

# MOZEČEK

David Kachlík

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# Mozeček = Cerebellum

10 % hmotnosti celého mozku

více než  $\frac{1}{2}$  neuronů celého mozku

$\frac{1}{4}$  -  $\frac{3}{4}$  plochy mozku



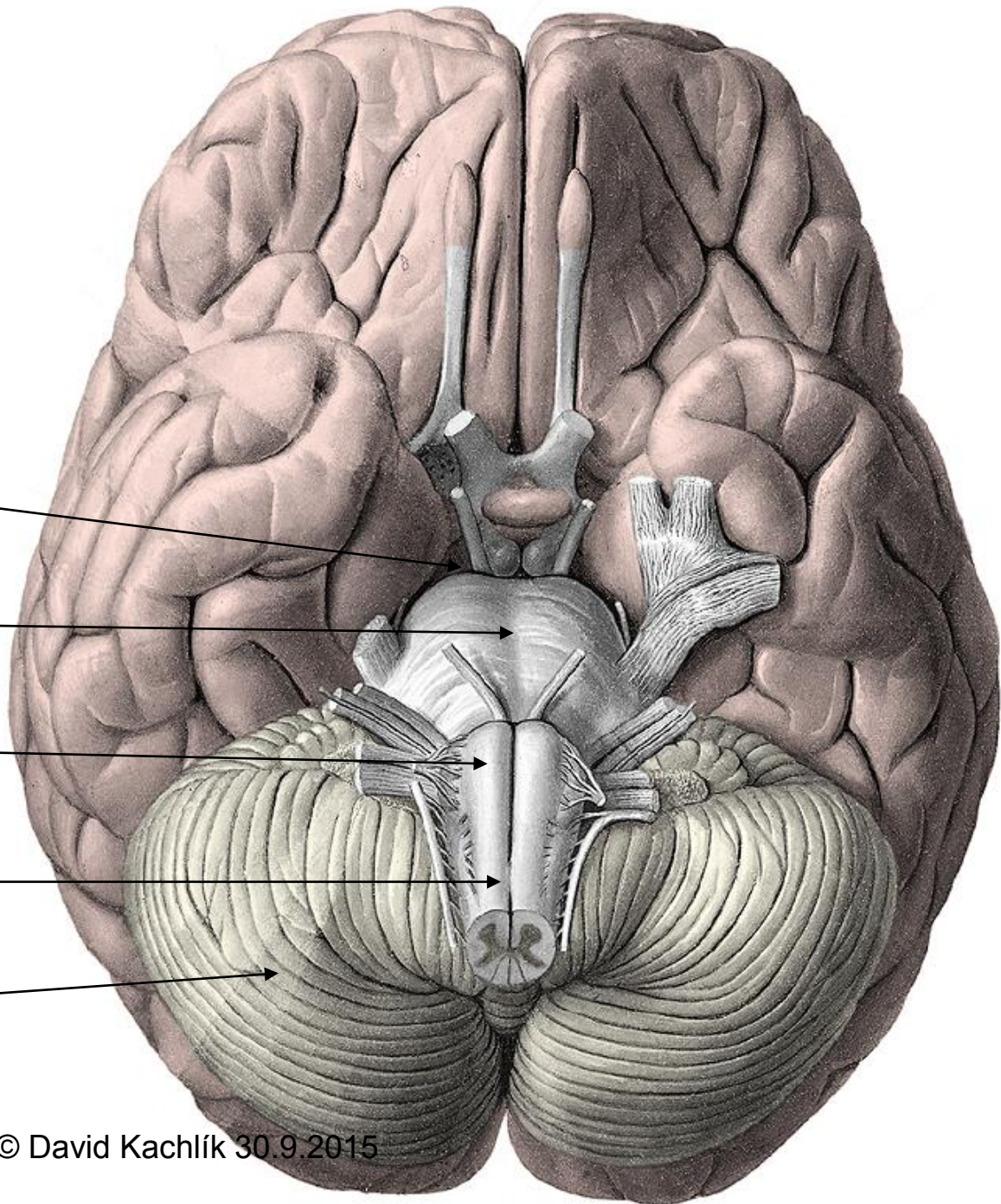
**Mesencephalon**

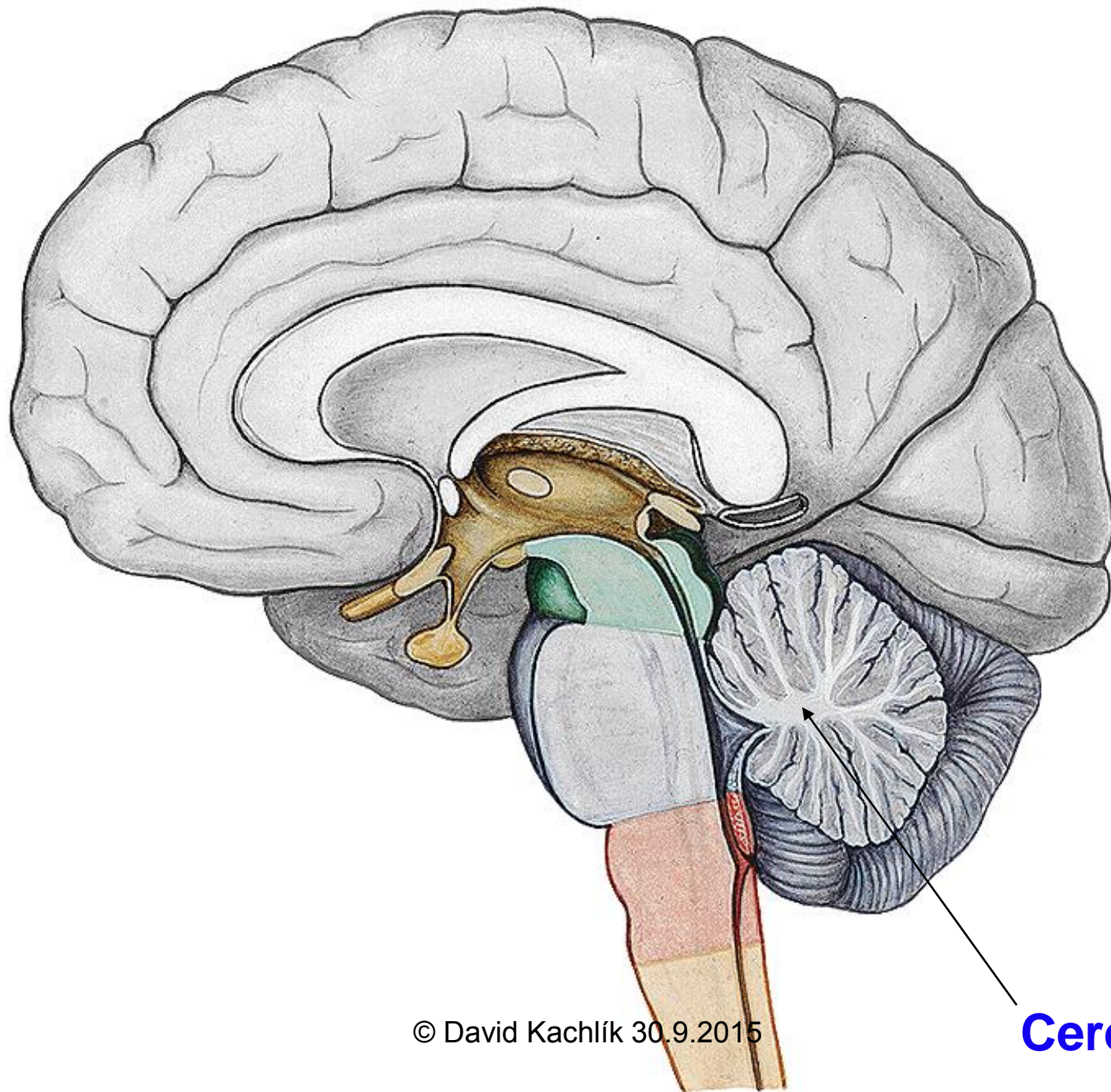
**Pons**

**Medulla oblongata**

**Medulla spinalis**

**Cerebellum**





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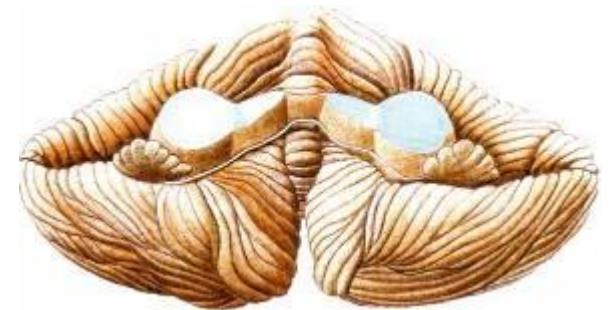
**Cerebellum**

