Neuroanatomy.
Cerebellum and diencephalon

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Parts of cerebellum

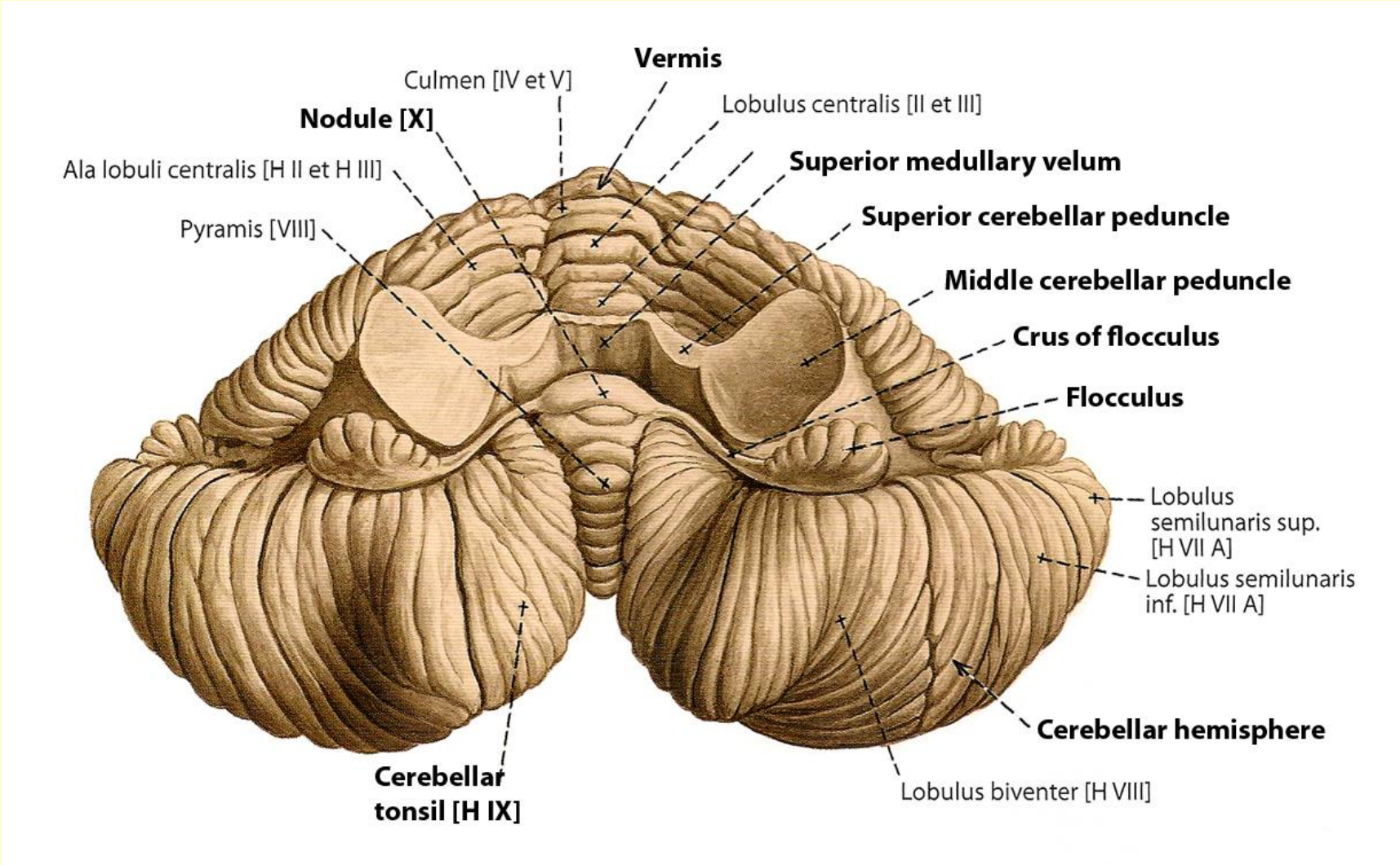
One possible division: vermis located in the middle **+ cerebellar hemispheres** located on both sides of the vermis

Another possible division: cerebellar cortex, which can be divided into 10 cerebellar lobes separated by deep, parallel cerebellar fissures. The lobes are further folded by less deep, parallel grooves called cerebellar folias.

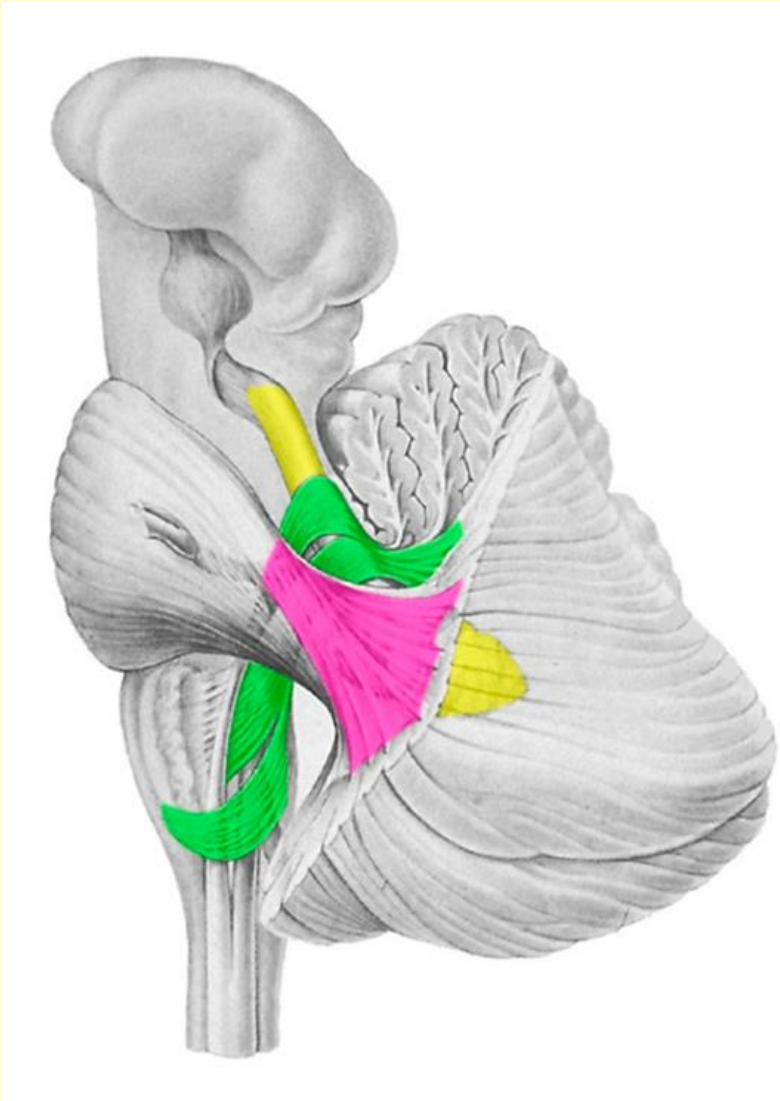
+ cerebellar nuclei: gray matter located deep into the cerebellum

+ cerebellar peduncles: white mater tracts with afferent (incoming) fibers reaching the cerebellar cortex and efferent (outgoing) fibers leaving the cerebellar nuclei

View of the cerebellum from the brainstem



Cerebellar peduncles



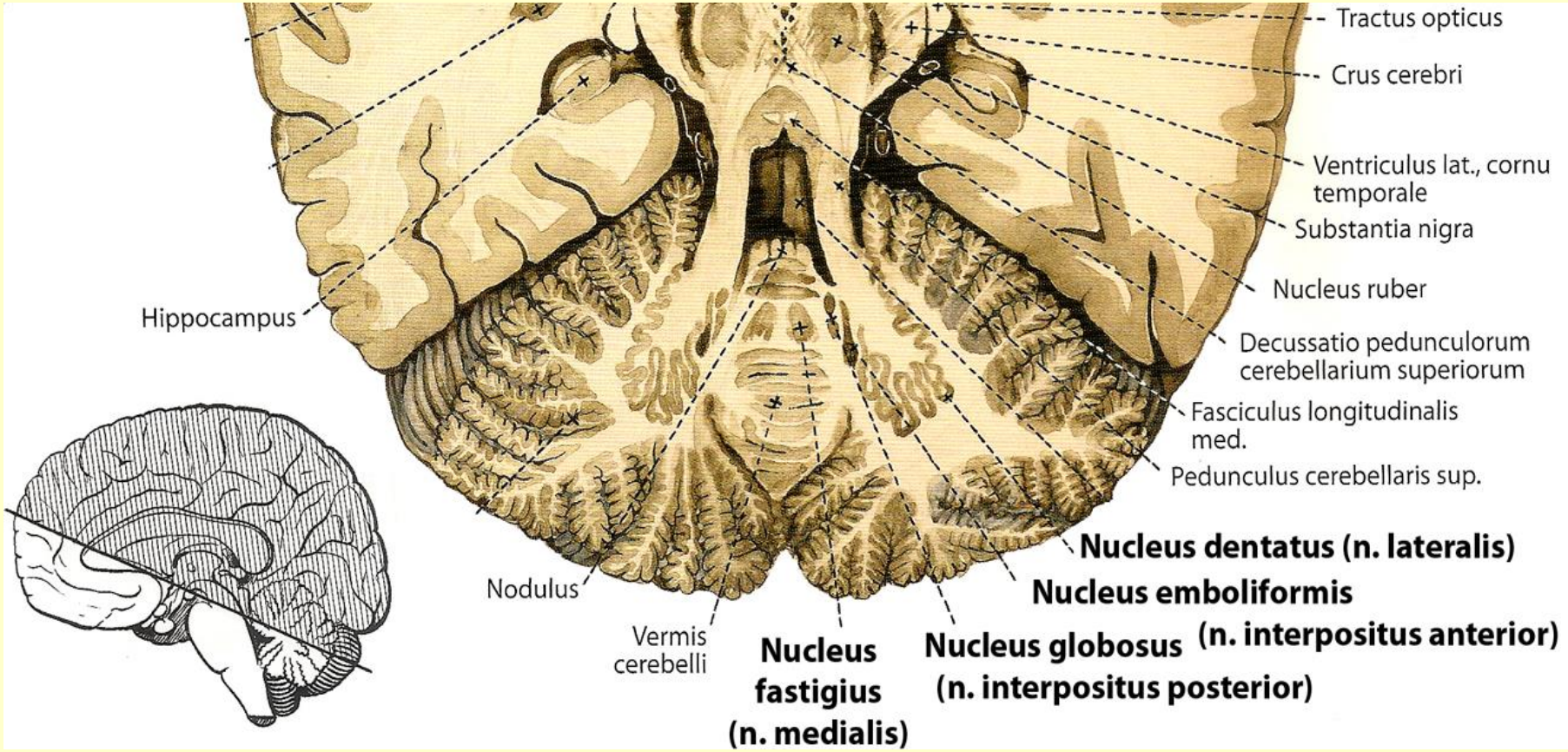
superior cerebellar peduncle

middle cerebellar peduncle

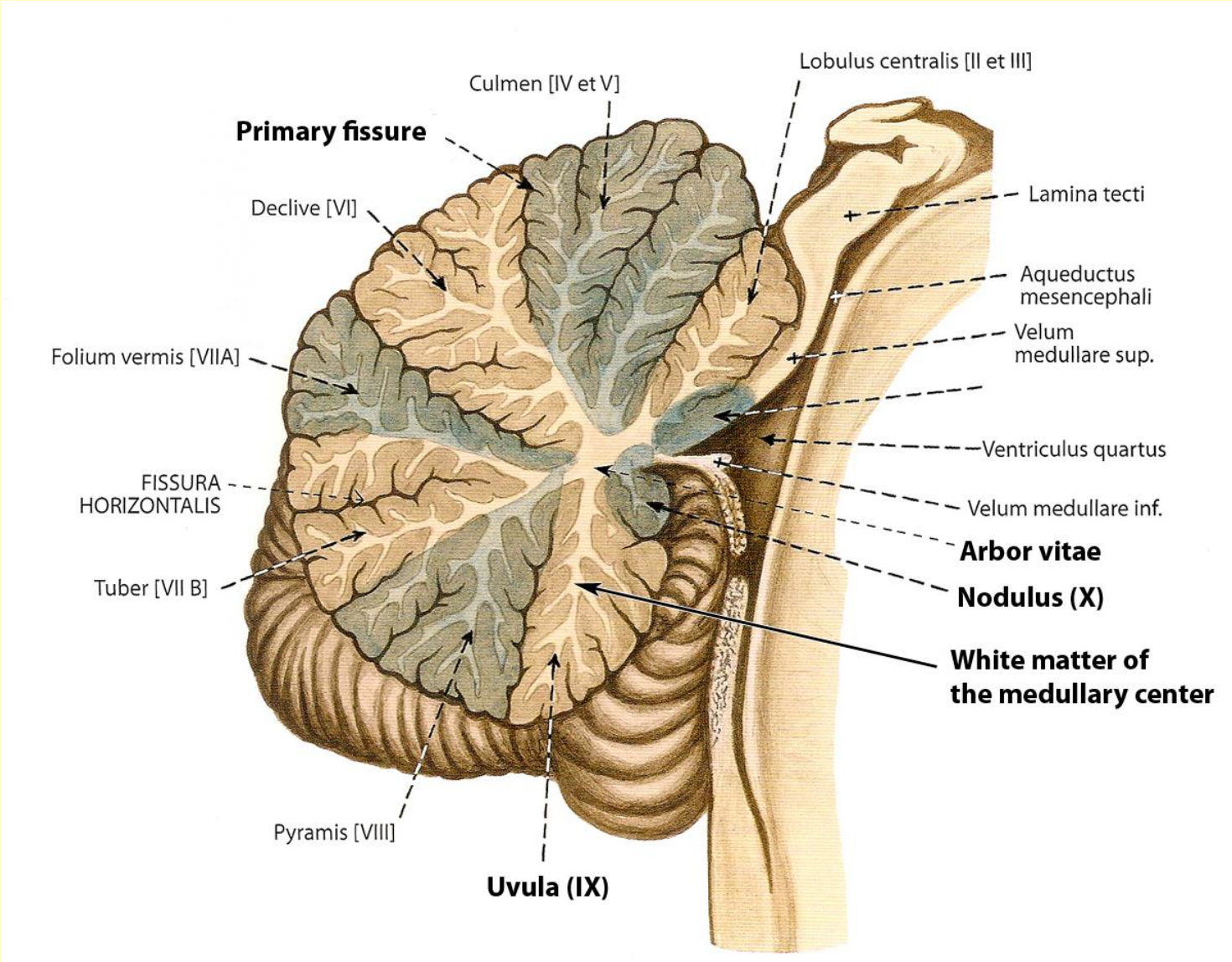
inferior cerebellar peduncle

Cerebellar nuclei

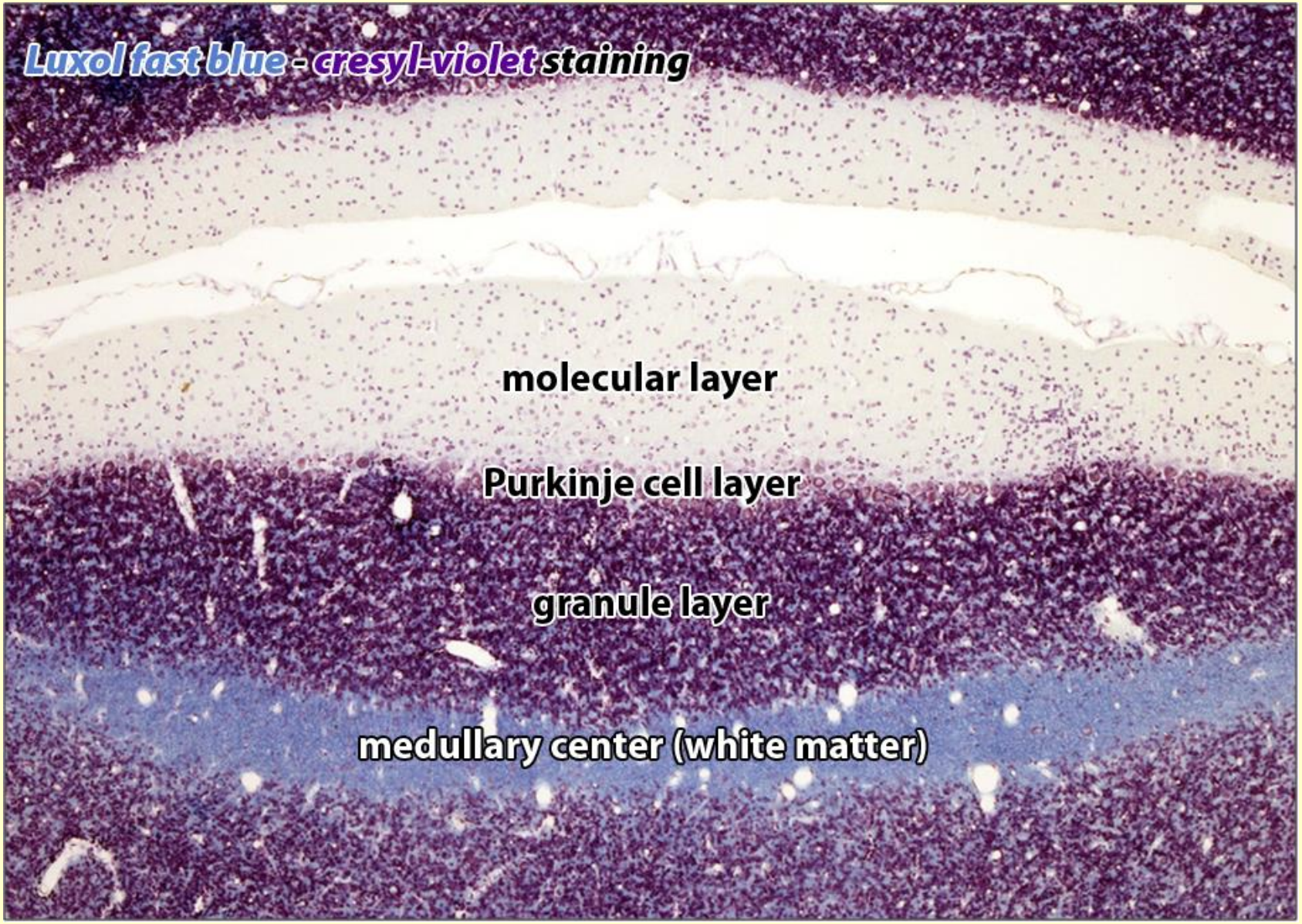
A near horizontal section of the cerebellum:



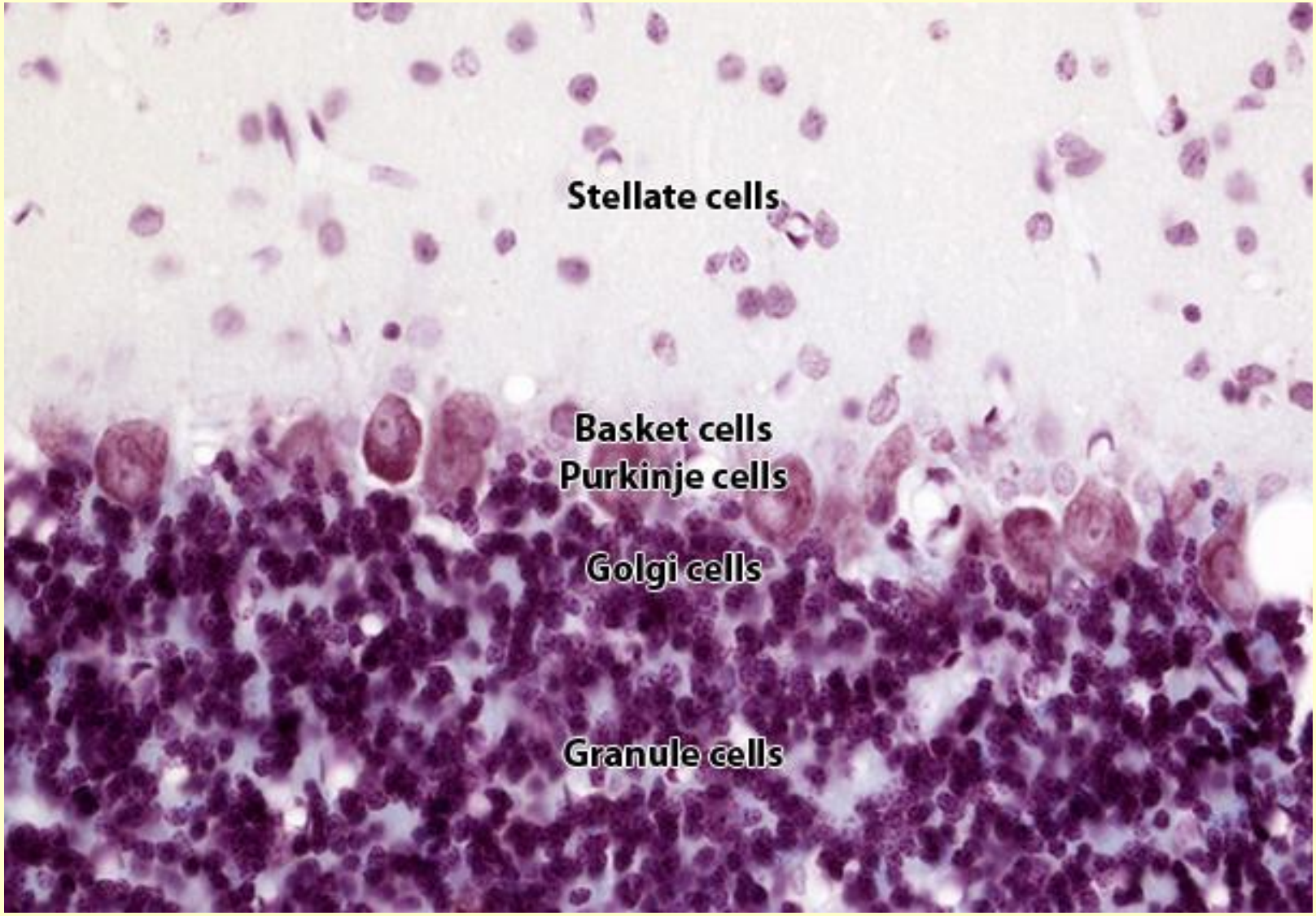
Mediosagittal section of the cerebellum



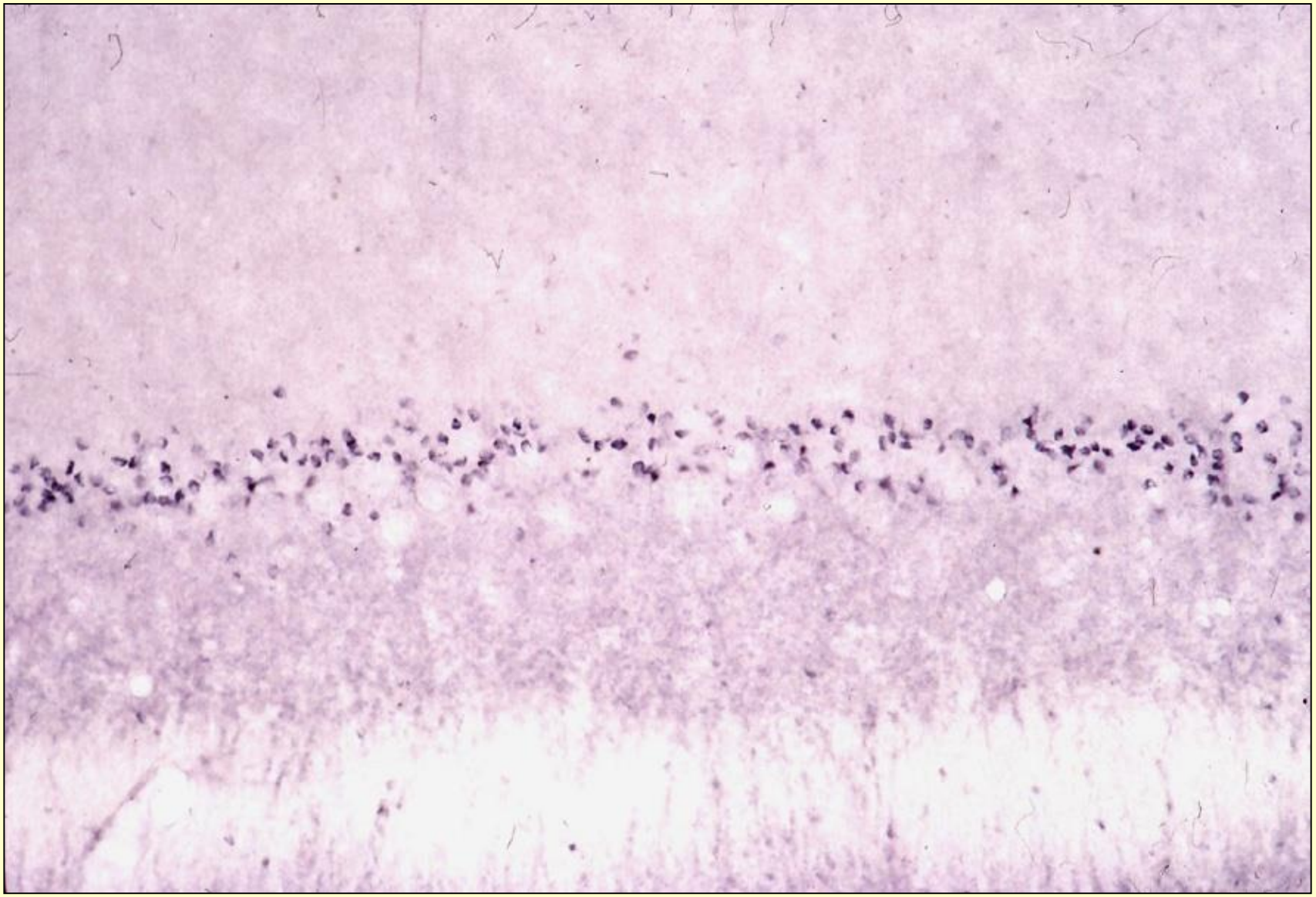
Microscopic layers of the cerebellar cortex



