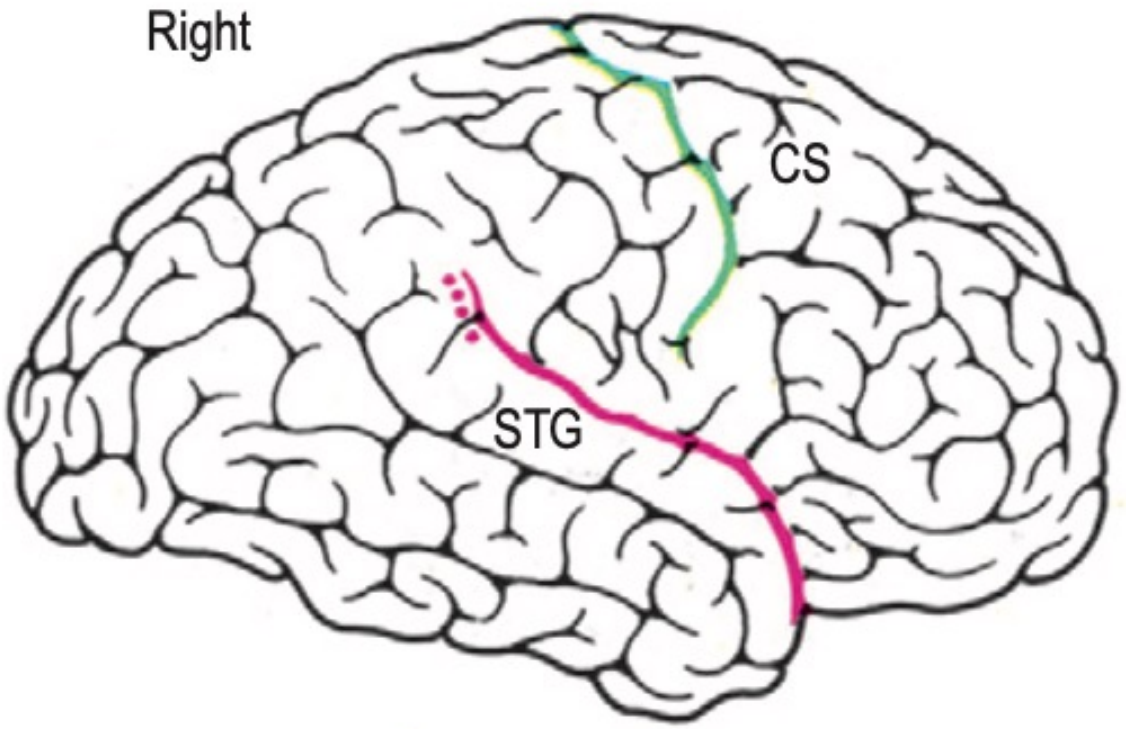
- Dominant hemisphere
  - In righthanded obviously left hemisphere
  - In half of lefthanded left hemisphere
  - In half of lefthanded right hemisphere
  - Plasticity

# Asymmetry of the brain

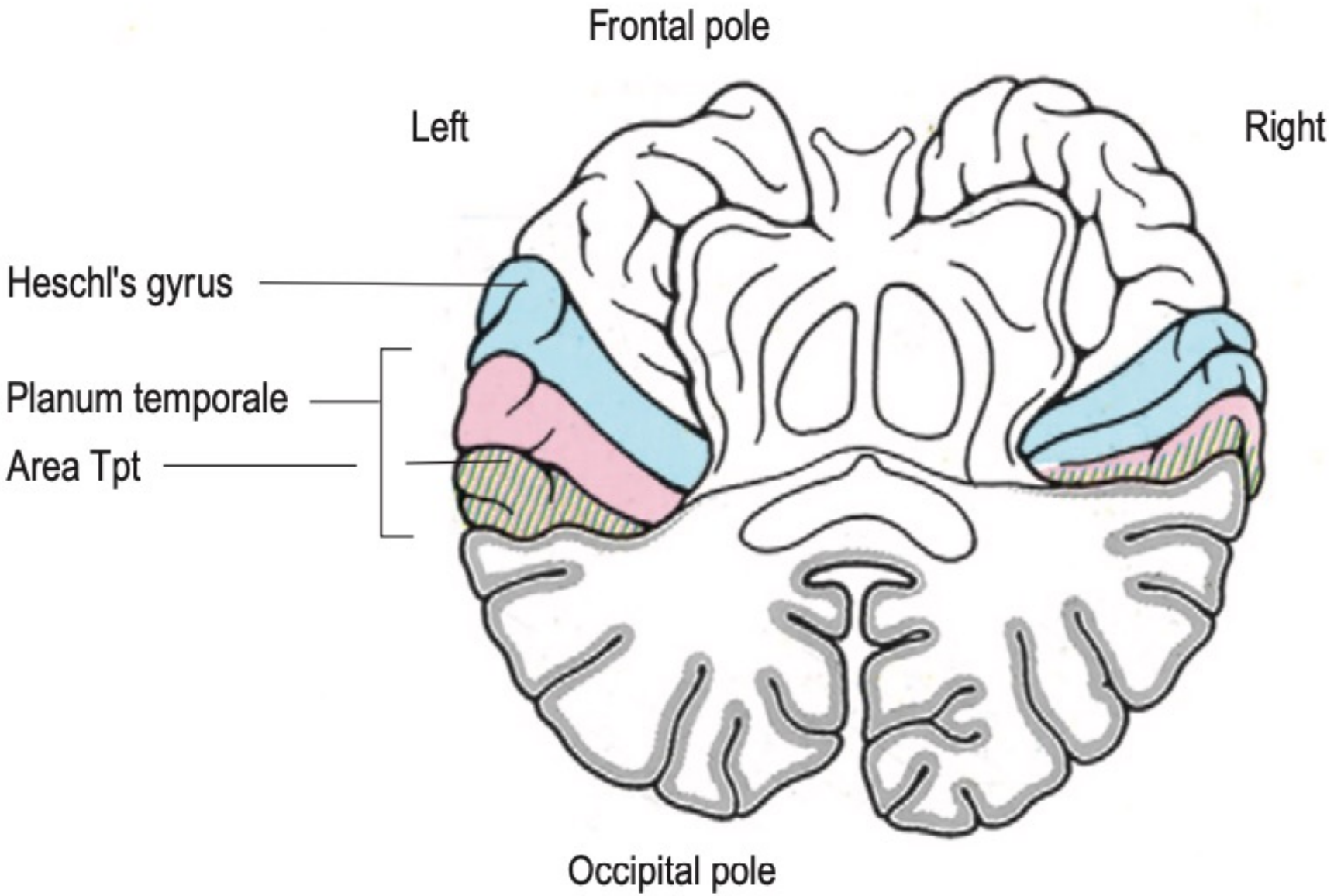


# Asymmetry


Left
Frontal
CS
Occipital
STG
Broca's area
Wernicke's area


Right
CS
STG

# Asymmetry


Frontal pole
Left
Right
Heschl's gyrus
Planum temporale
Area Tpt
Occipital pole

# Neuroanatomy – functional systems