# Mozeček – dělení

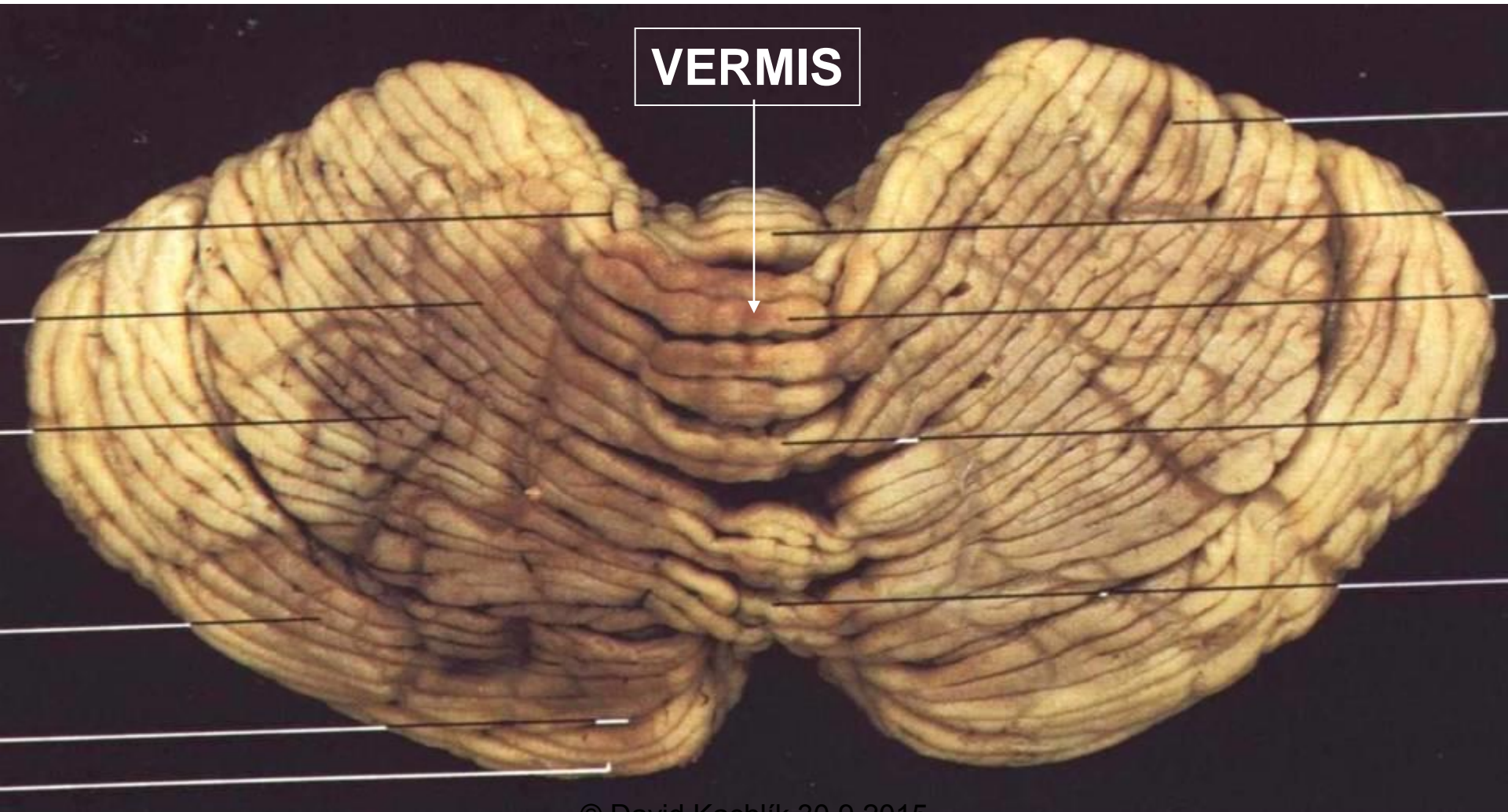
- dle vývoje:
  - archicerebellum
  - paleocerebellum
  - neocerebellum
- dle funkce:
  - vestibulocerebellum
  - spinocerebellum
  - cerebrocerebellum  
(= pontocerebellum)
- dle funkčního umístění:
  - vermis a lobus flocculonodularis
  - paravermální (intermediální) zóna
  - hemisféry (laterální zóna)
- dle vnější stavby:
  - lobus anterior
  - lobus posterior
  - lobus flocculonodularis

# Mozeček – popis

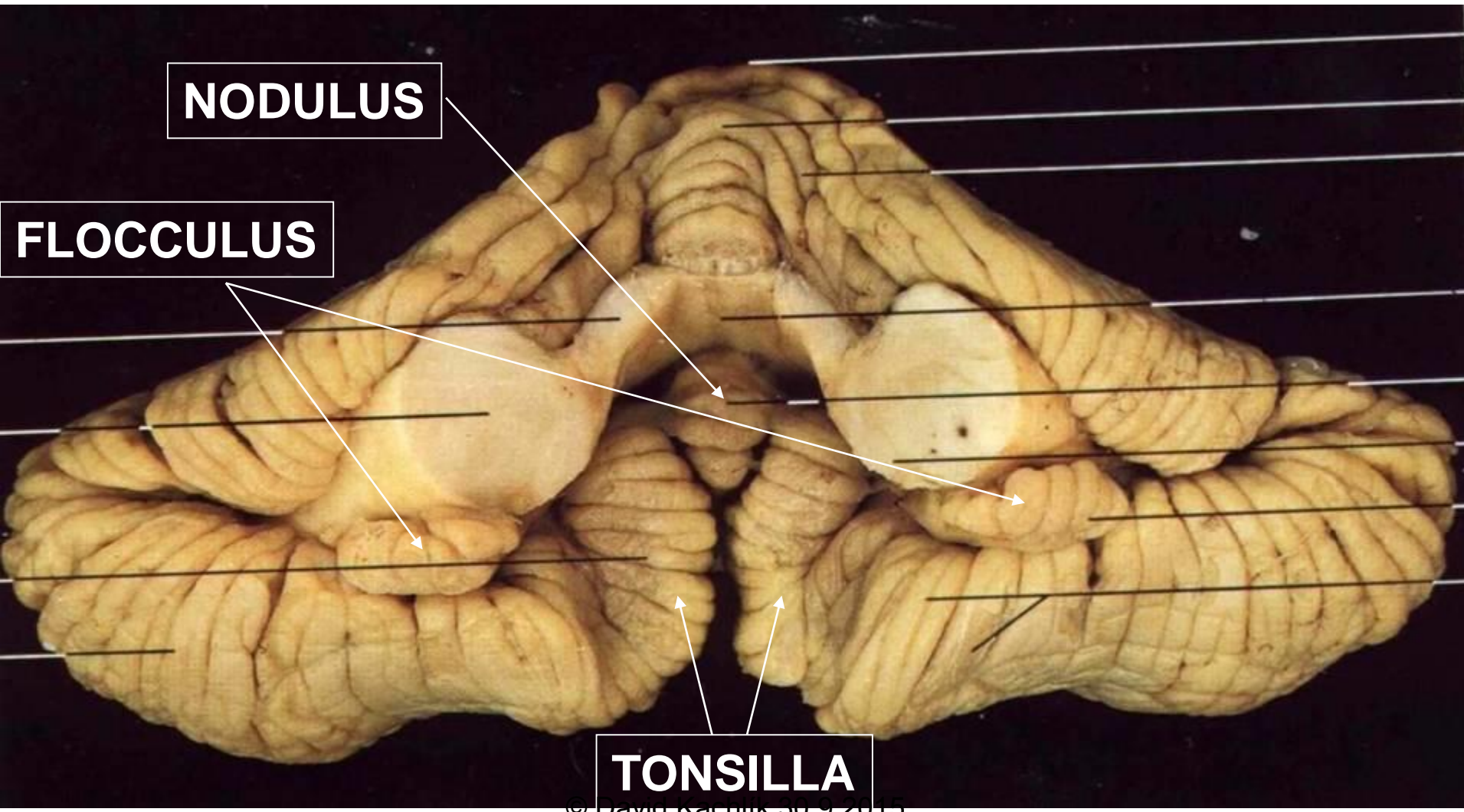
- **folia cerebelli** (*lístky*)
- **fissurae cerebelli** (*štěrbiny*)
- **vermis** (*červ*) – nepárový uprostřed
- **hemispheria** (*polokoule*) – párové
- **3 lobi** (*laloky*)
  - menší části
    - 10 v červu [I - X] – např. nodulus
    - 9 v polokoulích [H II - H X]
  - **tonsilla** – při otoku se vsouvá do foramen magnum a utlačuje kmen
  - flocculus