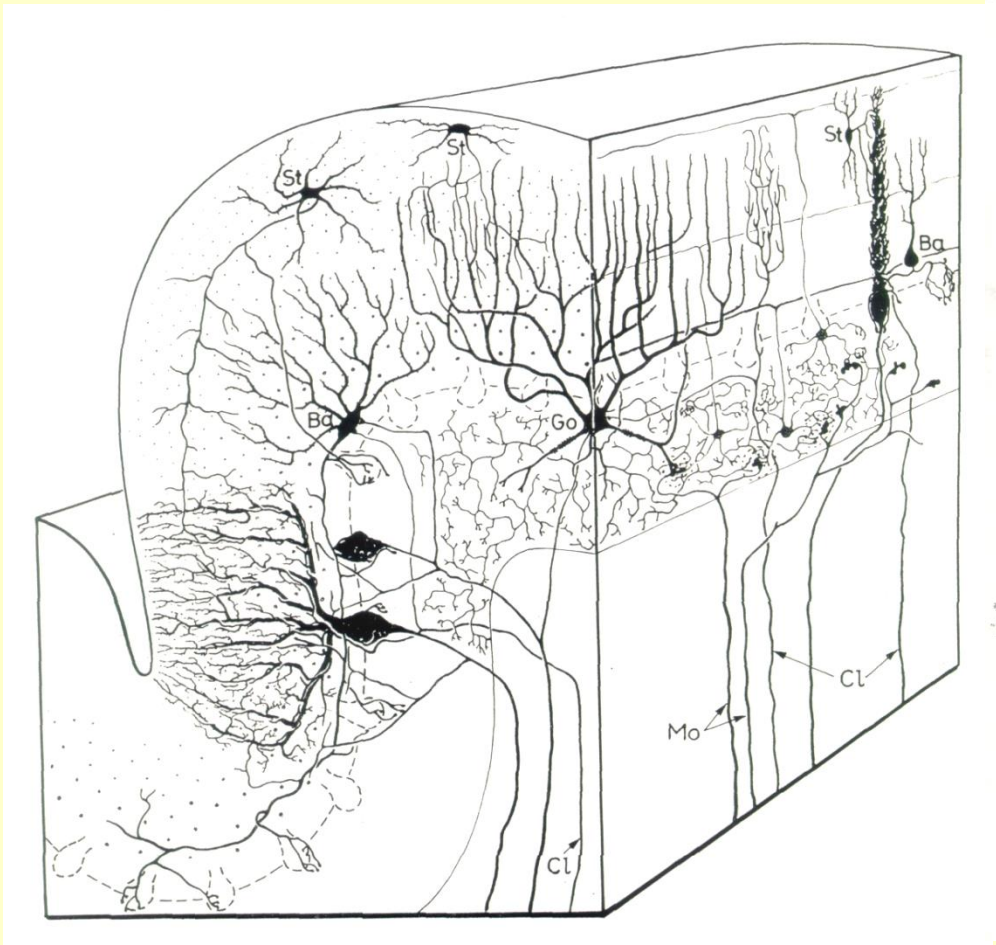
Cell types of the cerebellar cortex

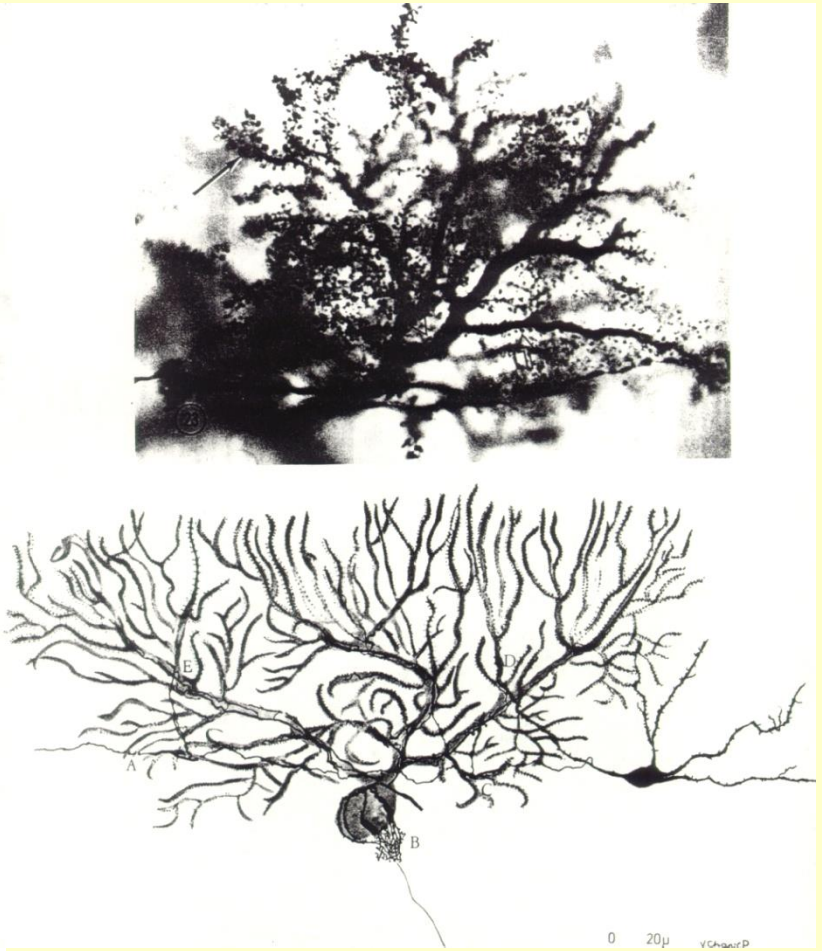


Cell bodies of cerebellar basket cells

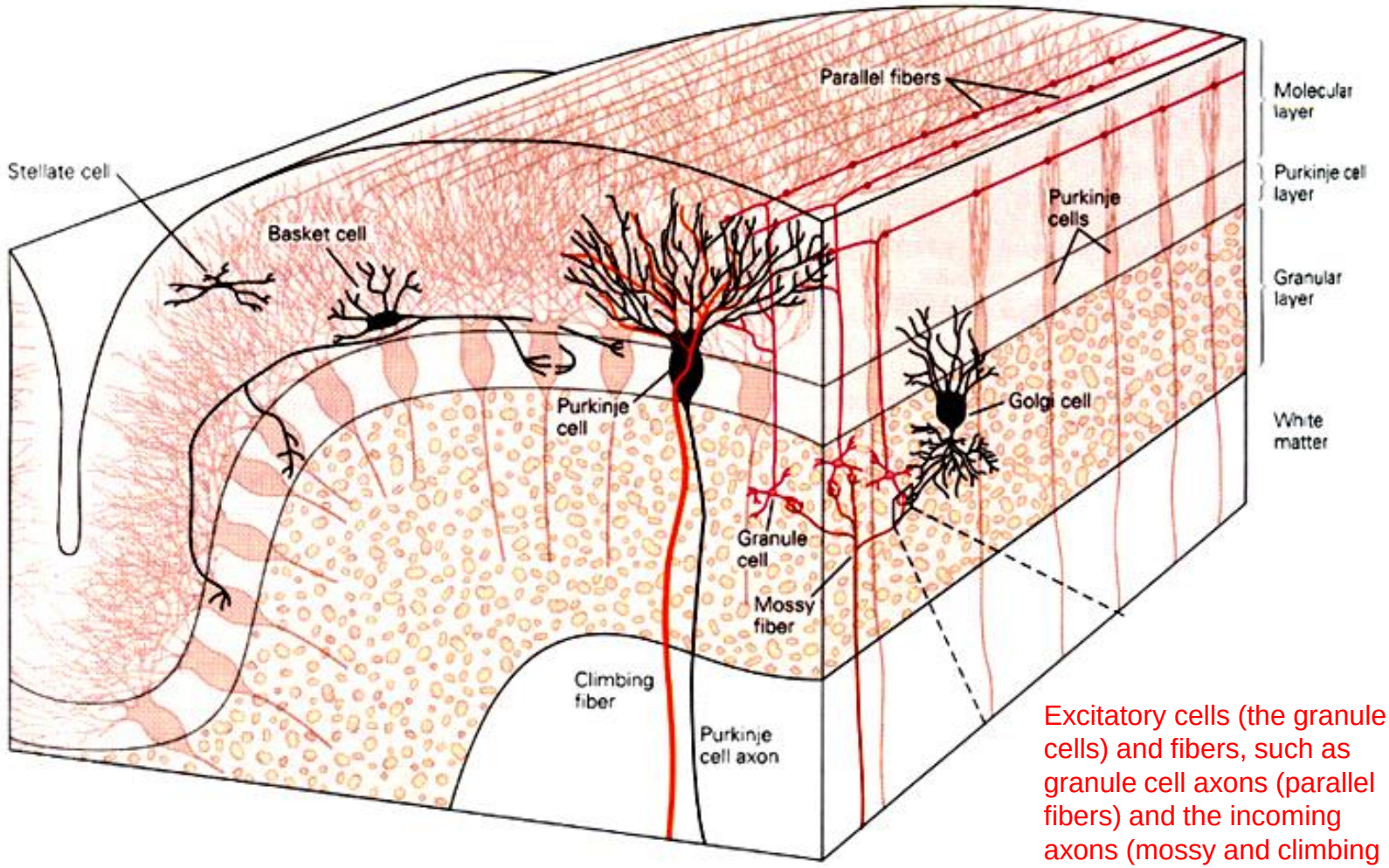


Axons and dendritic trees of Purkinje cells



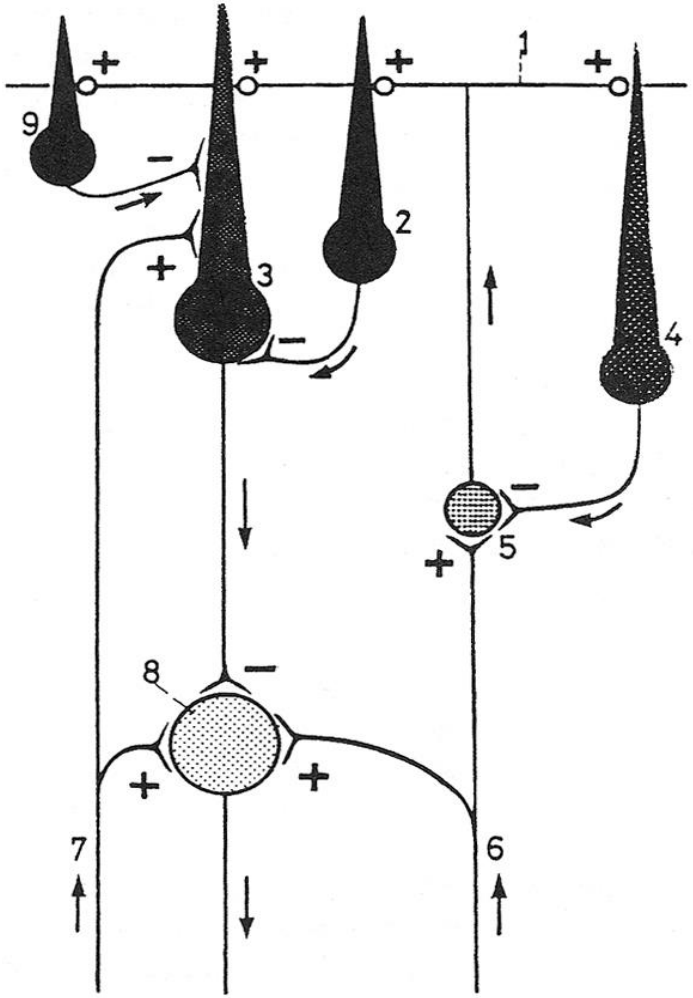


Morphology of the cells in the cerebellar cortex



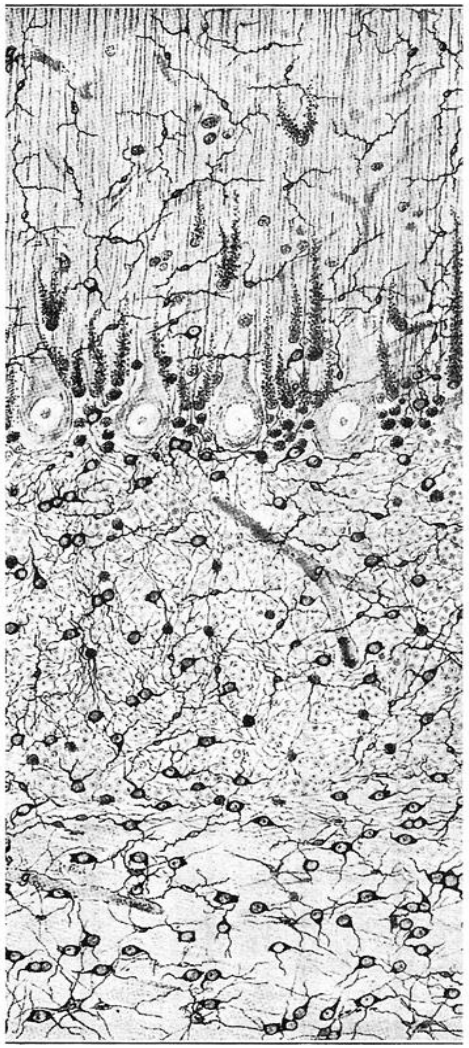
Excitatory cells (the granule cells) and fibers, such as granule cell axons (parallel fibers) and the incoming axons (mossy and climbing fibers) are red.

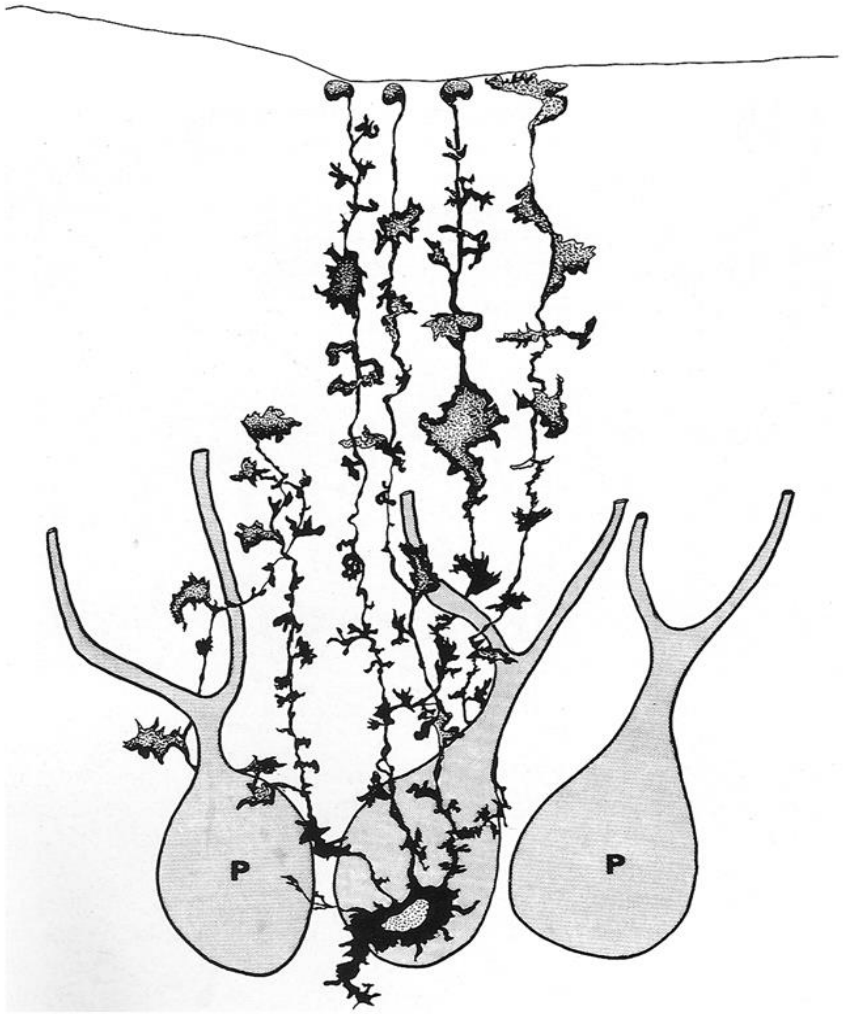
Output of the cerebellum is a negative mirror of the activity of Purkinje cells of the cerebellar cortex



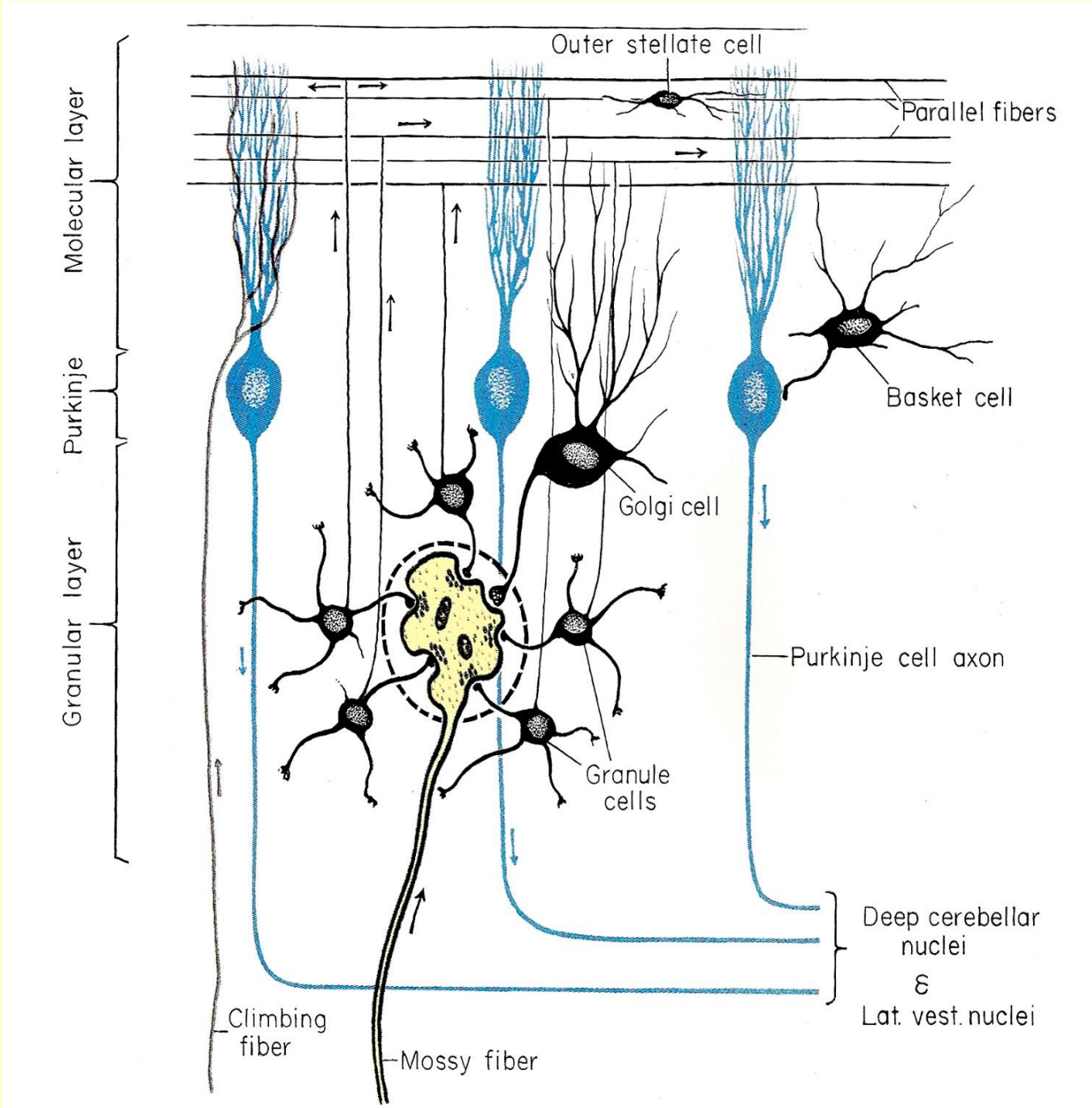
1. Parallel fibers
2. Basket cell
3. Purkinje cell
4. Golgi cell
5. Granule cell
6. Mossy fiber
7. Climbing fiber
8. Neuron in the cerebellar nu.
9. Stellate cell

Bergmann glia – the special astrocytic glial cell of the cerebellum

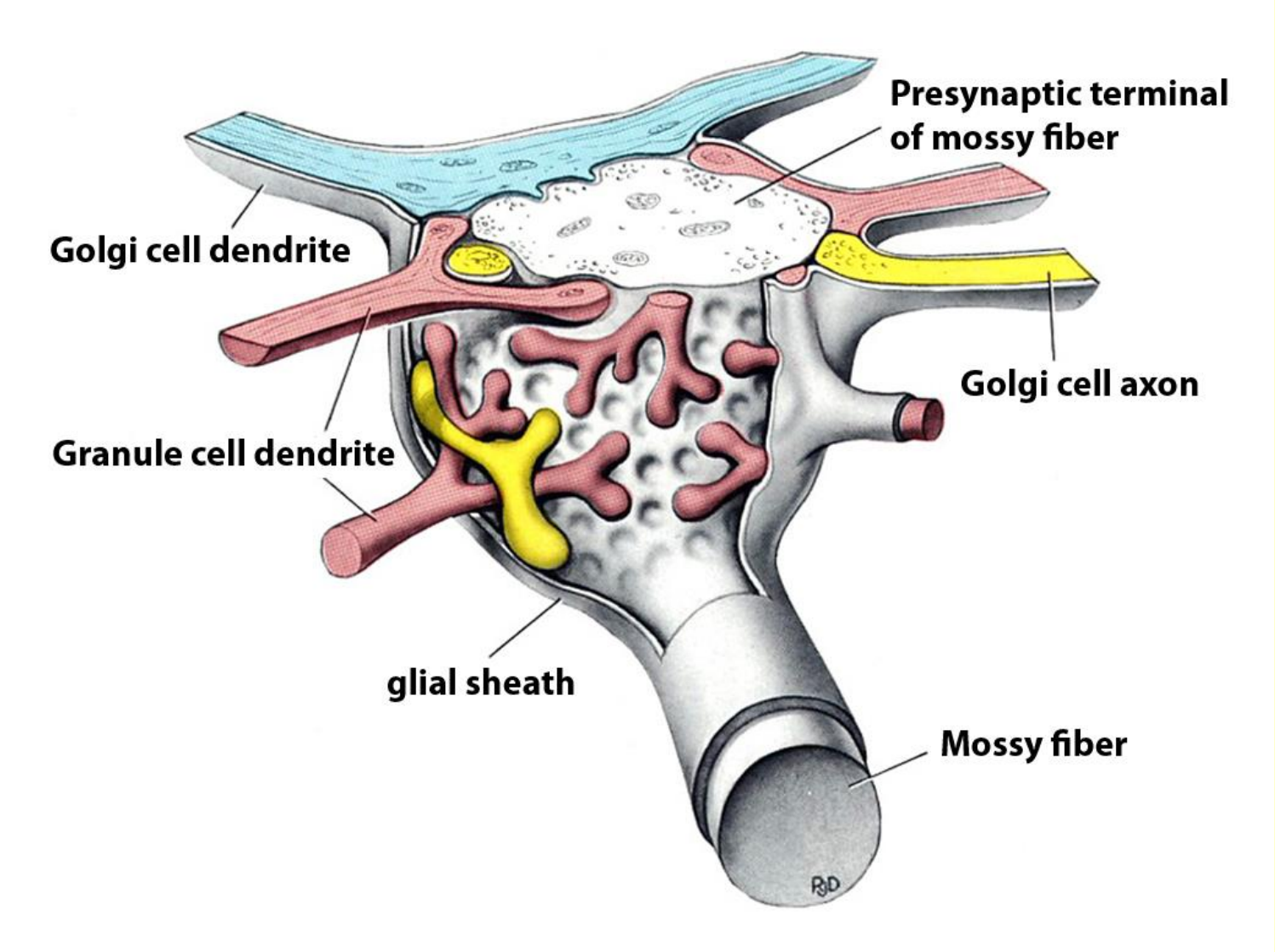




Inputs (climbing and mossy fibers) and outputs of cerebellar cortex



Structural model of cerebellar glomerulus



Components of the layers of cerebellar cortex

Molecular layer

cell bodies: basket and stellate cells
dendrites: Purkinje, basket, stellate, and Golgi cells
axons: granule, basket and stellate neurons, climbing fibers

Purkinje cell layer

cell body: Purkinje cell
dendrites: Passing dendrites of Golgi cells
axons: basket cells, passing axons of granule cells and climbing fibers

