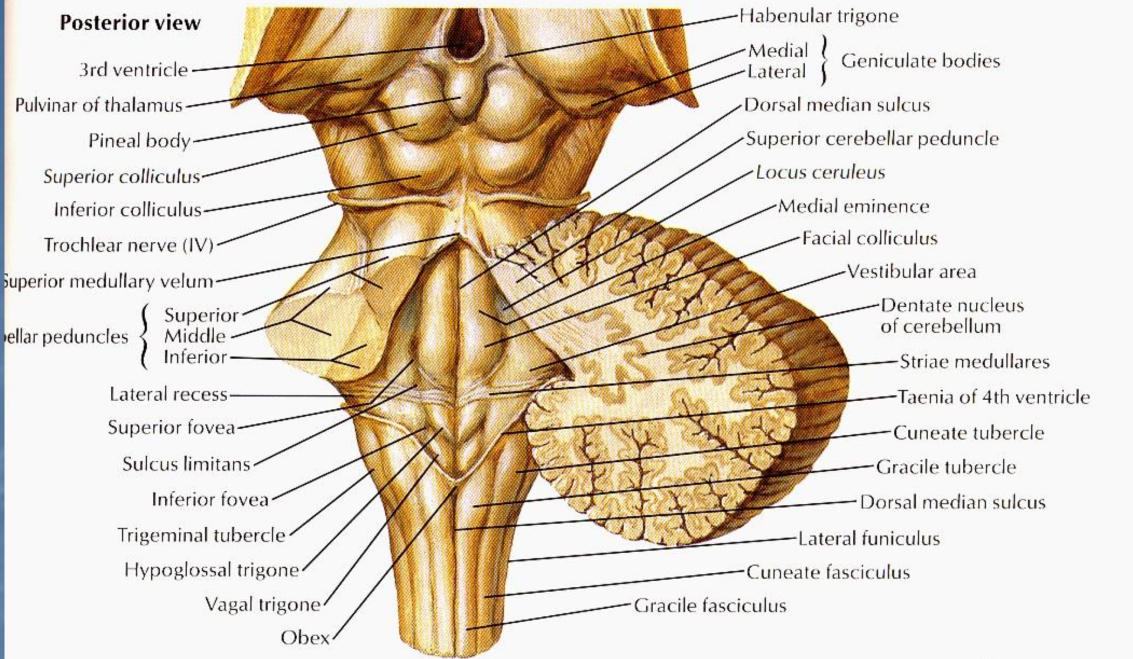
CEREBELLUM

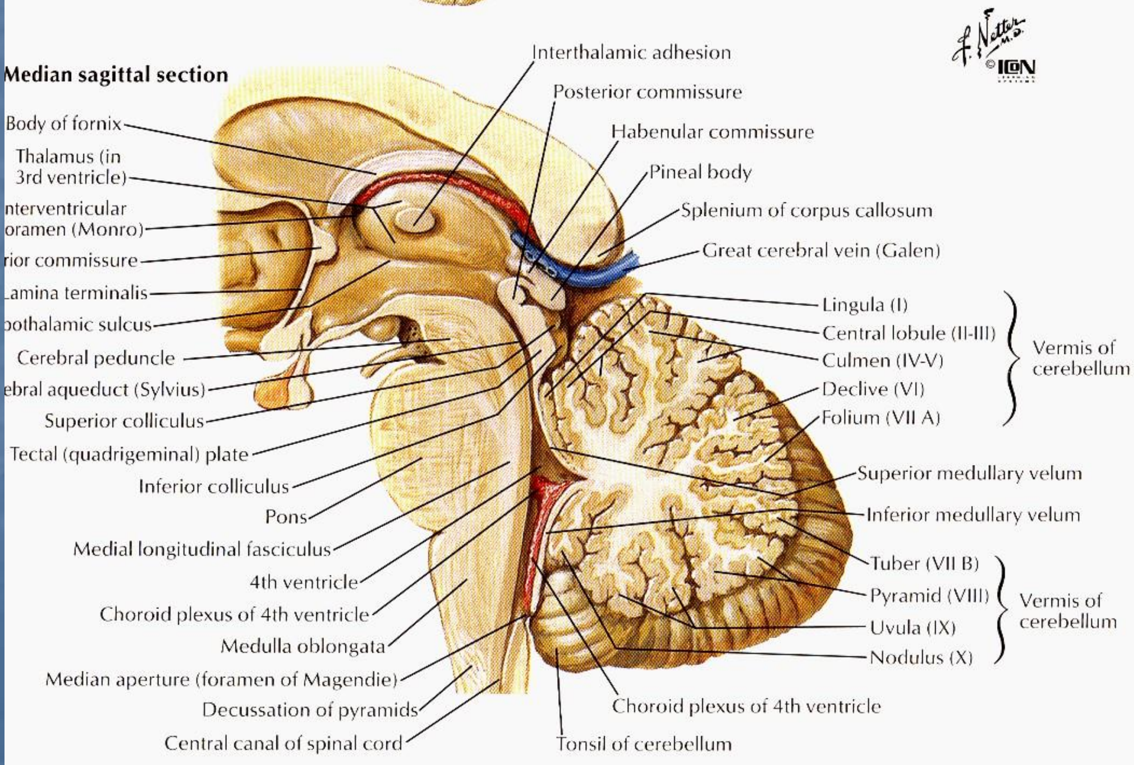
Institute of Anatomy, Second Faculty of Medicine

R. Druga

Posterior view

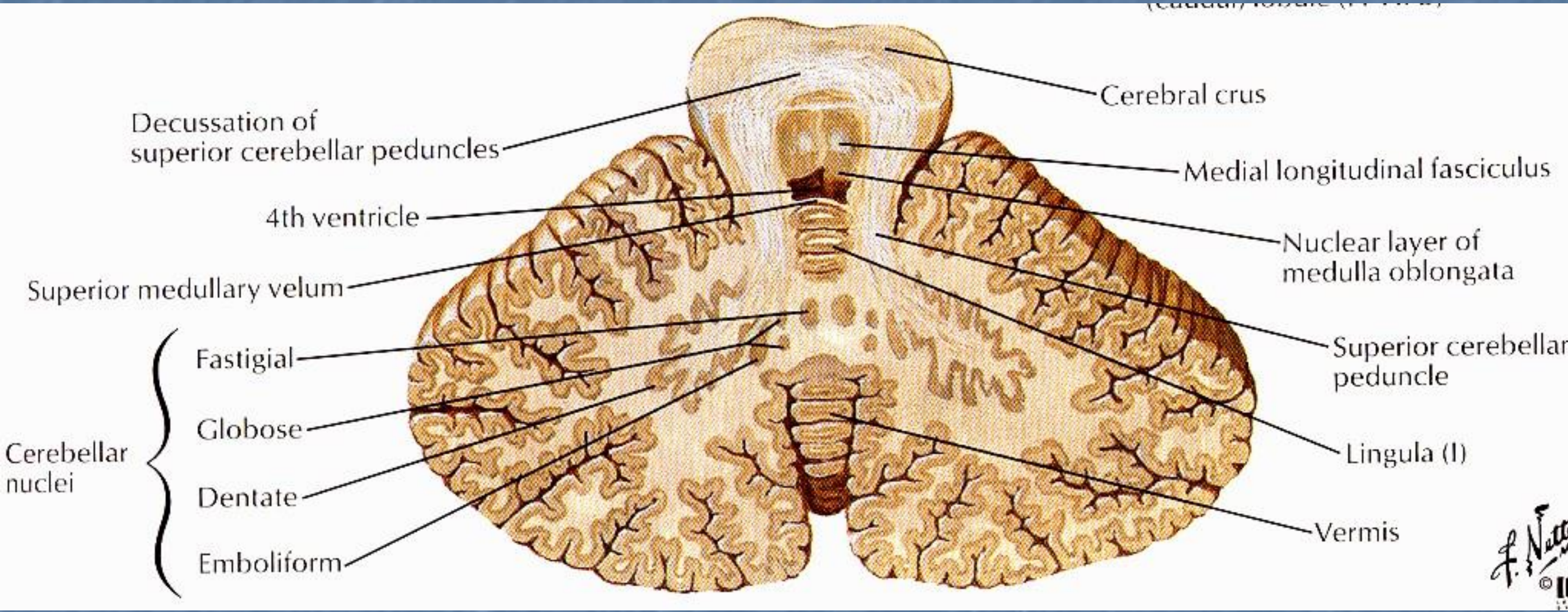


Median sagittal section



Cerebellar folia

Cortex, subcortical white matter, nuclei



Excessive folding of the cerebellar surface (cortex)

The cerebellum – relations and structure

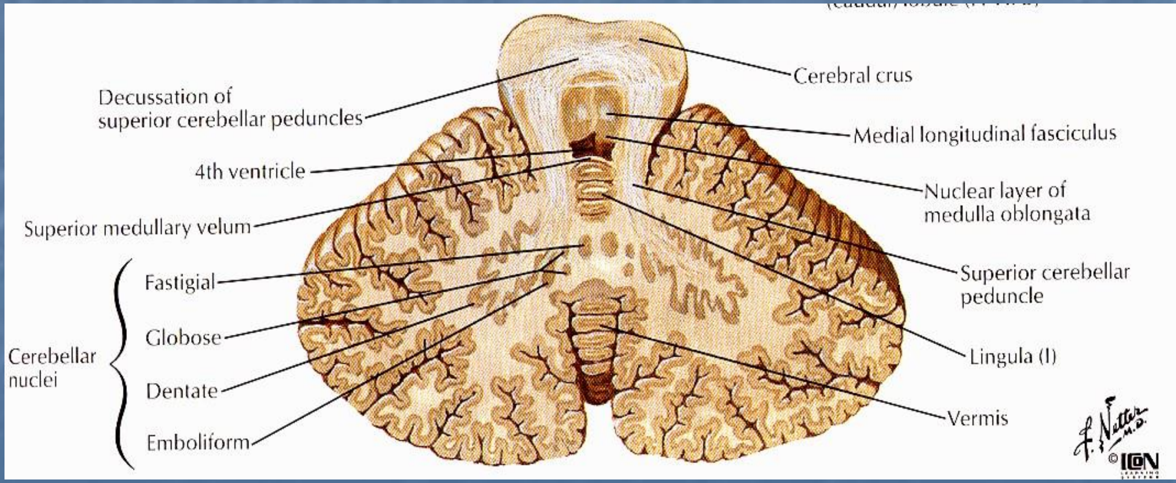
- Located in the posterior cranial fossa
- Connected with the brain stem- by peduncles (inferior, middle, superior)
- Is covered by the cerebellar cortex (3 layers). Cortex is extensively folded (folia-oriented mediolaterally)
- In the white matter are the cerebellar nuclei

Fossa cranii posterior

Pedunculi cerebellares (inferior, medius, superior)