# Mozeček – zadní pohled

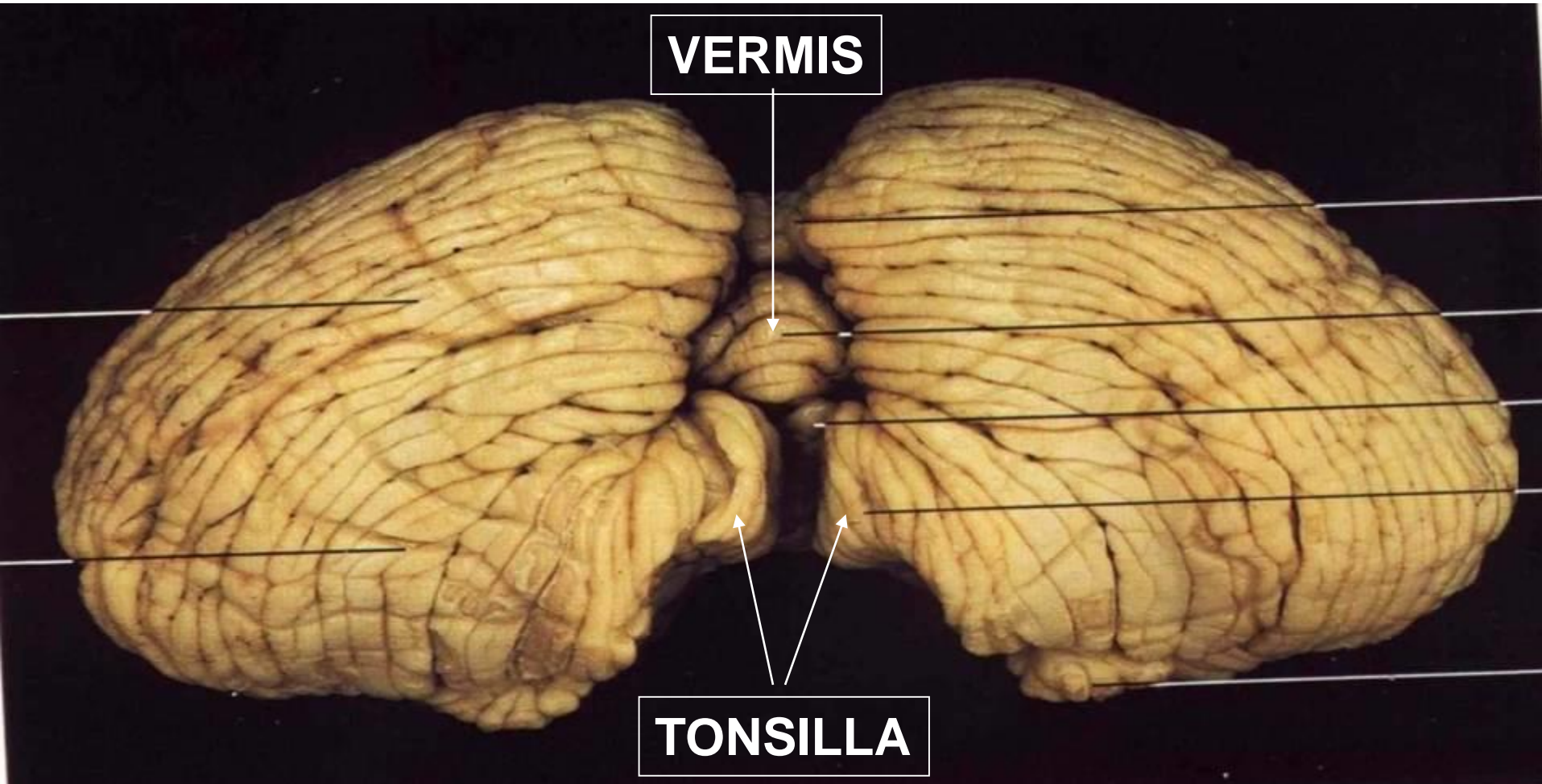


# Mozeček – přední pohled





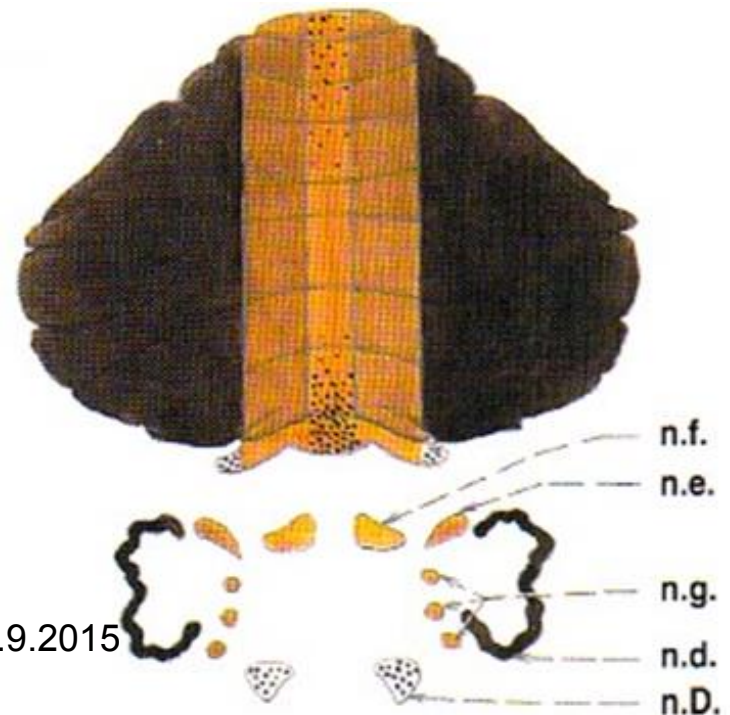
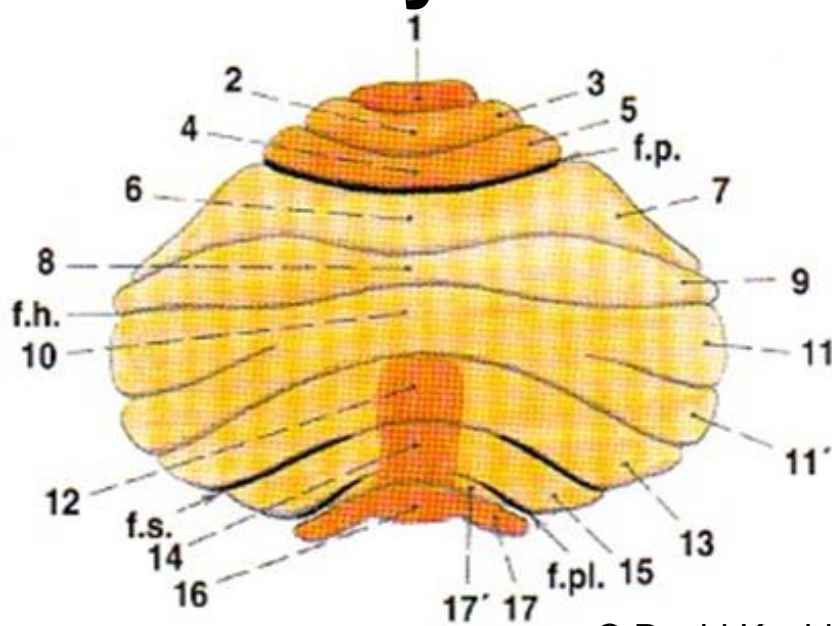
# Mozeček – dolní pohled