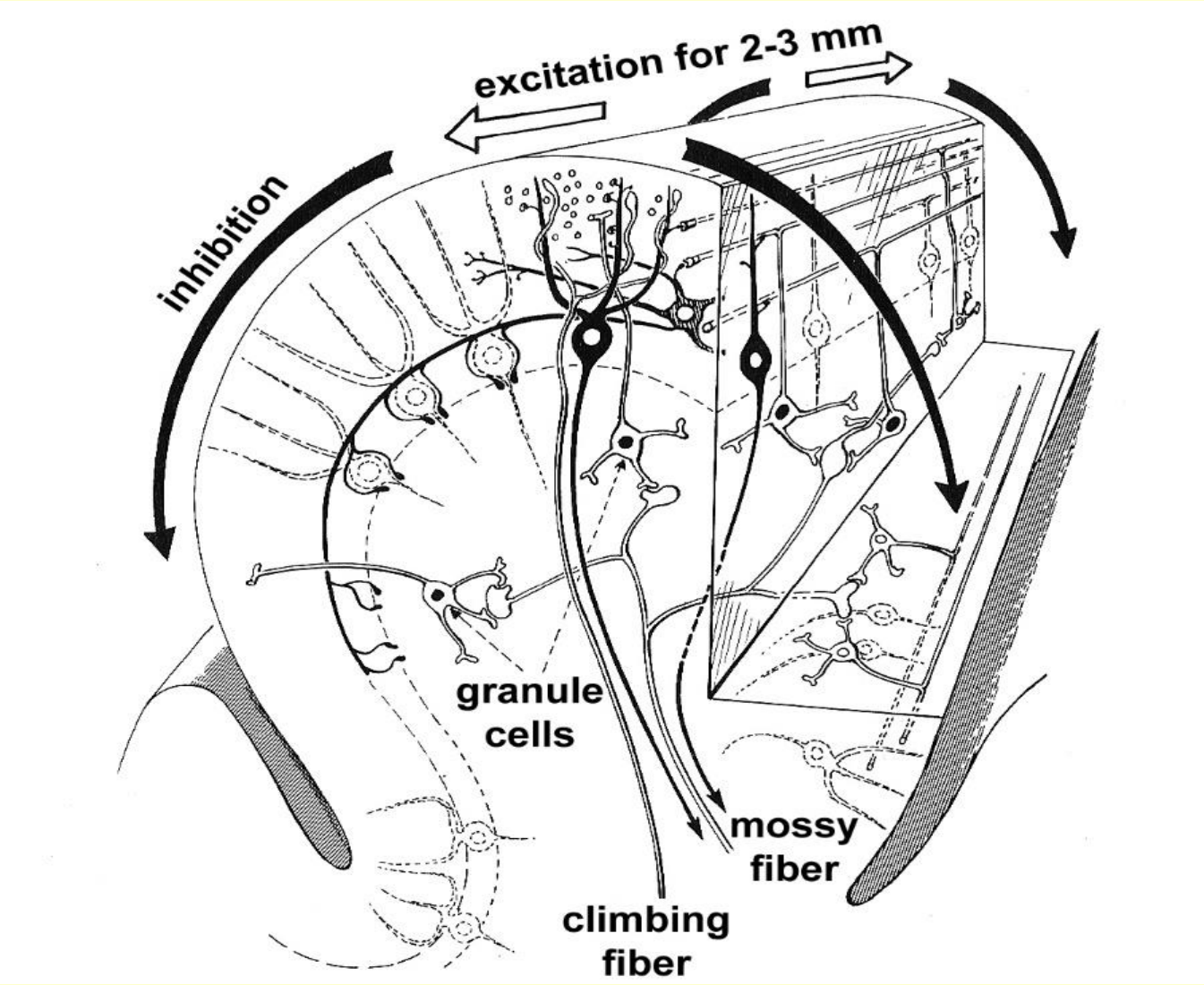
Granule cell layer

cell bodies: granule and Golgi cells
dendrites: granule and Golgi cells
axons: Golgi cell axons, mossy fibers, ascending granule cell axons, passing climbing fibers, and Purkinje cell axons

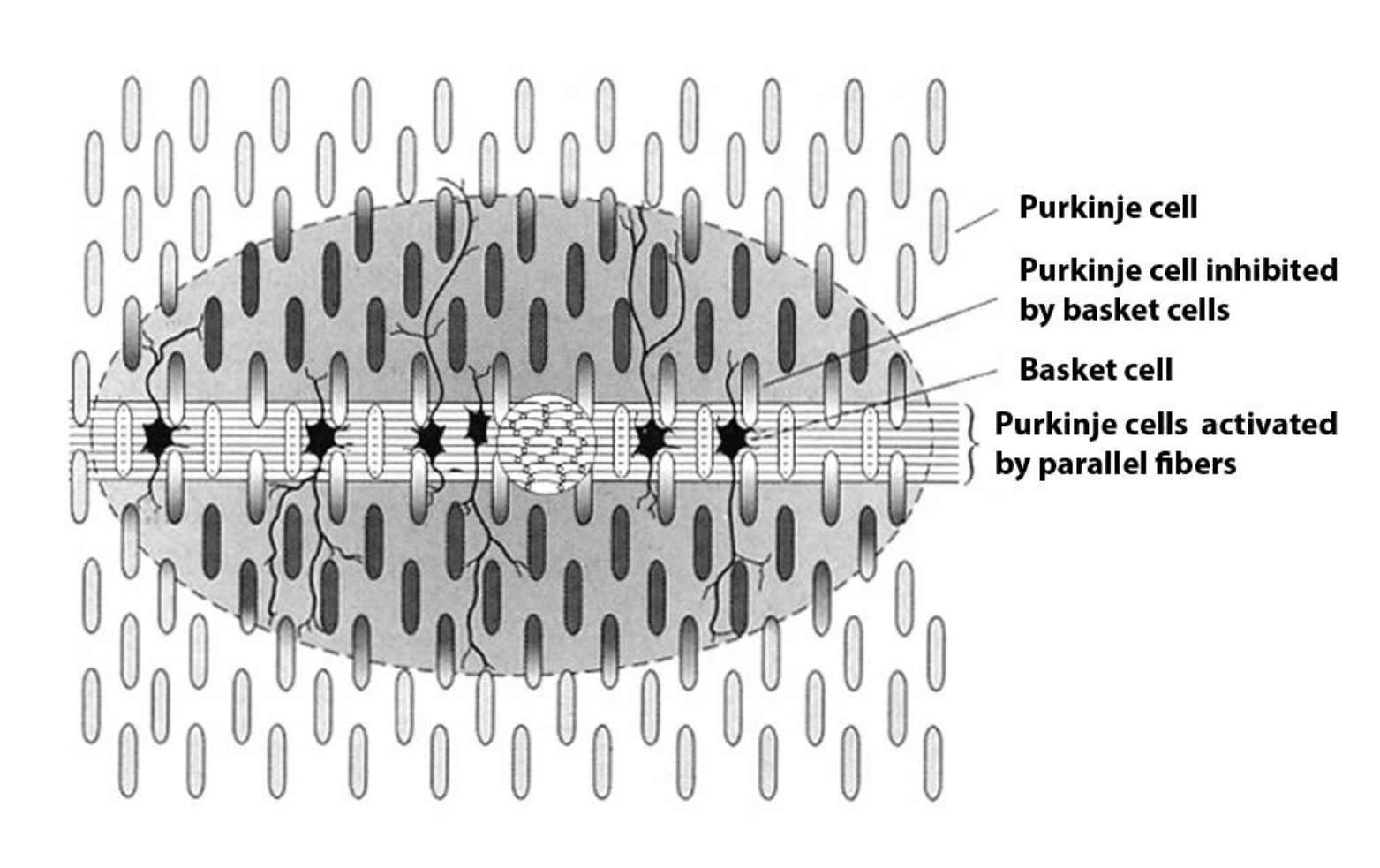
Connections of the cells of the cerebellar cortex

Cell type	Layer	Character	Target neuron
Projection neuron			
Purkinje cell	Purkinje cell layer	inhibitory	neurons in deep cerebellar and vestibular nuclei
Interneurons			
Granule cells	granule layer	excitatory	Purkinje, stellate-, basket- and Golgi cells
Basket cells	molecular layer	inhibitory (feed-forward)	Purkinje cells
Stellate cells	molecular layer	inhibitory (feed-forward)	Purkinje cells
Golgi cells	granule layer	inhibitory (feed-back)	granule cells

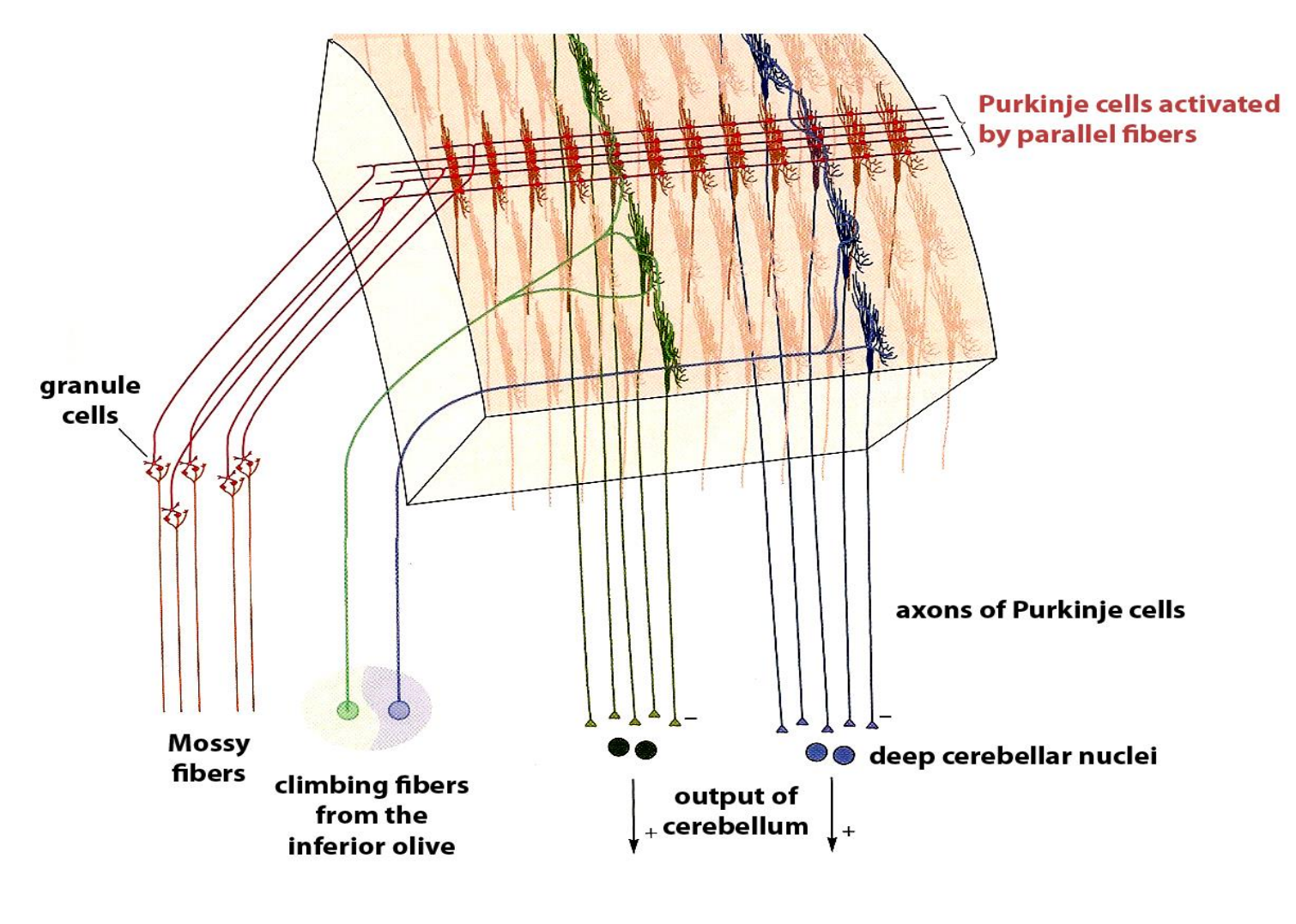
Excitatory and inhibitory actions of the parallel fibers of the granule cells



Functional unit of the cerebellar cortex: a line of Purkinje cells activated by parallel fibers with surrounding inhibited Purkinje cells



Climbing fibers activate individual Purkinje cells. If it coincides with activation by parallel fibers, the cells undergo prolonged inhibition by long-term depression: a proposed mechanism of motor learning



Cerebellar pathways and their connections with different parts of the cerebellum

Afferent pathways of the cerebellum

Pathways terminating in mossy fibers:

Pontocerebellar tract – crossed pathway in the middle cerebellar peduncle conveying information to the cerebellum from frontal, occipital and temporal lobes of the cerebral cortex

Vestibulocerebellar tract – uncrossed pathway in the inferior cerebellar peduncle carrying primary vestibular fibers as well as fibers from the medial and inferior vestibular nuclei

Spinocerebellar afferents (detailed in the next slide)

Pathways terminating in climbing fibers:

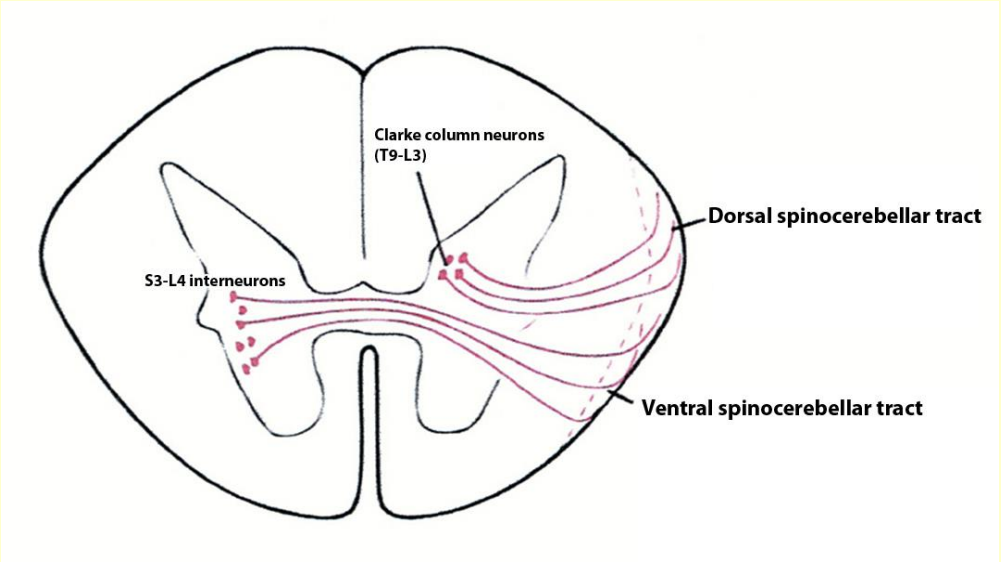
Olivocerebellar tract – crossed pathway in the superior cerebellar peduncle conveying input to the cerebellum via the inferior olive from the cerebral cortex, thalamus, red nucleus, vestibular nuclei and the spinal cord

Monoaminergic afferents:

Uncrossed noradrenergic fibers from the locus coeruleus and serotonergic fibers from the raphe nuclei in the superior and inferior cerebellar peduncles

Spinocerebellar afferent pathways

Dorsal/posterior spinocerebellar tract (Flechsig)
Uncrossed pathway in the inferior cerebellar peduncle originating in the nucleus dorsalis (Clarke nucleus) of the spinal cord to convey proprioceptive and epicritic sensibility from the lower body part to the cerebellum

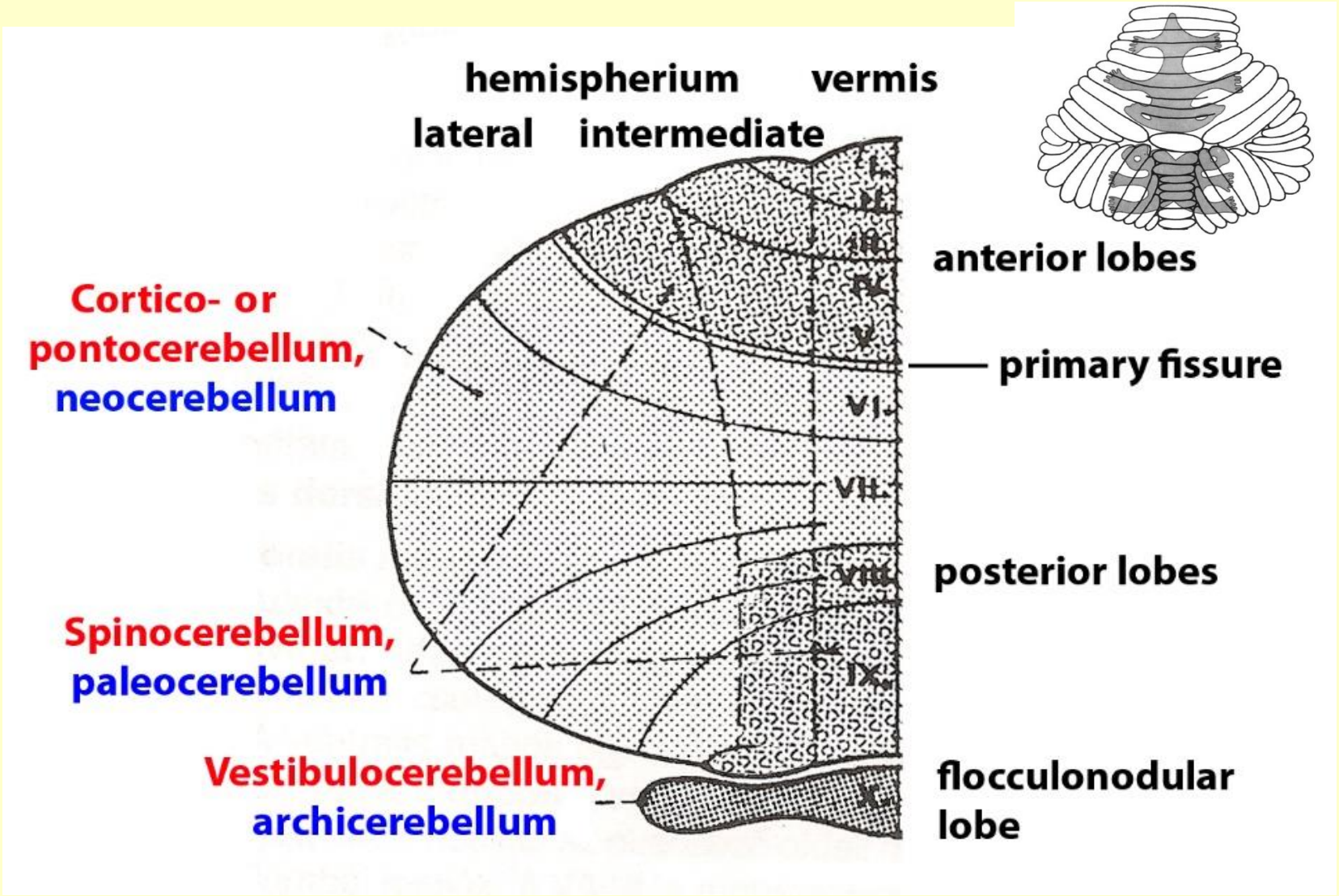


Ventral/anterior spinocerebellar tract (Gowers)
Crossed pathway in the superior cerebellar peduncle conveying information on motor orders to the lower body part to the cerebellum from premotor interneurons of the spinal cord

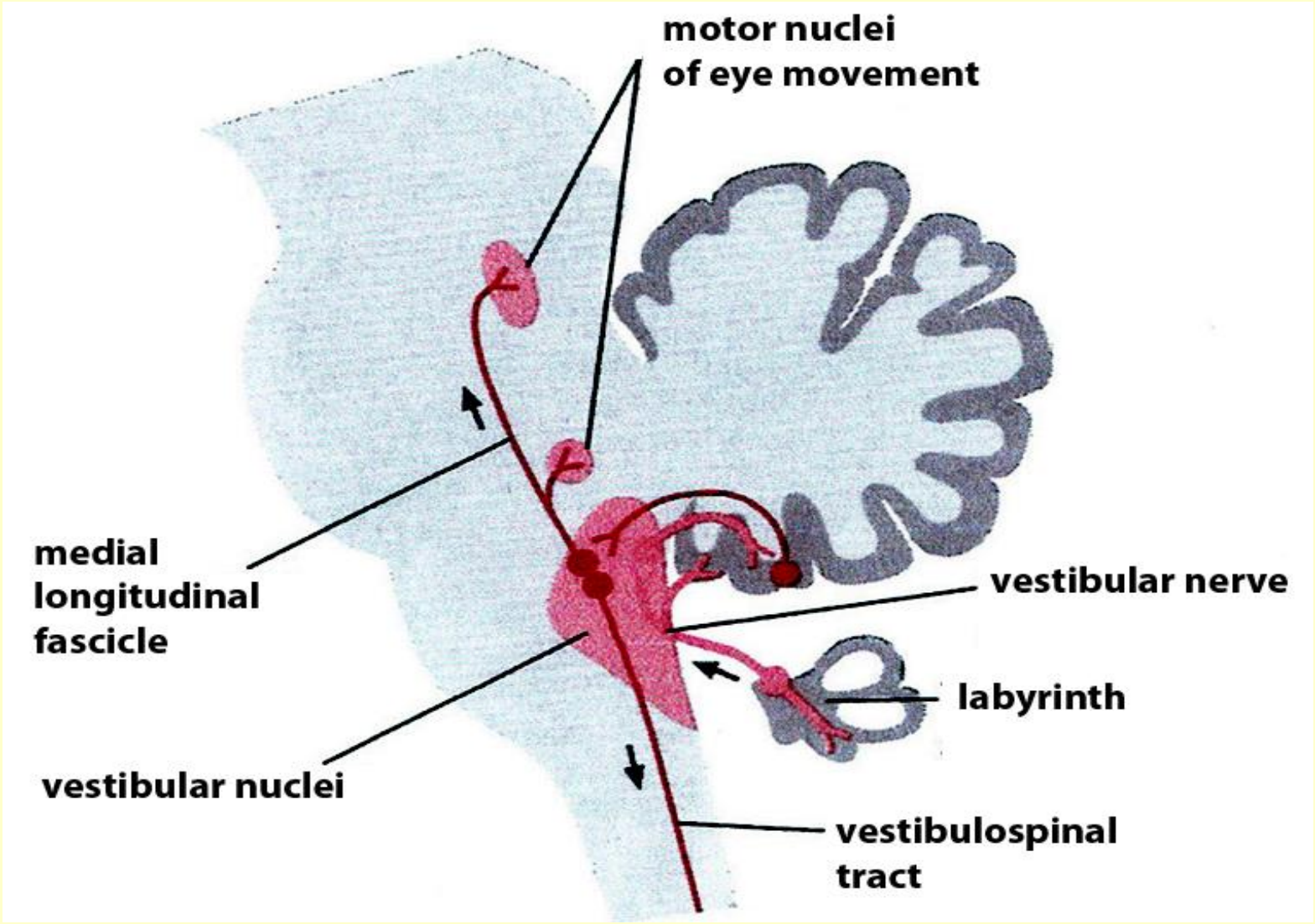
Cuneocerebellar tract
Uncrossed pathway in the inferior cerebellar peduncle originating in the external (or accessory) cuneate nucleus to convey proprioceptive and epicritic sensibility from the upper body part to the cerebellum.