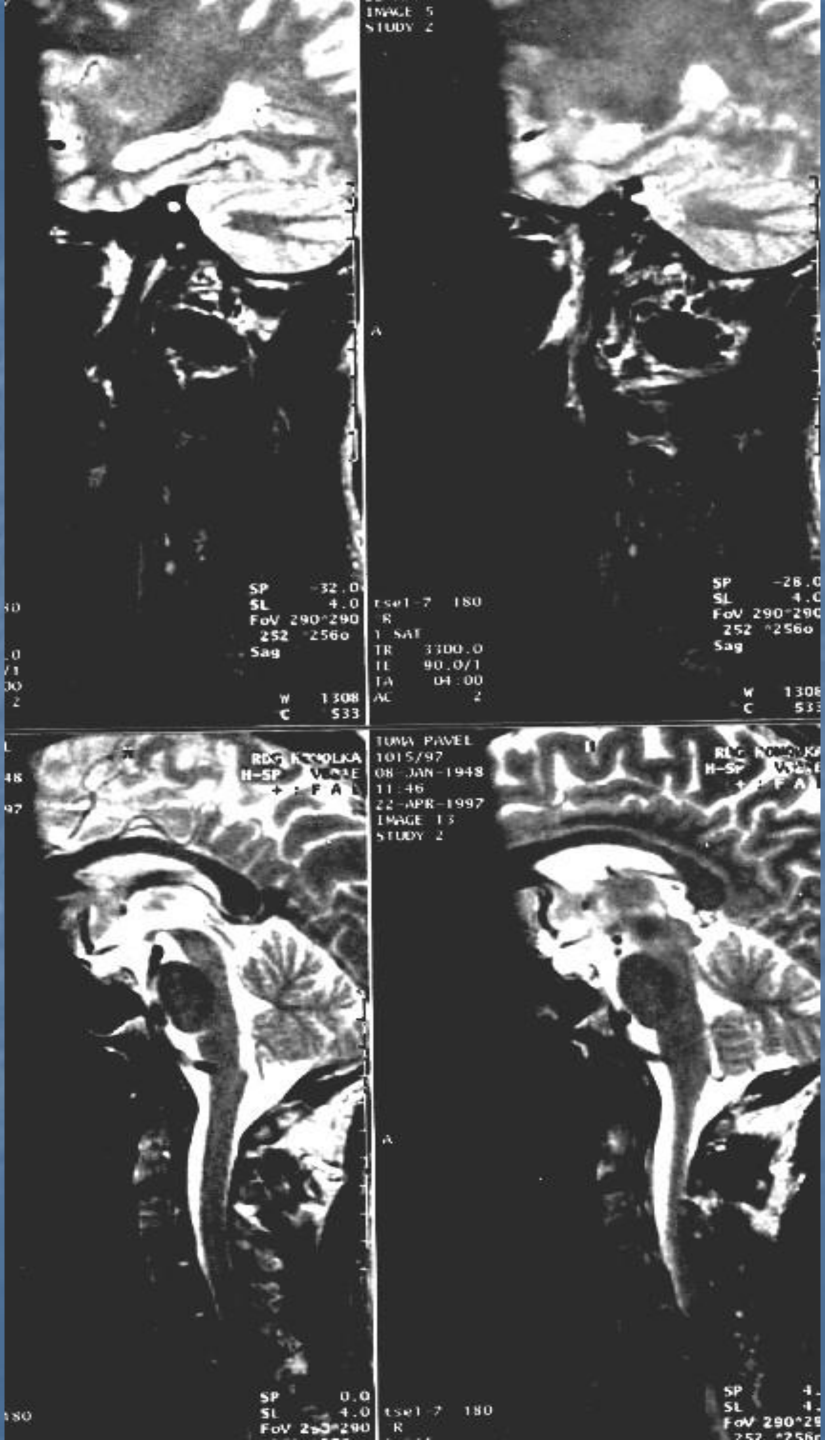
Cortex – 3 vrstvy

V bílé hmotě mozečková jádra



MR examination

Posterior cranial fossa

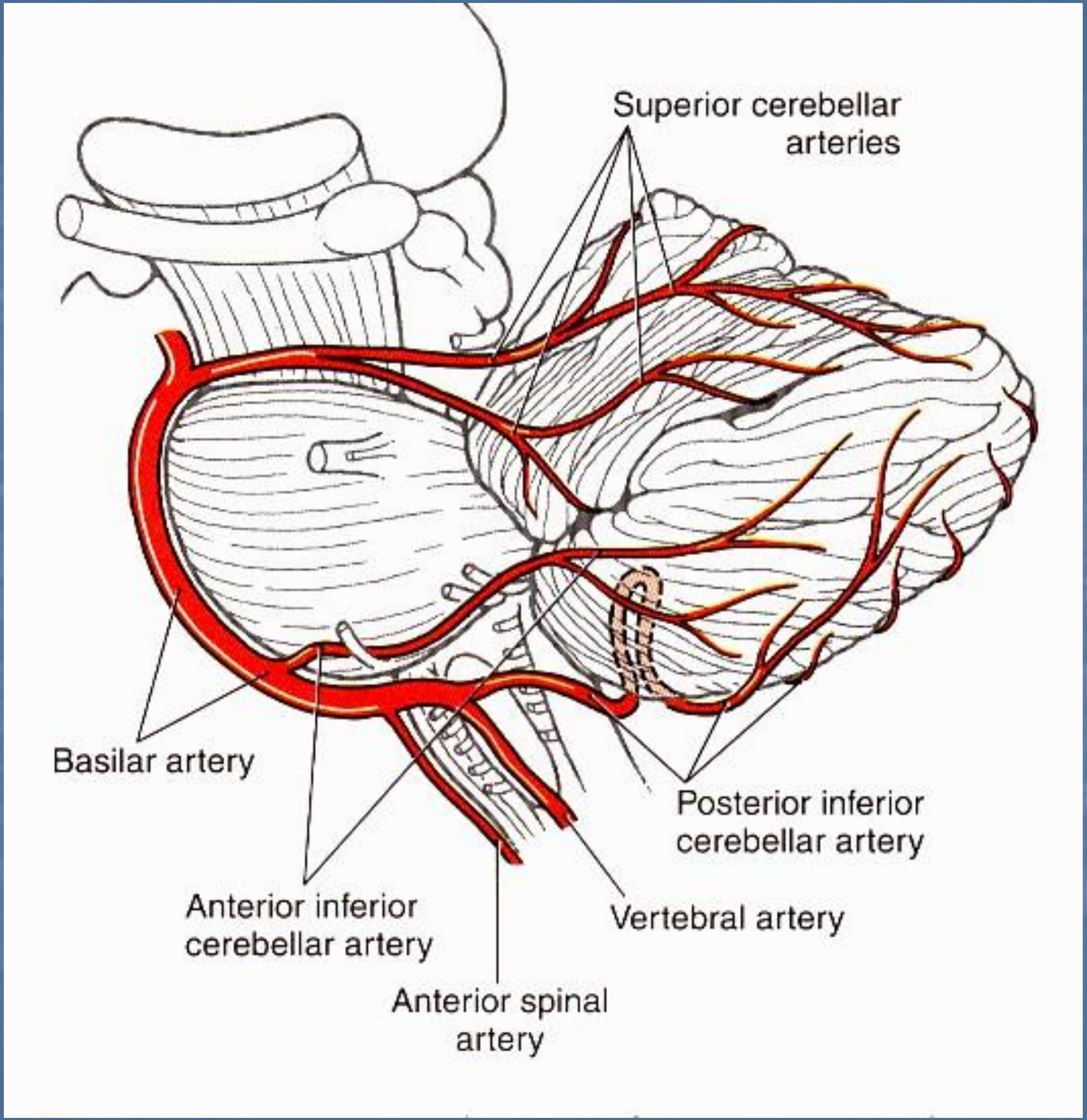


MR vyšetření

Fossa cranii posterior

Arterial supply

Arteriae cerebellares



AICA

PICA

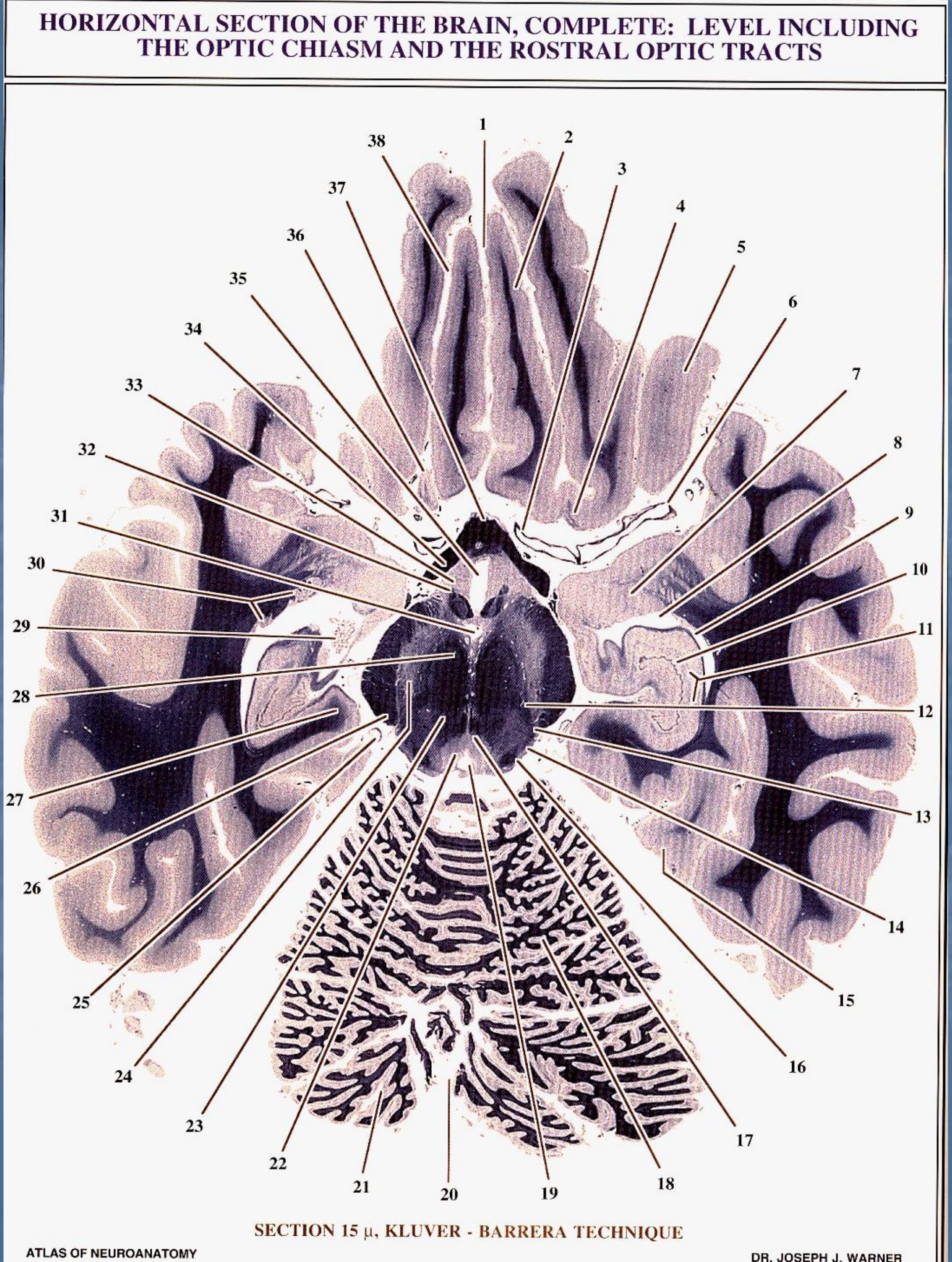
Weigert staining

Marchi

Staining

Kluver –

Barrera



Marchiho metoda

Kluver - Barrera

Unfolded surface

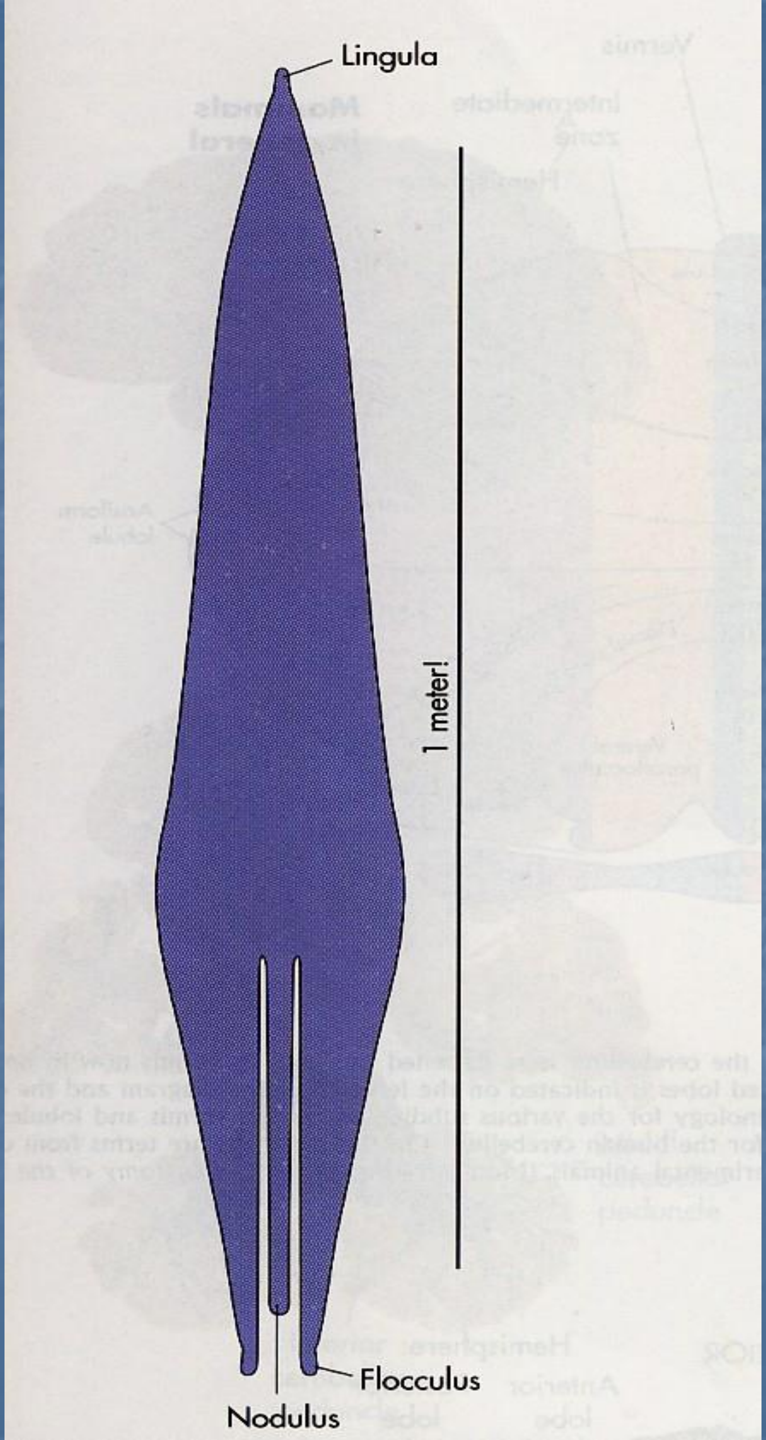
of the cerebellum

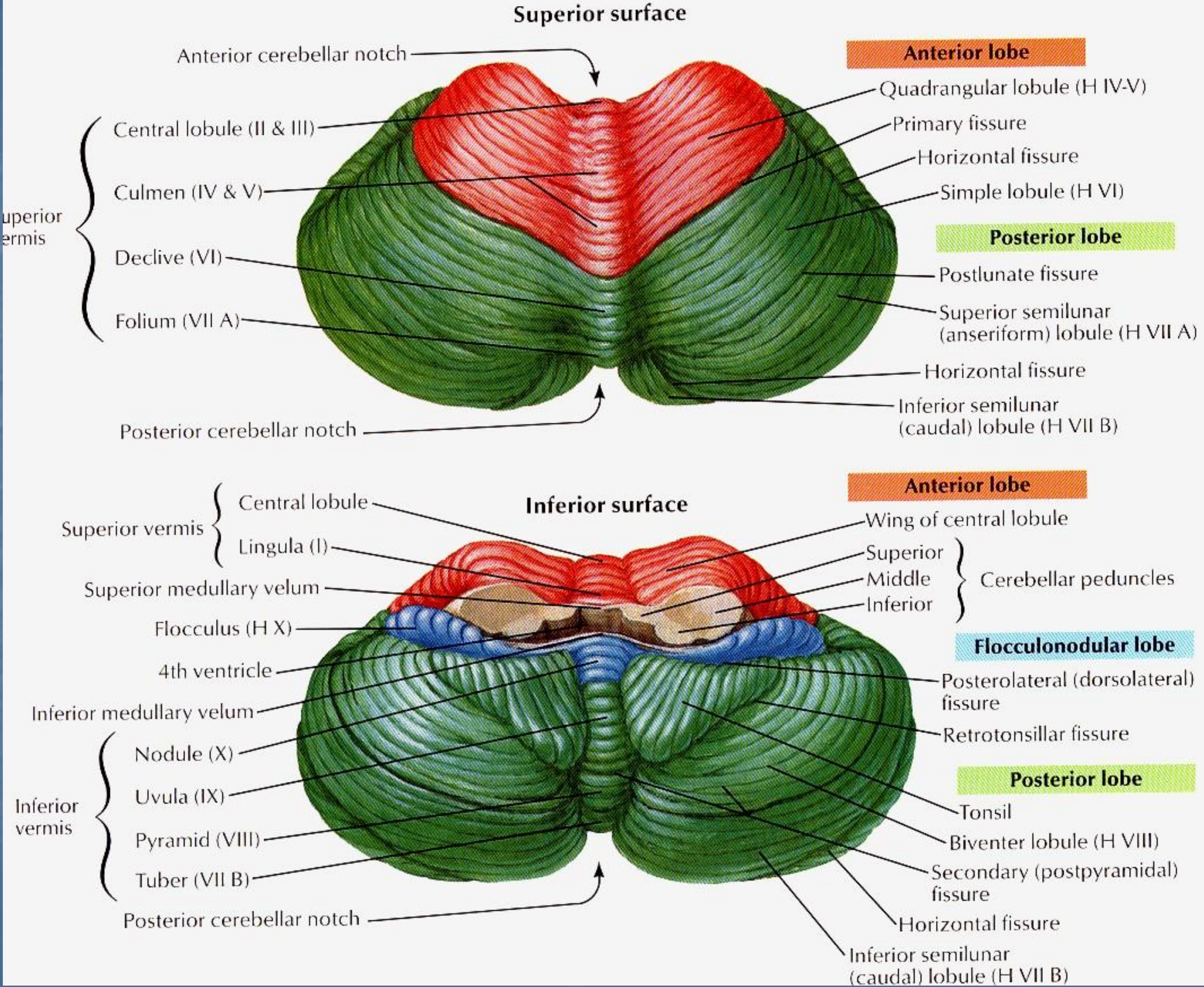
Dvourozněrná rekonstrukce povrchu (kůry)

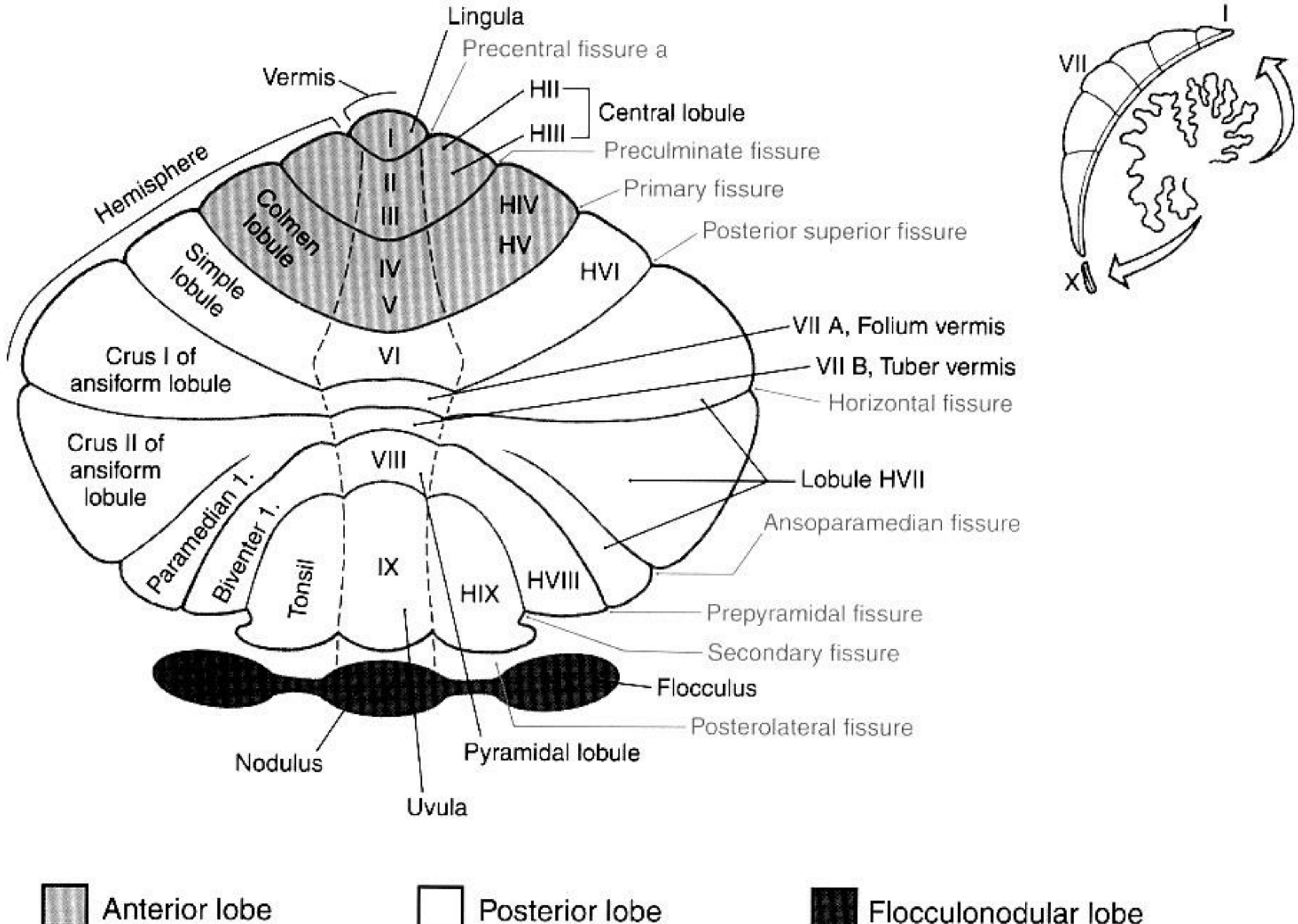
Mozečku

Two-dimensional reconstruction of the cerebellar surface

Length x width



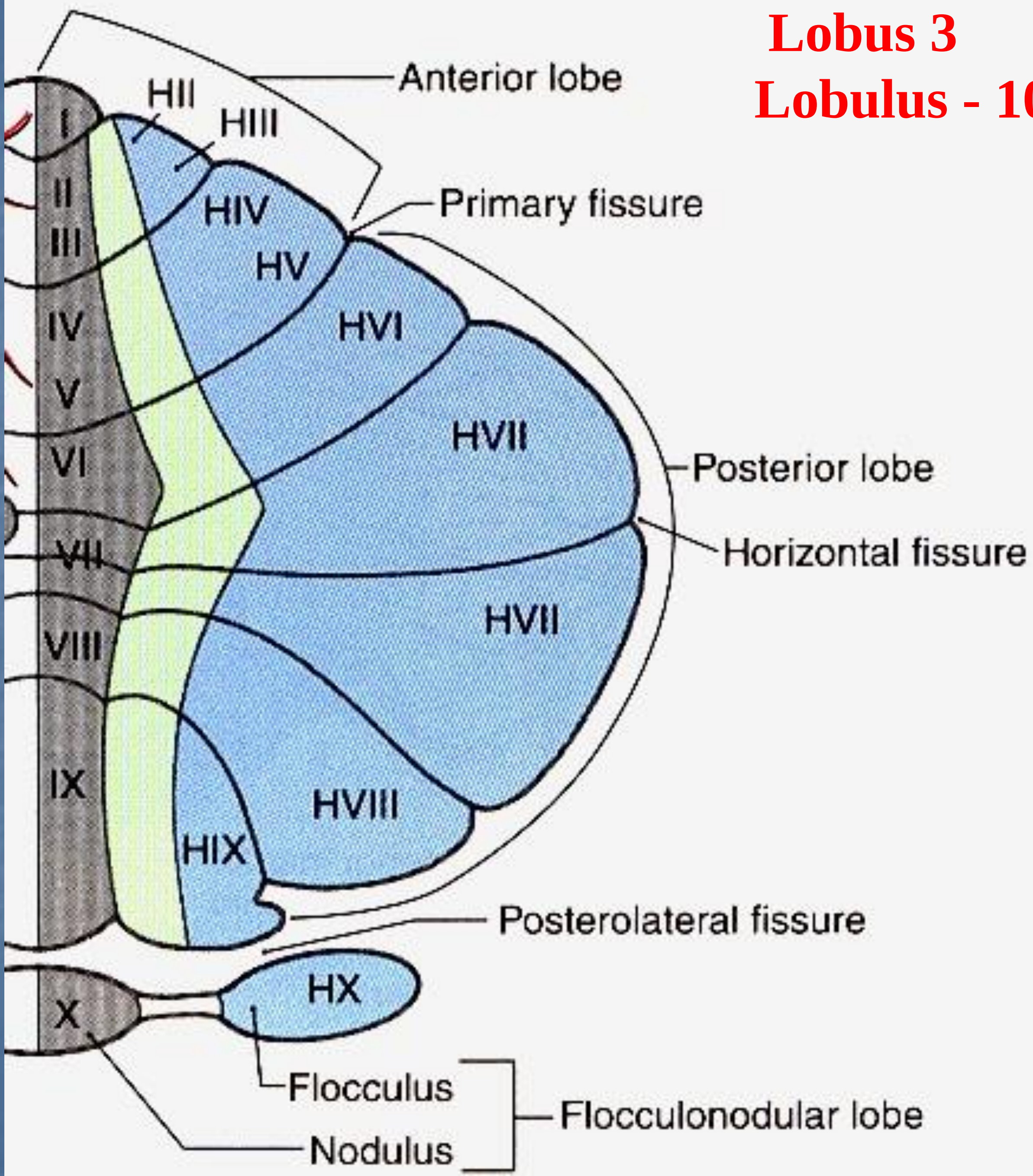

Superior surface
Anterior cerebellar notch
Anterior lobe
Quadrangular lobule (H IV-V)
Central lobule (II & III)
Primary fissure
Horizontal fissure
Culmen (IV & V)
Simple lobule (H VI)
uperior
ermis
Posterior lobe
Declive (VI)
Postlunate fissure
Superior semilunar
(anseriform) lobule (H VII A)
Folium (VII A)
Horizontal fissure
Inferior semilunar
(caudal) lobule (H VII B)
Posterior cerebellar notch
Anterior lobe
Central lobule
Inferior surface
Superior vermis
Wing of central lobule
Lingula (I)
Superior
Middle
Inferior
Cerebellar peduncles
Superior medullary velum
Flocculus (H X)
Flocculonodular lobe
4th ventricle
Posterolateral (dorsolateral)
fissure
Inferior medullary velum
Retrotonsillar fissure
Nodule (X)
Posterior lobe
Uvula (IX)
Inferior
vermis
Tonsil
Pyramid (VIII)
Biventer lobule (H VIII)
Tuber (VII B)
Secondary (postpyramidal)
fissure
Posterior cerebellar notch
Horizontal fissure
Inferior semilunar
(caudal) lobule (H VII B)



ure 27–2. Unfolded view (see *upper right*) of the cerebellar cortex showing lobes, lobules (by name and number), and main ures (printed in blue). The lobules of the hemisphere are designated by the prefix "H," to show which lobule of the nisphere (H) is continuous with its corresponding (designated by the Roman numeral) vermal lobule. l., lobule.

Cerebellar lobes and lobuli

Mozečkové Laloky (3) a Lalůčky (10)

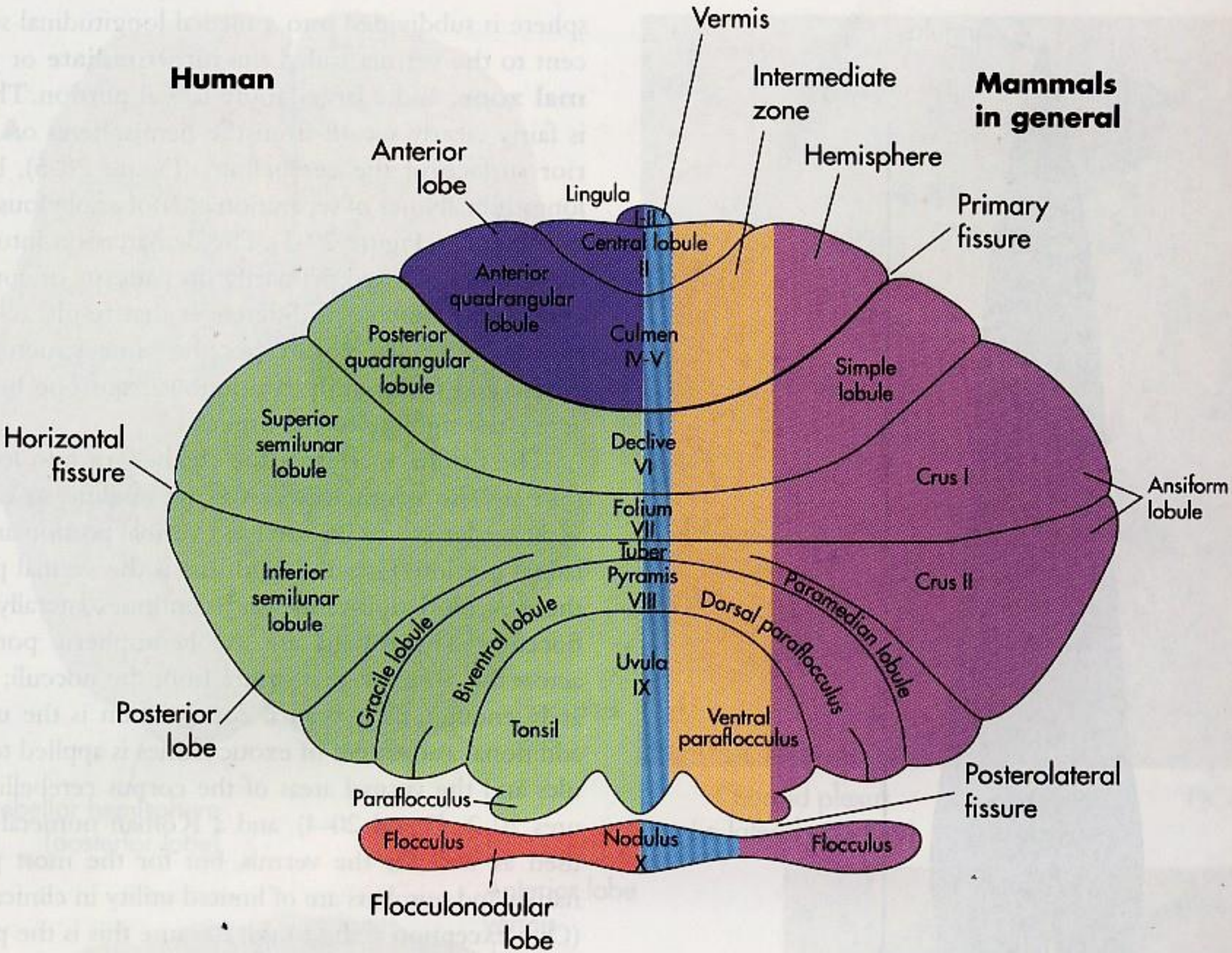


Lobus 3
Lobulus - 10

Vermis

Paravermální oblast (zóna)

Laterální část hemisféry


Human
Mammals in general
Vermis
Intermediate zone
Hemisphere
Anterior lobe
Lingula
I-II
Central lobule
III
Anterior quadrangular lobule
Culmen
IV-V
Primary fissure
Posterior quadrangular lobule
Simple lobule
Superior semilunar lobule
Declive
VI
Horizontal fissure
Crus I
Ansiform lobule
Folium
VII
Tuber
Crus II
Inferior semilunar lobule
Pyramis
VIII
Paramedian lobule
Dorsal paraflocculus
Gracile lobule
Biventral lobule
Uvula
IX
Posterior lobe
Tonsil
Ventral paraflocculus
Paraflocculus
Posterolateral fissure
Flocculus
Nodulus
X
Flocculus
Flocculonodular lobe

CEREBELLAR NUCLEI, neurons glutamatergic, excitatory, high spontaneous activity

Mozečková jádra

Neurony glutamátergní (excitační), vysoká spontánní aktivita

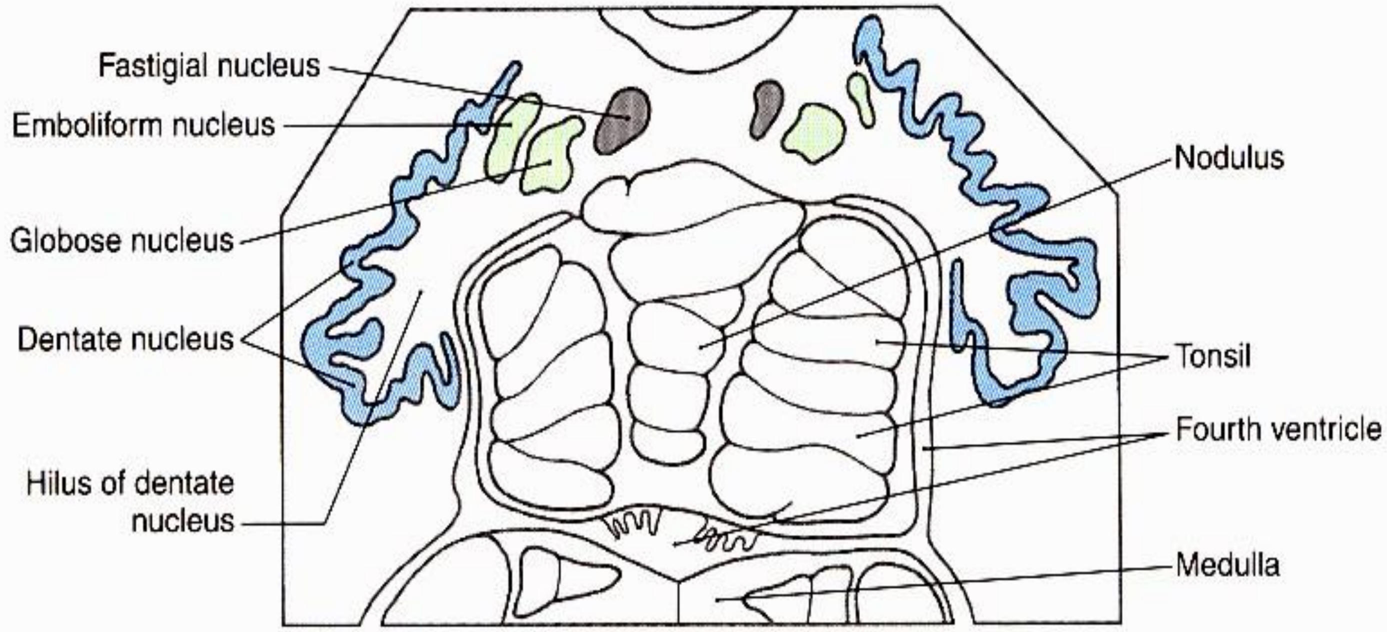


Figure 27–5. The cerebellar nuclei in cross section, drawn from a slide. The color coding of each nucleus corresponds to its appropriate zone in Figure 27–4.