# Cerebellum – funkční části

3 podélné zóny

- **vermis + lobus flocculonodularis**
- **paravermální kůra**
- **hemisféry**



# VÝVOJ MOZEČKU

*dorzální pohled (pohled shora)*

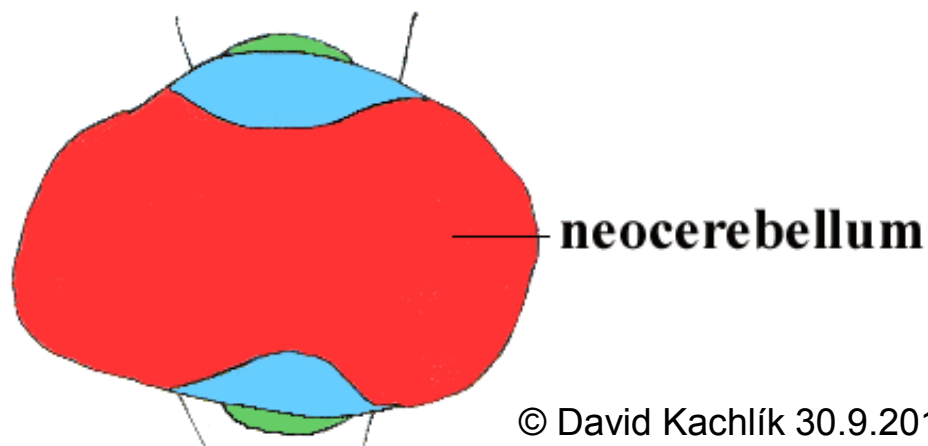
RYBY



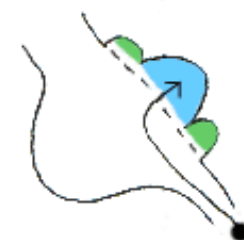
PLAZI



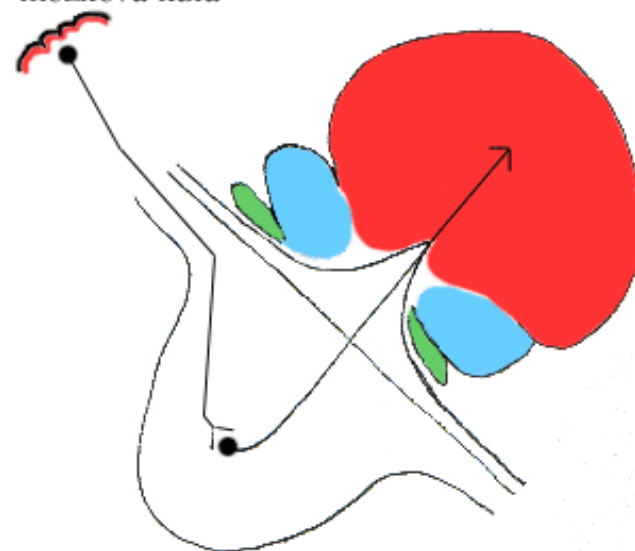
SAVCI



*laterální pohled*



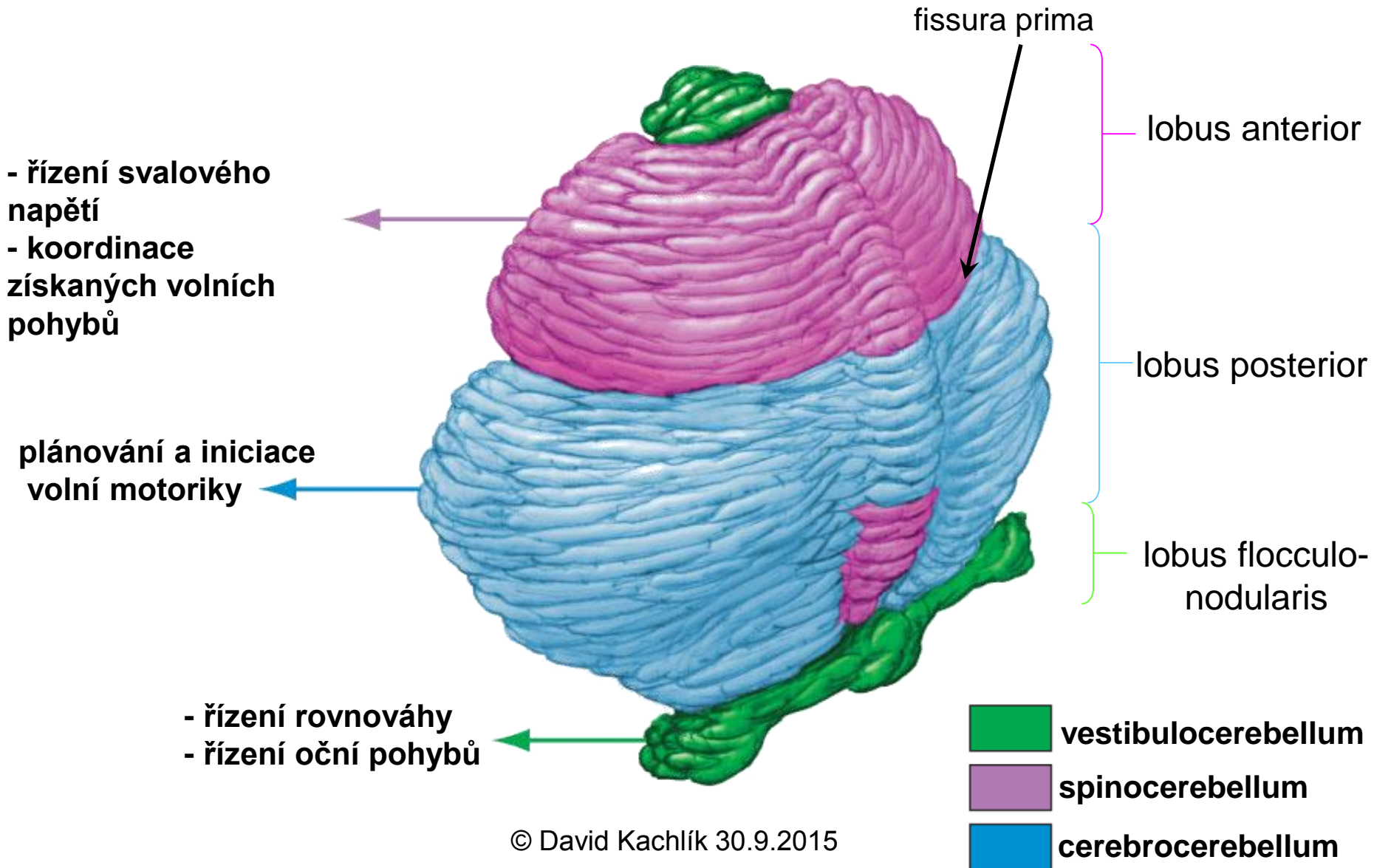
mozková kůra



# Mozeček – vývojové části

- lobus anterior [I-V + H II - H V]  
= **spinocerebellum = paleocerebellum**  
*fissura prima*
- lobus posterior [VI-IX + H VI - H IX]  
= **pontocerebellum = neocerebellum**  
*fissura posterolateralis*
- lobus flocculonodularis [X + H X]  
= **vestibulocerebellum = archicerebellum**