Rostral spinocerebellar tract
Crossed pathway in the superior cerebellar peduncle conveying information on motor orders to the upper body part to the cerebellum from premotor interneurons of the brainstem

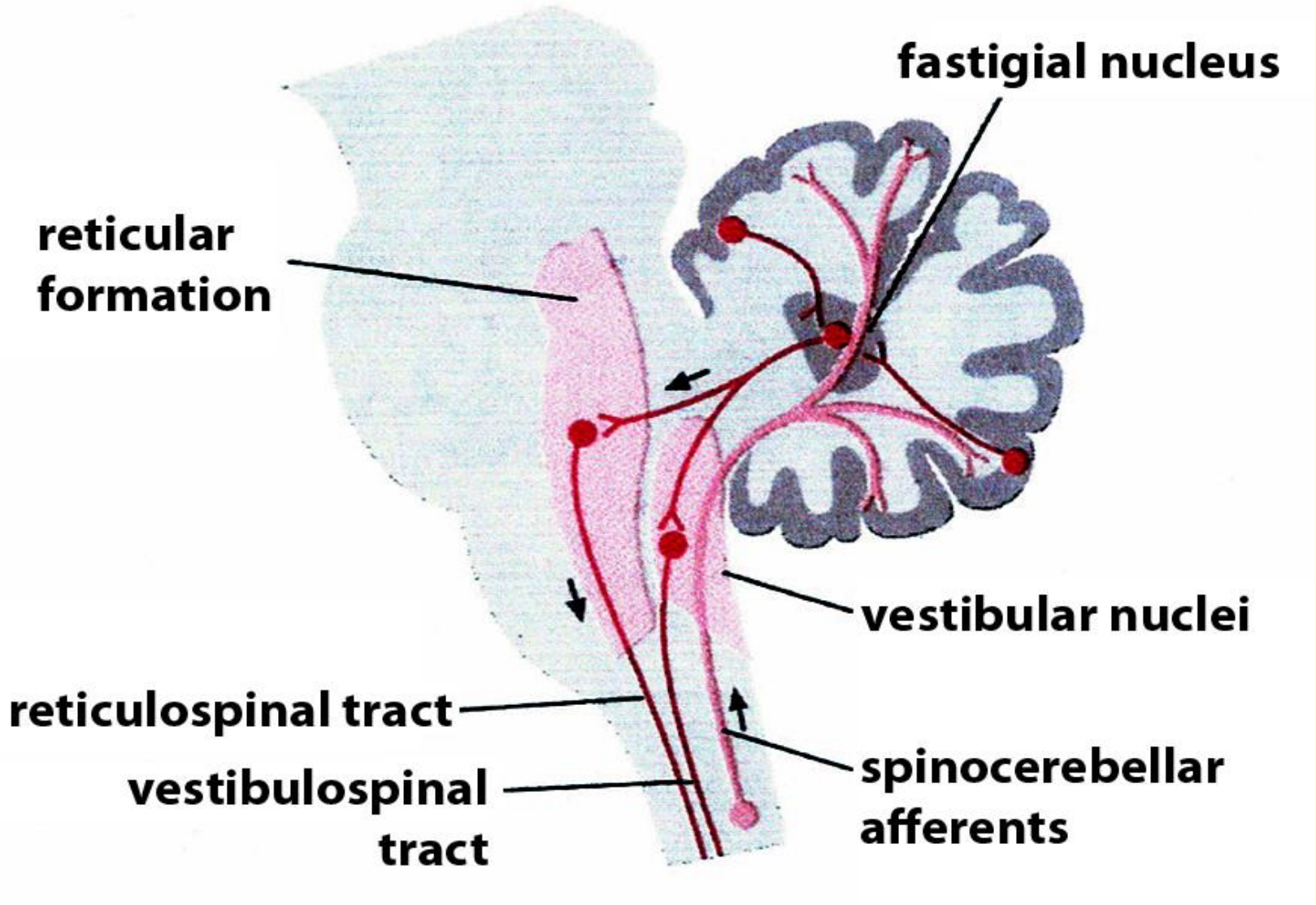
Division of the cerebellum based on the origin of inputs and filogenetic development



Outputs of vestibulocerebellum

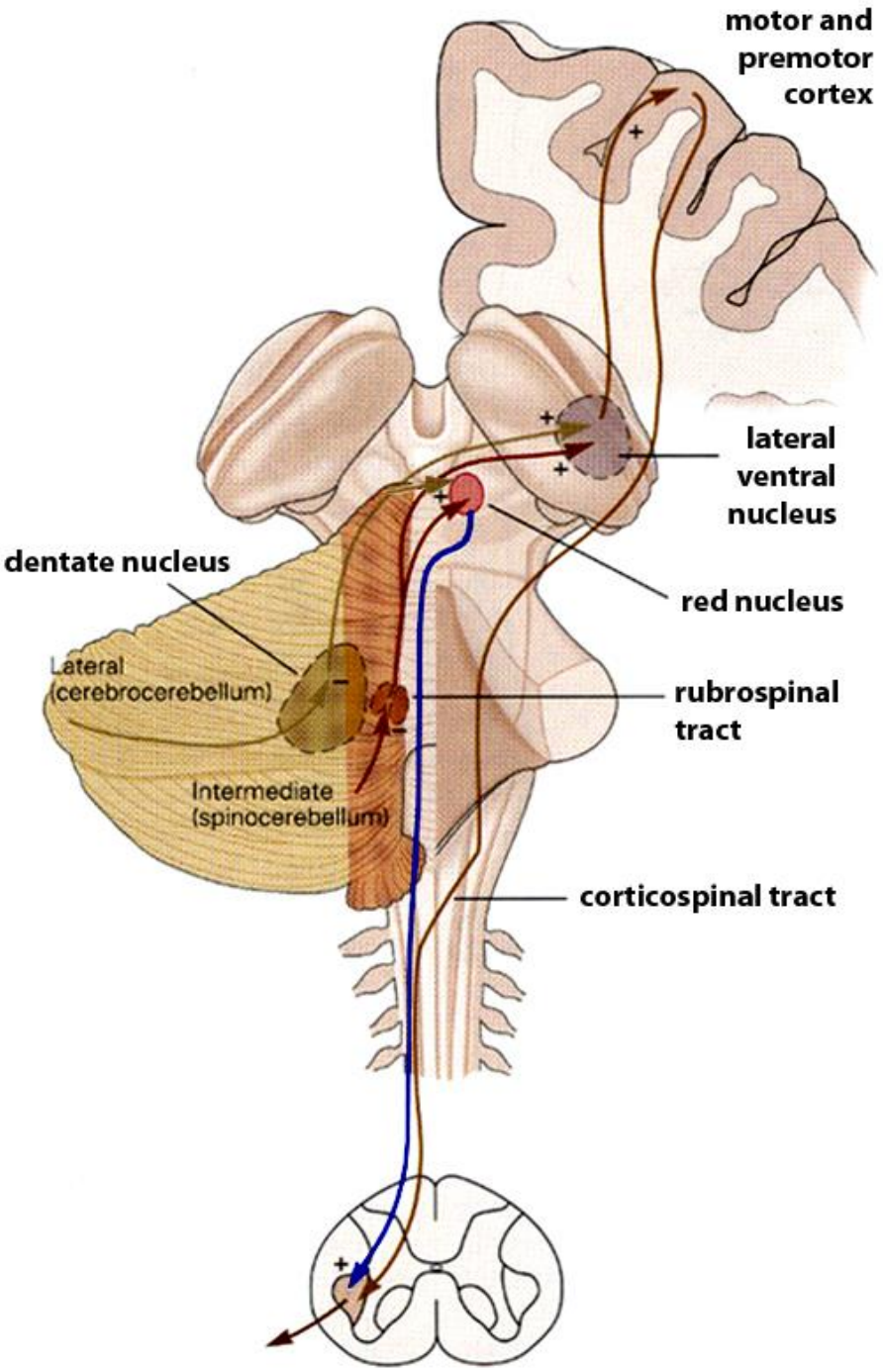


Outputs of spinocerebellum from the vermis
(cerebelloreticular and cerebellovestibular tracts)

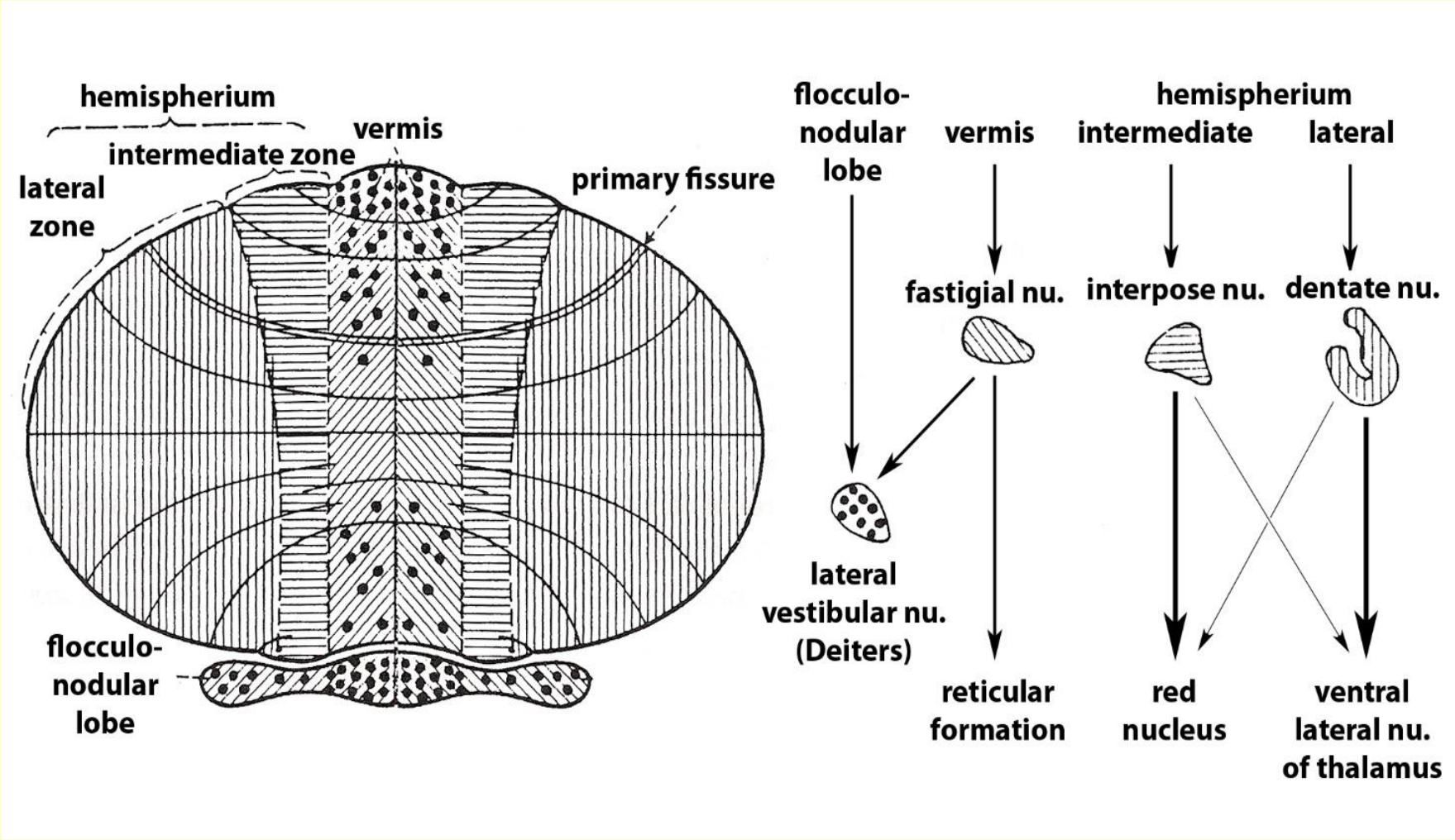


Outputs of the cerebellum originating in the hemispheres

(cerebellorubral and cerebellothalamic tracts)



Summary of targets of Purkinje cells



Afferent and efferent pathways in the cerebellar peduncles

Superior cerebellar peduncle:

ventral spinocerebellar tract (Gowers)
rostral spinocerebellar tract
cerebellothalamic tract
cerebellorubral tract

Middle cerebellar peduncle:

pontocerebellar tract

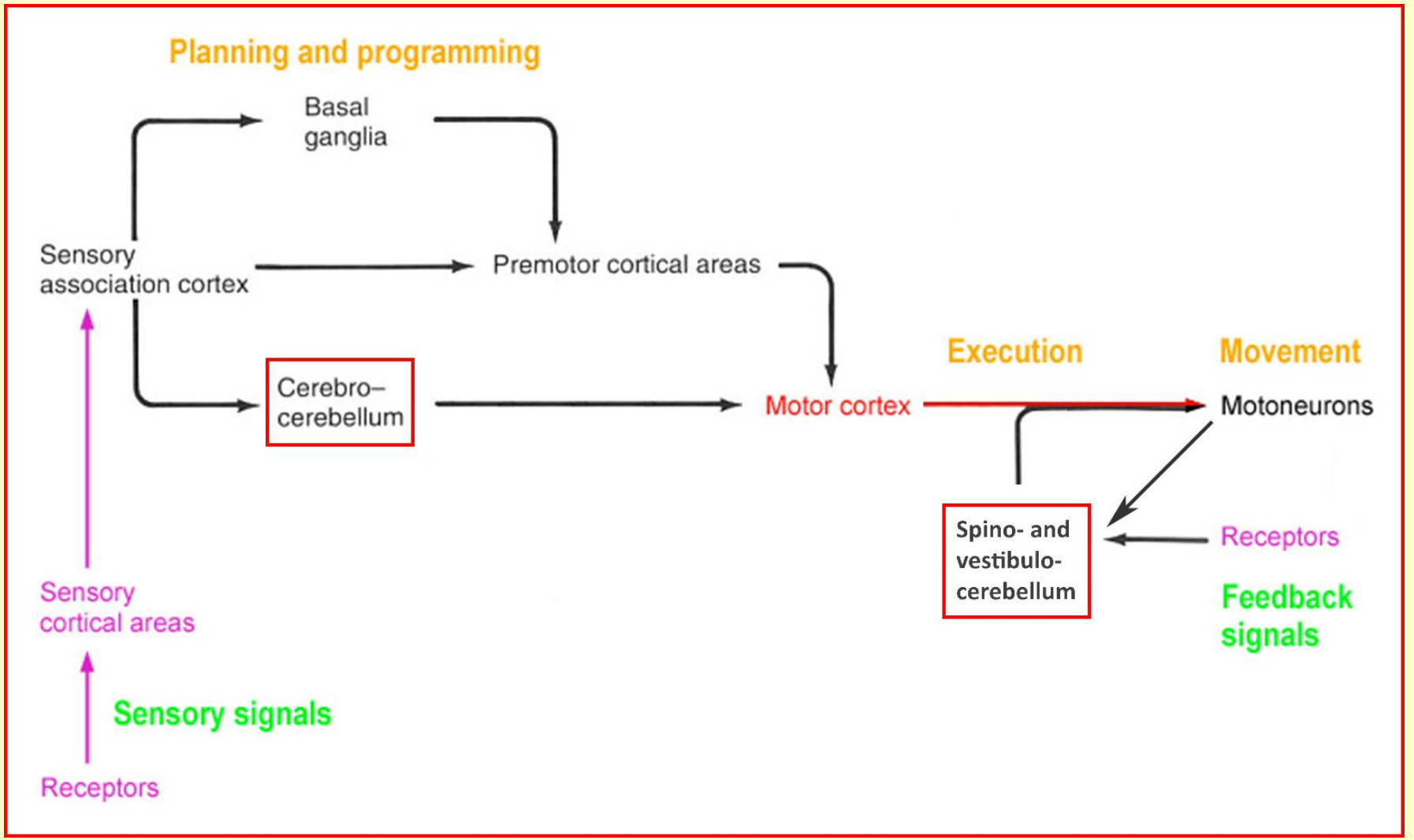
Inferior cerebellar peduncle:

olivocerebellar tract *(the only pathway with climbing fibers)*
dorsal spinocerebellar tract (Flechsig)
cuneocerebellar tract
vestibulocerebellar tract
cerebellovestibular tract
cerebelloreticular tract

Functional divisions of the cerebellum

	Anatomical regions	Incoming information	Relay nucleus	Termination	Function
Vestibulocerebellum	flocculonodular lobe	vestibular labyrinth	lateral vestibular	spinal and eye movement motoneurons	eye movement, neck muscles, body balance
Spinocerebellum	vermis	vestibular nuclei, spinal cord	fastigial	vestibular nuclei, reticular formation	muscle tone, posture, coordination of trunk muscles
	intermedier cortex	spinal cord	interpose	red nucleus (magno-cellular), thalamus (VL) - motor cortex	execution of movements, coordination of limbs
Cerebrocerebellum	lateral cortex	cerebral cortex	dentate	thalamus (VL) - motor cortex, red nucleus (parvo-cellular)	initiation of movements, temporal planning of movements, cognitive functions

The role of the cerebellar cortex in the control of movement



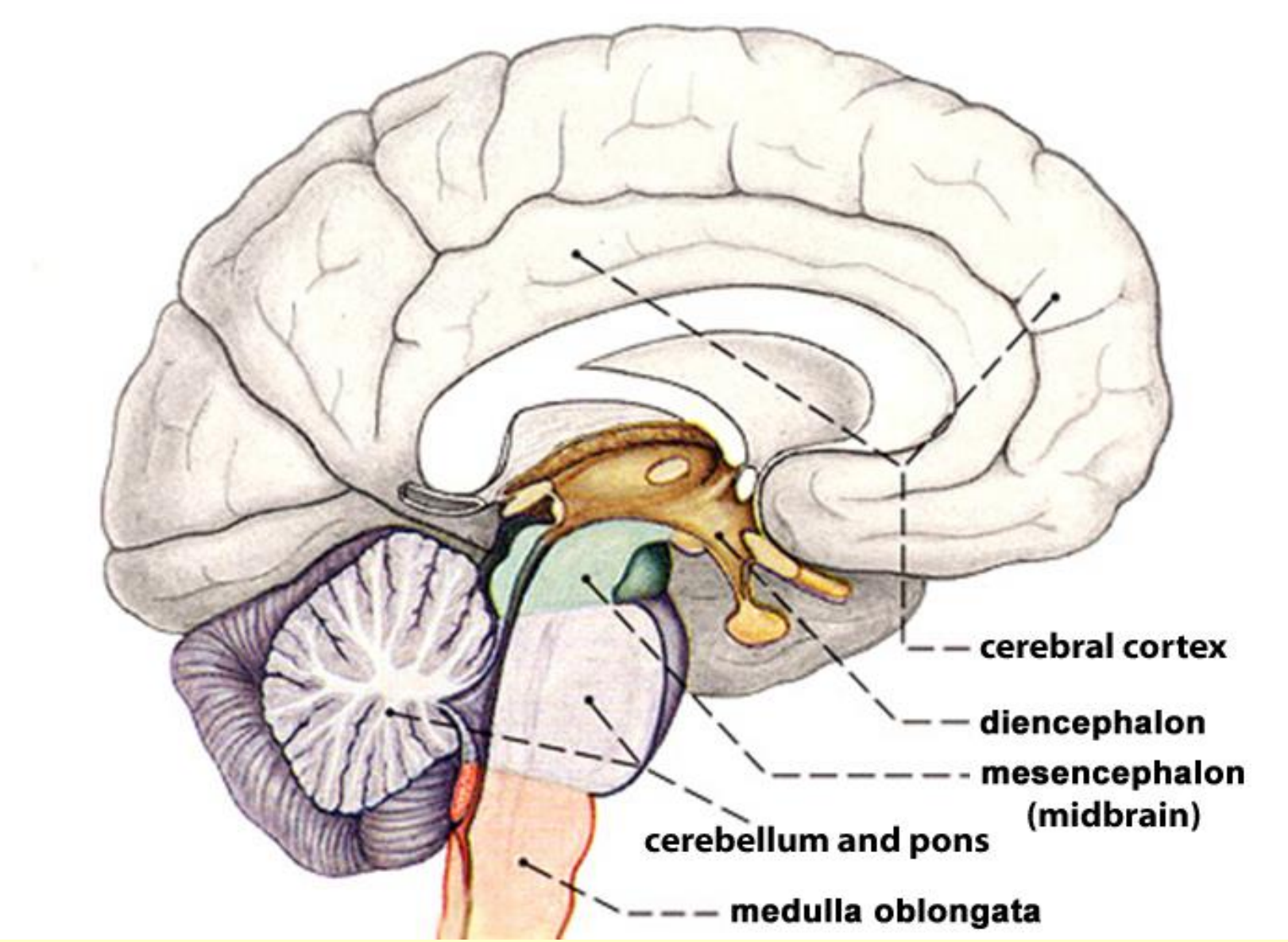
Cerebellar syndromes

Ataxia: clumsy movement caused by a disorder in the coordination of voluntary muscle movements (imbalance, e.g. unsteady gait; inaccuracy of hand movements, e.g. writing, eating, sewing).
If it is caused by injury to the cerebellum (as opposed to cerebral cortex), it is not significantly affected by closing the eye.
For example, Friedrich's ataxia, a cerebellum-specific brain disorder of genetic origin.

Arnold-Chiari syndrome is also a congenital disorder, in which some parts of the cerebellum (the tonsils) block the foramen magnum, which restricts the flow of the cerebrospinal fluid and causes an increase in brain pressure.

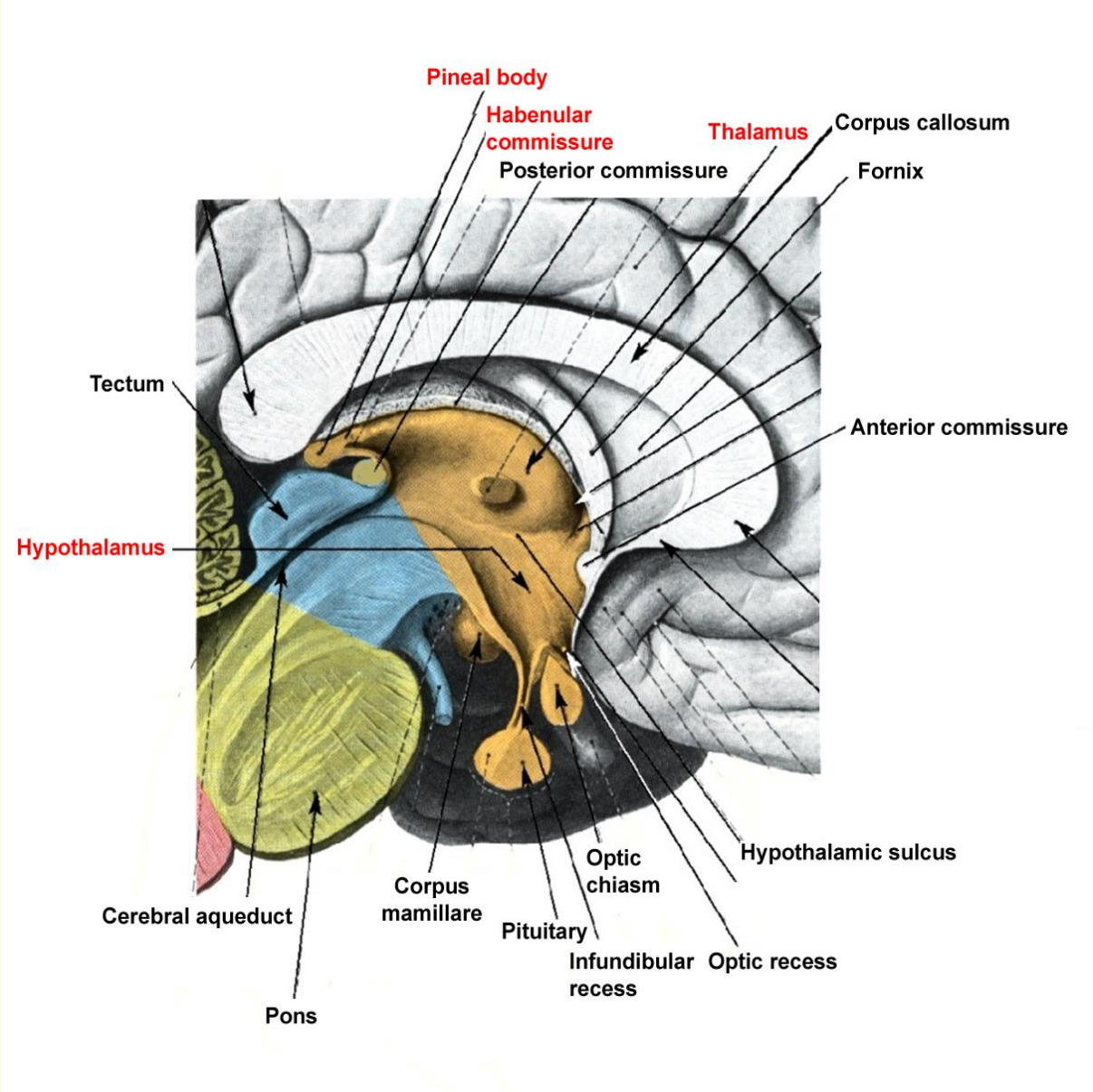
The defect of cerebellum is not limited to motor function. In the case of cerebrocerebellar damage, there may be a deficit in abstract logic, an inaccurate language use, inadequate reasoning, and behavior. These are called: Cerebellar cognitive affective syndrome.

The position of the diencephalon in the brain

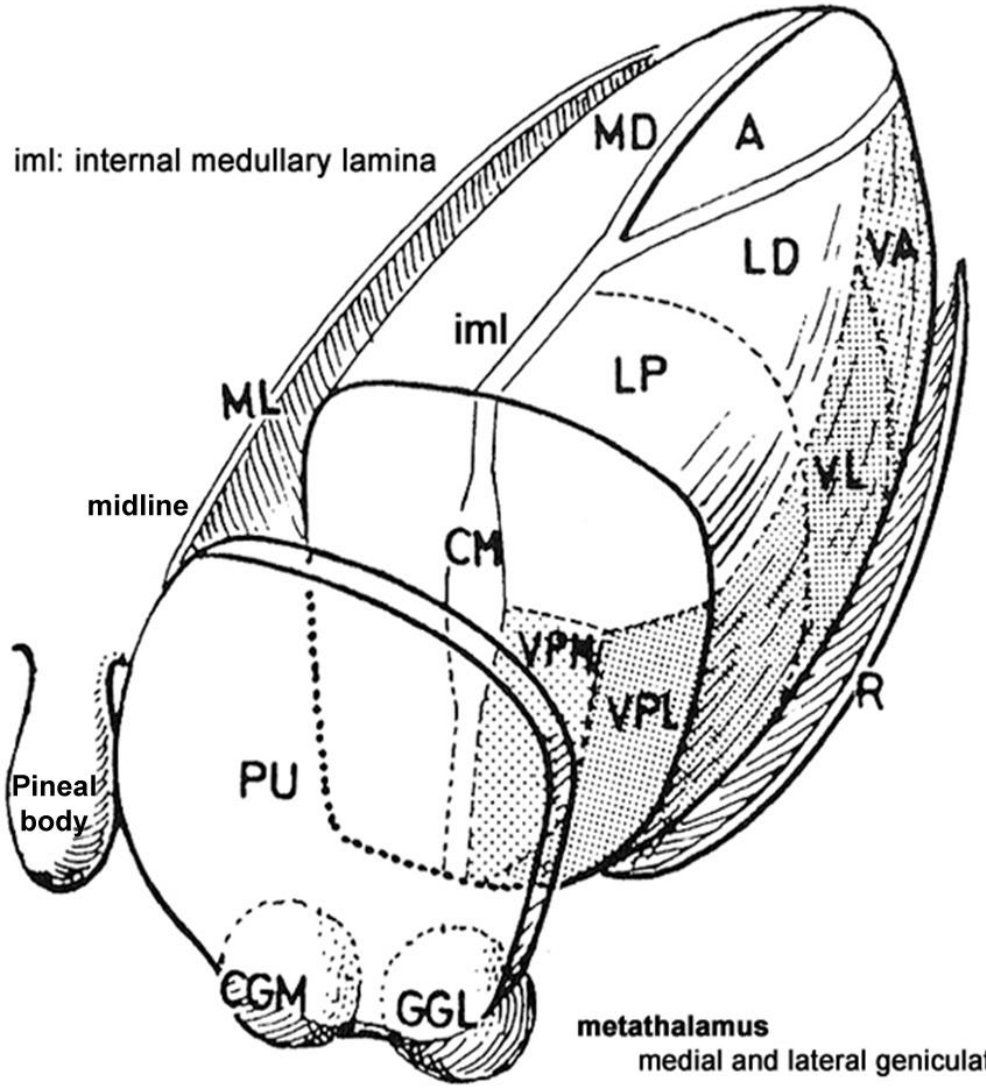


Parts of the diencephalon

- **Thalamus**
- **Epithalamus**
  - Pineal body
  - Habenulae
  - Trigonum habenulae
  - Habenular nuclei
  - Habenular commissure
  - Stria medullaris
- **Metathalamus**
  - Medial geniculate body
  - Lateral geniculate body
- **Subthalamus**
  - Subthalamic nucleus
  - Zona incerta
  - H fields of Forel
- **Hypothalamus**



Nuclear groups and nuclei of the thalamus



anterior nuclear group (A)
- anteromedial nu.
- anterodorsal nu.
- anteroventral nu.

medial nuclear group
- mediodorsal nu. (MD)

lateral nuclear group
- **dorsal nuclei**
  - lateral dorsal nu. (LD)
  - lateral posterior nu. (LP)
  - pulvinar (PU)
- **ventral nuclei**
  - ventral anterior nu. (VA)
  - ventral lateral nu. (VL)
  - ventral posterolateral nu. (VPL)
  - ventral posteromedial nu. (VPM)

midline nuclei (ML)

intralaminar nuclei
- **anterior intralaminar nuclei**
- **posterior intralaminar nuclei**
  - central medial nu. (CM)
  - parafascicular nu.
  - subparafascicular nu.