Mozečková kůra – 3 vrstvy

Structure of the cerebellar cortex - 3 layers:

I.molecular layer - inhibitory interneurons
I.Molekulární vrstva – inhibiční interneurony

II. Purkyně cell layer – inhibitory projecting neurons
II. Vrstva Purkyňových buněk (stratum purkinjese)– inhibiční, projekční neurony

III. granular layer - prevail excitatory neurons
III. Vrstva granulárních buněk – převaha excitačních neuronů


Strat. cinereum
Strat. gangliosum
Strat. ferrugineum
weißes Marklager

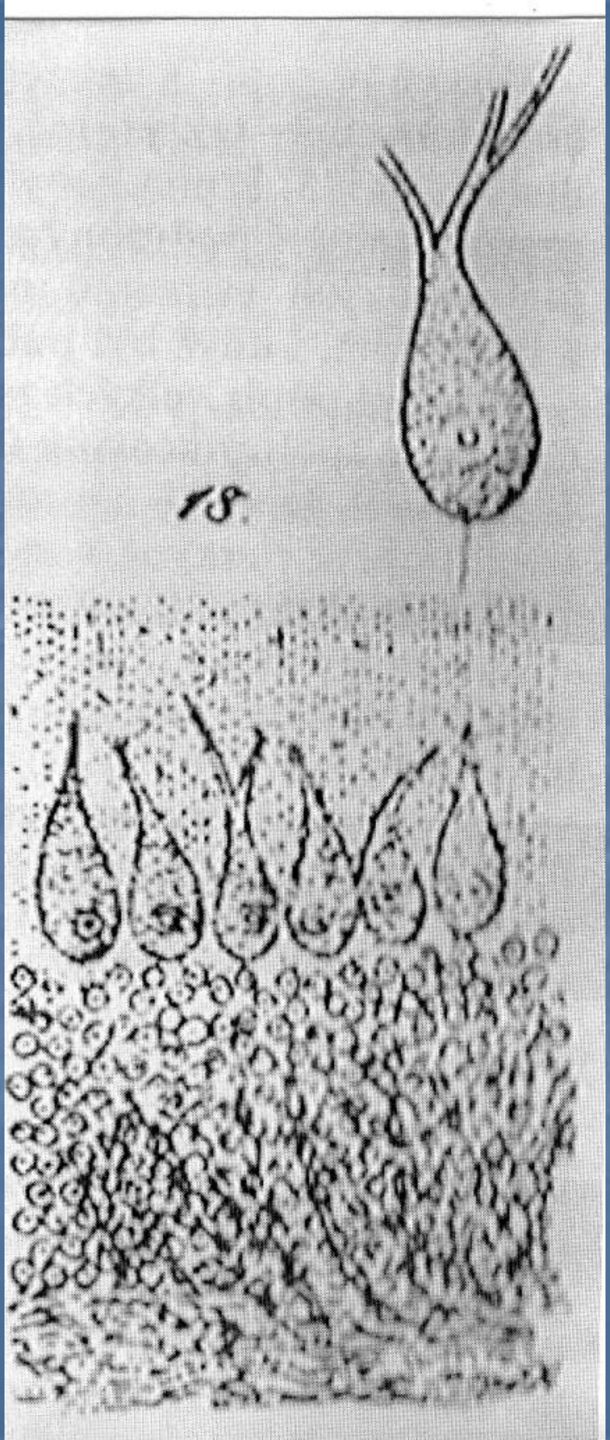
J.E. Purkyně 1837

1832 první mikroskop

Univerzita ve Vratislavi

Prof. Heidenheim :

………" hatte Purkyně den charakteristischen, allgemainen Unterschied zwischen Tier und Pflanzenzellen zun erstmale mit vollkommener Klarheit erkannt „



R. y Cajal : Histologie du systeme nerveux, 1911.

Cellules de Purkinje. — Ces cellules, dont le nom rappelle celui du savant qui les a découvertes [1], sont volumineuses, ovoïdes, semi-lunaires ou mitrales et disposées en une rangée discontinue, juste aux confins de la couche plexiforme et de celle des grains. Leur diamètre, quelque peu variable suivant les mammifères, oscille chez l'homme entre 35 et 65 μ.

1. Purkinje, Bericht auf der Versammlung deutscher Naturforscher in Prag, 1837.

Santiago Ramon y Cajal 1911

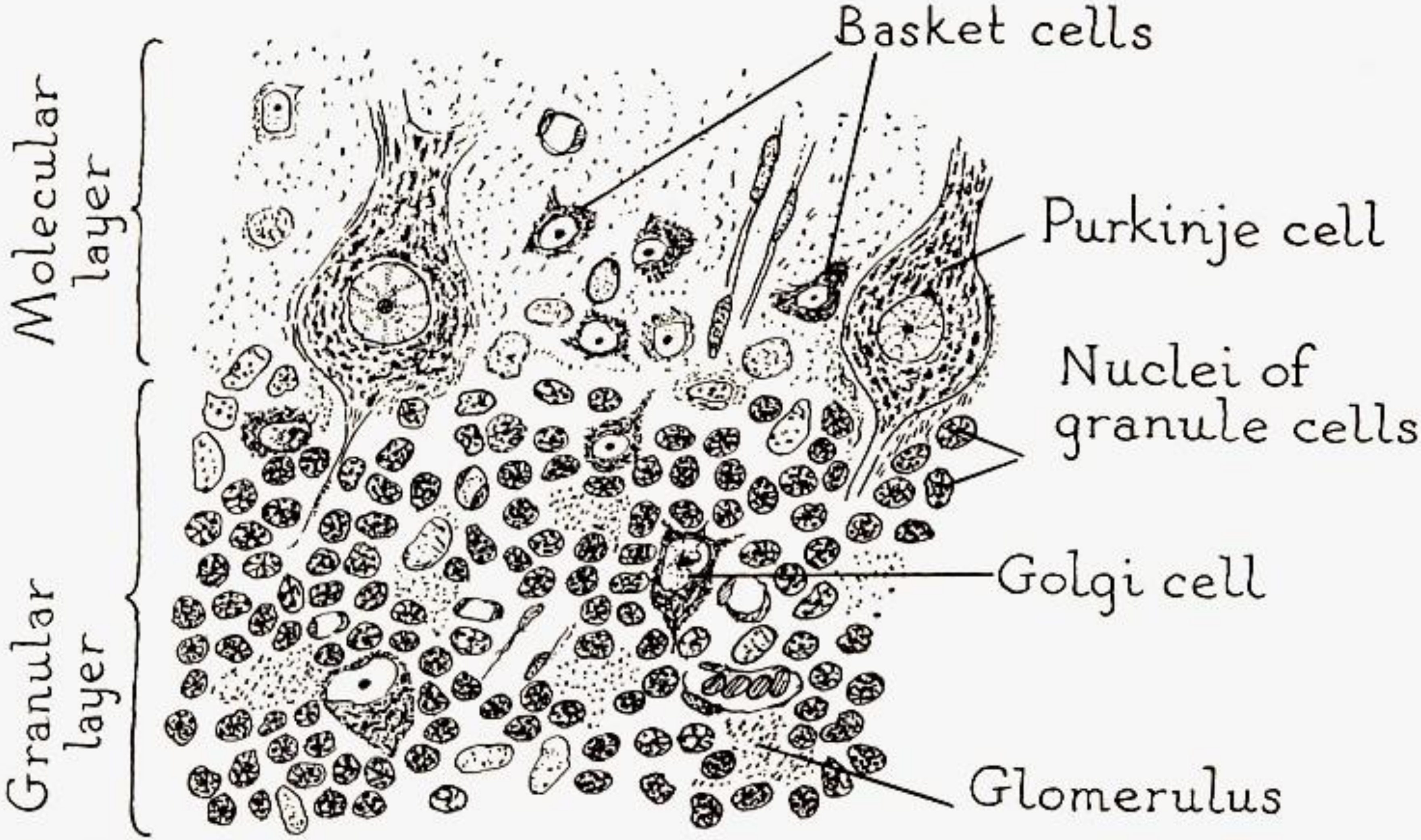
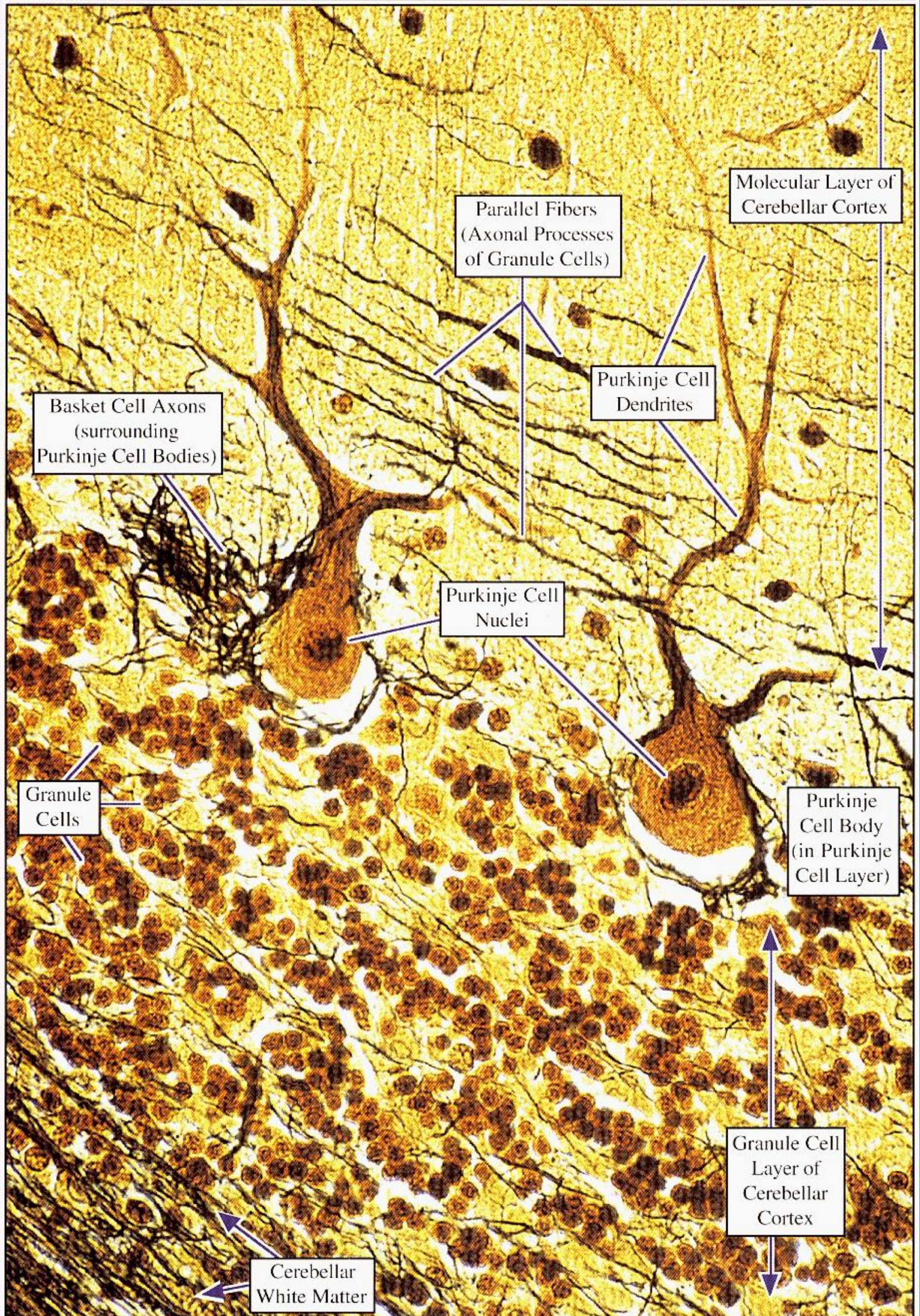


FIG. 246. Part of a section through human cerebellar cortex. Nissl stain. (After Cajal)

CEREBELLAR CORTEX: 400X ORIGINAL MAGNIFICATION, 15 μ SECTION, BIELSCHOWSKY SILVER TECHNIQUE



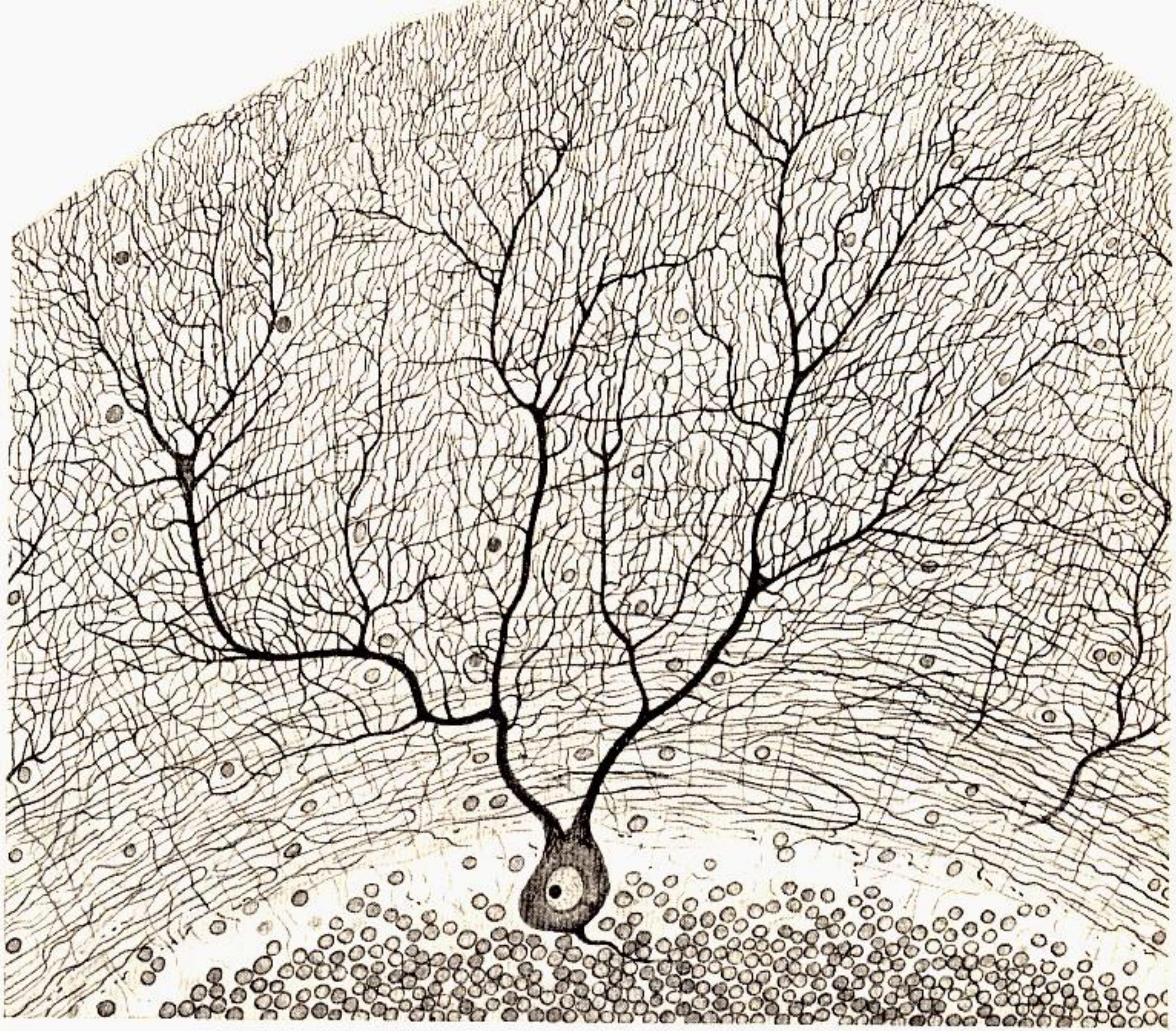


Abb. 261. Purkinjesche Zelle aus der menschlichen Kleinhirnrinde. Die Dendriten bilden untereinander ein zusammenhängendes Netzwerk. Gros-Schultze-Methode. Vergr. etwa 300fach

Basket cells, inhibitory interneurons, GABAergic

Košíčkové buňky, inhibiční interneurony

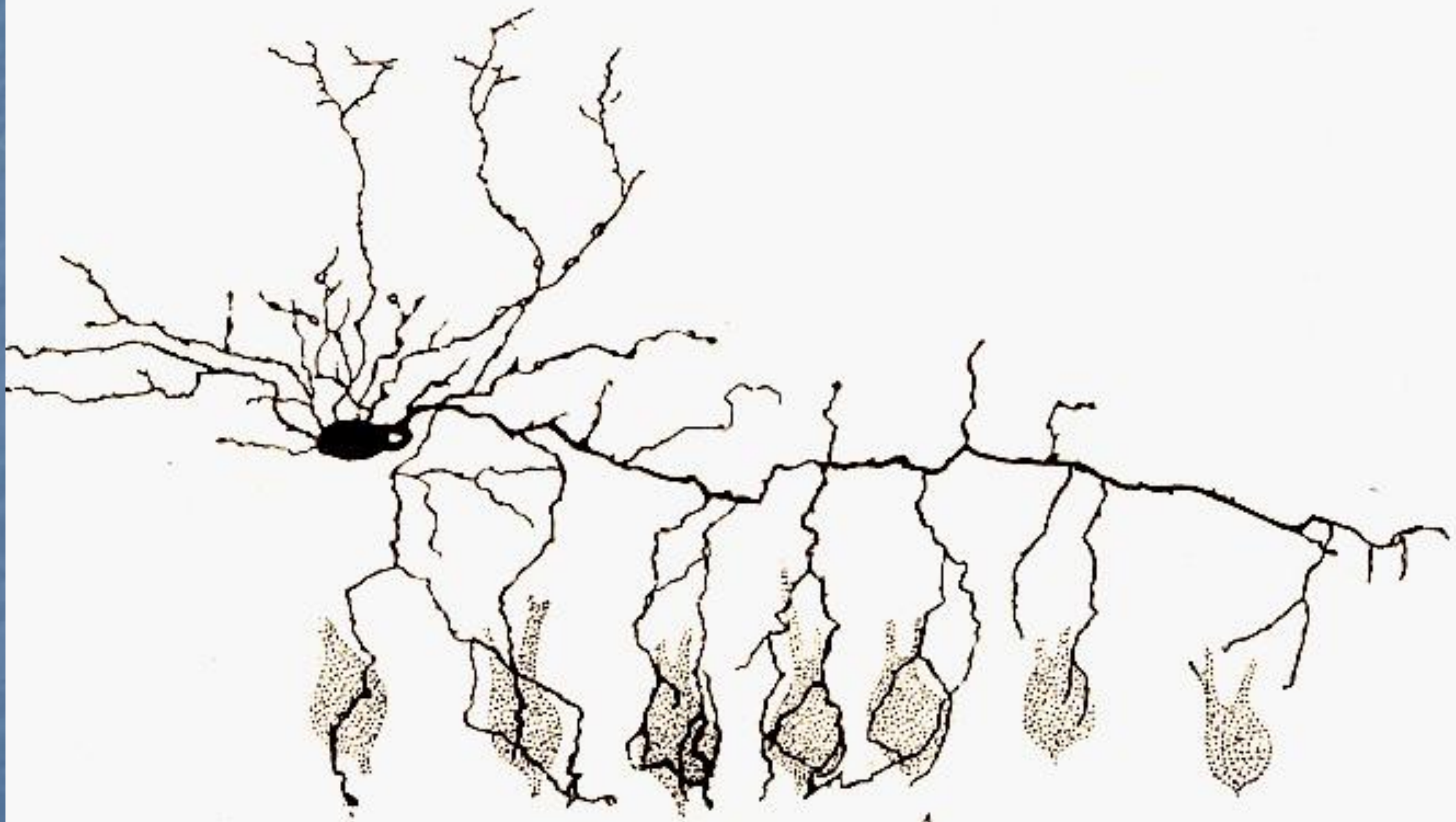
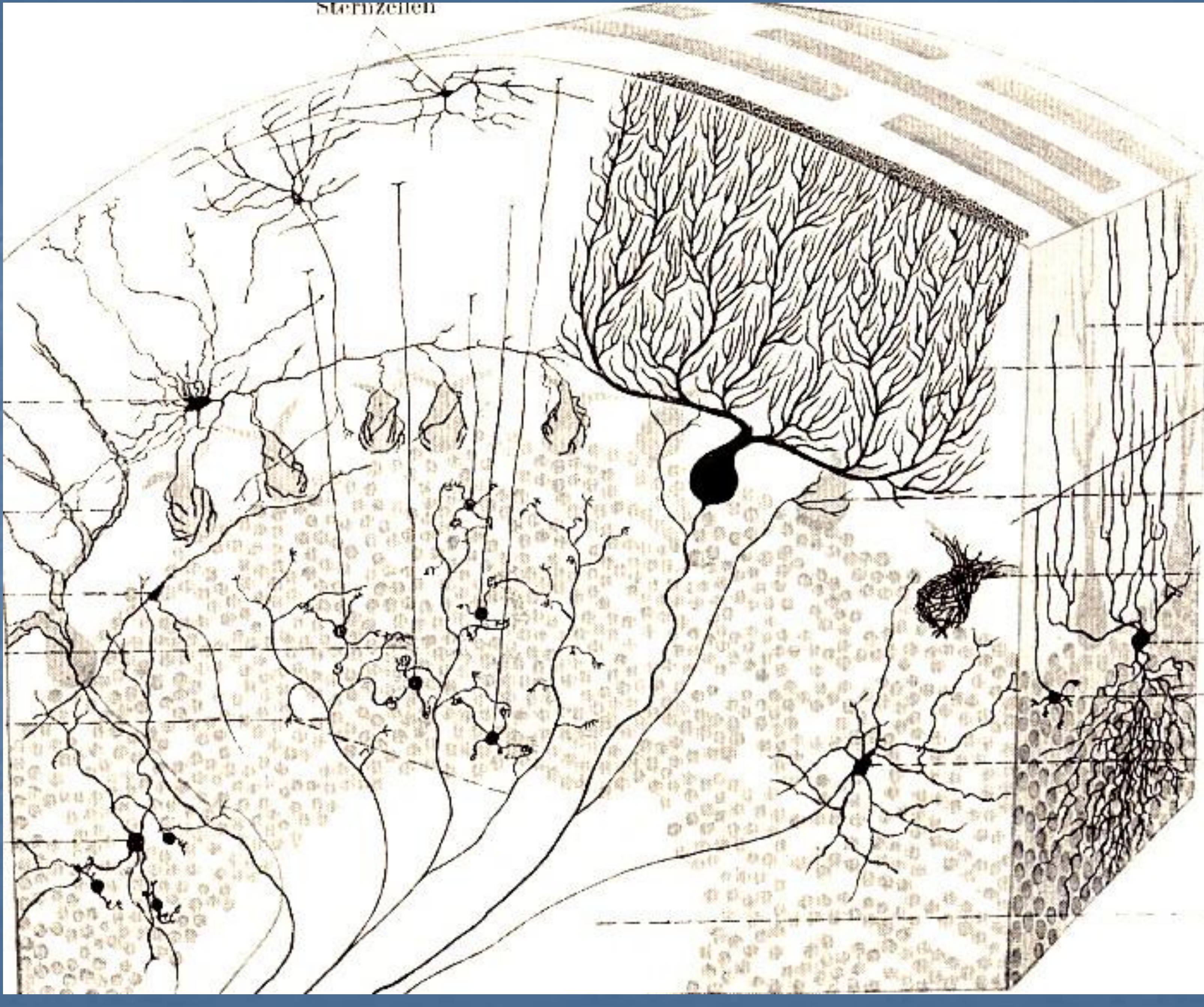
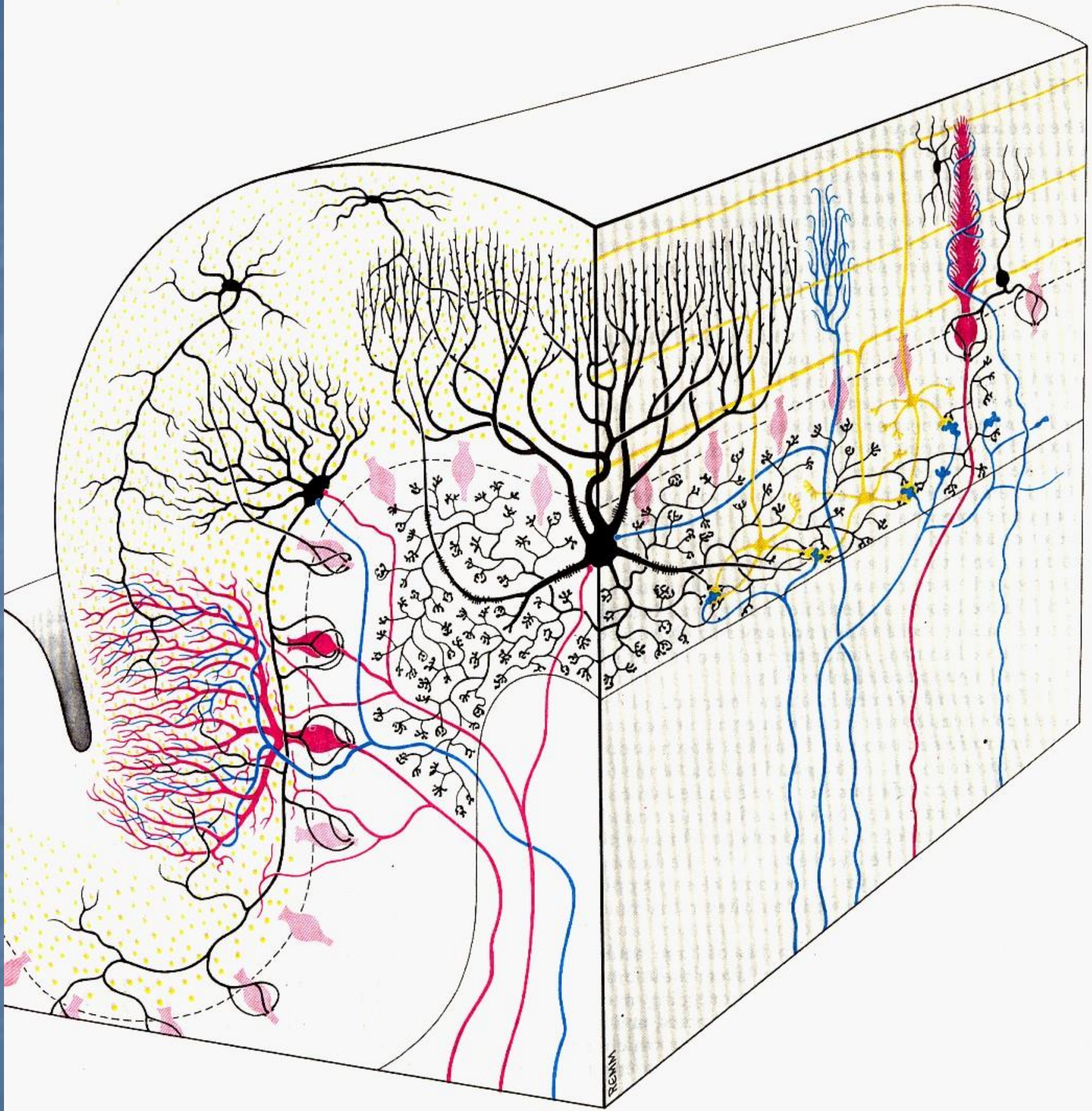