# Mozeček

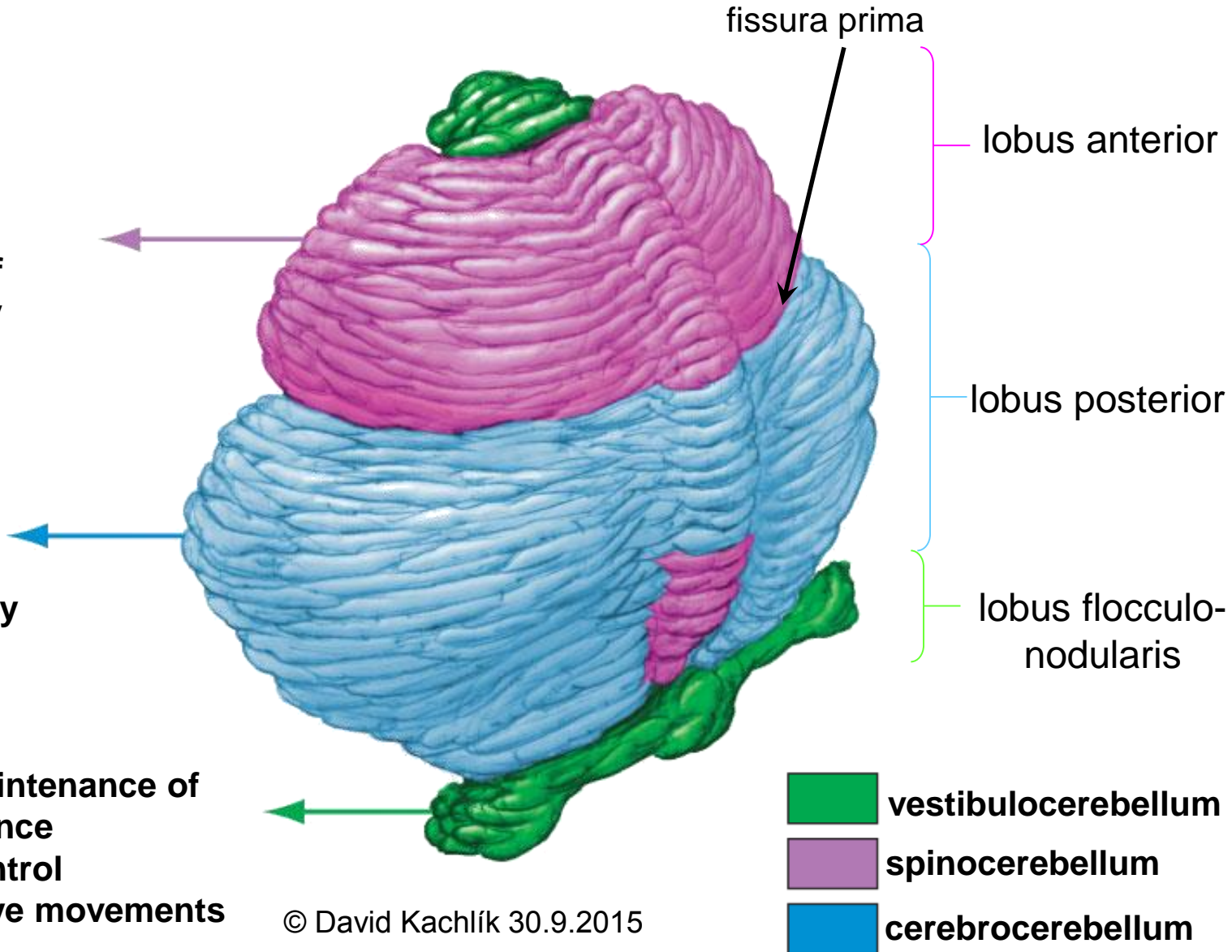


# Cerebellum

- regulation of muscle tone  
- coordination of skilled voluntary movement

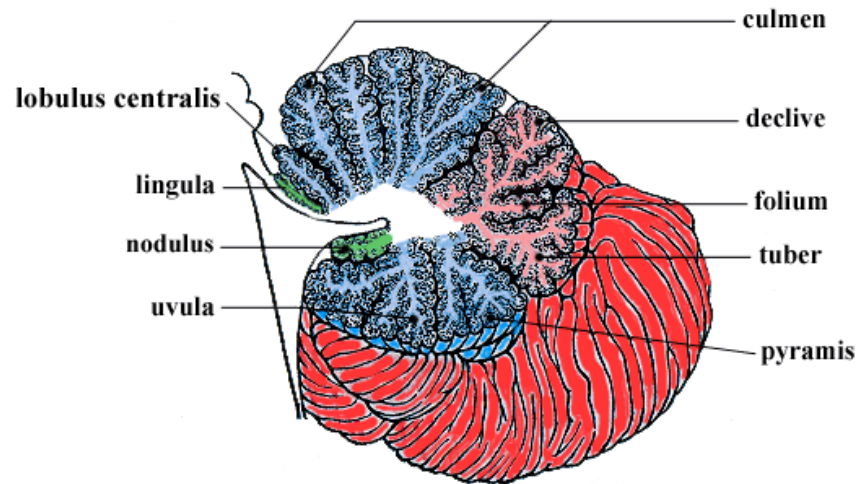
planning and initiation of voluntary activity

- maintenance of balance  
- control of eye movements



# SCHÉMA FYLOGENETICKÉHO VÝVOJE MOZEČKU

pohled na sagitální řez skrz vermis cerebelli



PŮVODNÍ  
HYPOTETICKÝ STAV



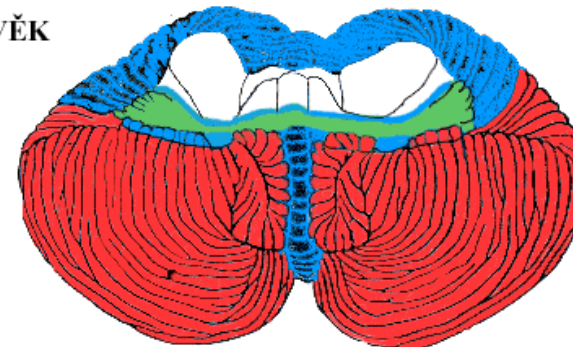
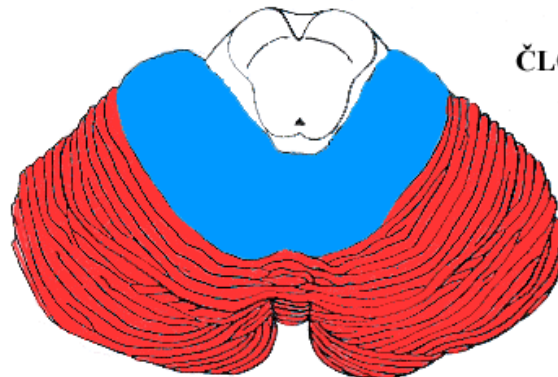
PLAZI