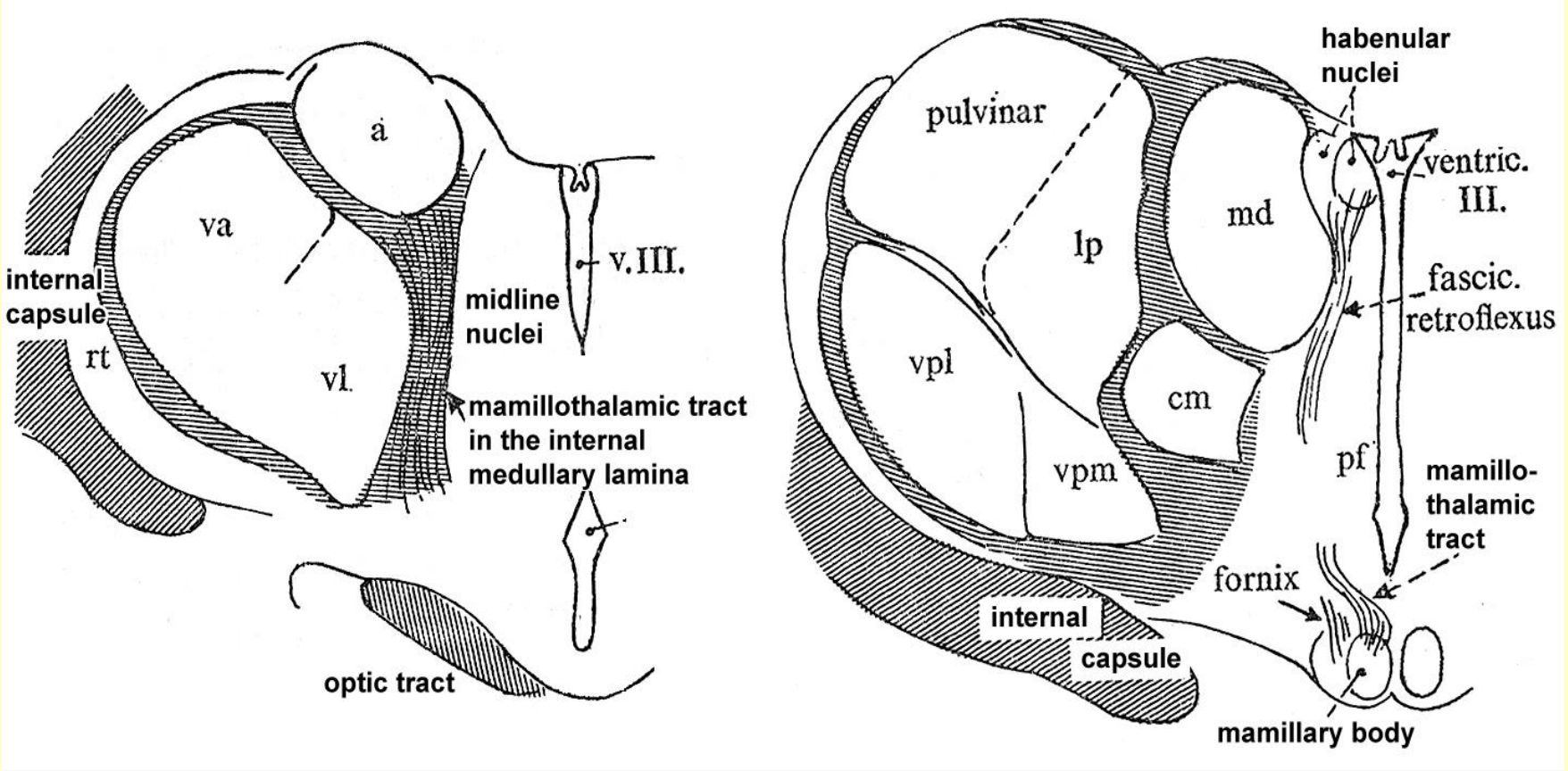
reticular thalamic nu. (R)

metathalamus
medial and lateral geniculate body (MGB or CGM, and LGB or CGL)

Frontal sections of the thalamus

Anterior section

Middle section



Functional classification of thalamic nuclei

- **Specific nuclei:** specific input, project to specific part of the cortex
  - sensory relay nuclei: VPL, VPM, MGB, LGB
  - motor relay nuclei: VA, VL
  - limbic relay nuclei: AV, AD, AM

  - **Association nuclei:** cortical input, project to multimodal association areas of the cortex
  - MD, LD, LP, pulvinar

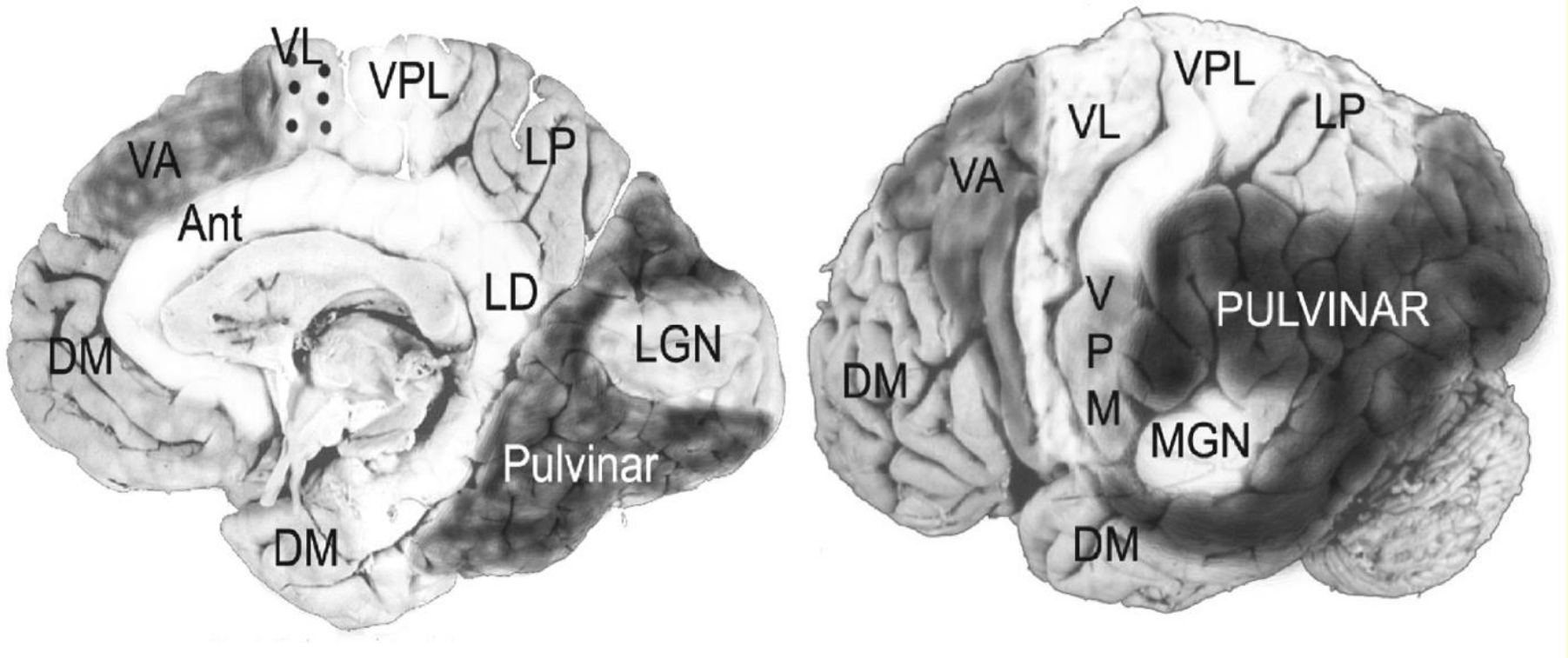
- **Non-specific nuclei:** ascending input, diffuse projection to the cortex
  - midline and intralaminar nuclei

- **Nuclei not projecting to the cerebral cortex**
  - n. reticularis thalami, n. parafascicularis, n. subparafascicularis

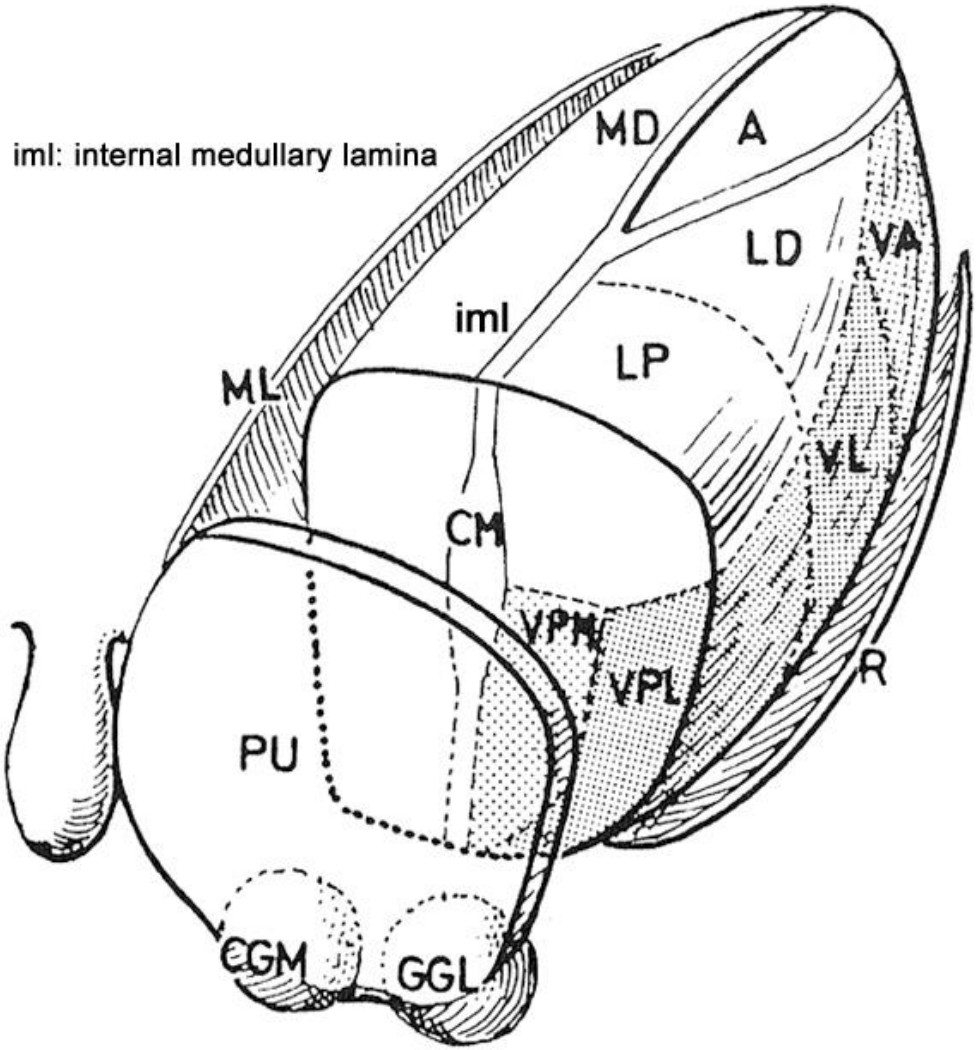
Cortical projections of (specific and association) thalamic nuclei

mediosagittal view

lateral view



Specific sensory relay nuclei



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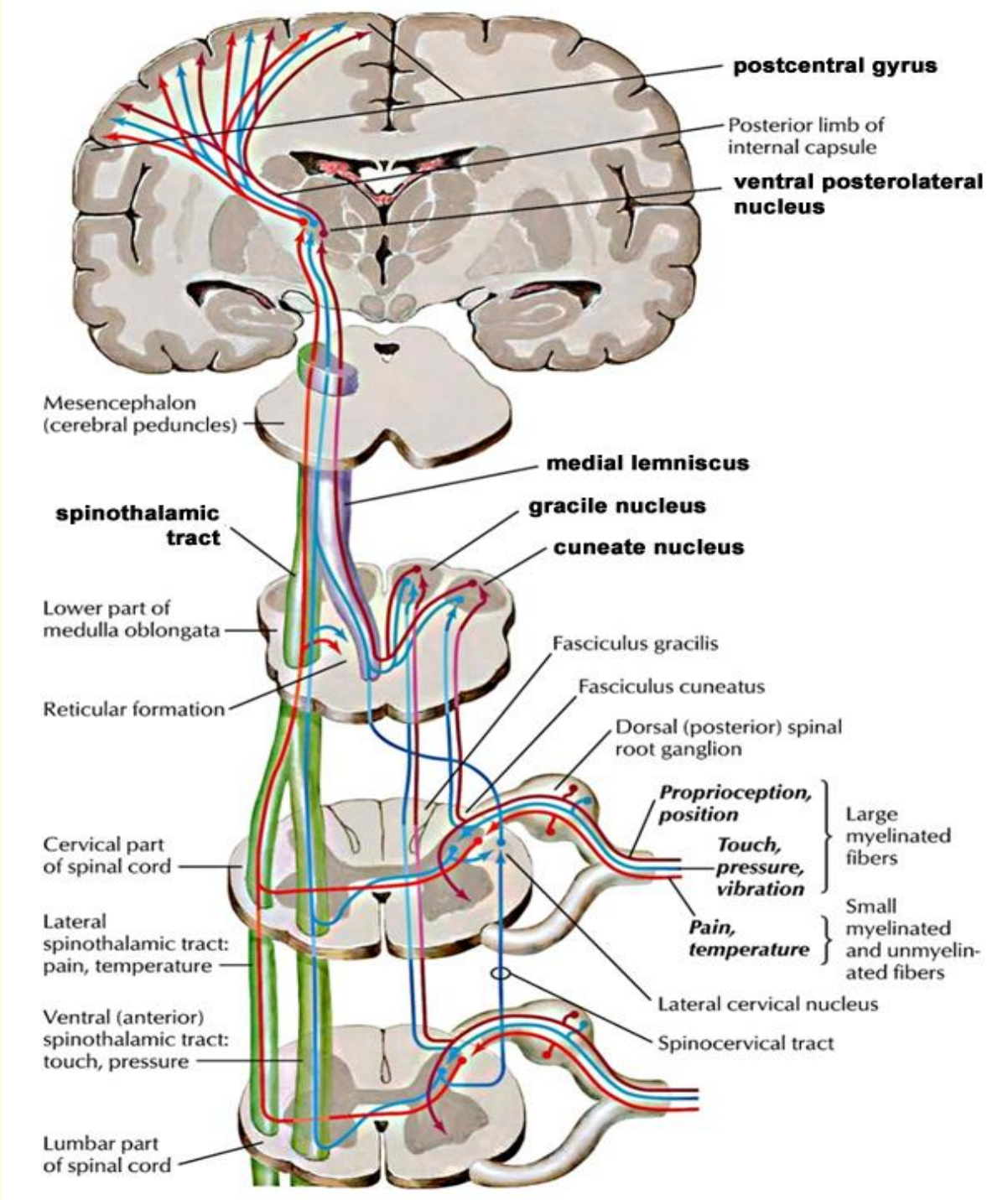
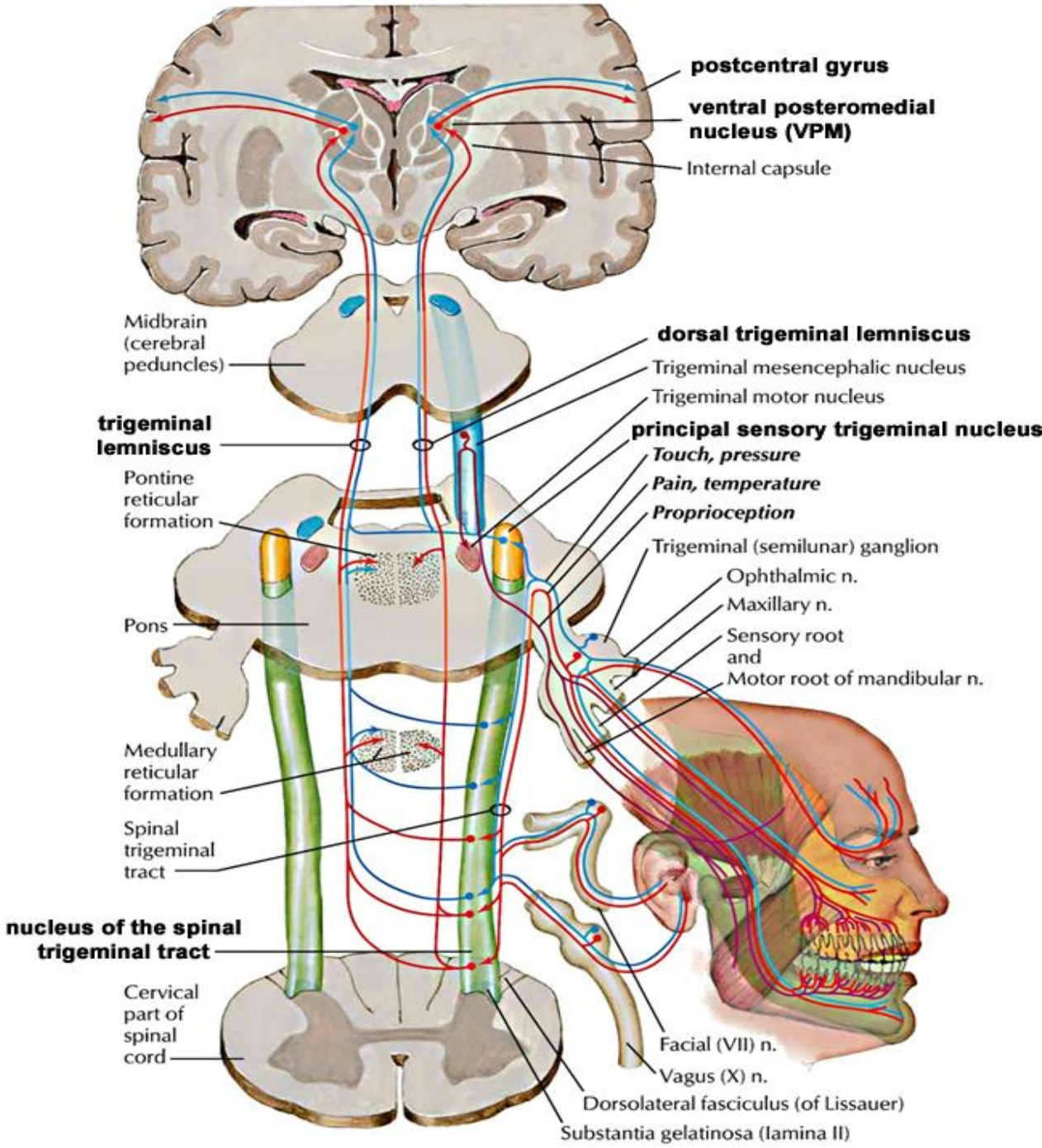
The VPL relays sensory inputs from the body to the cerebral cortex

(Input: spinothalamic tract and the medial lemniscus)

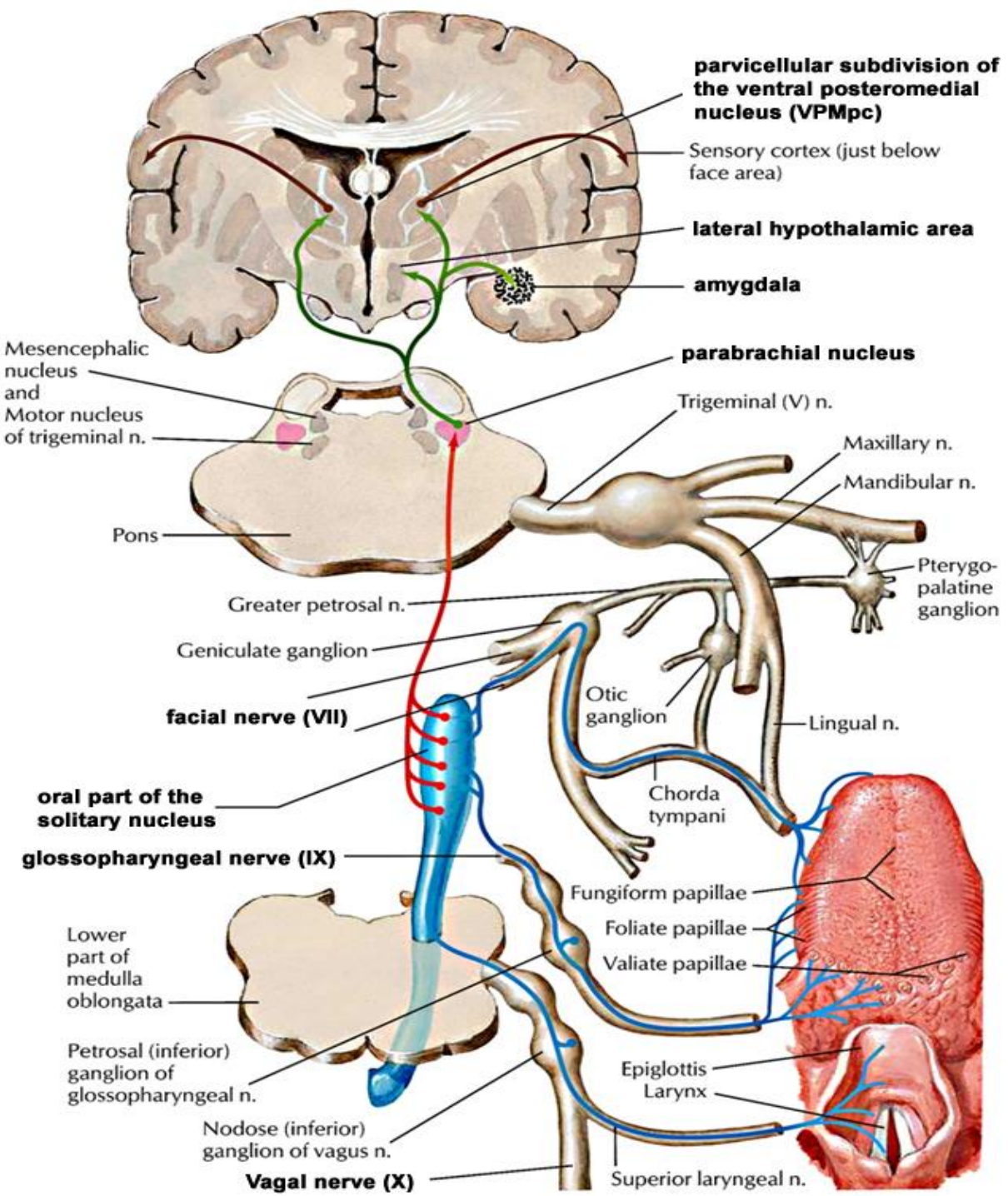


The VPM relays sensory inputs from the head to the cerebral cortex

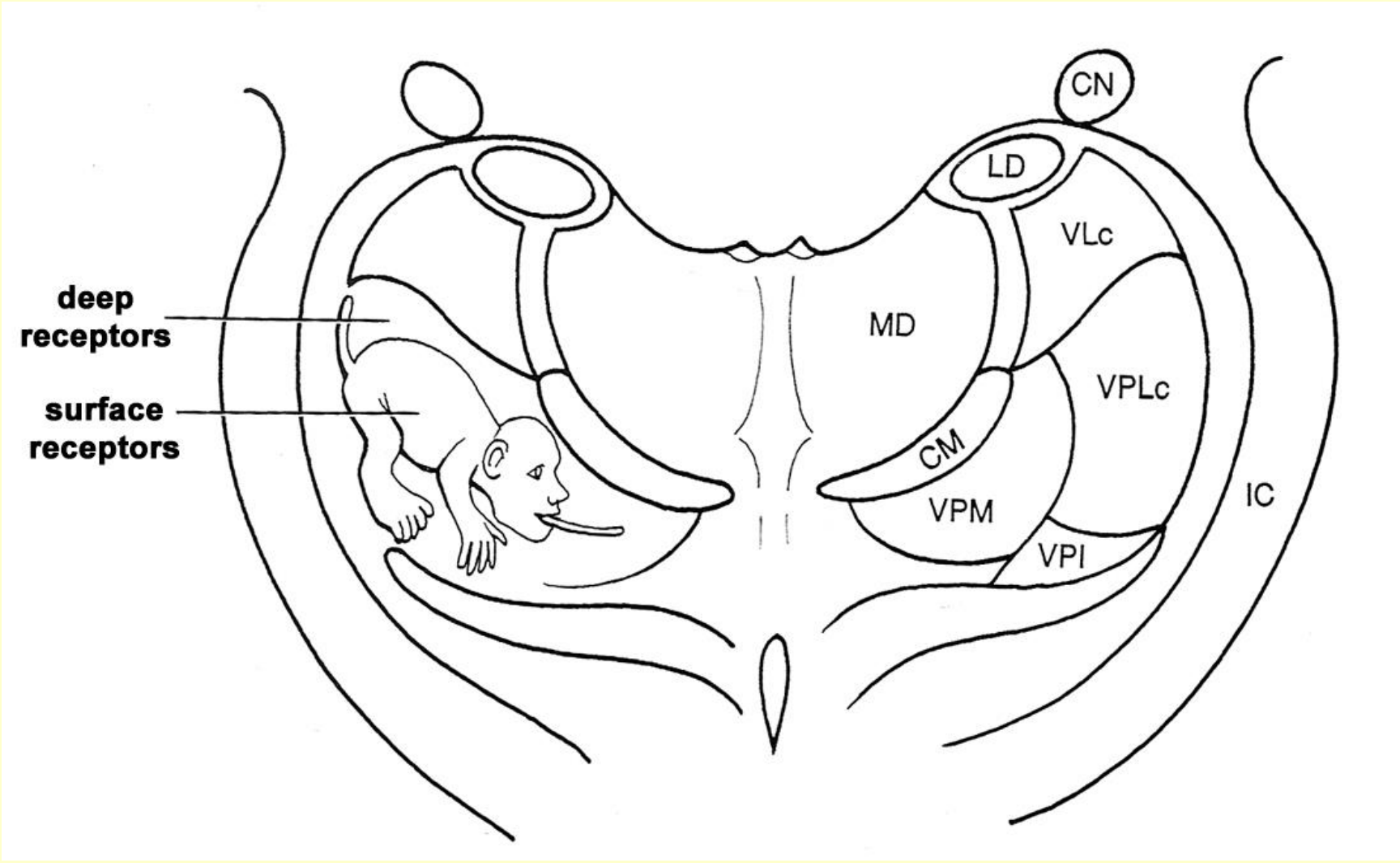
(Input: trigeminal and dorsal trigeminal lemniscus pathways)