Abb. 265. Korbzelle mit ihrem Neuriten und dessen kollateralen Verzweigungen an den Purkinjeschen Zellen. Mensch. Golgi-Präparat. (Nach Jakob, Hdb. mikr. Anat. d. Menschen 4, I (1928))


Sternzellen



79 The general organization of the cerebellar cortex: a single cere-
llar folium has been sectioned vertically, both in its longitudinal axis
ght part of the diagram) and transversely (on the left). Note: (1)
rkinje cells (red); (2) inhibitory interneurons (black) including outer
ellate, basket and Golgi cells; (3) granule cells and their ascending
ons which bifurcate into longitudinally disposed horizontal fibres (yellow); (4) climbing fibres and mossy afferents (blue). Note also the synaptic glomeruli formed between the terminals of the mossy afferent fibres, the complex dendrite tips of the granule cells, and the ramifications of the Golgi cell axon. (Redrawn from: *The Cerebellum as a Neuronal Machine* by J. C. Eccles, M. Ito and J. Szentágothai. With the permission of the authors and the publishers Springer, 1967.)

Mossy fibers –

Granule cells-

Parallel fibers –Purkyně cells

Mechová

Vlákna- granulární b.

Paralelní vl.

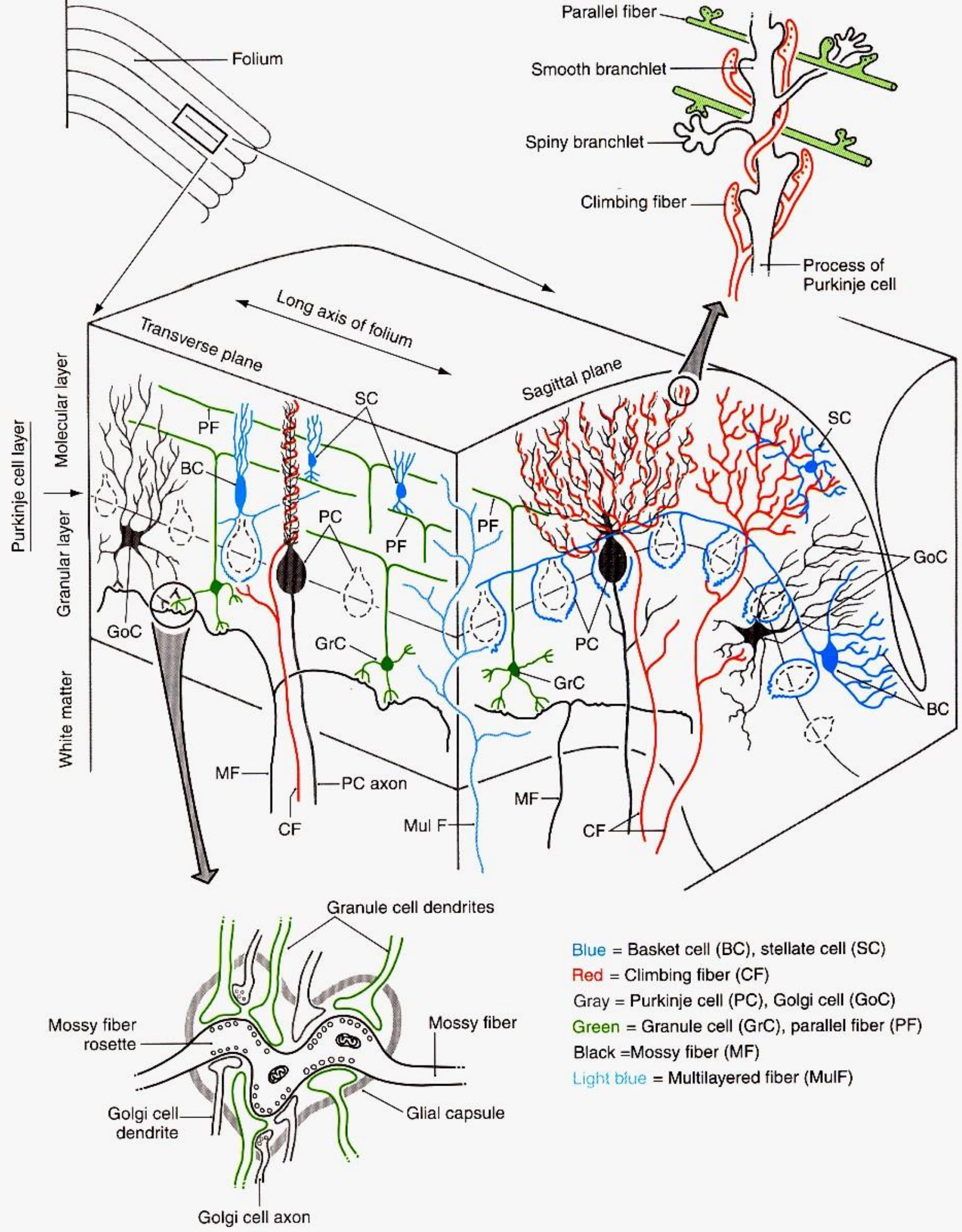


Figure 27–8. Cell types and synaptic relations in the cerebellar cortex in transverse and sagittal planes. Note the struct the cerebellar glomerulus (*lower left*) and the interaction of parallel and climbing fibers (*upper right*) with the dendritic pro of Purkinje cells. Compare with Figure 27–9.

Climbing fiber –

Purkyně cell

Šplhavá

Vlákna –

Purkyňovy bb.

Aferentní a eferentní spoje kůry mozečku

Afferent and efferent connections

- Tracts
- Vestibulocerebellar (from the labyrinth and vestibular nuclei)
- Spinocerebellar ant., post.,
- rostral, cuneocerebellar
- Olivocerebellar
- Reticulocerebellar
- Nucleocerebellar
- Pontocerebelar !! (cortico-ponto-cerebellar)

- Corticonuclear (from the cerebellar cortex to the nuclei)
- Vermis – ncl. fastigii
- Paravermal zone – ncl. Emboliformis + globosus
- Lateral hemisphere – ncl. dentatus

- From cerebellar nuclei to the brain stem and to the thalamus

Spinocerebellar

Pathways

Posterior T1 – L2, uncrossed

ICP, proprioceptors

Anterior L3 – L5

2x-crossed, SCP, cutaneous signals

Rostral C4 – C8

Uncrossed, ICP

Cutaneous signals

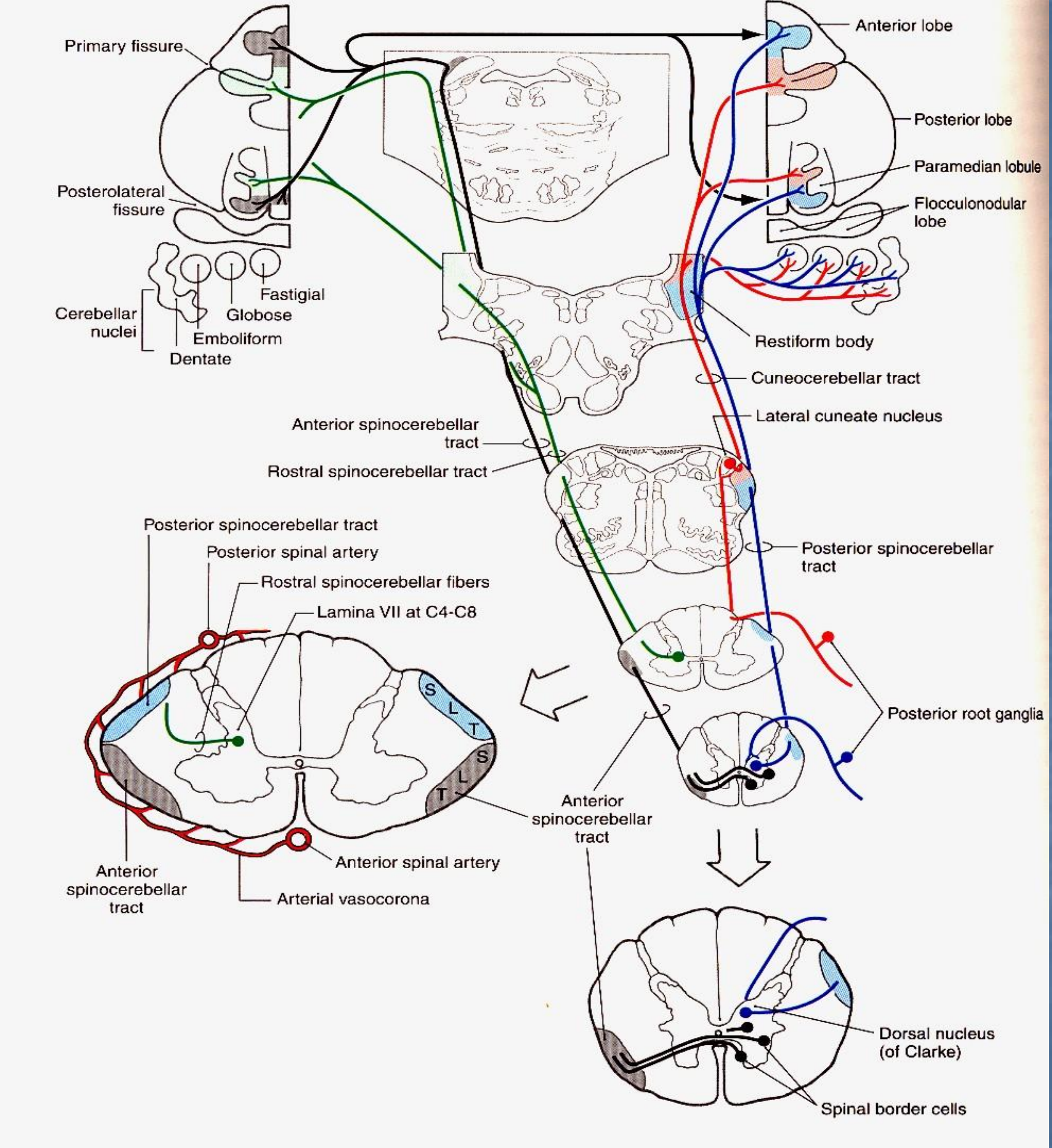
Cuneocerebellar

C2 – T4

uncrossed

Lateral cuneate nc., propriocept.

ICP

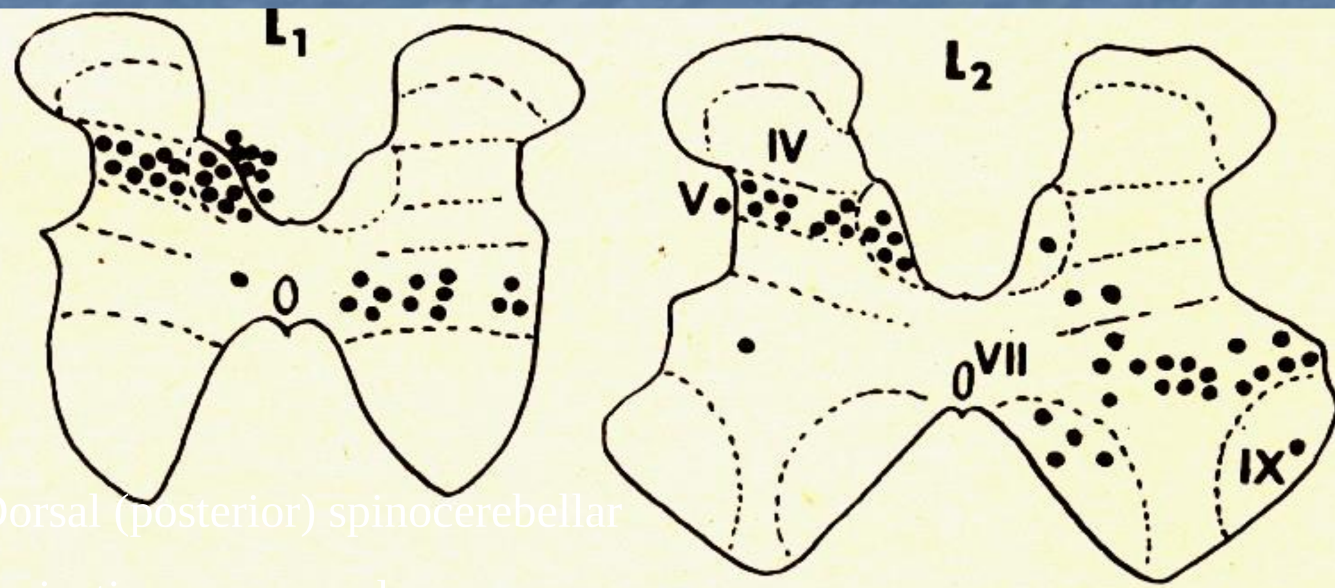


Lamina V- - VIII

Origin of the spinocerebellar pathways

a

b

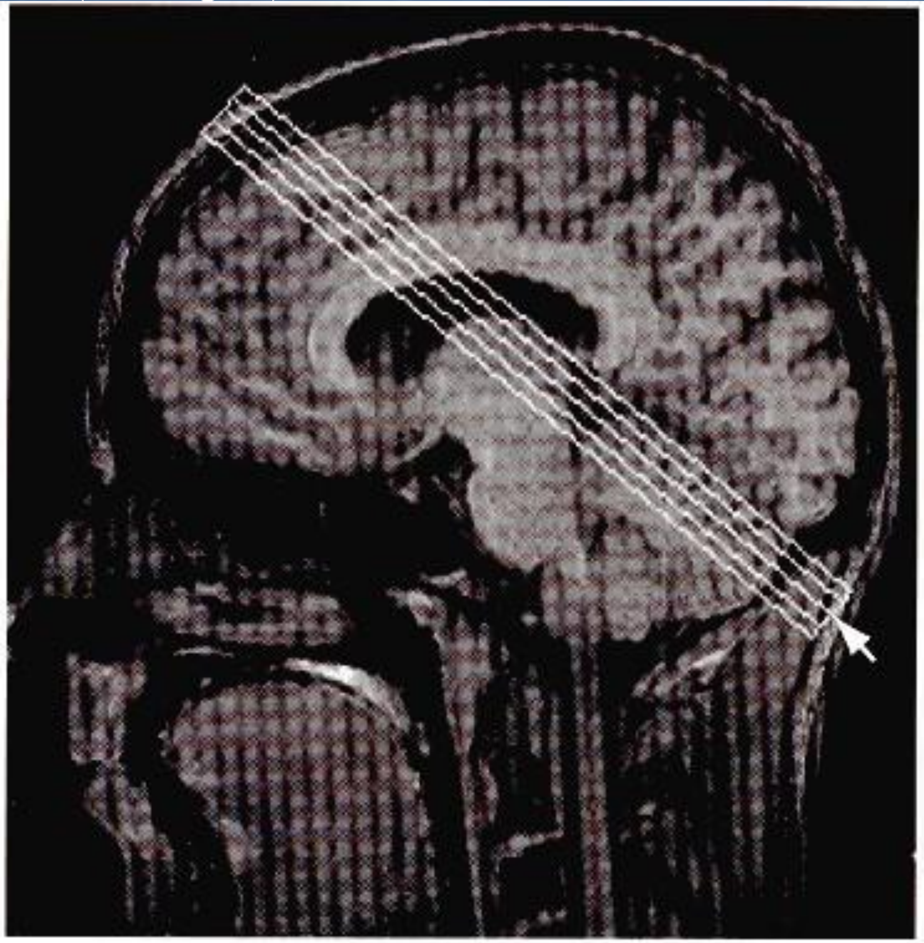


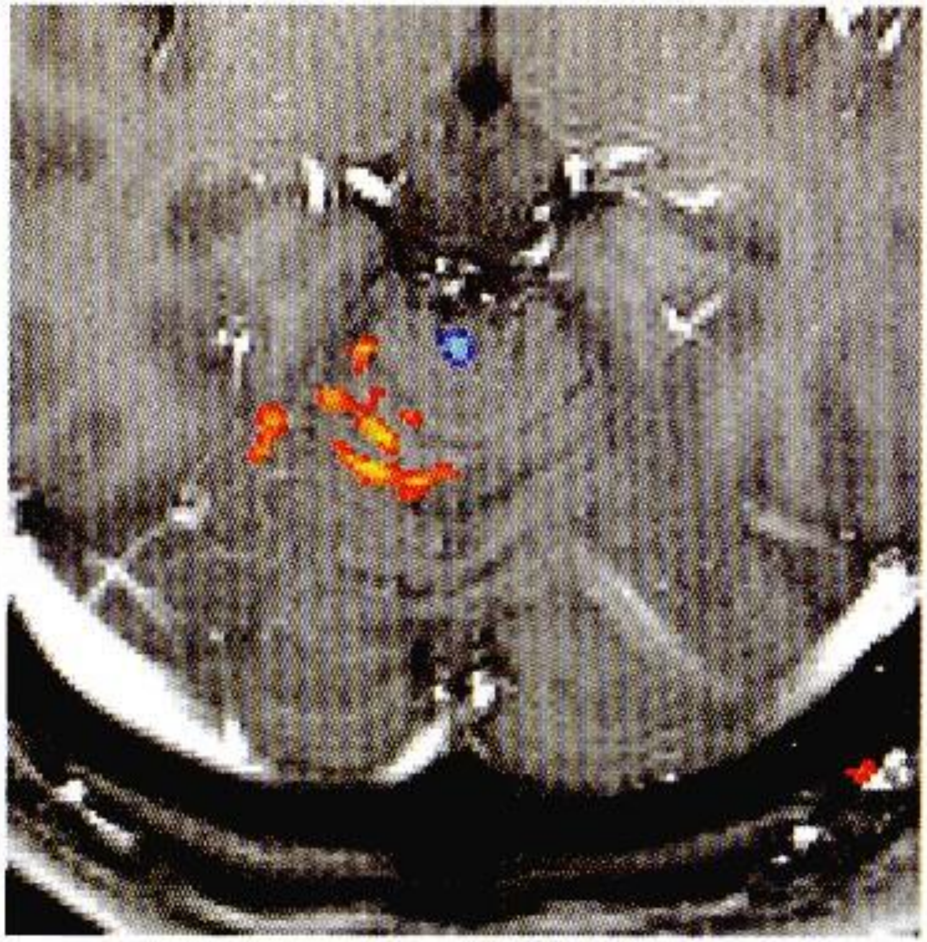
Dorsal (posterior) spinocerebellar projection- uncrossed

Ventral (anterior) spinocerebellar projection - crossed

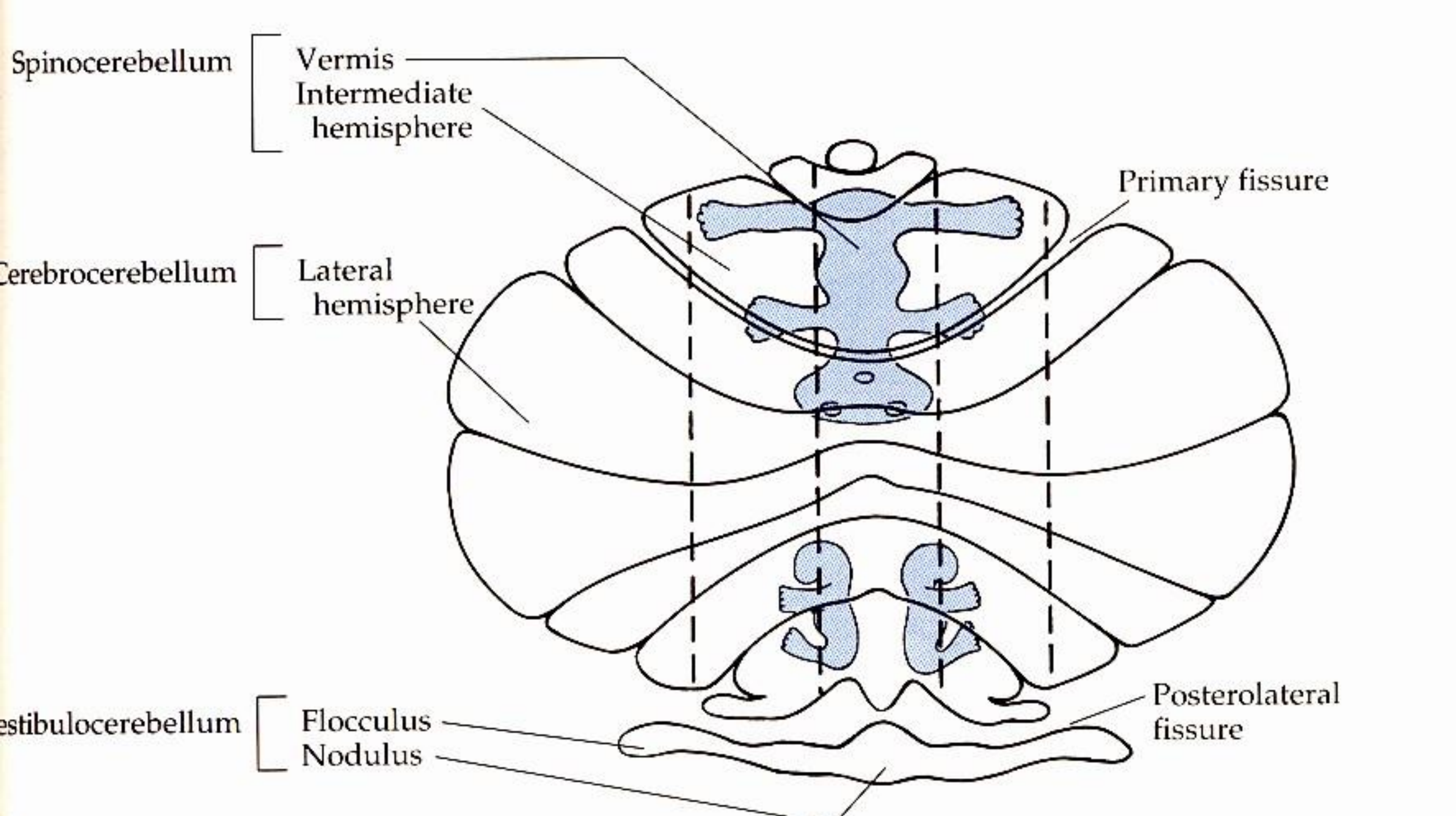
FMI – increased blood flow during flexion and extension of ipsilateral hand (red, orange signal) and foot (blue signal)