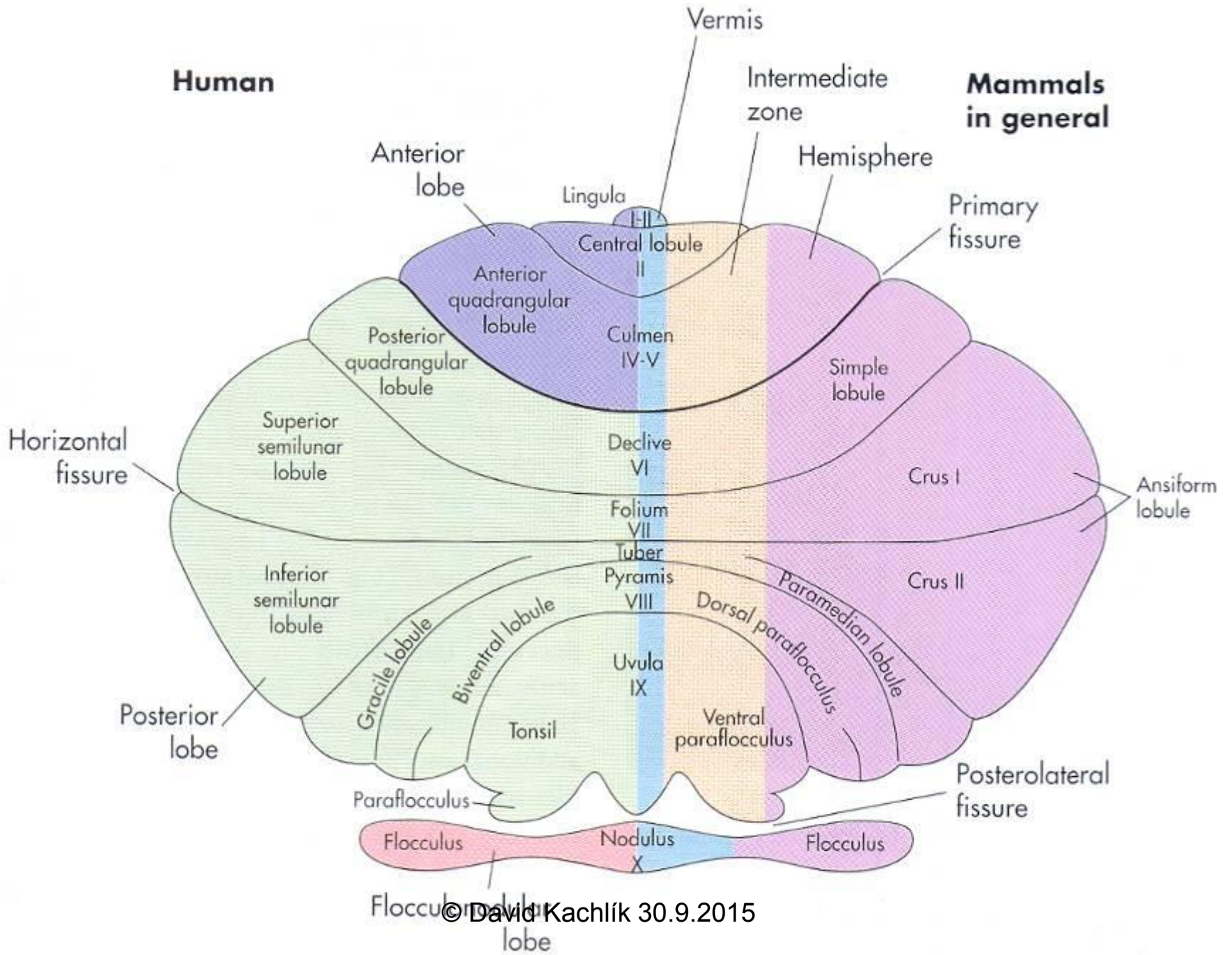
SAVCI



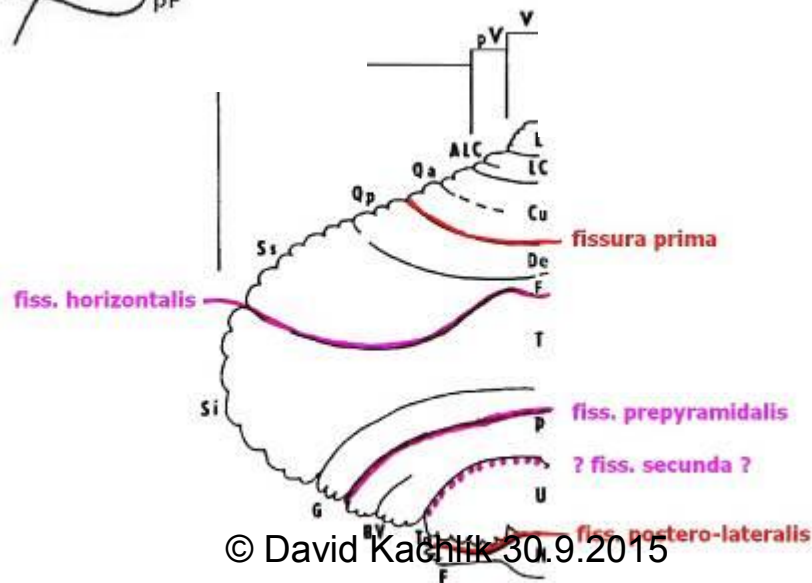
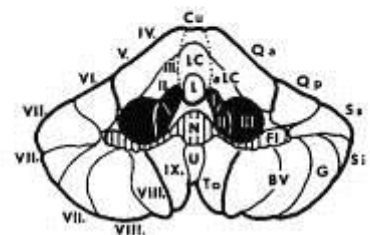
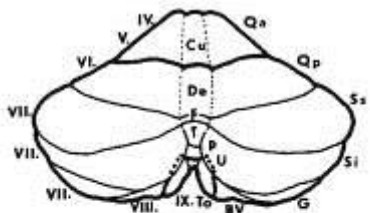
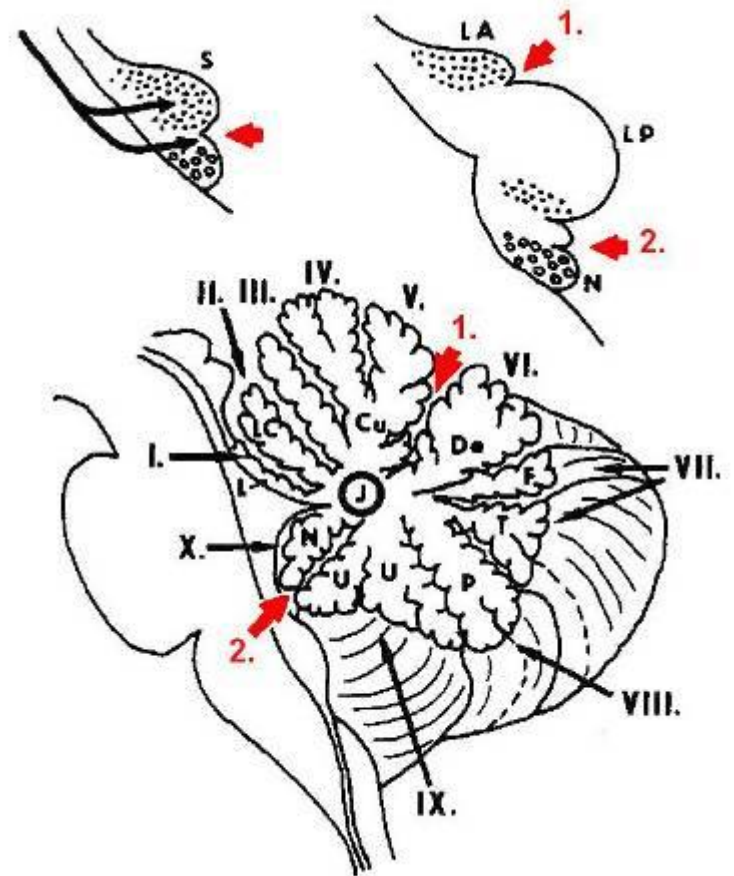
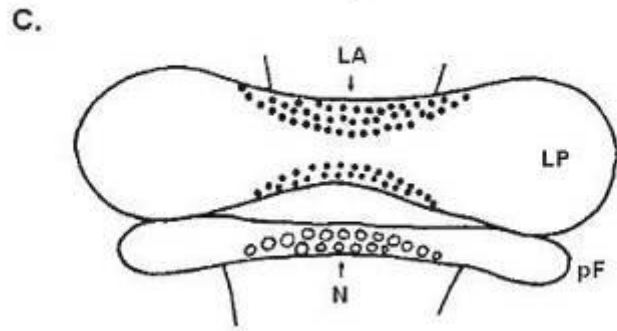
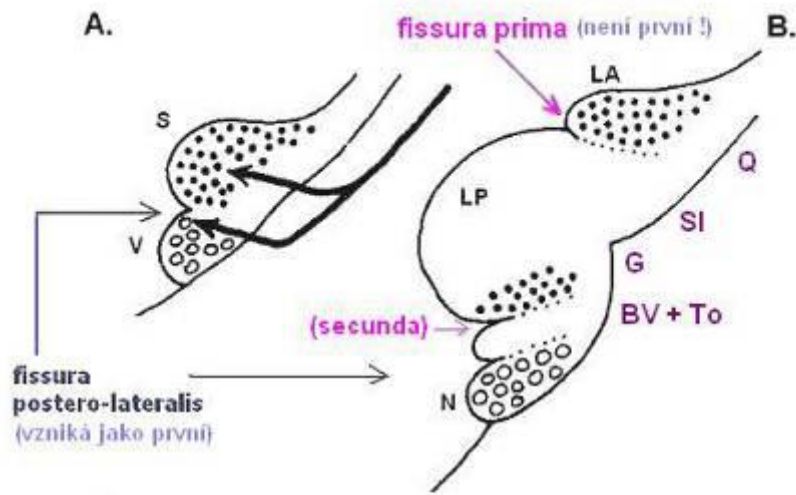
ČLOVĚK