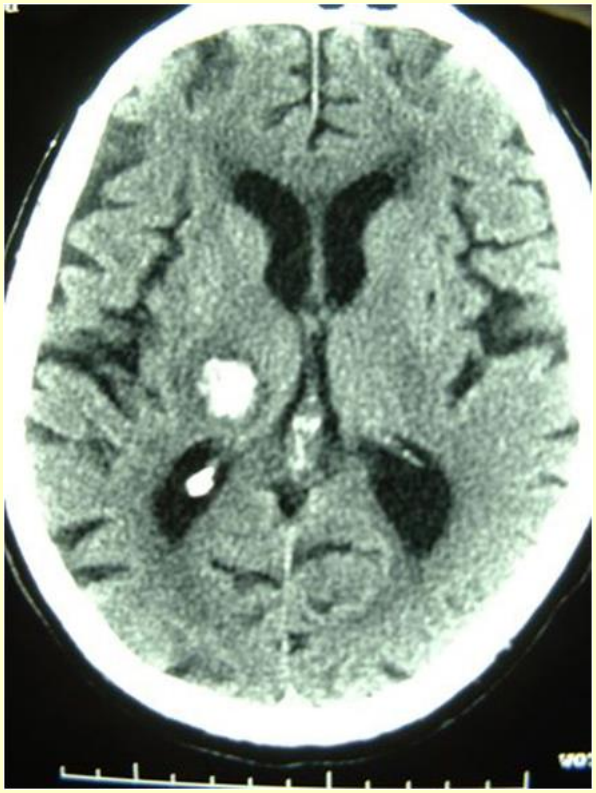
Relay of gustatory inputs to the cortex takes place in the VPMpc

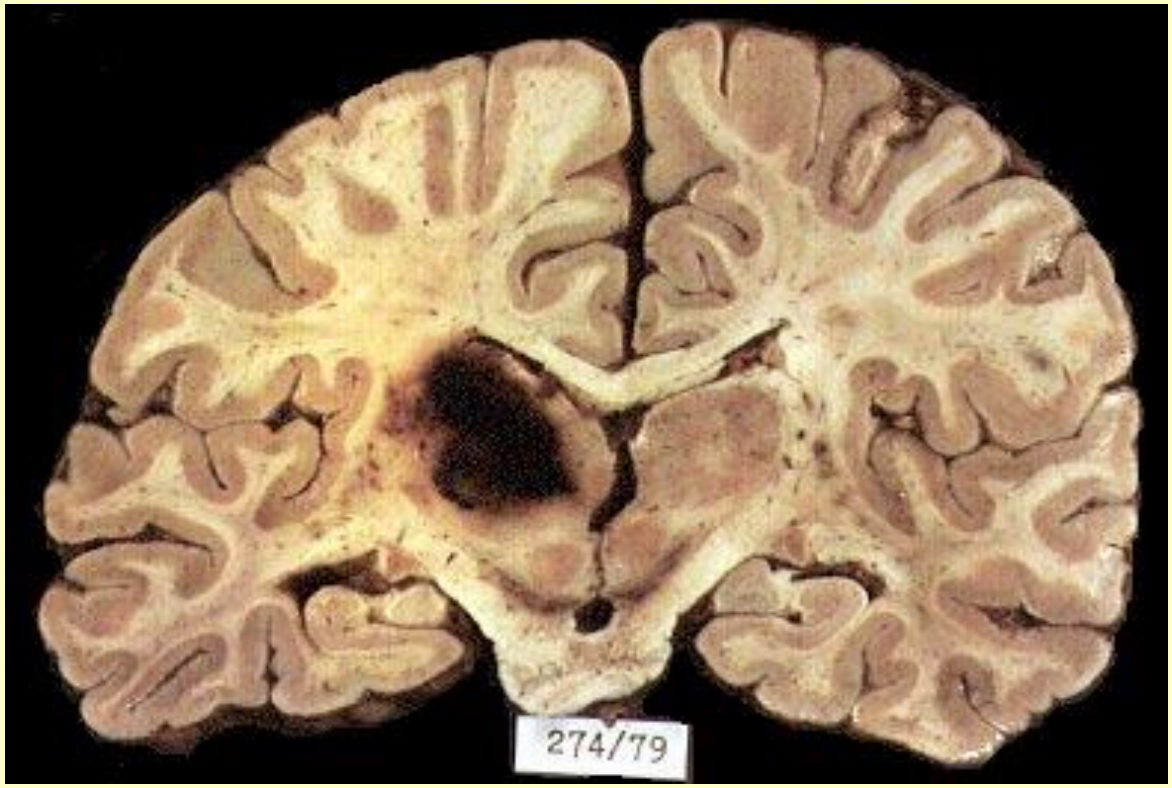


Somatotopy in the VPM/VPL

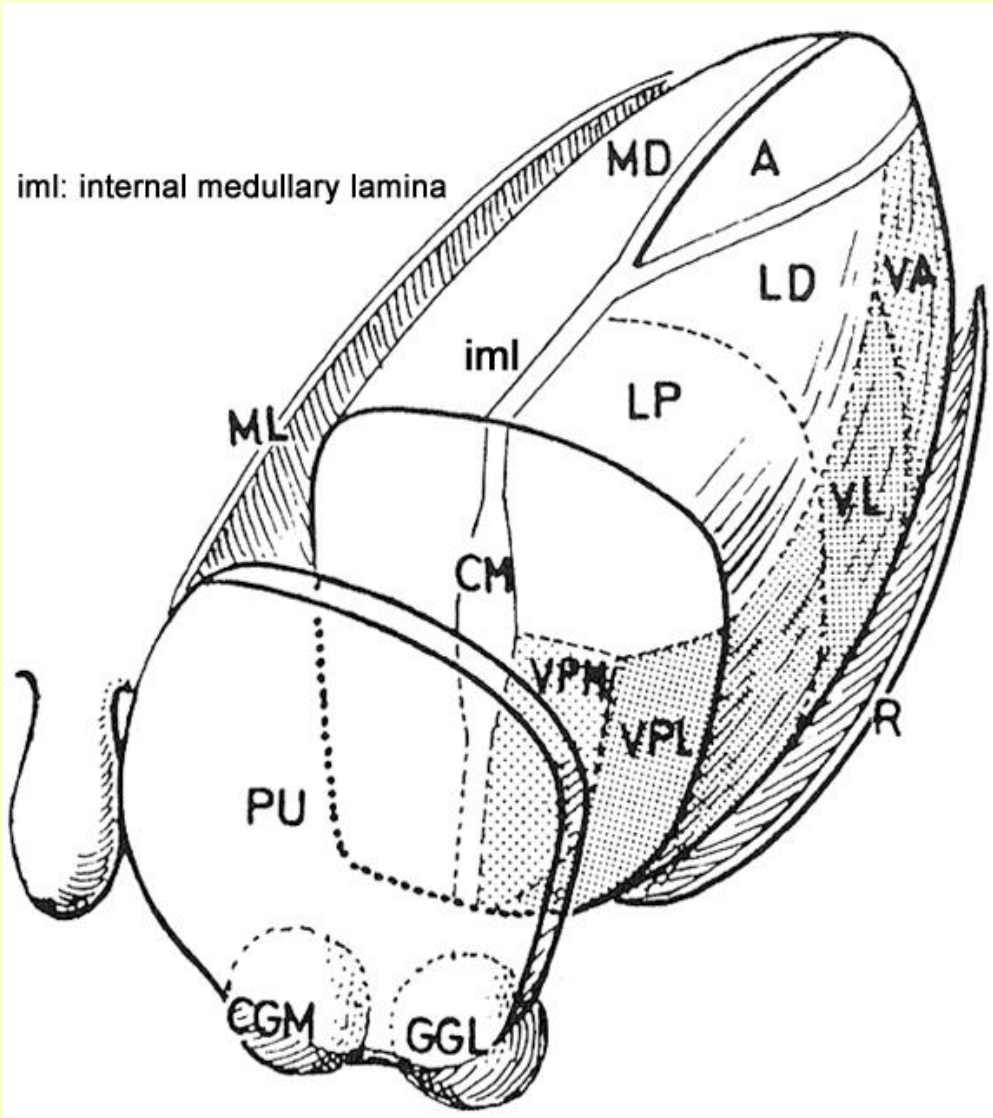


The thalamus pain (or Dejerine-Roussy) syndrome





Specific motor relay nuclei



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- medial and lateral geniculate body (MGB and LGB)

Inputs and projections of the motor relay nuclei in the ventral column of the lateral nuclear group

Specific thalamic motor relay nuclei:

Ventral anterior nucleus (VA)

Afferents (inputs): basal ganglia (pallidum)

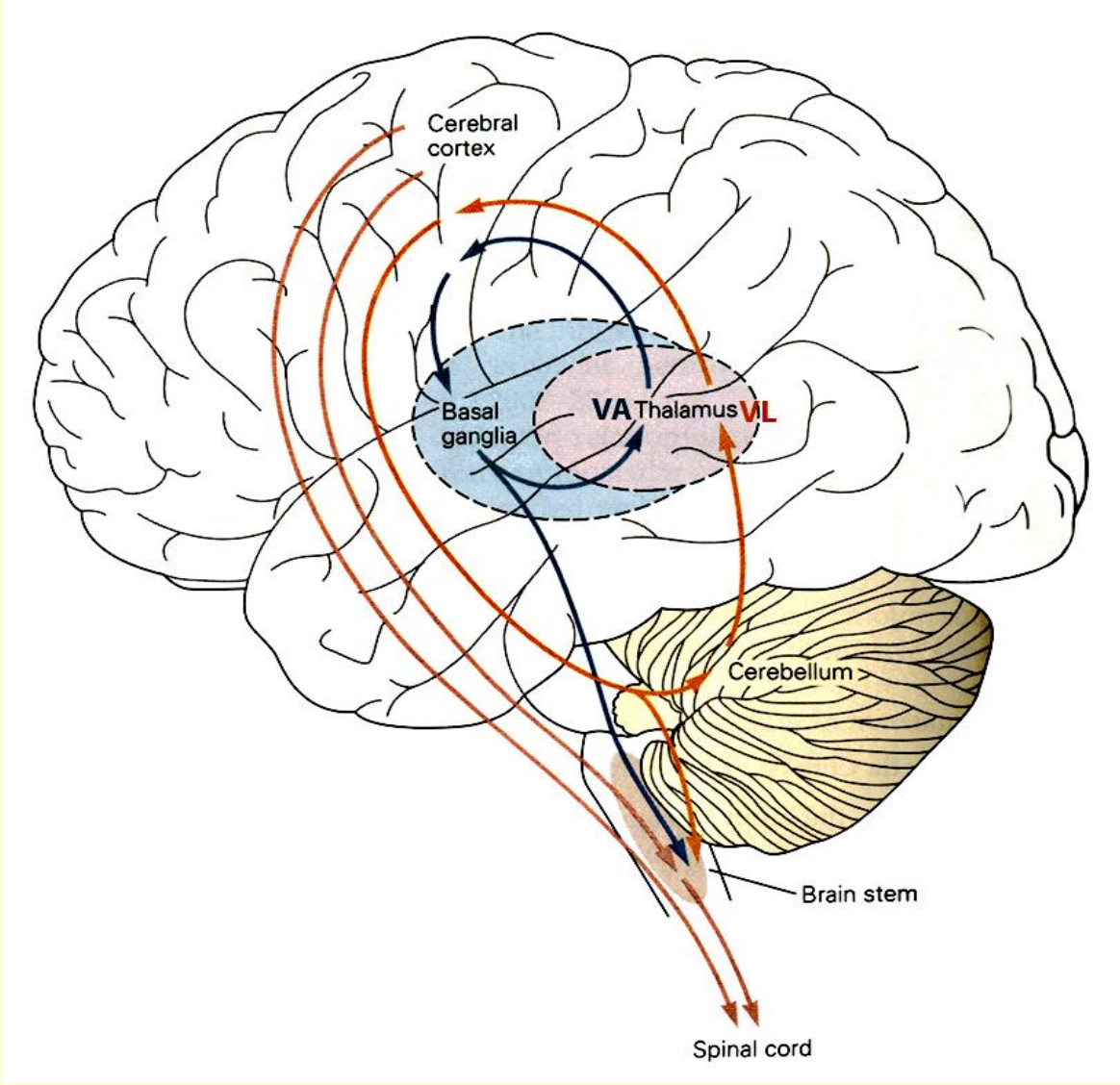
Efferents (projections): pre- and supplementer motor cortex

Ventral lateral nucleus (VL)

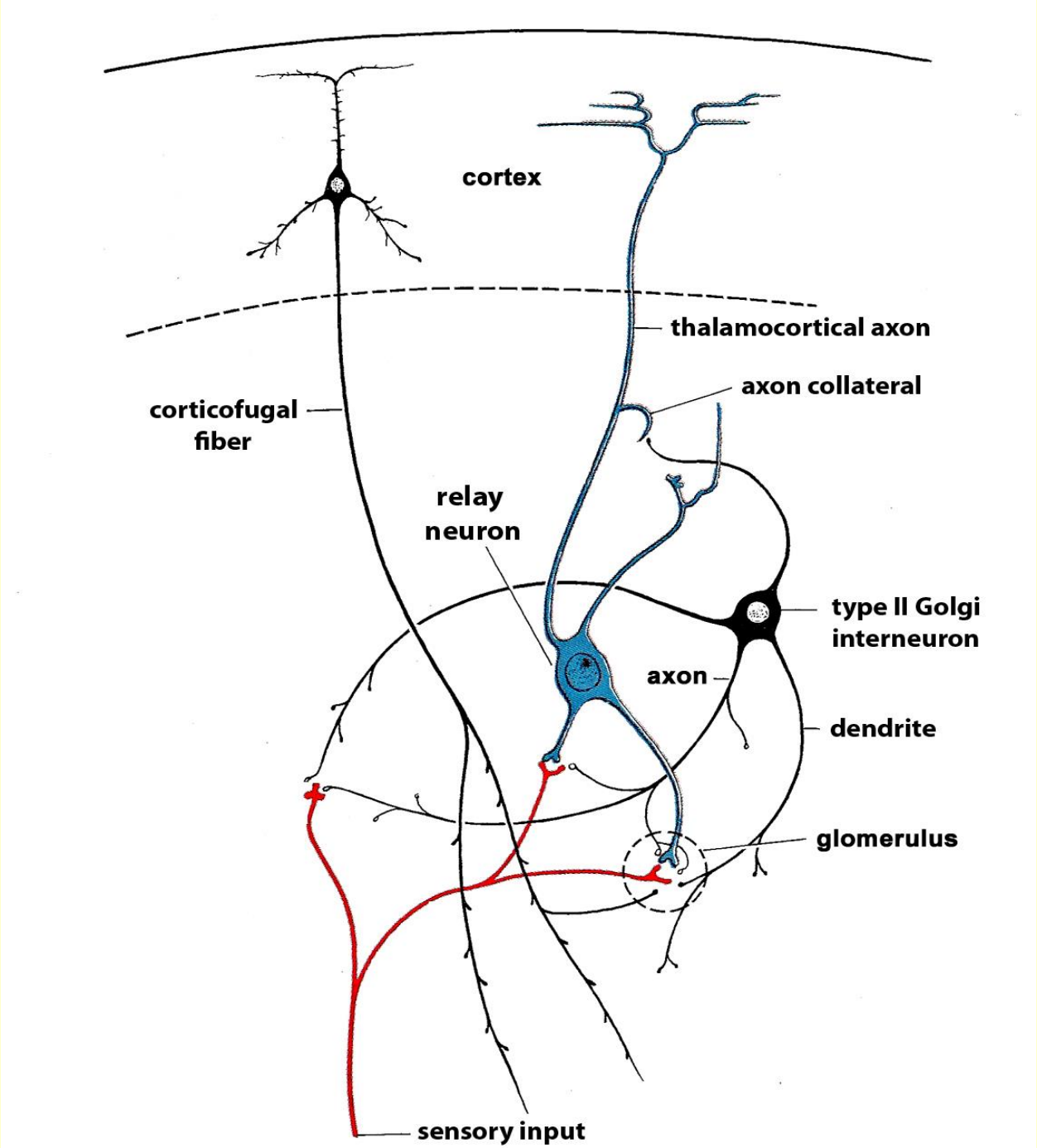
Afferents (inputs): cerebellum (dentate nucleus)

Efferents (projections): primary motor cortex (gyrus precentralis)

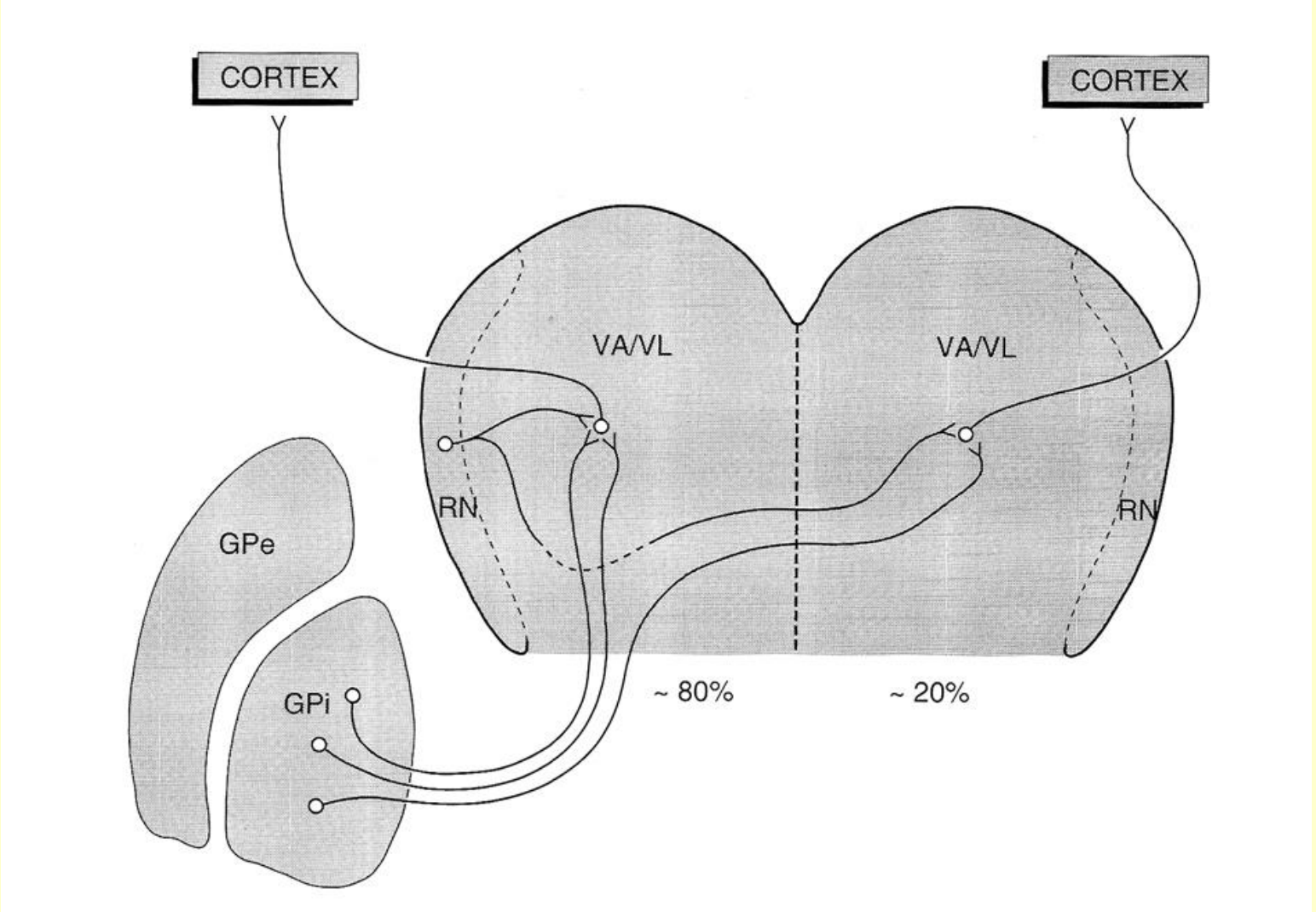
The motor thalamic relay nuclei participate in different motor circuits



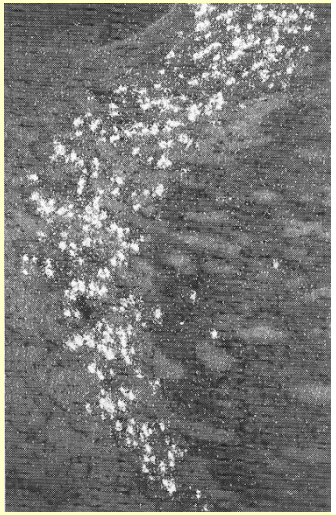
Neuronal circuit of information relay in the specific thalamic nuclei

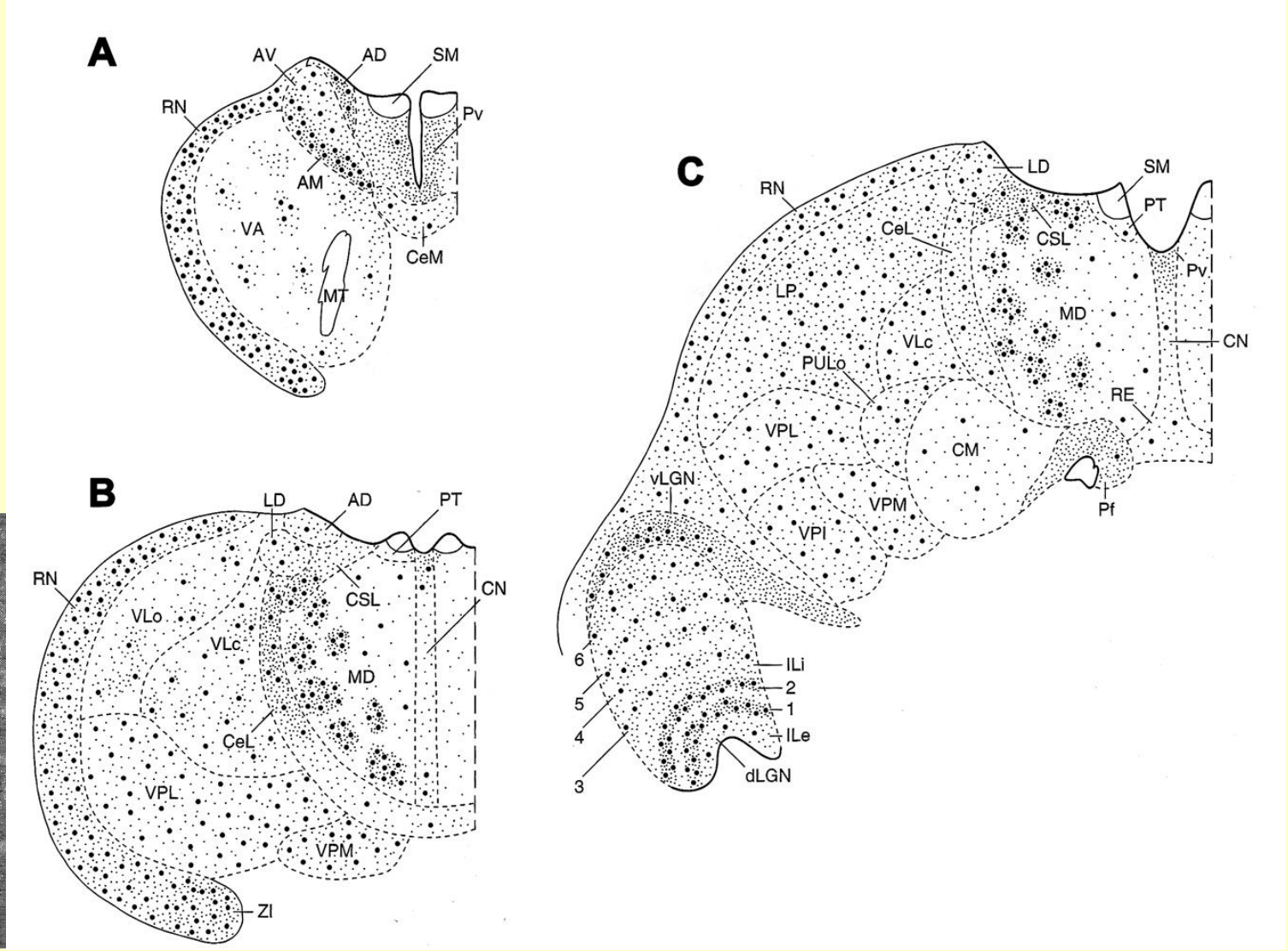


Thalamic reticular nucleus: a regulator of the relay function of specific thalamic nuclei