Funkční MR, flexe a extense ruky (červený, oranžový signál), nohy (modrý signál)





Zvýšení průtoku krve ve spinálním mozečku (lobus anterior)

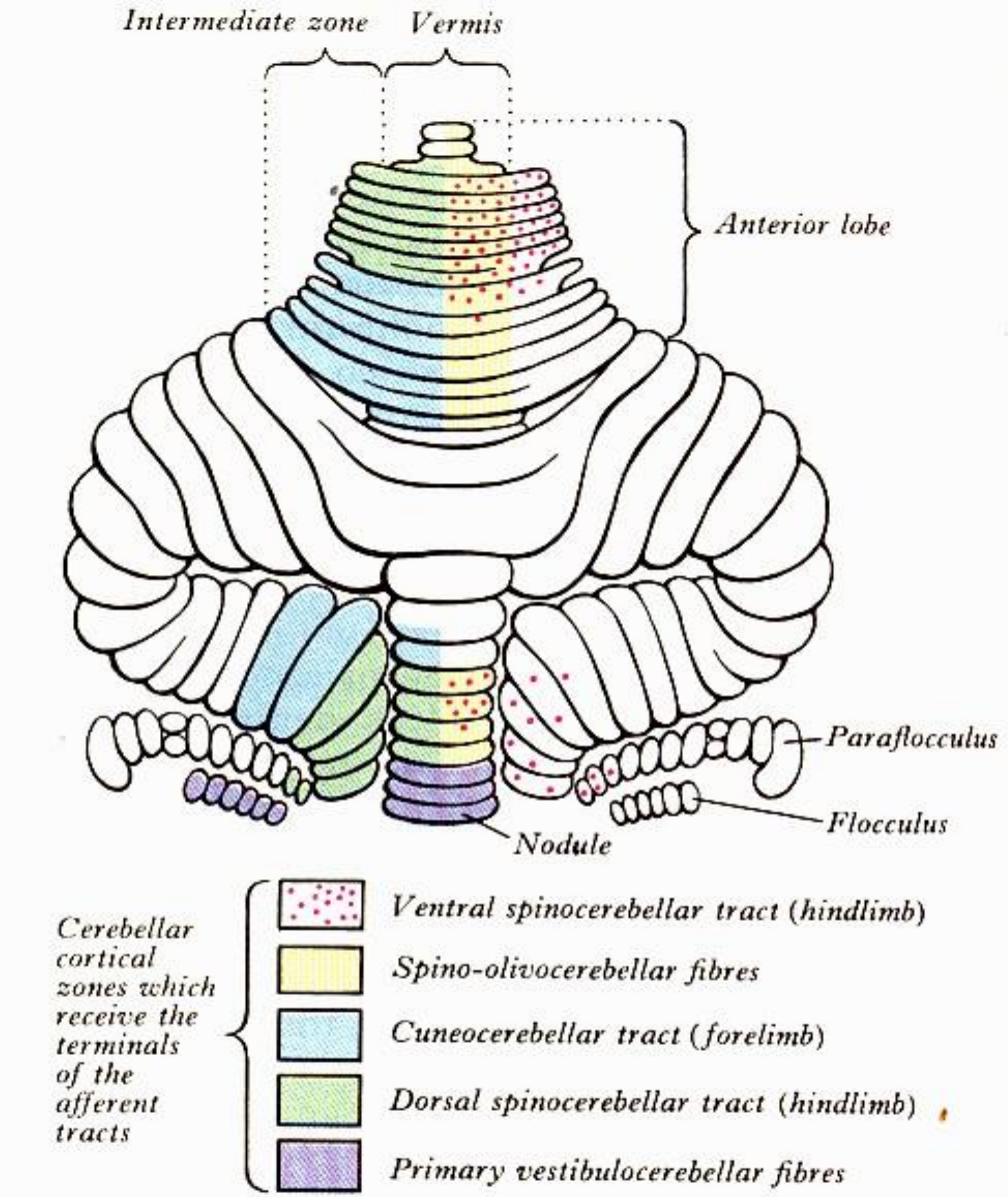


Spinocerebellum
Vermis
Intermediate hemisphere
Primary fissure
Cerebrocerebellum
Lateral hemisphere
estibulocerebellum
Flocculus
Nodulus
Posterolateral fissure

Afferent projections

Aferentní Spoje

Mossy fibers



he cerebellar cortical areas of termination of the afferent tracts

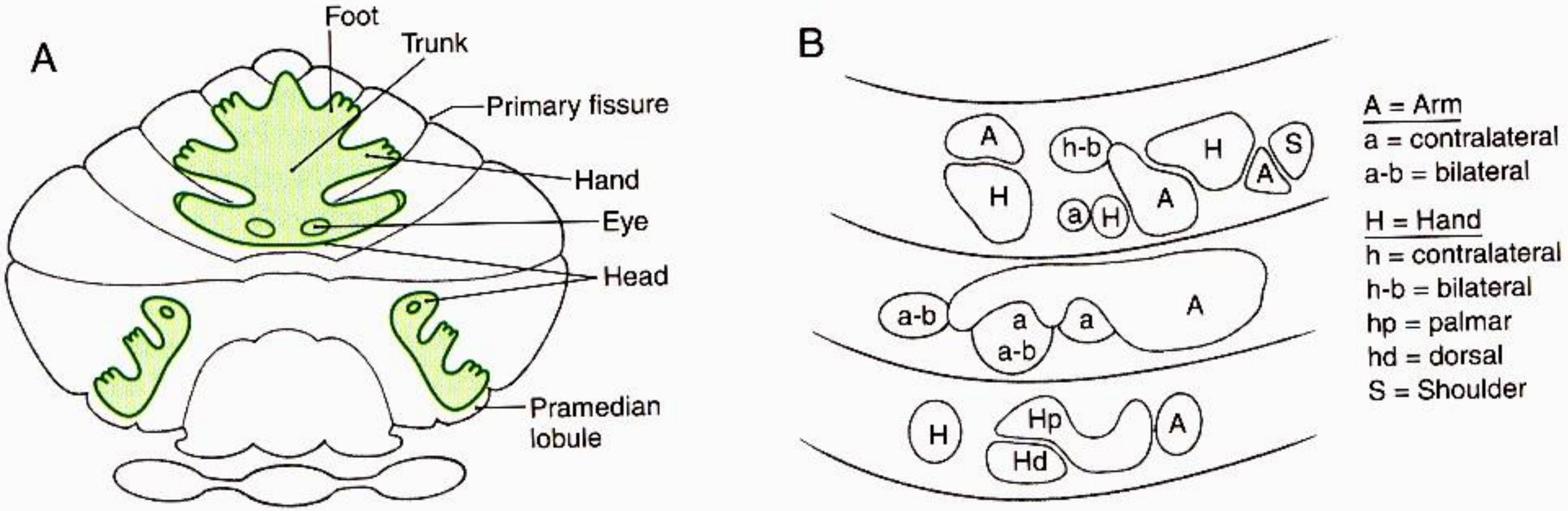
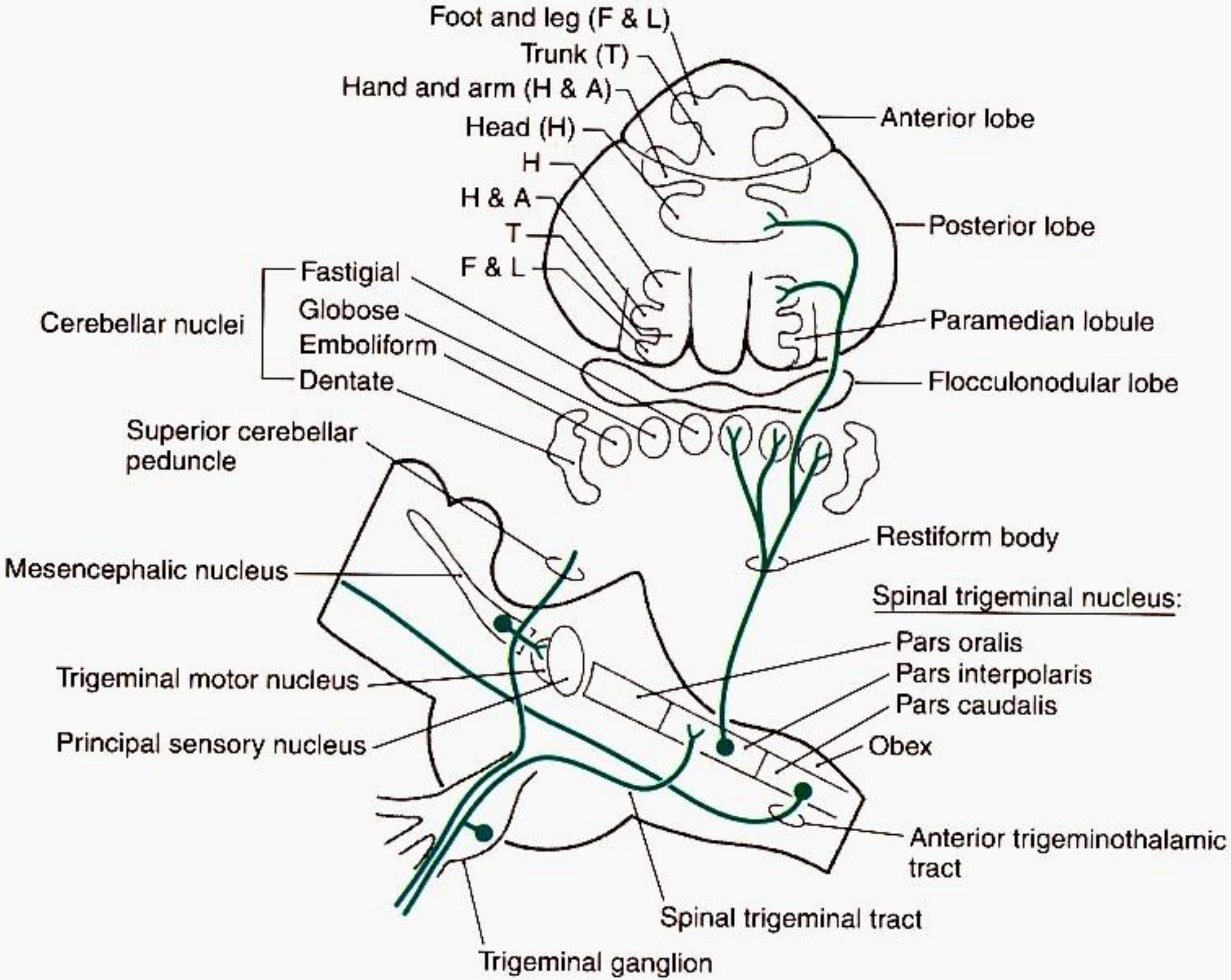


Figure 27–10. Somatotopy in the cerebellar cortex (*A*) and a summary representation of fractured somatotopy in the paramedian lobule (*B*) of a primate. In the somatotopic map, body areas were originally thought to be continuous (*A*), but more recent studies suggest that discontinuous body parts (or areas) may be represented in immediately adjacent cortical regions (*B*). (*B* is adapted from Welker et al, 1988, with permission.)

Lobulus I – V, VIII.

Trigeminocerebellar Connections



AFFERENTS TO THE CEREBELLAR CORTEX I.

- **Climbing fibers (Šplhavá vlákna**)

– inferior olive (each P.cell receives only 1 c.f., many synapses with P.c.), excitatory (glutamate), firing frequency of the c.f. is very low (1 impulse/sec), c.f. elicit burst of action potentials in the P.c.

- C.f. inform about errors in the execution of movements – error indicators !!

Climbing Fibers

Olivo-cerebellar projections

(crossed)

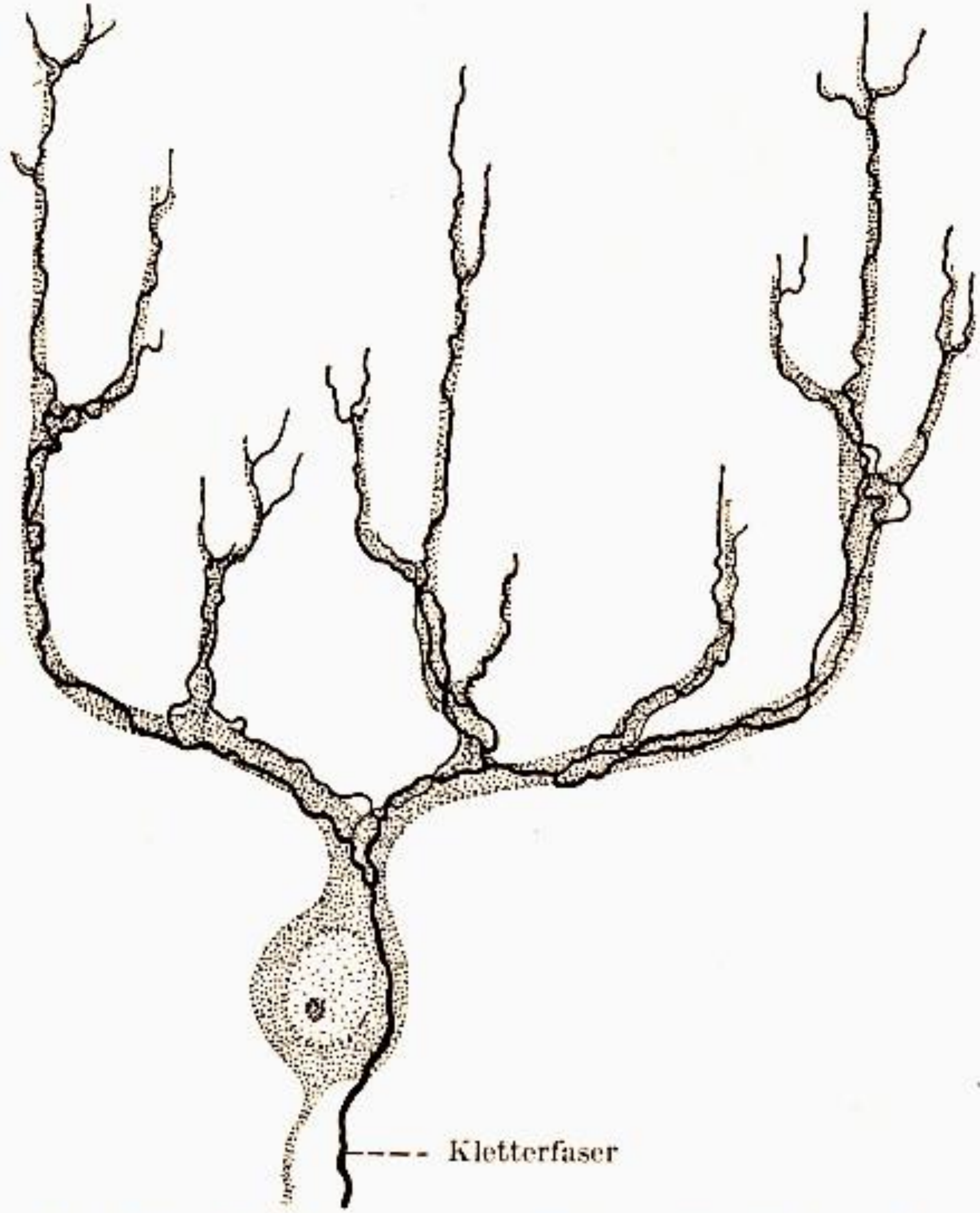


Abb. 264. Purkinjesche Zelle mit Kletterfaser (halbschematisch)

Šplhavá vlákna

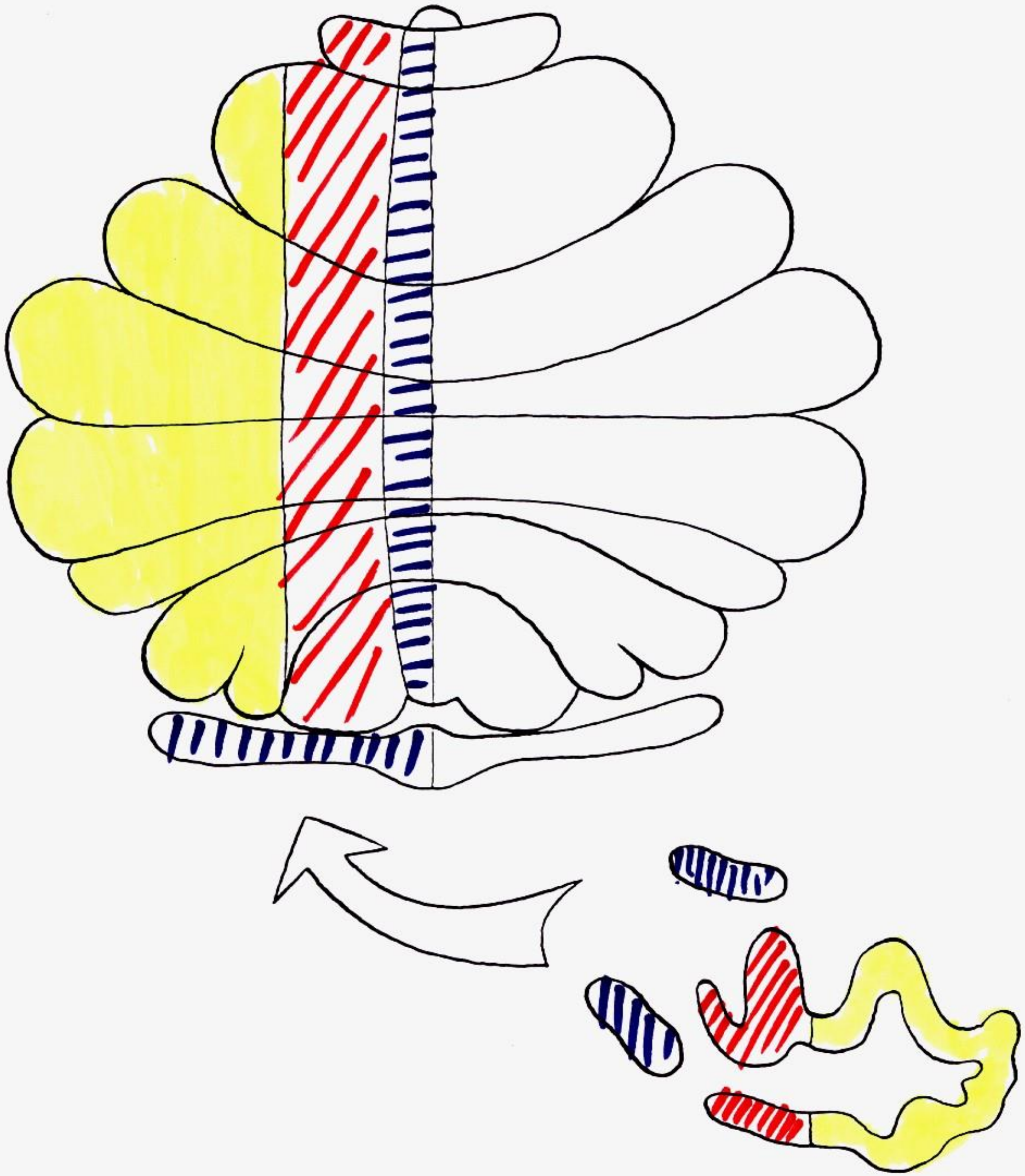
Olivocerebelární

Projekce

(zkřížená)

Climbing fibers

Šplhavá vlákna



Olivocerebellar projection

AFFERENTS TO THE CEREBELLAR CORTEX II

- **Mossy fibers (Mechová vlákna)** - spinal cord, RF, pontine nuclei, ncll. of cranial nerves.
- End in the granular layer and each of which contacts large number of granular neurons. Granular cell axon contacts large number of P. c. via parallel fibers.
- Mossy fibers are excitatory (glutamate).
- Each mossy fiber influences many P.c. but the excitatory effect is weak. Many mossy fibers must be active together to provide sufficient excitation to fire a P.c.
- **Mossy fibers provide precisely graded information about movements, skin stimulations, joint position and about motor comands issued from the cerebral cortex.**

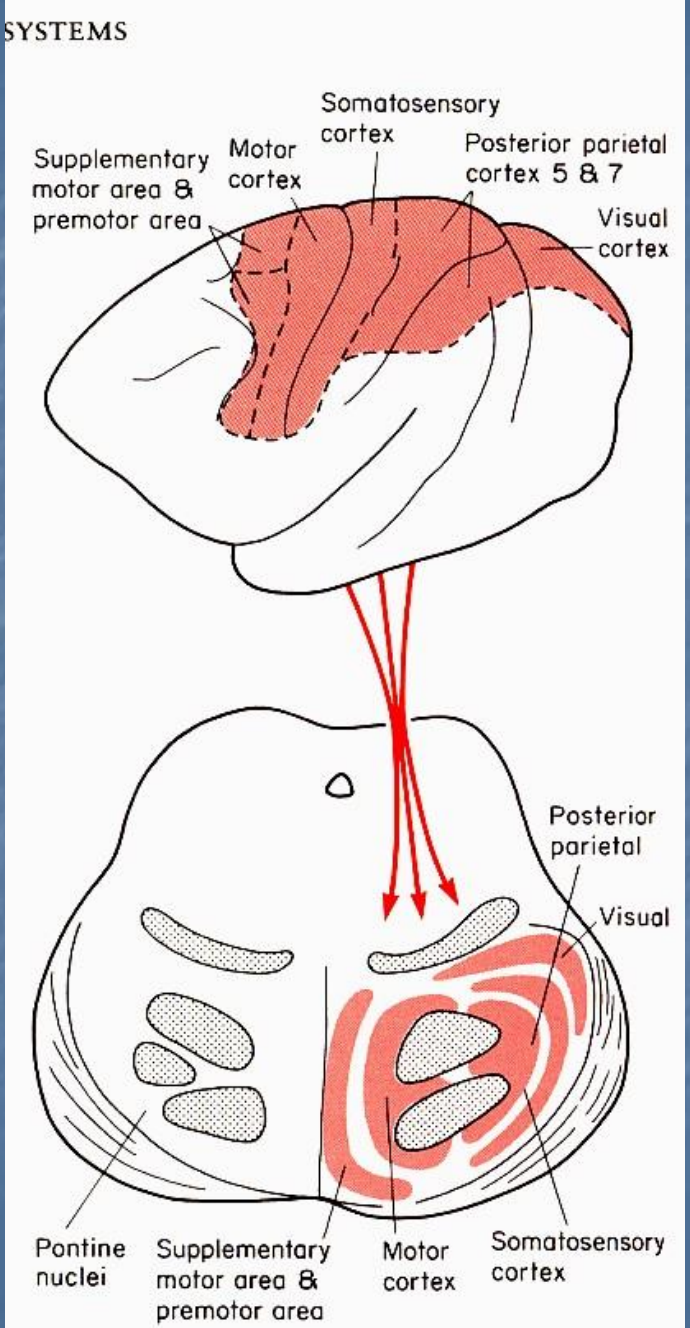
Cortico-pontine pathway, 17 millions fibers