zeleně - vestibulocerebellum  
modře - vermis  
červeně - neocerebellum  
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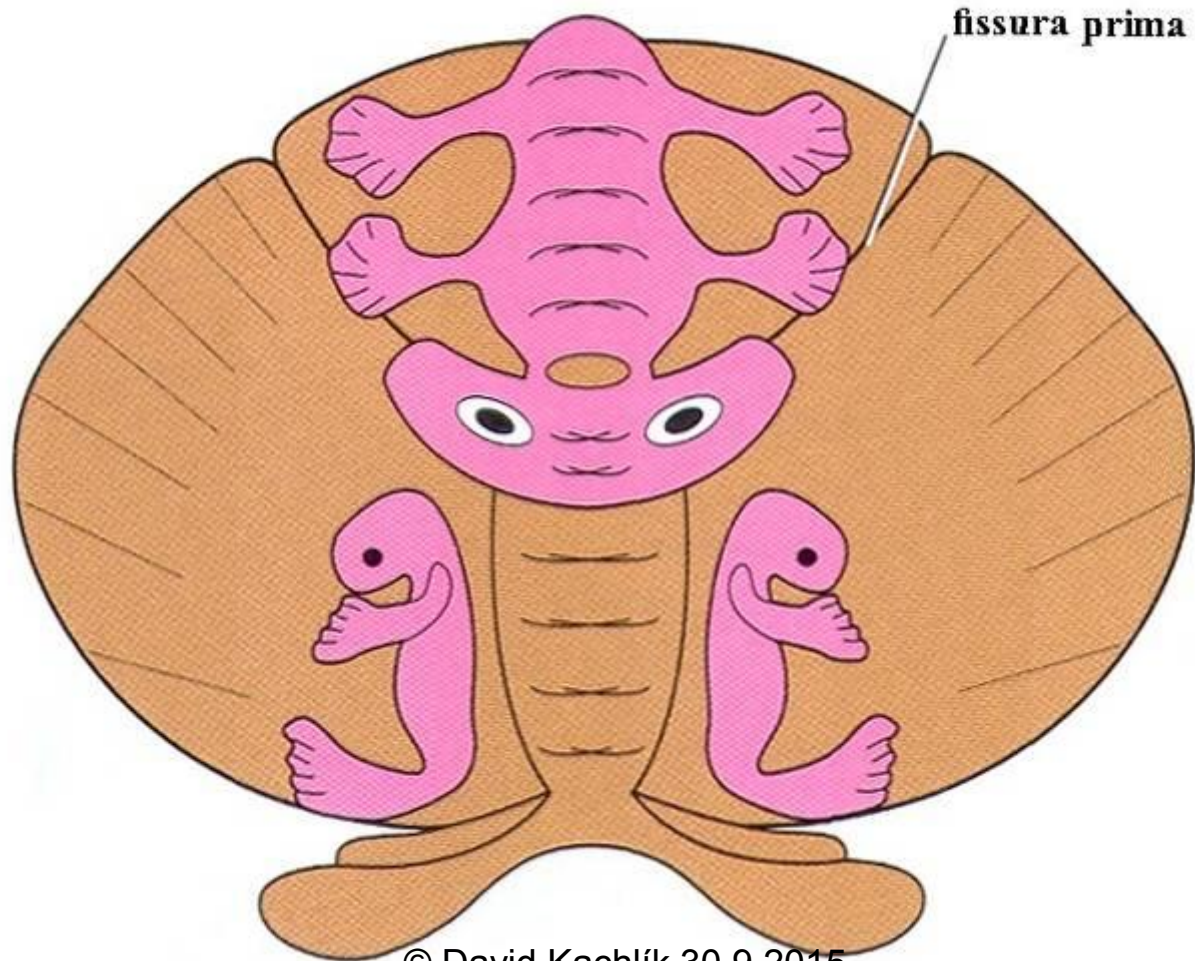