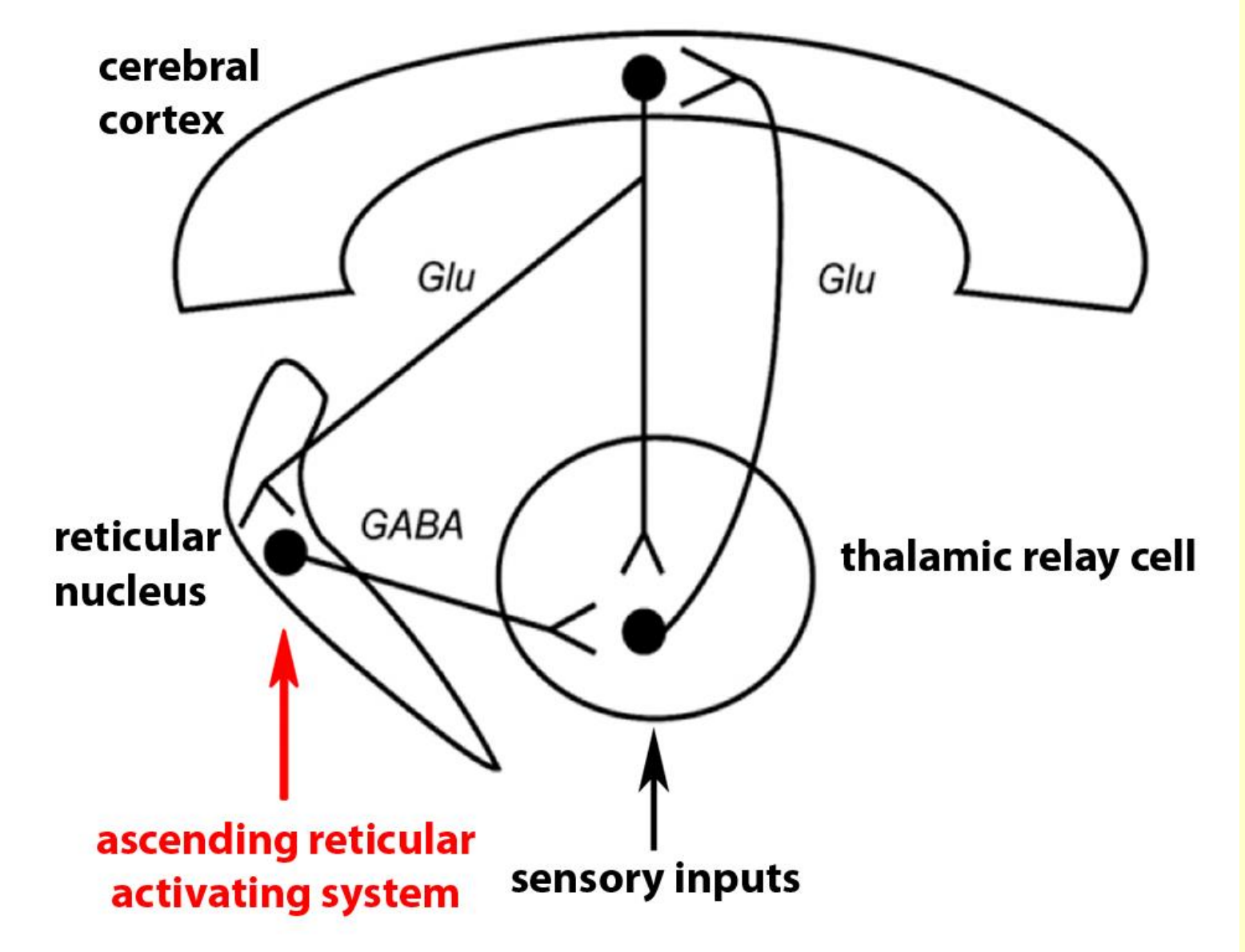


GABA-erg inhibitory neurons in the thalamus

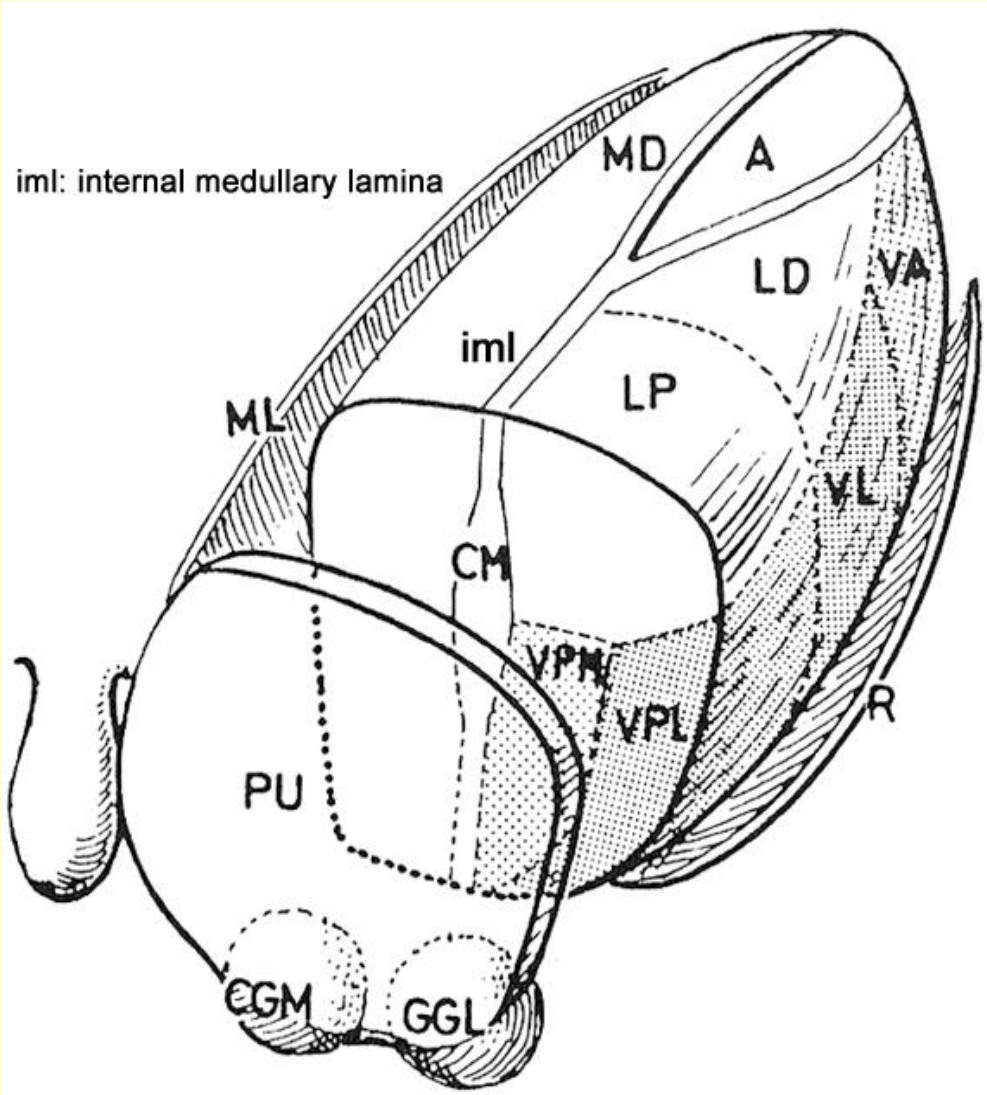




State-dependent modes of relay cell function



Midline and intralaminar nuclei of the thalamus



anterior nuclear group (A)
- anteromedial nu.
- anterodorsal nu.
- anteroventral nu.

medial nuclear group
- mediodorsalis nu. (MD)

lateral nuclear group
- **dorsal nuclei**
  - lateral dorsal nu. (LD)
  - lateral posterior nu. (LP)
  - pulvinar (PU)
- **ventral nuclei**
  - ventral anterior nu. (VA)
  - ventral lateral nu. (VL)
  - ventral posterolateral nu. (VPL)
  - ventral posteromedial nu. (VPM)

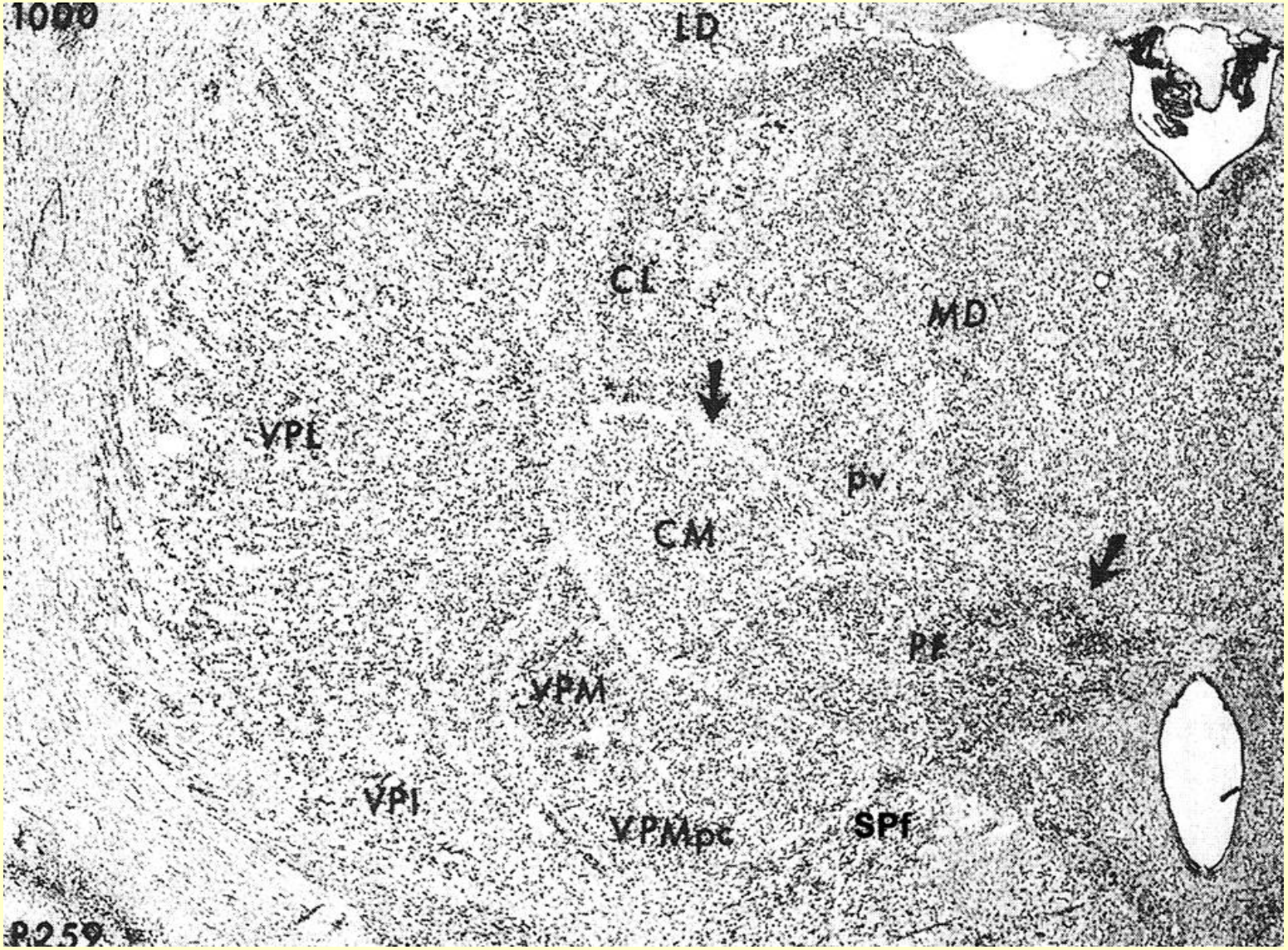
midline nuclei (ML)

intralaminar nuclei
- **anterior intralaminar nuclei**
- **posterior intralaminar nuclei**
  - central medial nu. (CM)
  - parafascicular nu.
  - subparafascicular nu.

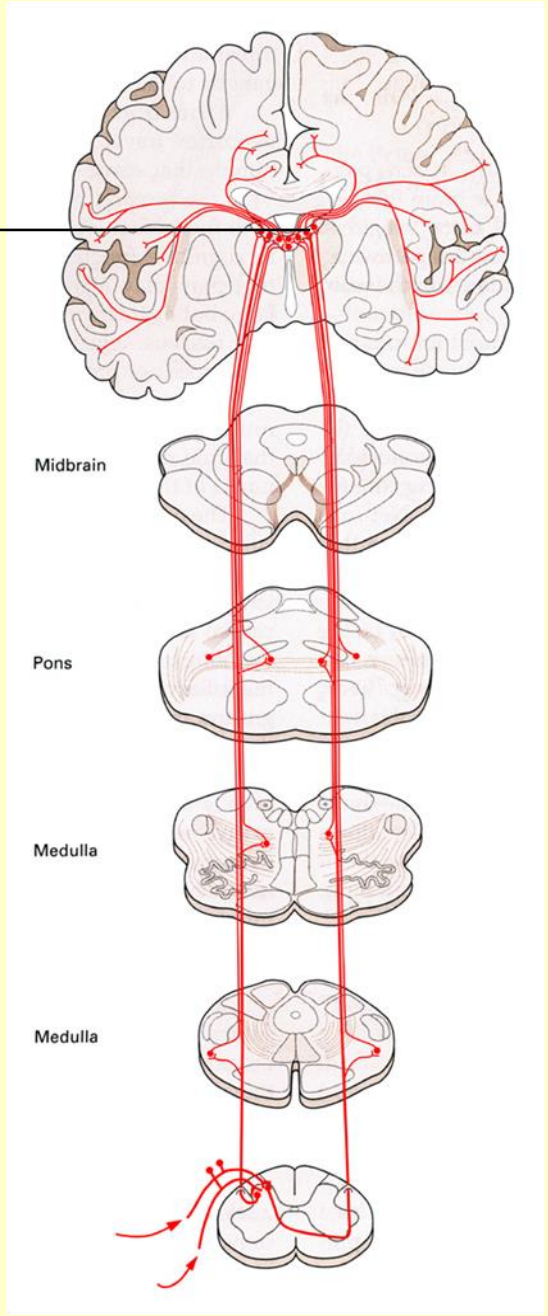
reticular thalamic nu. (R)

metathalamus
- medial and lateral geniculate body (MGB and LGB)

Nissl-stained monkey brain at the level of the caudal intralaminar nuclei



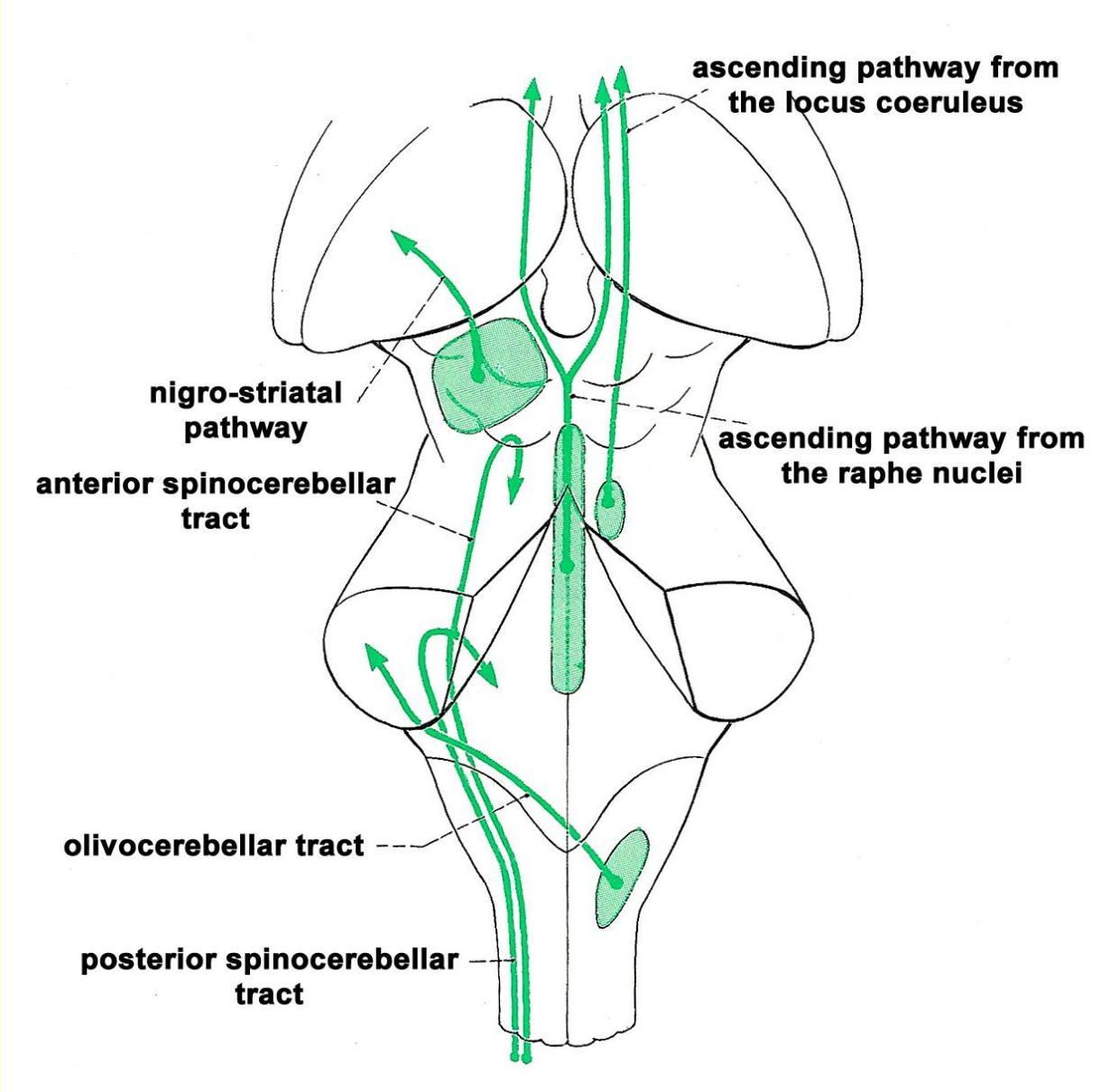
Major inputs and projections of midline and intralaminar thalamic nuclei



Spino-reticulo-thalamic tract

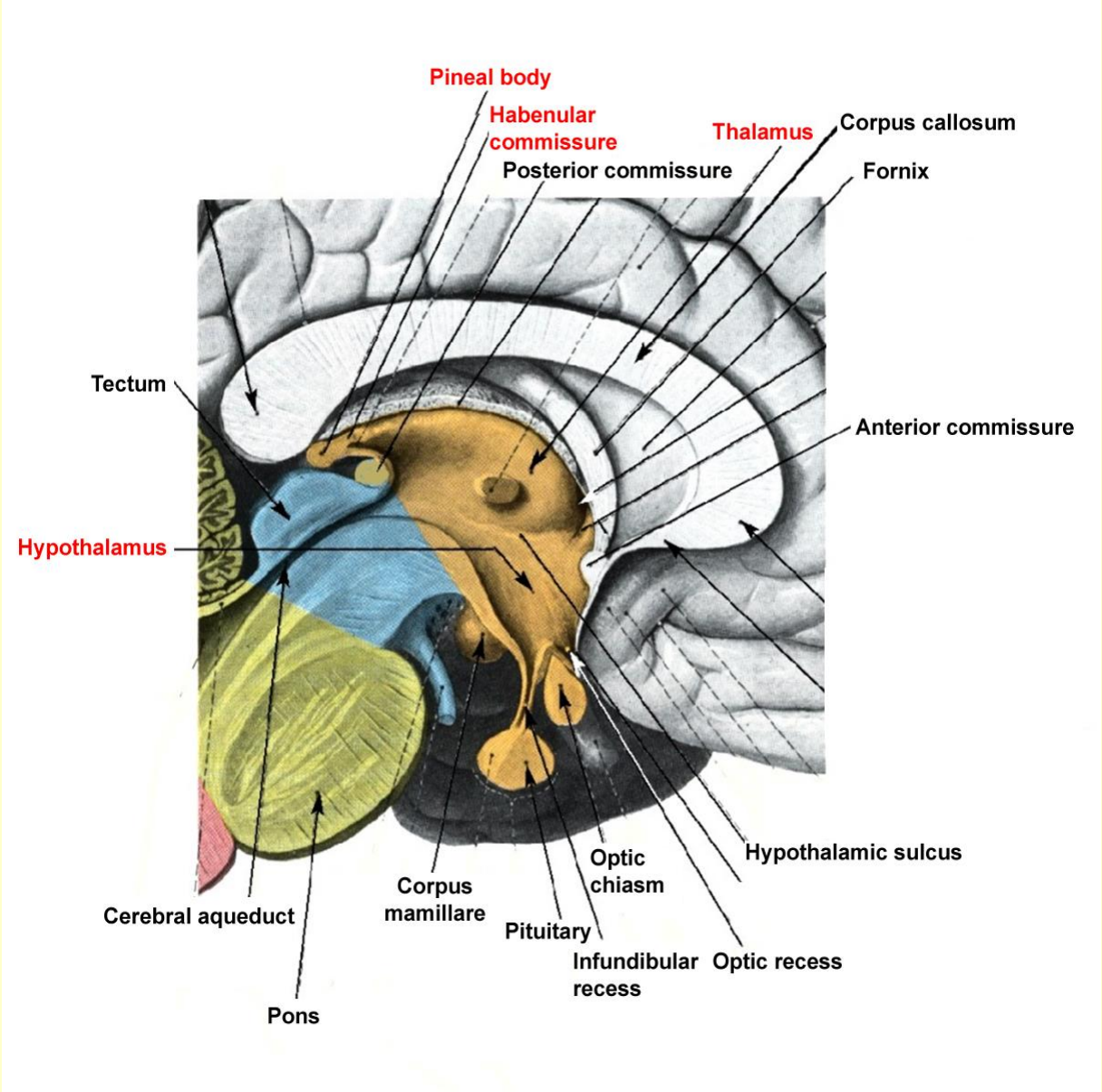
– part of the „ascending reticular activating system”, a regulator of cortical alertness

Ascending pathways without relay in the thalamus



The hypothalamus

- **Thalamus**
- **Epithalamus**
  - Pineal body
  - Habenula
  - Trigonum habenulae
  - Habenular nuclei
  - Stria medullaris
  - Habenular commissure
- **Metathalamus**
  - Medial geniculate body
  - Lateral geniculate body
- **Subthalamus**
  - Subthalamic nucleus
  - Zona incerta
  - H fields of Forel
- **Hypothalamus**



Structure and major functions of the thalamus and hypothalamus are profoundly different