Neocortex –

ipsilat. pontine ncll. - pontocerebellar pathway –

contralateral cerebellar cortex (mossy fibers)

Pontocerebellar fibers = largest contingent of mossy fibers



Kortiko-pontinní dráha

17 milionů vláken

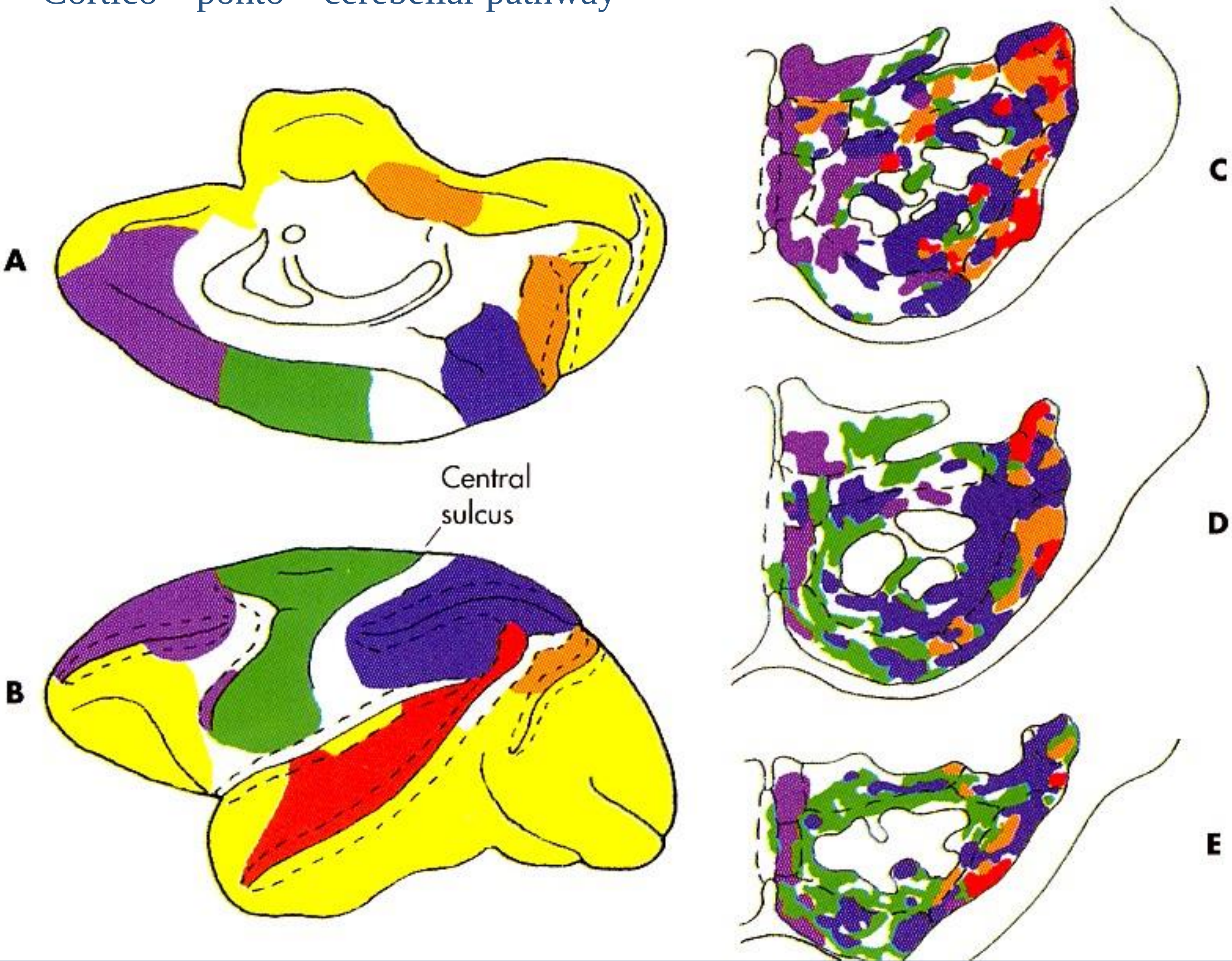
Neokortex – ipsilaterální pontinní jádra

Pontocerebelární dráha –

Kontralaterální mozečková kůra (mechová vlákna)

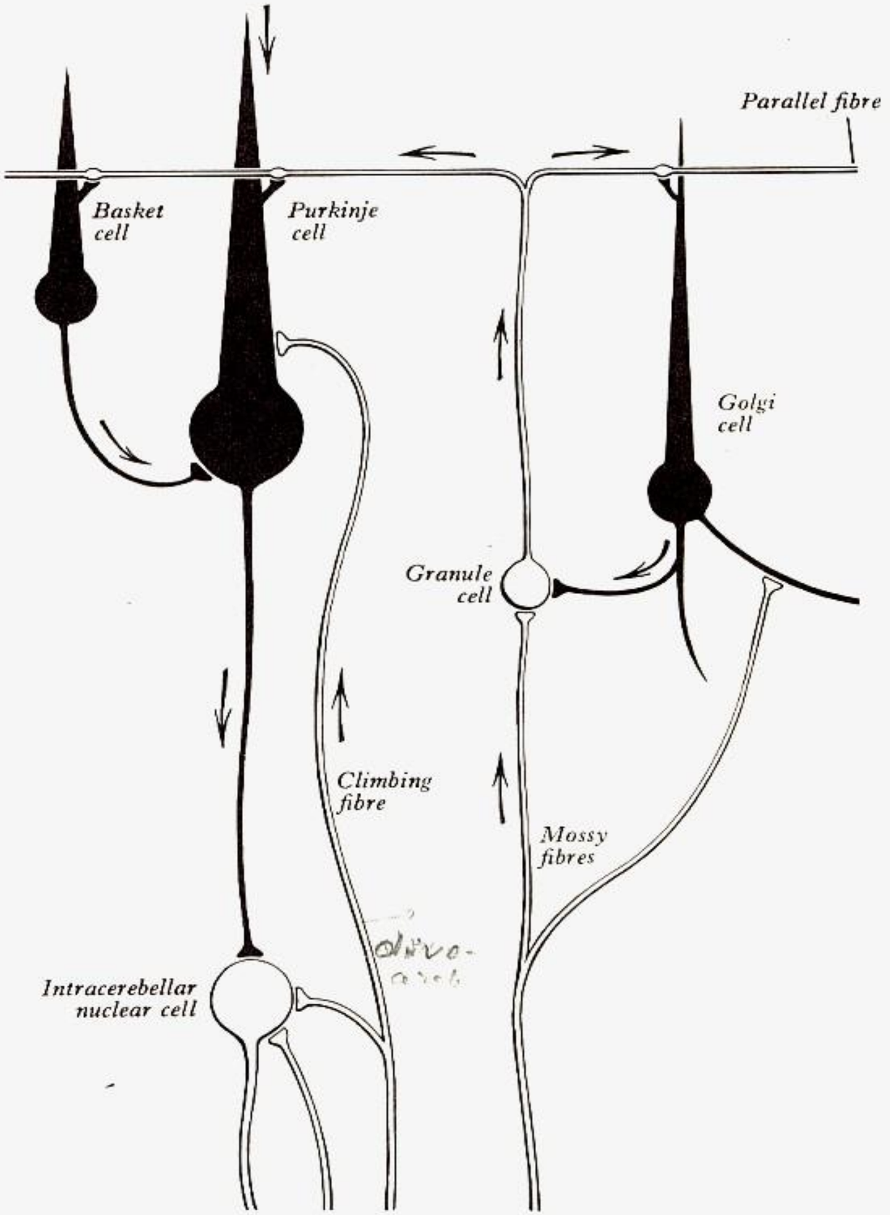
Cortico-ponto-cerebellar pathway

Cortico – ponto – cerebellar pathway



J. Eccles 1967

Nobel Prize in Physiology and medicine 1963



7.82 An analysis of the essential circuitry and synaptic contacts between the climbing and mossy afferent fibres, the main neuronal elements of the cerebellar cortex, and the neurons of the intracerebellar nuclei, based upon cytological and microelectrode studies. Excitatory cells, neurites and terminals are white surrounded by a black line; inhibitory elements are solid black. By courtesy of Professor J. C. Eccles.

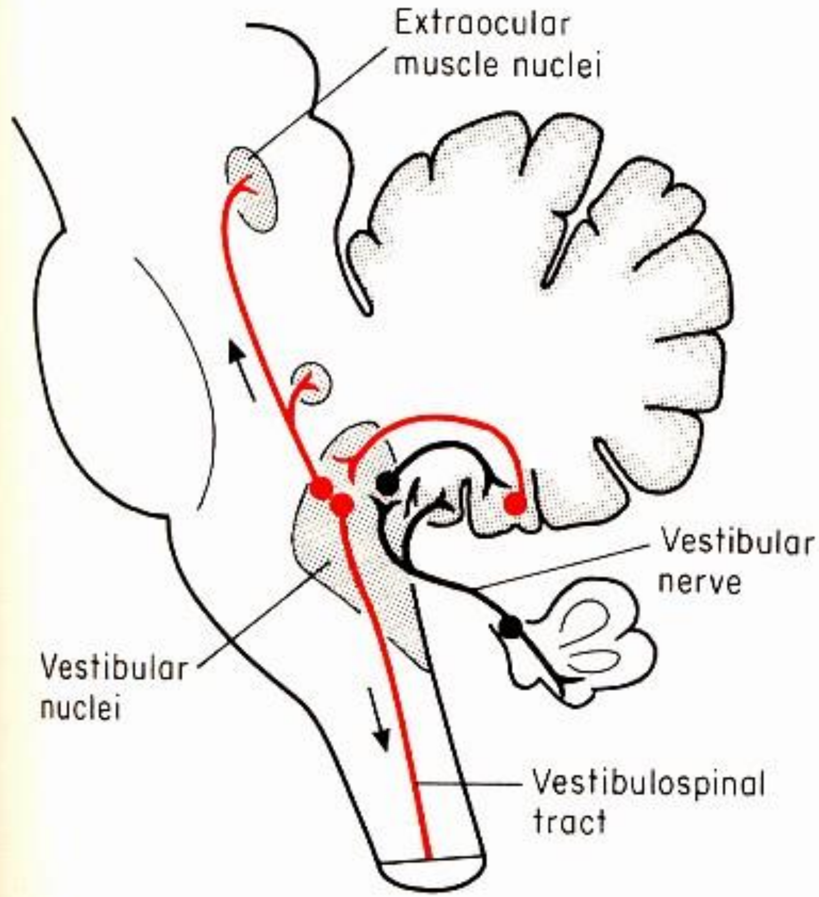


Fig. 11.3. *The main connections of the vestibulocerebellum.* Afferents are shown in black and efferents in red in a schematic drawing of a sagittal section through the brain stem. Note primary and secondary vestibulocerebellar fibers and the projection back to the vestibular nuclei. In addition to afferents from the vestibulocerebellum, the vestibular nuclei also receive cerebellar afferents from the anterior lobe vermis and from the fastigial nucleus.

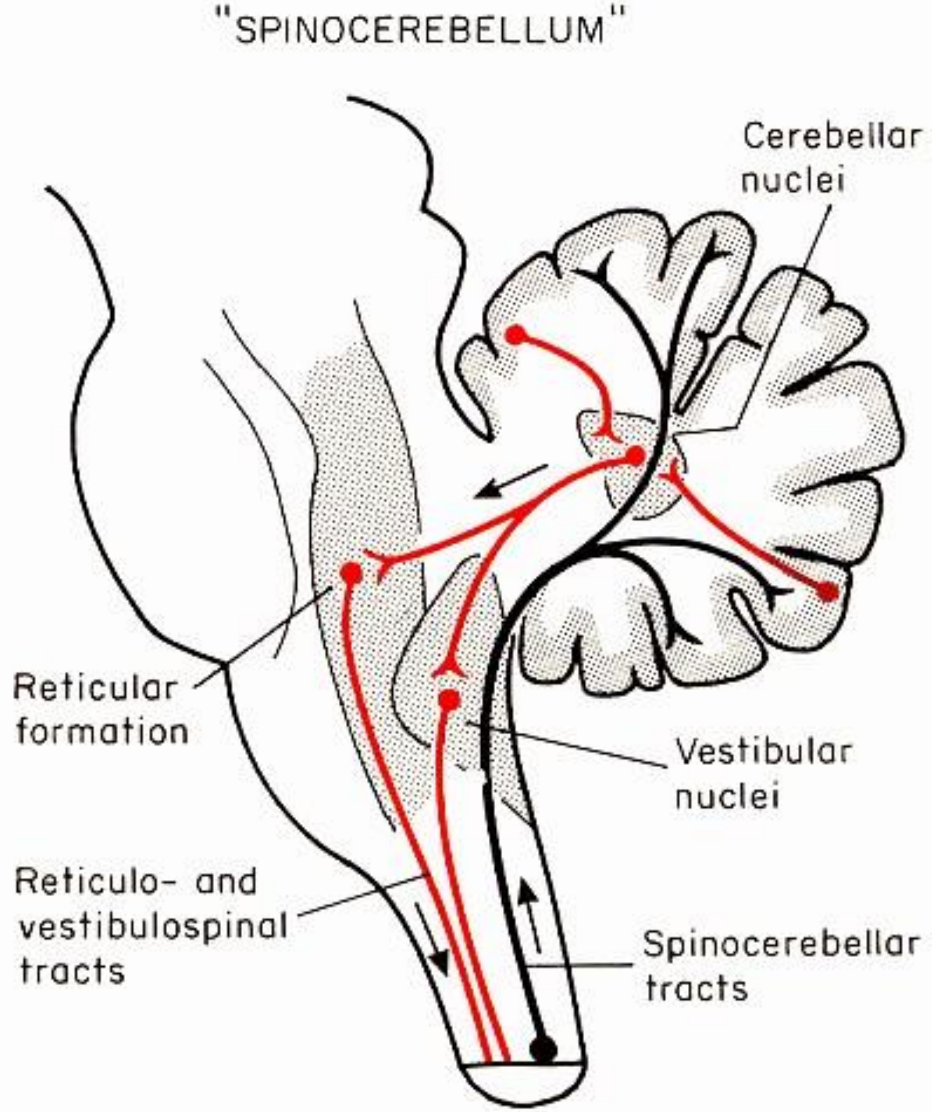


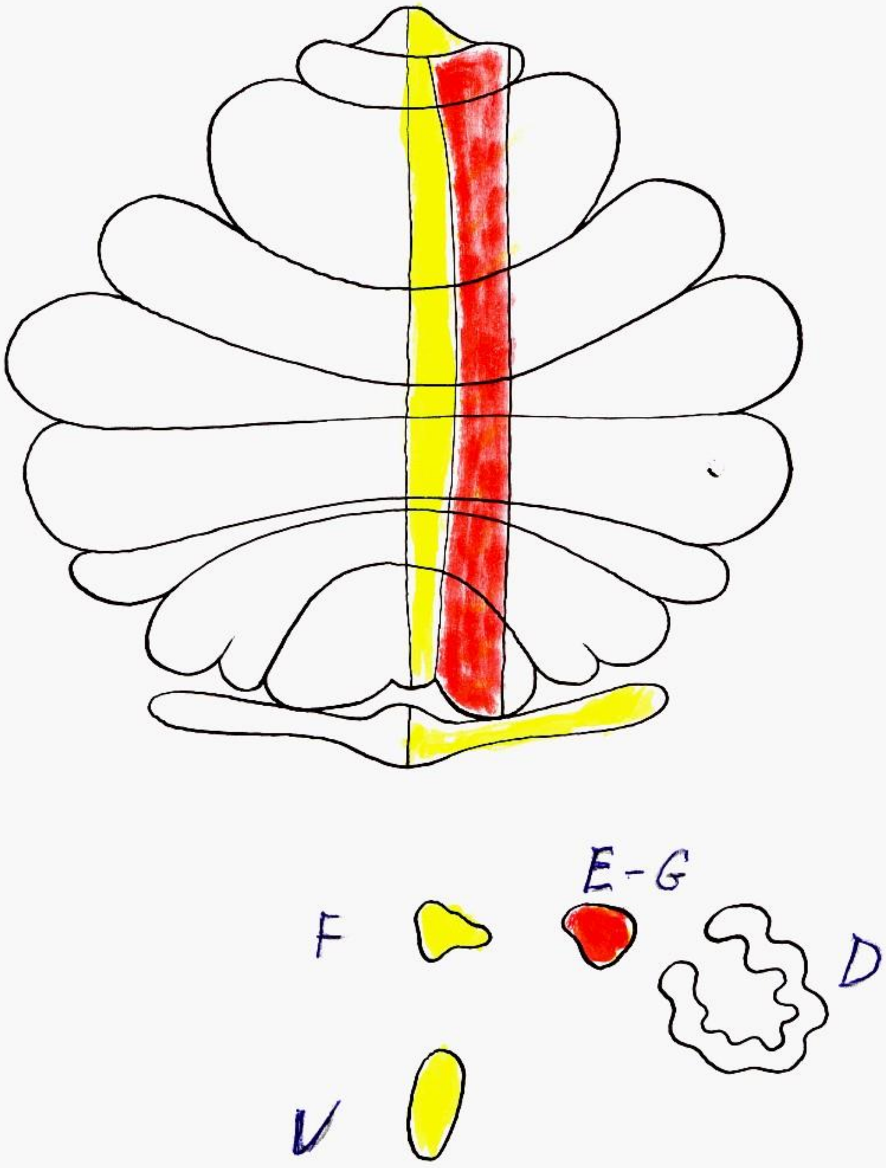
Fig. 11.4. *The main connections of the spinocerebellum.* Note that the spinocerebellum can influence spinal motoneurons via reticulospinal and vestibulospinal pathways.

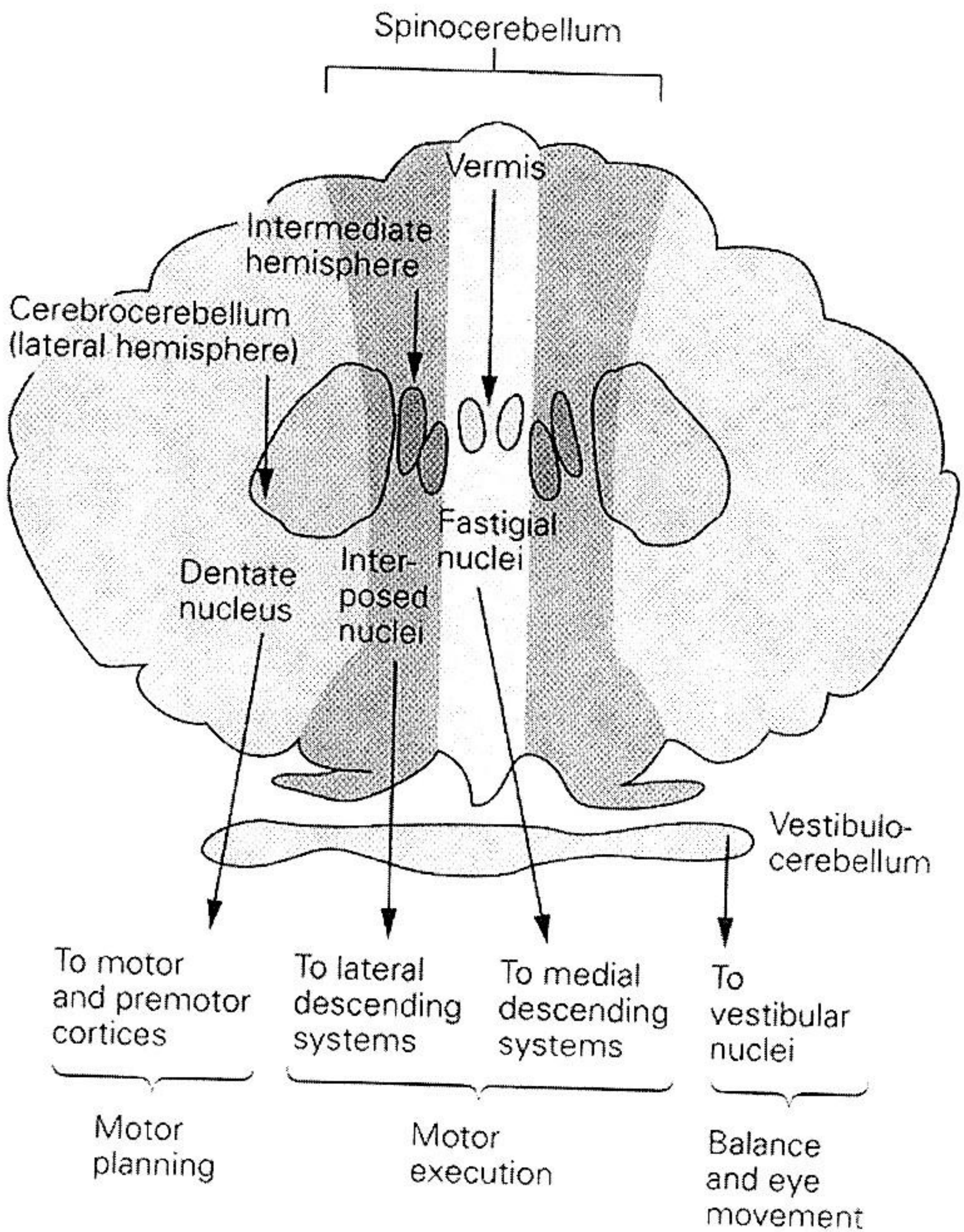
Efferent connections of the cerebellar cortex
Eferentní spoje mozečkové kůry

Cerebellar cortex – cerebellar nuclei

vermis – ncl. fastigii, ncll. vestibulares
pavermal zone – ncl. emboliformis, globosus.
lateral hemisphere – ncl. dentatus

Corticonuclear projection





Spinocerebellum
Vermis
Intermediate hemisphere
Cerebrocerebellum (lateral hemisphere)
Fastigial nuclei
Dentate nucleus
Inter-posed nuclei
Vestibulo-cerebellum
To motor and premotor cortices
To lateral descending systems
To medial descending systems
To vestibular nuclei
Motor planning
Motor execution
Balance and eye movement

Efferent connections of the cerebellar nuclei
Eferentní spoje mozečkových jader

- **Fastigial nucleus** – vestibular nuclei, reticular formation
- **Emboliformis + globosus nucleus** - reticular formation, ncl. ruber, thalamus
- **Nucleus dentatus –** ncl. ruber, contralateral thalamus (**ventrolateral nucleus,** intralaminar thalamic nuclei, ventral anterior nc.,

- **Ventrolateral nucleus (VL) – primary motor cortex (area 4)**

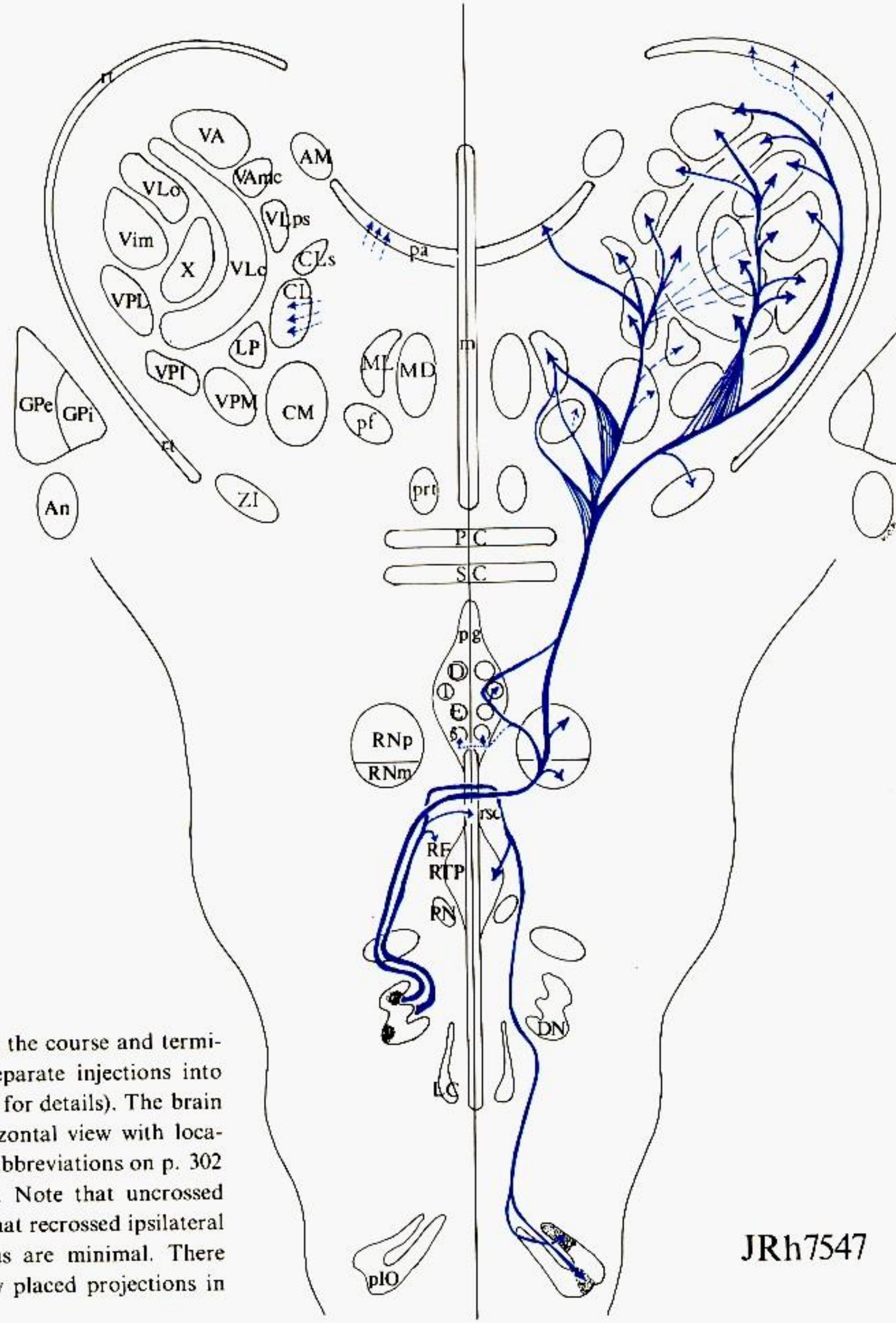


Fig. 13-7c. Summary diagram showing the course and terminations of labeled axons after two separate injections into the dentate nucleus, JRh 7547 (see text for details). The brain stem and thalamus are shown in horizontal view with locations of nuclei indicated according to abbreviations on p. 302 (Compare with Figs. 13-4c to 13-8c). Note that uncrossed ipsilateral projections are absent and that recrossed ipsilateral projections to the ipsilateral thalamus are minimal. There is a pronounced emphasis on laterally placed projections in the thalamus

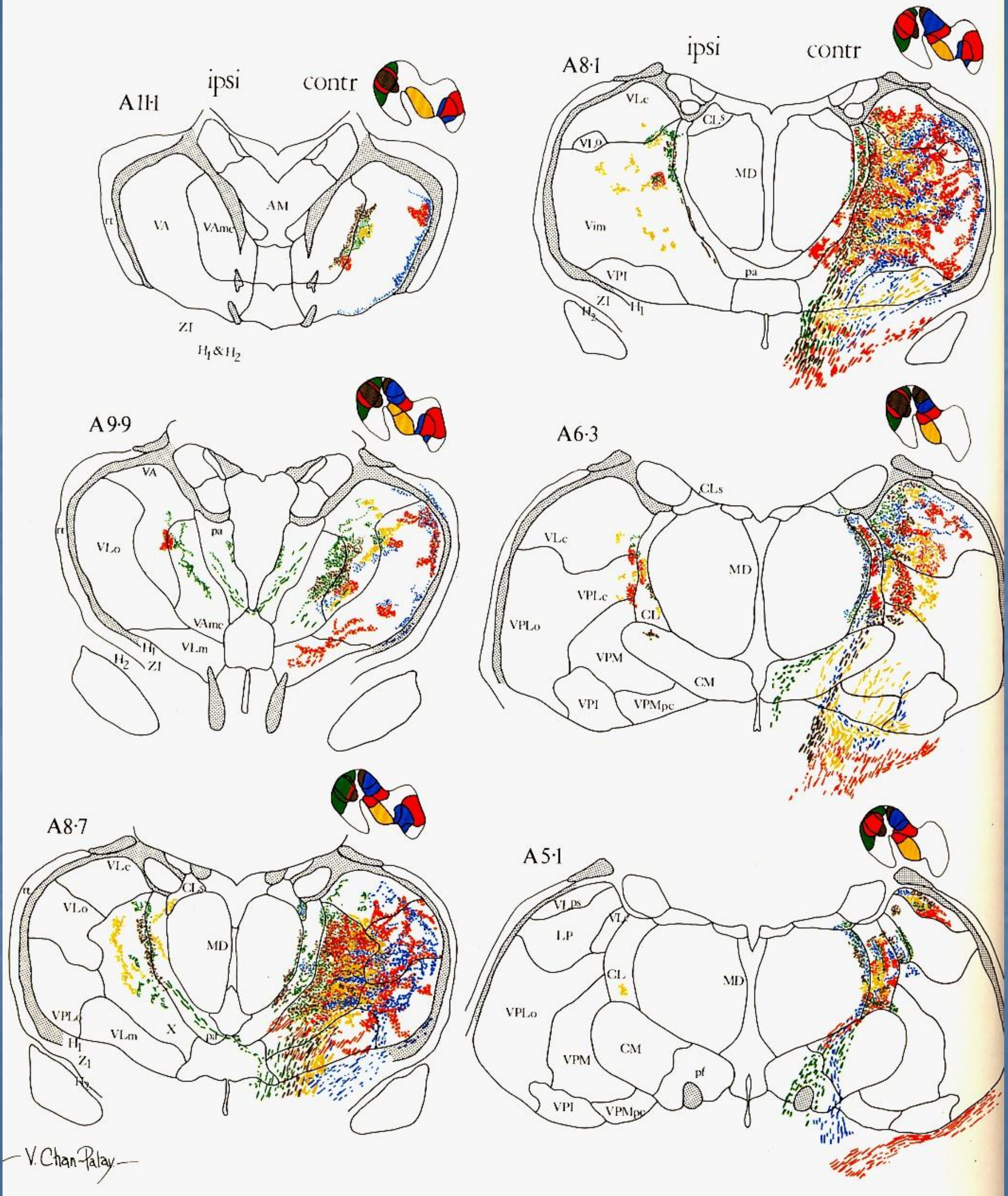
Thalamus

Ncl. Ventralis

Lateralis

Ncl. VL –

Motor cortex

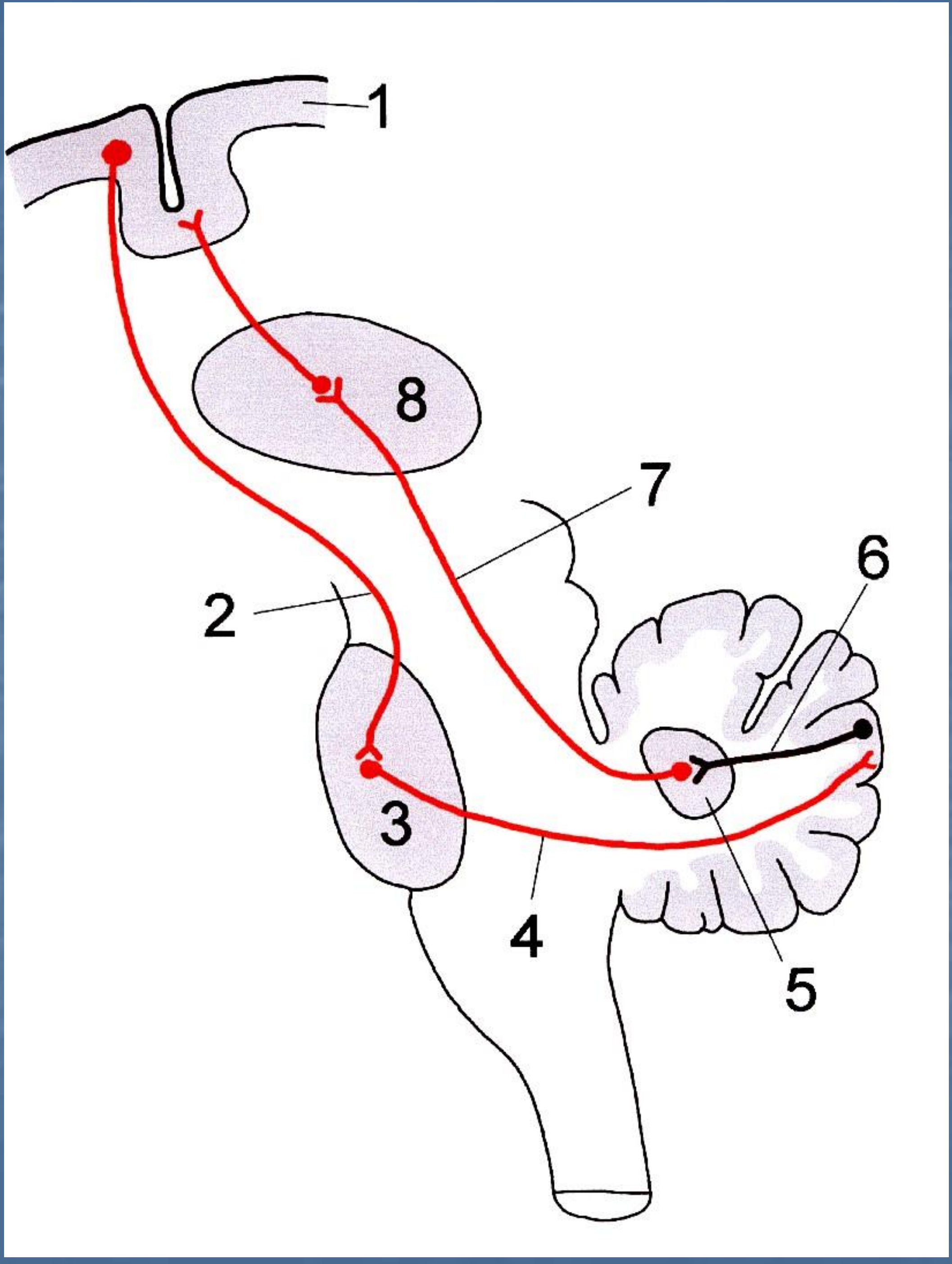


Victoria Chan-Palay, author and illustrator, attended Smith College and holds a Ph.D. in Anatomy from Tufts University School of Medicine. The present volume is an expanded version of an honours thesis which was presented to the Harvard Medical School at the conclusion of her clinical studies in 1975. It earned for her the degree of M.D. *summa cum laude,* a rare distinction at that institution. She also received the Leon Reznick Memorial Prize for excellence and accomplishment in research at the Harvard Medical School the same year.

Dr. Chan-Palay is a native of Singapore, a champion swimmer, an ardent supporter of equal rights for all women, the author of numerous articles in neuroscience journals and the co-author and illustrator of the book "Cerebellar Cortex – Cytology and Organization". This book was one of the "Fifty Best Books in 1974 in the Federal Republic of Germany, judged according to typography, printing, illustration and binding". It was awarded a special citation for its jacket design and received the 1975 Award for the Best Book for Professional Readership given by the American Medical Writers Association.

Cortico-ponto-cerebello-cortical circuit

(Transcerebellar Circuit)



Mozeček

- **Přijímá sensitivní signály, ale neúčastní se volní diskriminace, nebo interpretace**
- **Ovlivňuje motorické funkce, ale resekce mozečku nevyvolává obrny**
- **Stimulace mozečku nevyvolává pohyb**
- **Ovlivňuje kognitivní funkce, zejména motorické učení a vyšší mentální funkce (uvažování, plánování)**

Mozečkové syndromy

- **Vestibulární mozeček a vermis (zejména v lobus anterior) – poruchy rovnováhy, stoje a chůze, chůze o široké bazi, nystagmus**
- **Spinální mozeček – kontroluje axiální svalstvo a proximální svaly končetin. Při poškození zvýšení tonu extensorů.**
- **Pontinní mozeček (hemisféry) - přestřelování pohybů (hypermetrie, prst – lalůček, prst- špička nosu). Adiadochokinéza, třes(méně než 5 Hz- zhoršuje se na konci zacíleného pohybu), poruchy řeči a výslovnosti (dysartrie, skandovaná řeč), poruchy plánování, paměti, uvažování (kognitivní poruchy).**
- **Cerebellární kognitivně - afektivní syndrom (1998) – vermis, lobus posterior**

CEREBELLUM

1) Receives extensive sensory input, but is not involved in voluntary discrimination or interpretation

2) Influences motor functions, but resection of the cerebellar cortex does not result in lasting paralysis

3) Stimulation of the cerebellar cortex does not evoke movements

4) Inflences cognitive functions namely motor learning and higher mental functions

Paleocerebellar lesions (syndrome)

equilibrium

MIDLINE LESIONS

The midline portions of the cerebellum may be invaded by a tumor, typically a "medulloblastoma" that occurs in childhood. In adults, a similar syndrome may be seen in chronic alcoholism, which causes degeneration of the vermis. The patient has an unsteady, staggering **ataxic gait**, walks on a wide base, and sways from side to side. **Cerebellar nystagmus** is "pendular," with eye movements of equal speed in both directions, usually in the horizontal plane. It is attributed to interruption of connections of the vermis with the ocular motor nuclei by way of the vestibular nuclei and the reticular formation. The signs are at first limited to a disturbance of equilibrium; however, additional cerebellar signs appear when a tumor invades other parts of the cerebellum.

Neocerebellar syndrome (lesion of the hemisphere)

The following signs, in varying degrees of severity, are those of a neocerebellar syndrome. Movements are **ataxic** (intermittent or jerky). There is **dysmetria**; for example, when the patient reaches out with the finger to an object, the finger overshoots the mark or deviates from it (**past-pointing**). Rapidly alternating movements, such as flexion and extension of the fingers or pronation and supination of the forearm, are performed in a clumsy manner (**adiadochokinesis**). **Asynergy** is separation of smoothly flowing voluntary movements into successions of mechanical or puppet-like movements (**decomposition of movement**). There may be **hypotonia** of muscles, which also tire easily. Cerebellar **tremor**, which occurs most frequently with demyelinating lesions in the cerebellar peduncles, usually occurs at the end of a particular movement (**intention tremor**). **Dysarthria** is evident if asynergy involves muscles used in speech, which is then thick and monotonous (slurring; scanning speech). There may be nystagmus, if the lesion encroaches on the vermis. The deficits noted are superimposed

Cerebellar - cognitive affective syndrome

- **Schmahmann and Sherman (1998) in patients with cerebellar lesions described CCAS**
- **Executive dysfunction (disturbances in planning, abstract reasoning, memory)**
- **Language symptoms (agrammatisms)**
- **Behavior – affective disturbances (blunting of affect, disinhibited and inappropriate behavior**

- **Lesions of the cerebellum interrupt communication with the motor systems, association cortex.**
- **Psychiatric disorders result from midline vermis lesions (communication with the limbic system)**

THE END

Cajal 1911

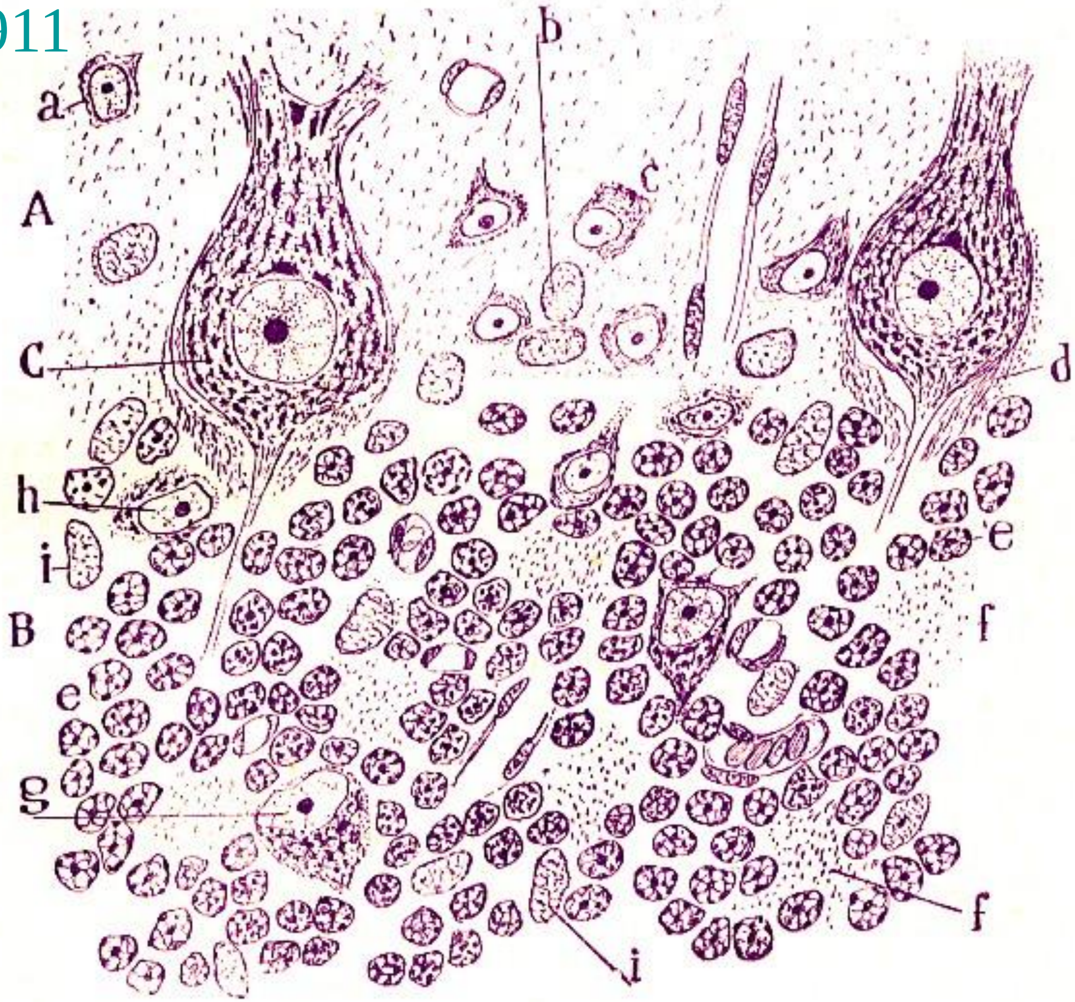


Fig. 1. — Portion d'une coupe de l'écorce du cervelet ; homme adulte. Méthode de Nissl ; obj. apochrom. 1,30.

A, région inférieure de la couche plexiforme ; — B, couche des grains ; — C, corps des cellules de Purkinje ; — *a*, cellule étoilée de la couche plexiforme ; — *b*, noyaux des cellules épithéliales ; — *c*, autre cellule étoilée avec chromatine marginale ; — *d*, masse fibrillaire correspondant aux corbeilles qui embrassent les corps des cellules de Purkinje ; — *e*, noyaux des grains ; — *f*, ilots granuleux ou cérébelleux ; — *g*, *h*, cellules de Golgi ou à cylindre-axe court de la zone des grains ; — *i*, noyaux des cellules névrogliques.

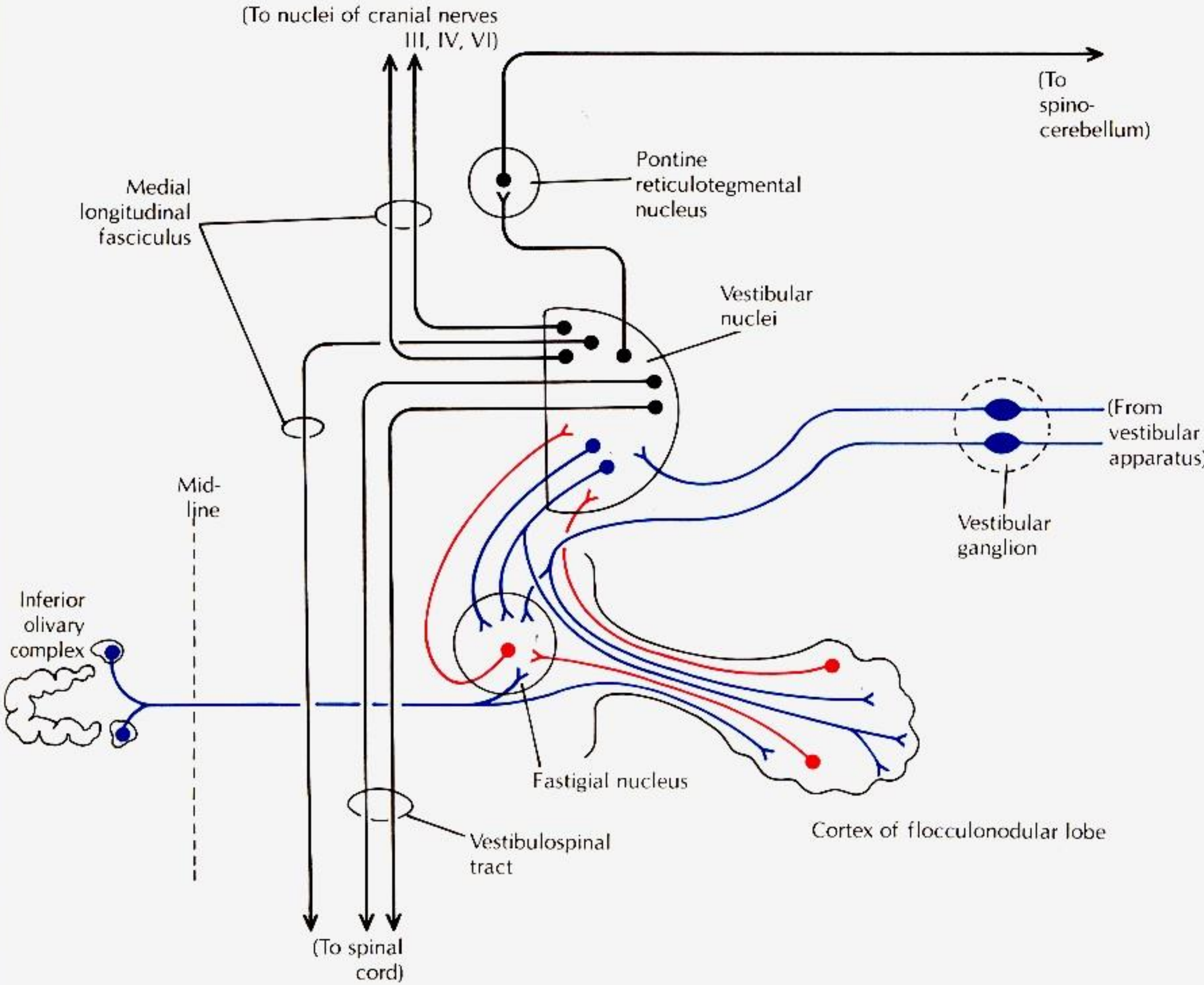


Figure 10-13. Connections of the vestibulocerebellum and vestibular nuclei.