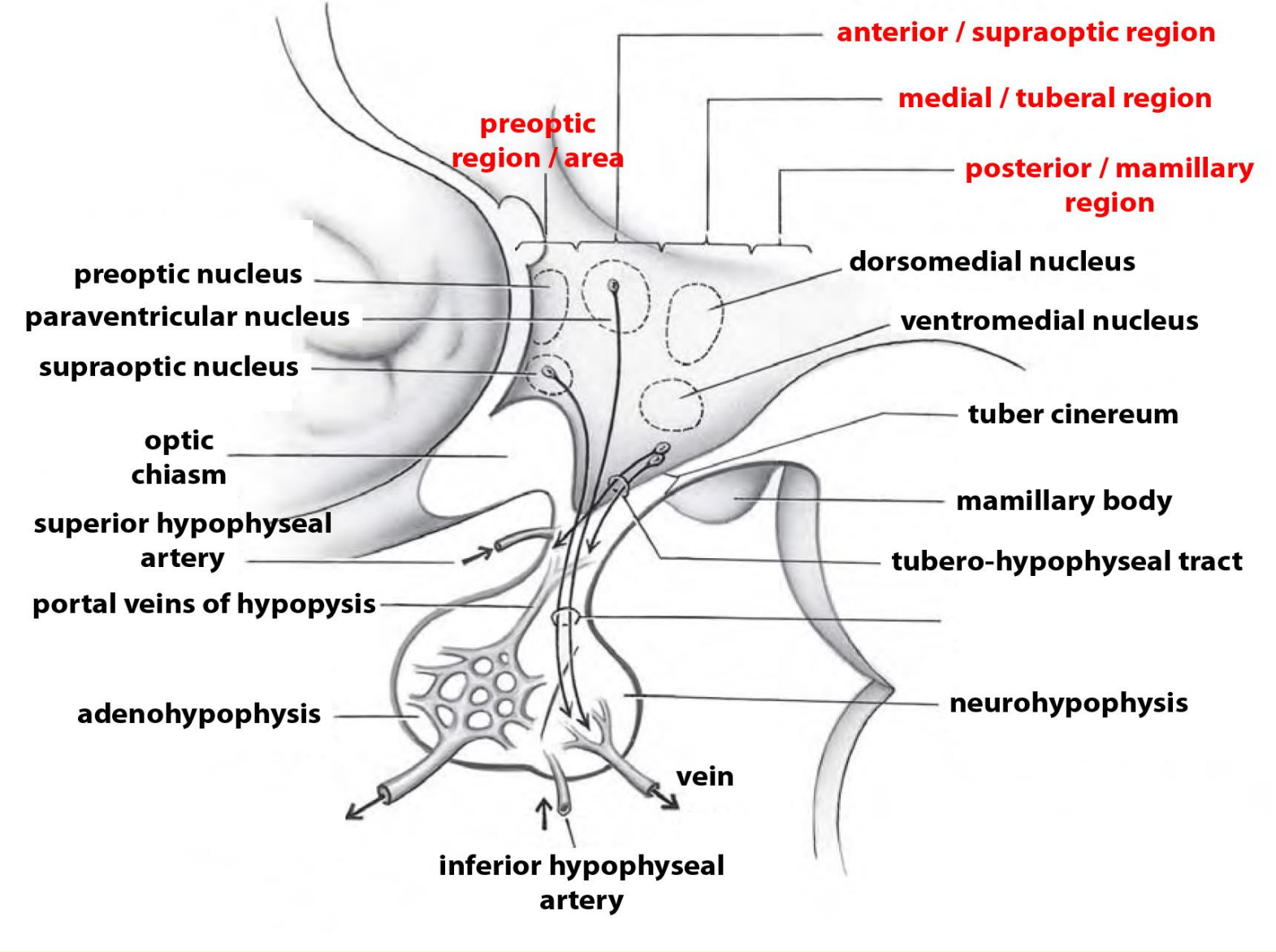
Thalamus:

- well delineated nuclei
- relay and modulation of cortical inputs

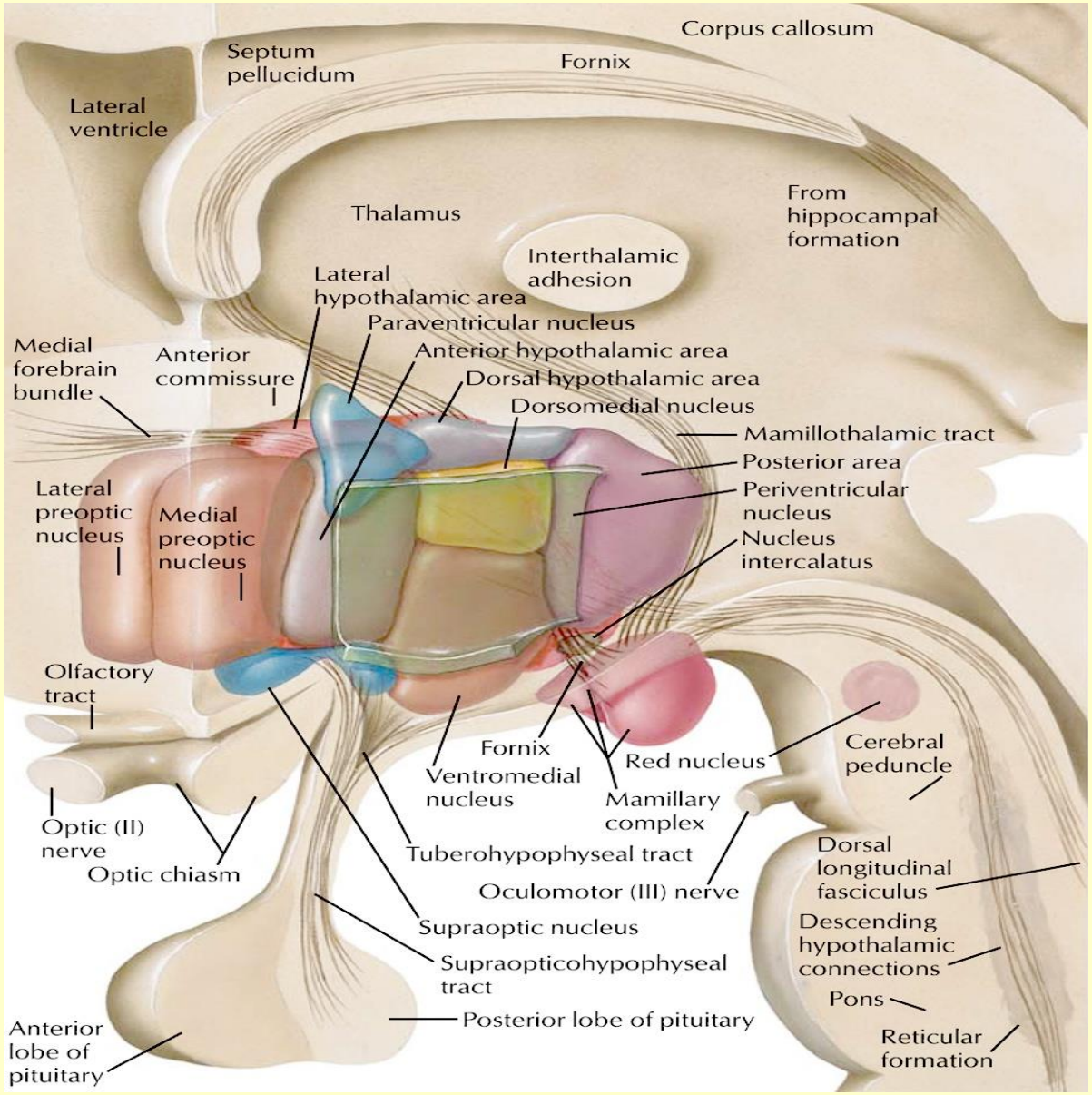
Hypothalamus:

- neurons with different functions are intermingled, not well separated
- homeostatic regulations that do not require cortical processing

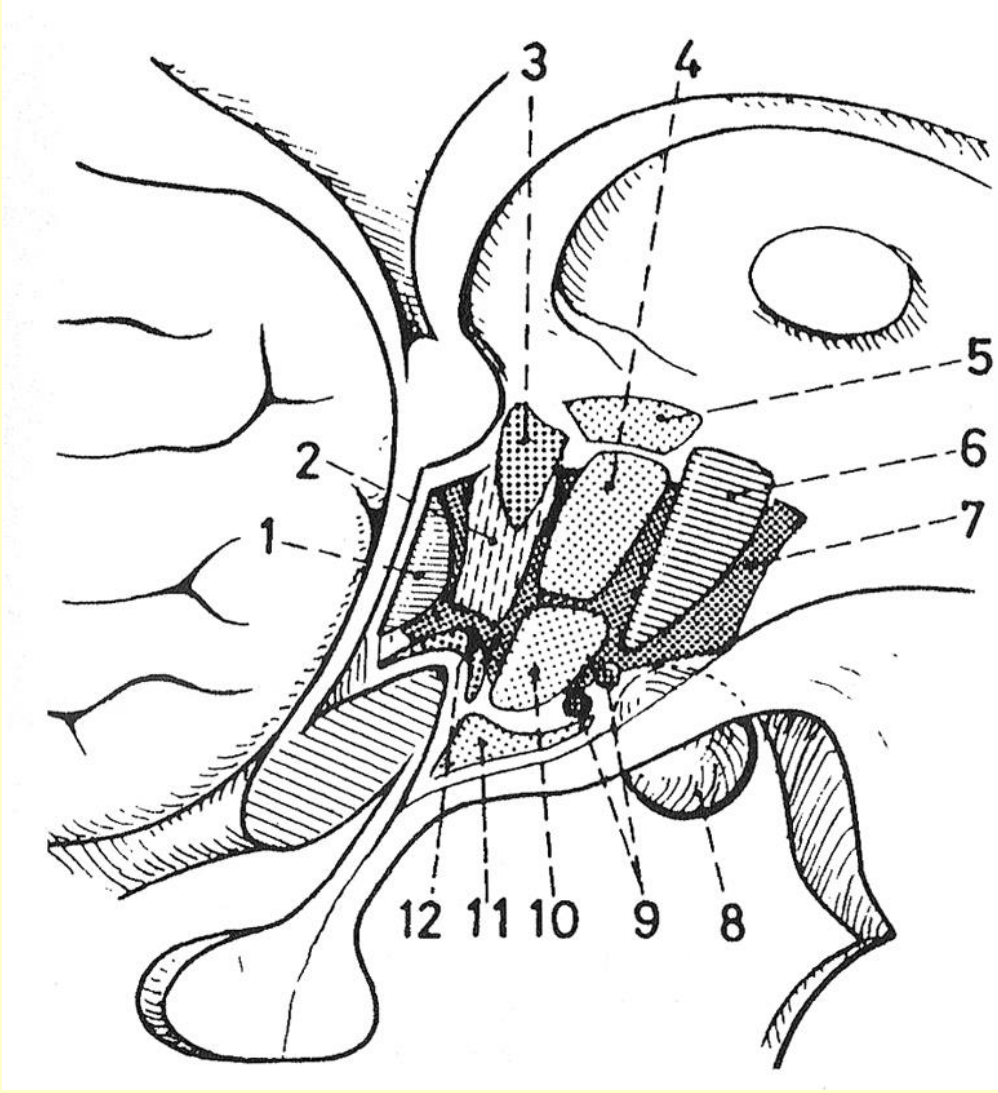
Antero-posterior regions of the hypothalamus



Medio-lateral zones of the hypothalamus

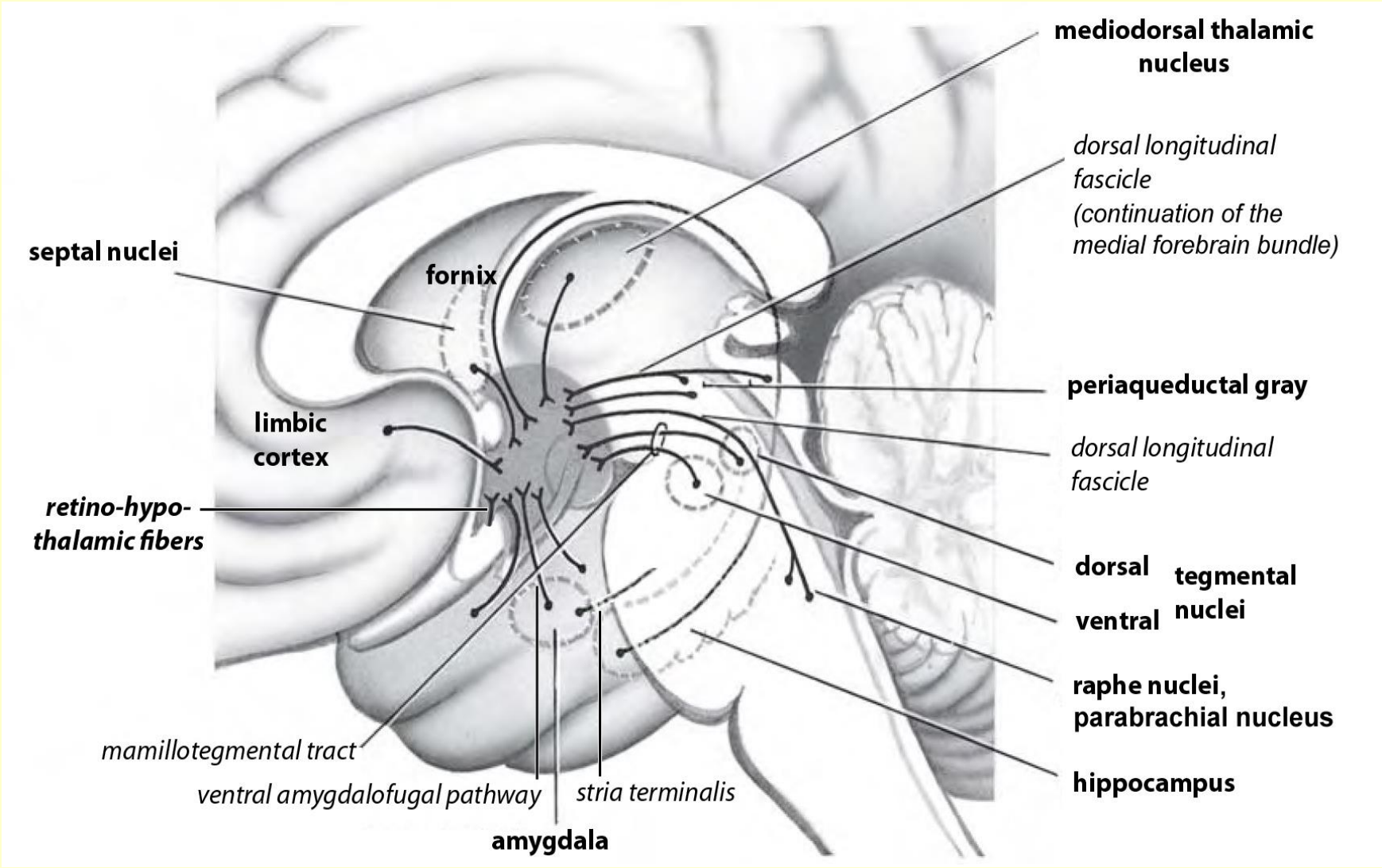


Nuclei in the medial zone of the hypothalamus

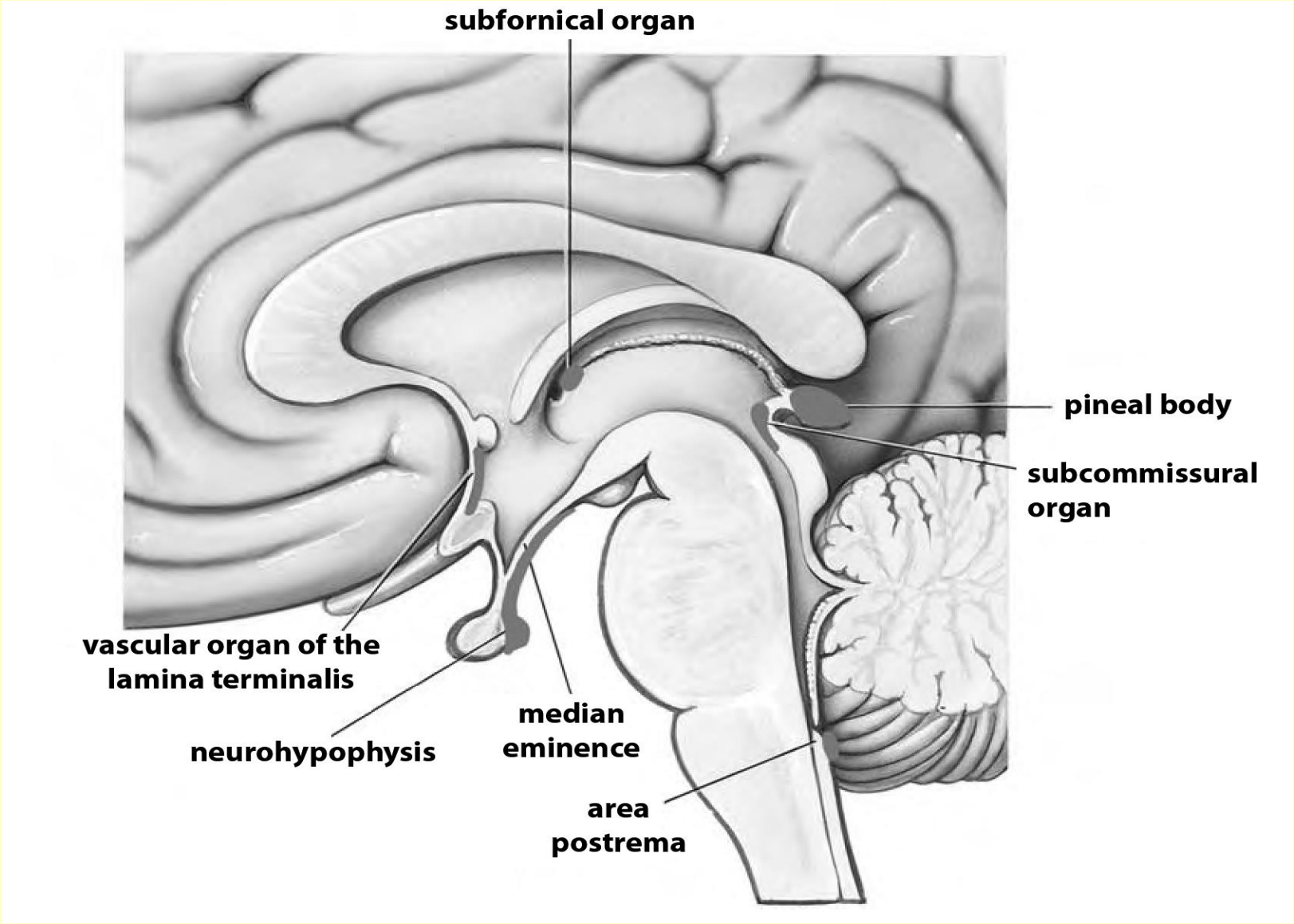


1. preoptic nucleus
2. anterior hypothalamic nu.
3. paraventricular nucleus
4. dorsomedial hypoth. nucleus
5. dorsal hypothalamic area
6. posterior hypothalamic nu.
7. lateral zone of the hypoth.
8. mamillary body
9. tuberomamillary nuclei
10. ventromedial hypoth. nu.
11. infundibular (arcuate) nu.
12. supraoptic nucleus

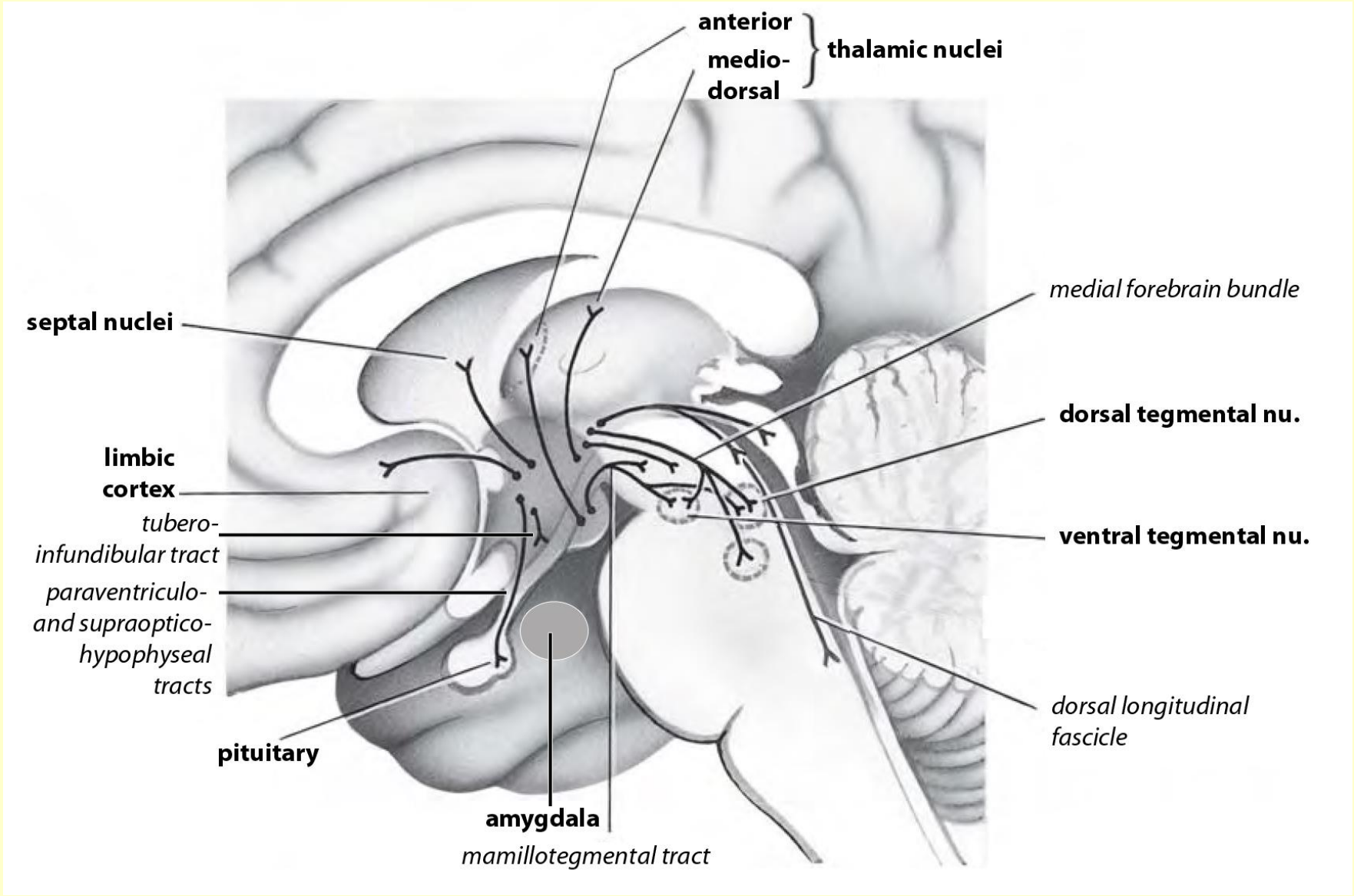
Neuronal inputs to the hypothalamus



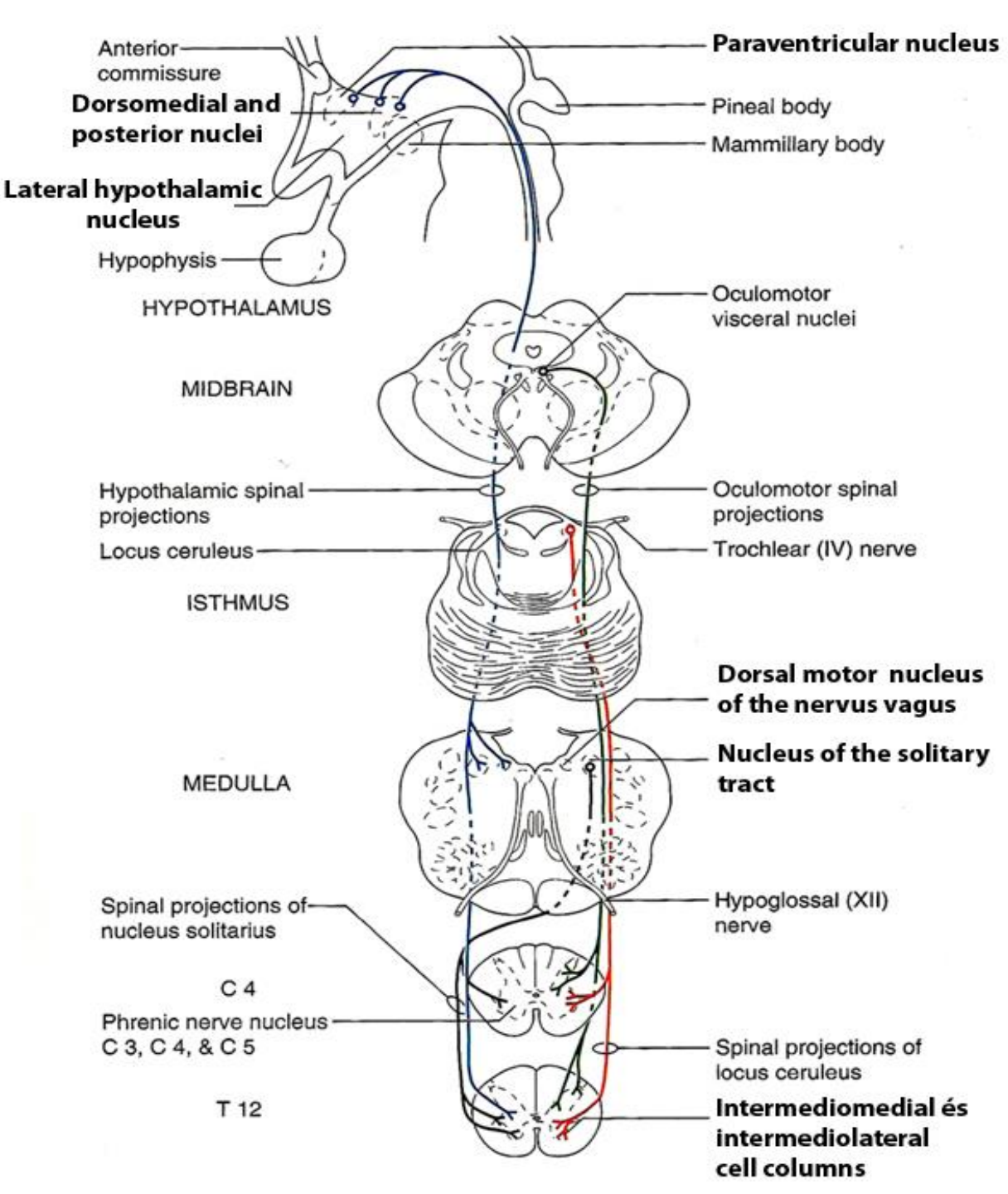
Circumventricular organs – humoral inputs



Extrahypothalamic projections of hypothalamic nuclei



Hypothalamo-spinal tract and other descending pathways regulating vegetative functions



Regulatory functions of hypothalamic nuclei

- Vegetative regulations
- Neuroendocrine regulations
- Salt and water balance
- Food intake and body weight
- Temperature
- Circadian rhythms
- Sleep
- Reproduction

Thank you for
your attention!