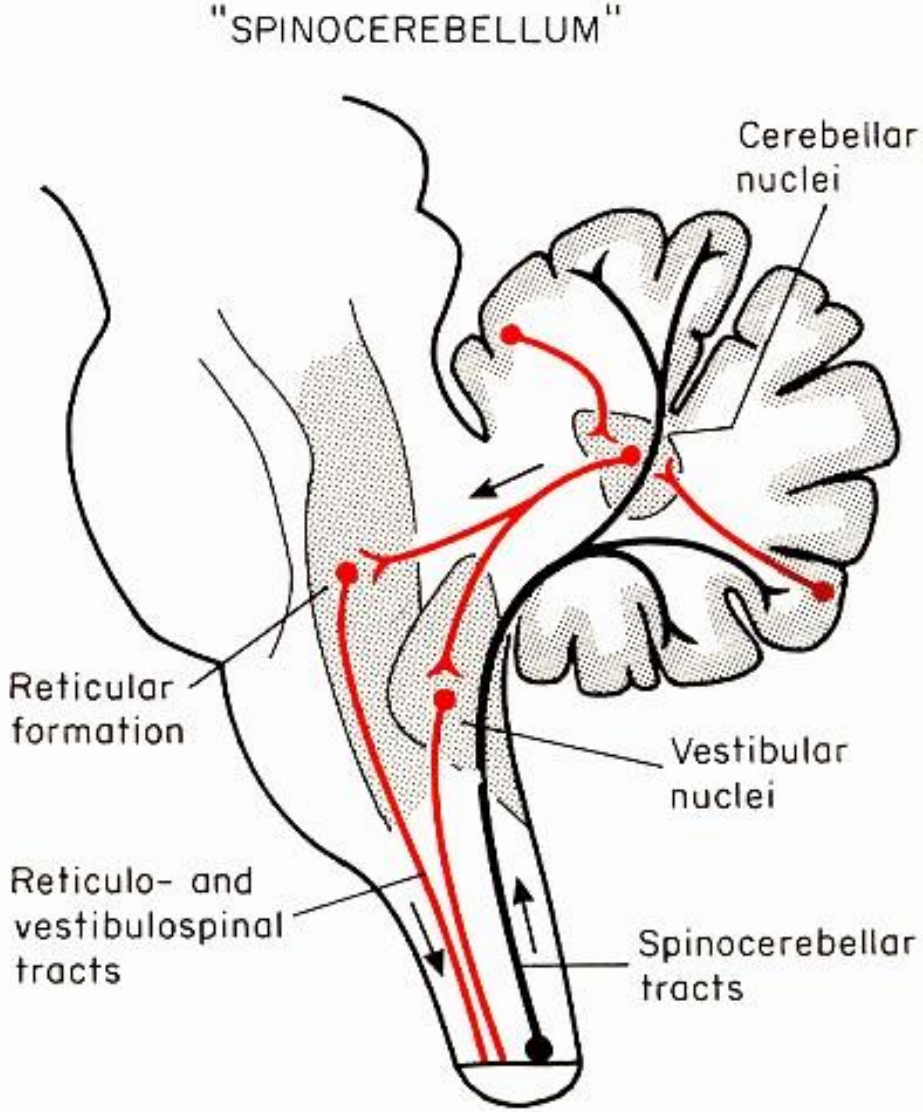


Fig. 11.4. *The main connections of the spinocerebellum.* Note that the spinocerebellum can influence spinal motoneurons via reticulospinal and vestibulospinal pathways.

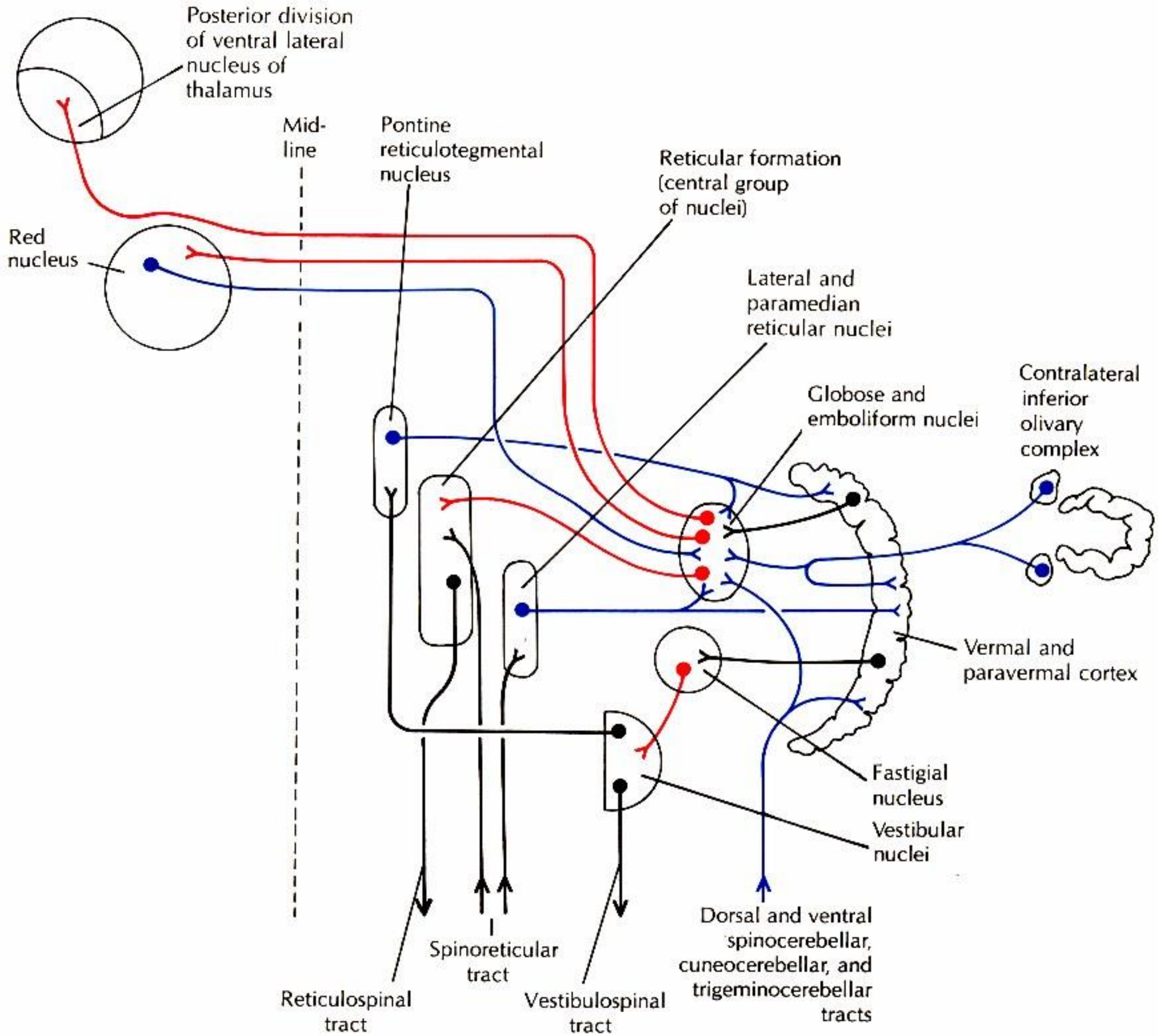


Figure 10-14. Connections of the spinocerebellum.

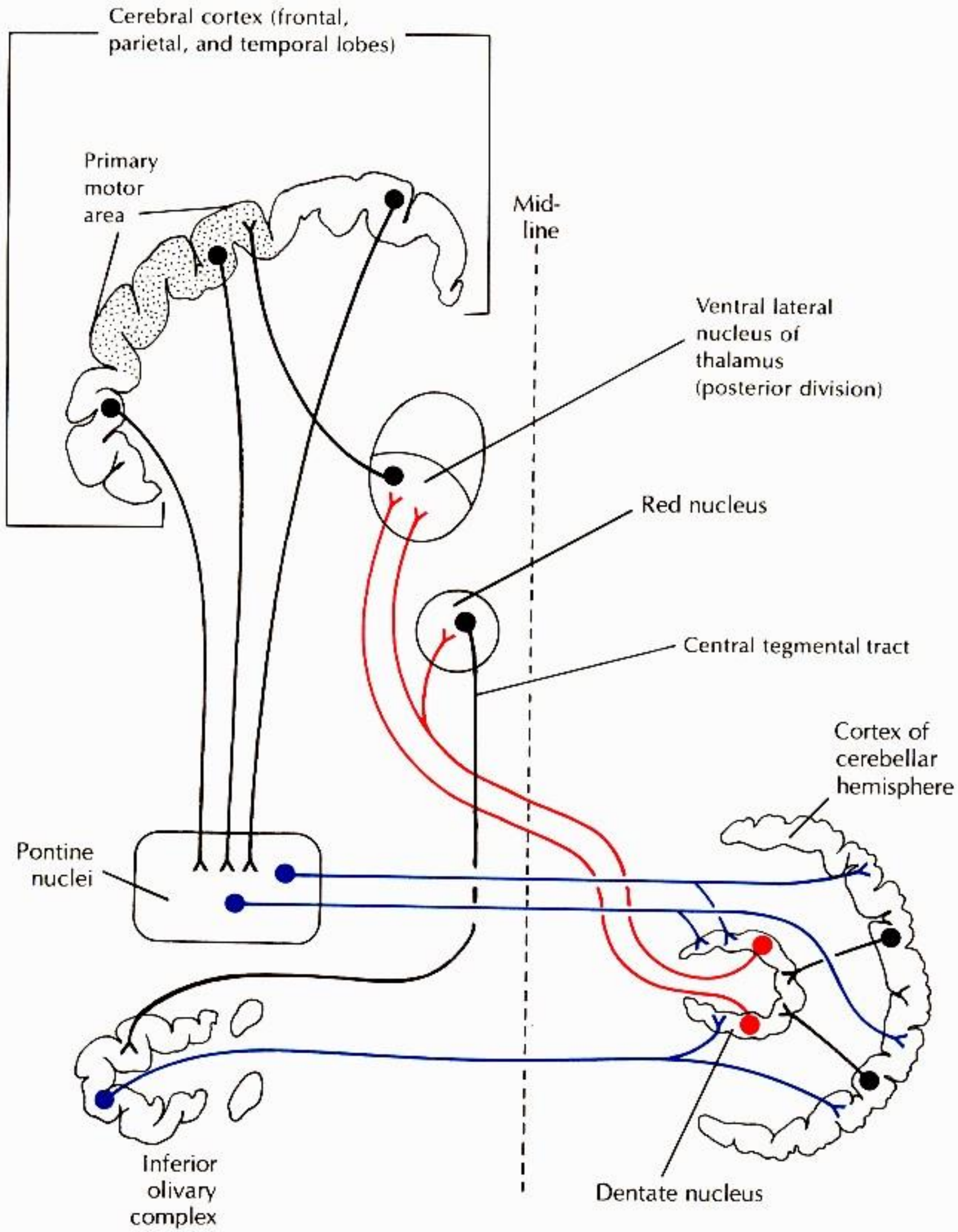


Figure 10-15. Connections of the pontocerebellum.

Vestibulocerebellum

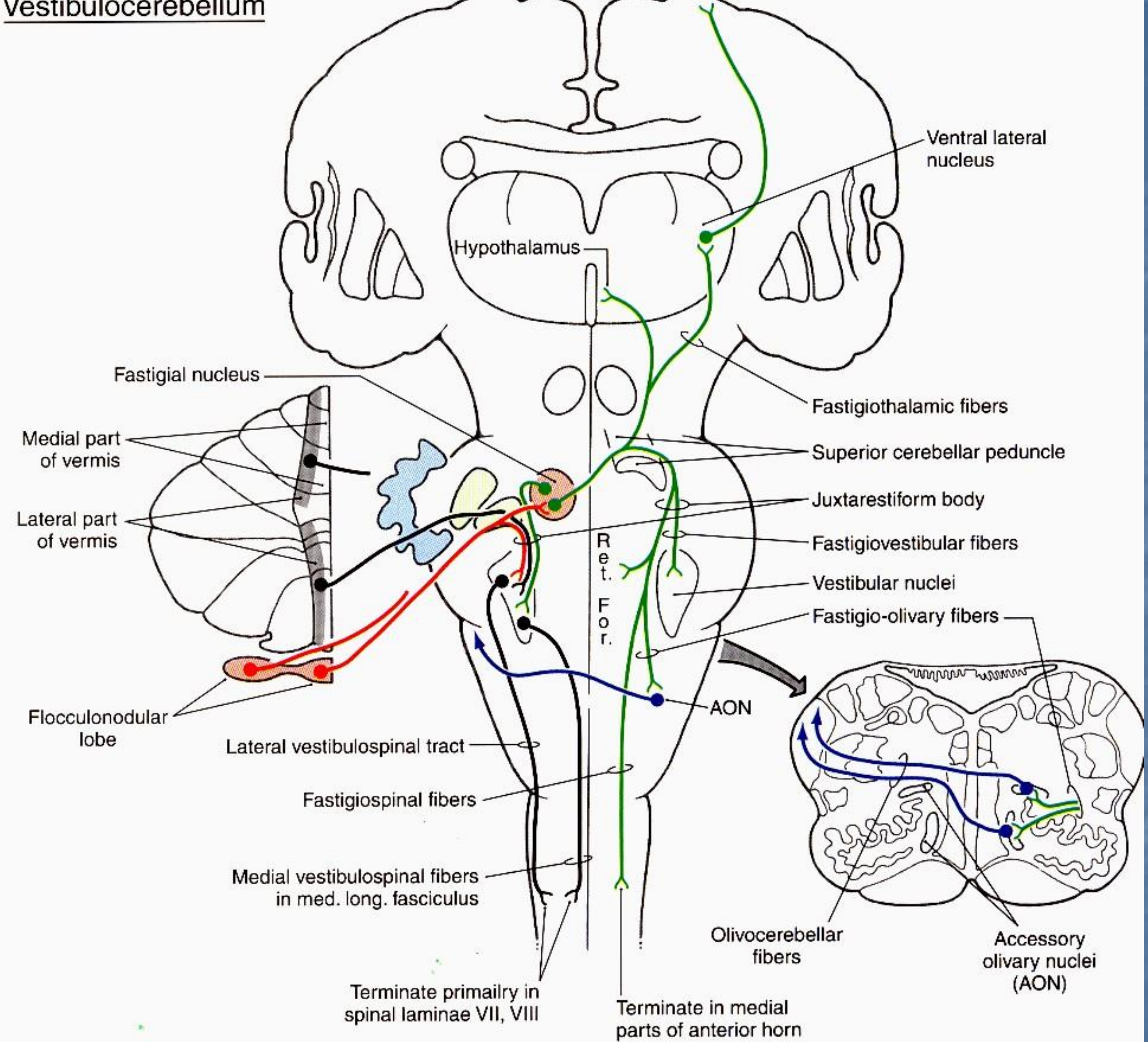


Figure 27–14. Projections of the vestibulocerebellum and of the lateral part of the medial zone through the fastigia vestibular nuclei. med. long., medial longitudinal; Ret. For., reticular formation.

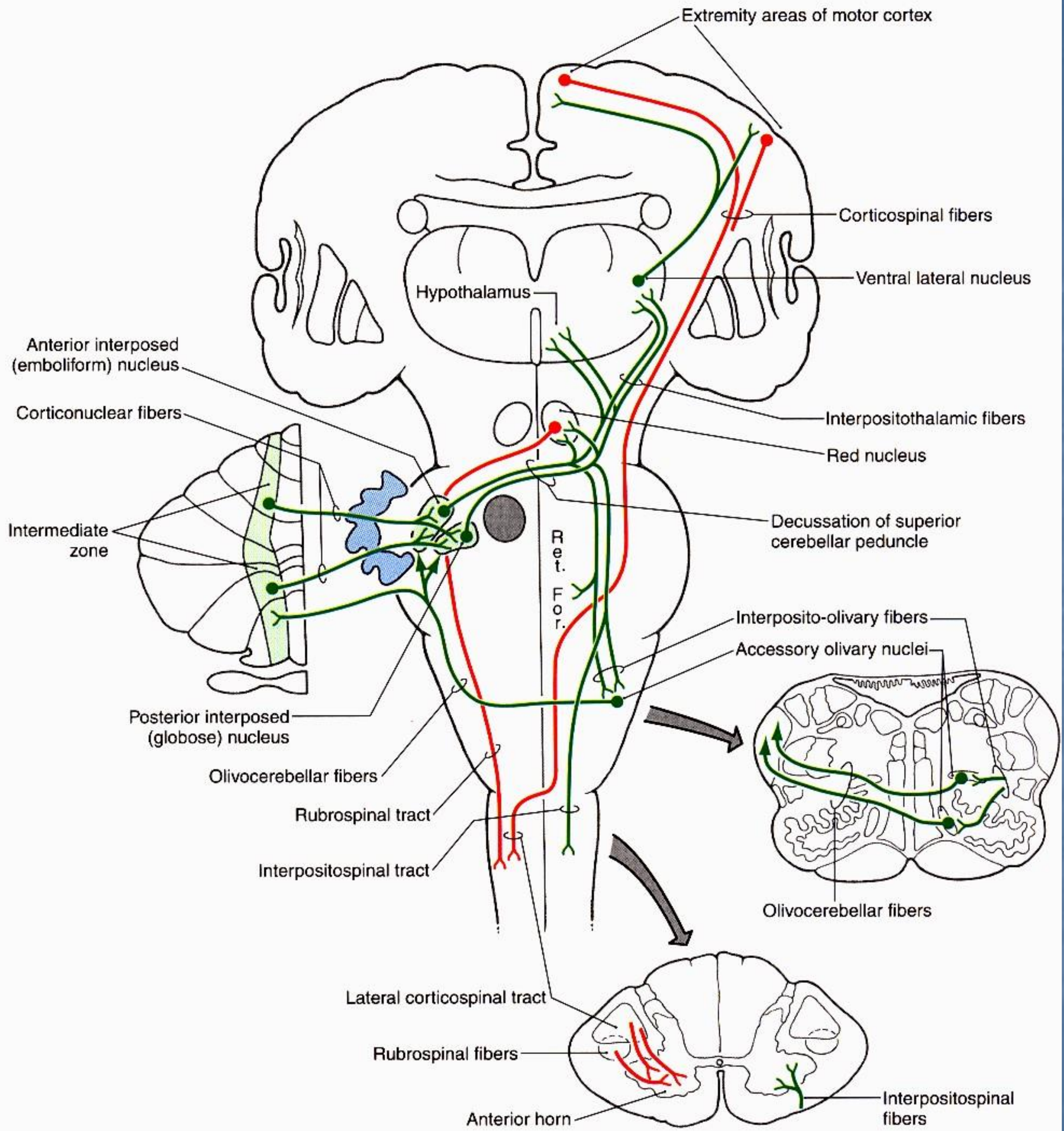


Figure 27–16. Projections of the spinocerebellum (intermediate zone) through the emboliform and globose nuclei. Ret. reticular formation.

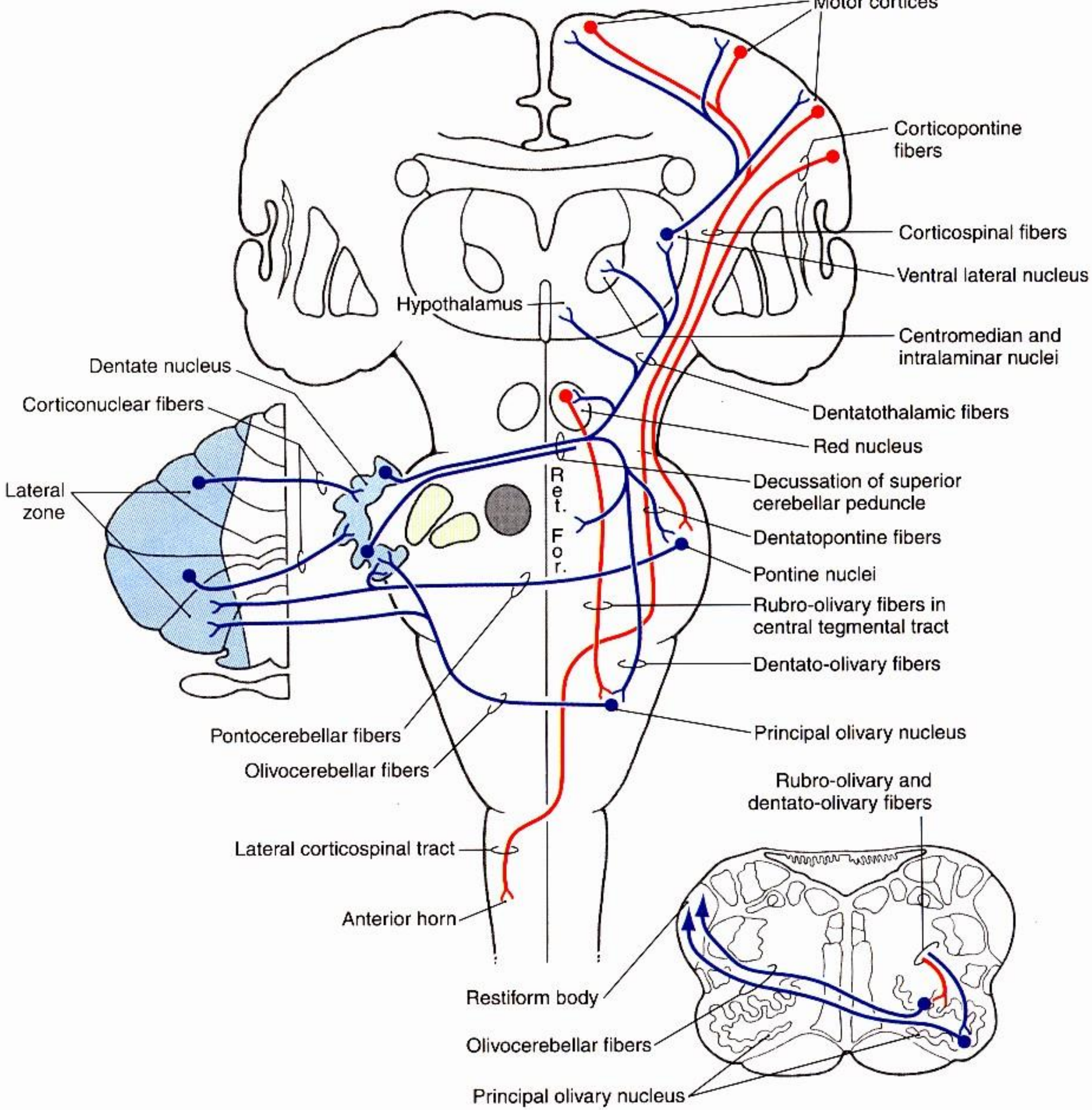


Figure 27–17. Projections of the pontocerebellum (lateral zone) through the dentate nucleus. Ret. For., reticular forma