# Mozečkový homunkulus

PROJECTIO SOMATOSENSORIA

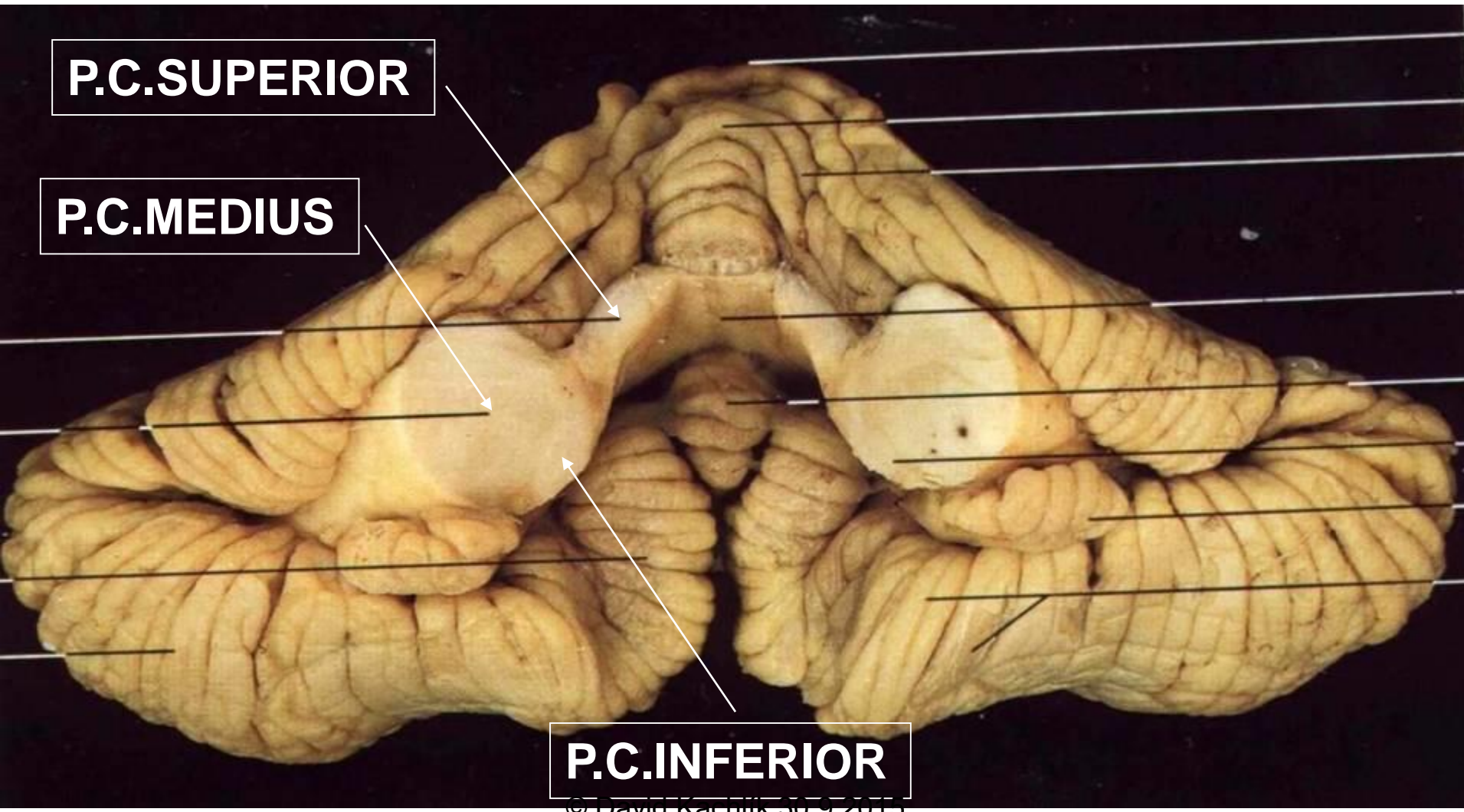


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# Mozeček – stopky

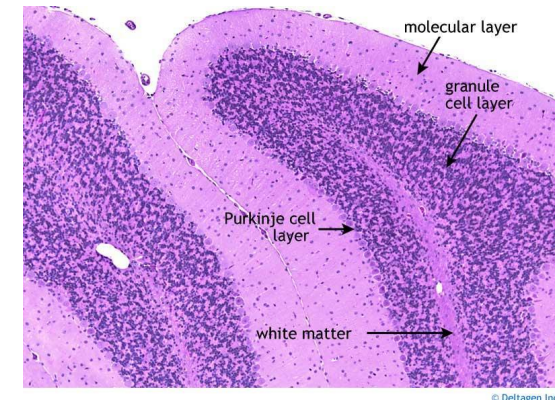
- **pedunculus cerebellaris inferior**
  - corpus restiforme
  - corpus juxtarestiforme
- **pedunculus cerebellaris medius**  
(= brachium pontis)
  - AF: *tractus cortico-ponto-cerebellaris*
- **pedunculus cerebellaris superior**  
(= brachium conjunctivum)

# Mozeček – přední pohled

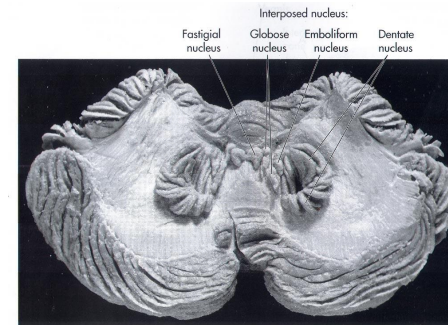


# Mozeček – vnitřní stavba

- **cortex cerebelli (kůra mozečku):** strata (3 vrstvy) – *arbor vitae*
  - stratum moleculare
  - stratum purkinjese
  - stratum granulosum



- **corpus medullare cerebelli:** nuclei cerebelli 4 párová jádra („Don't Eat Greasy Food“)
  - nucleus dentatus (= lateralis cerebelli)
  - nucleus emboliformis (= interpositus anterior)
  - nucleus globosus (= interpositus medialis)
  - nucleus fastigii (= medialis cerebelli)



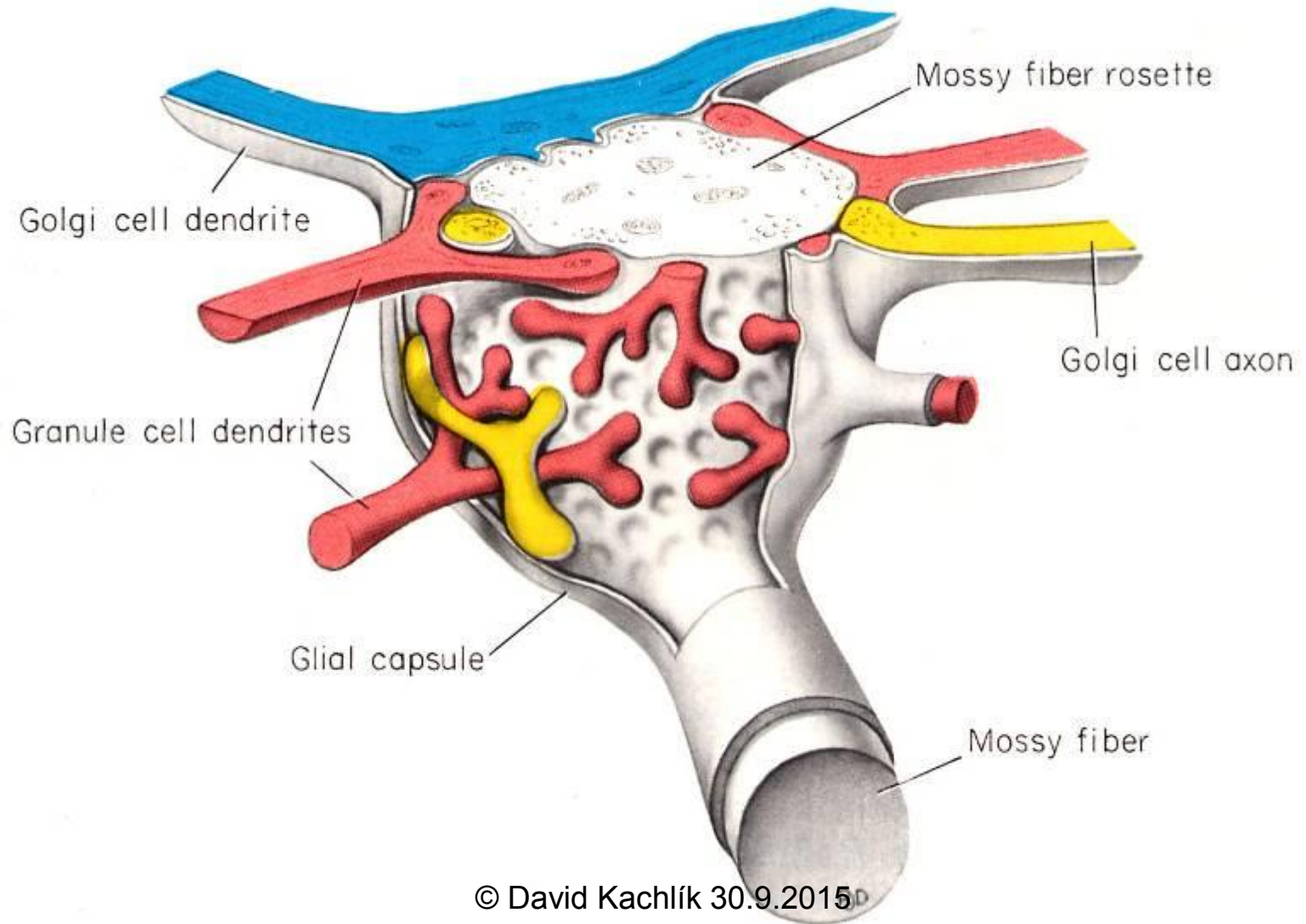
# Mozeček – vrstvy kůry

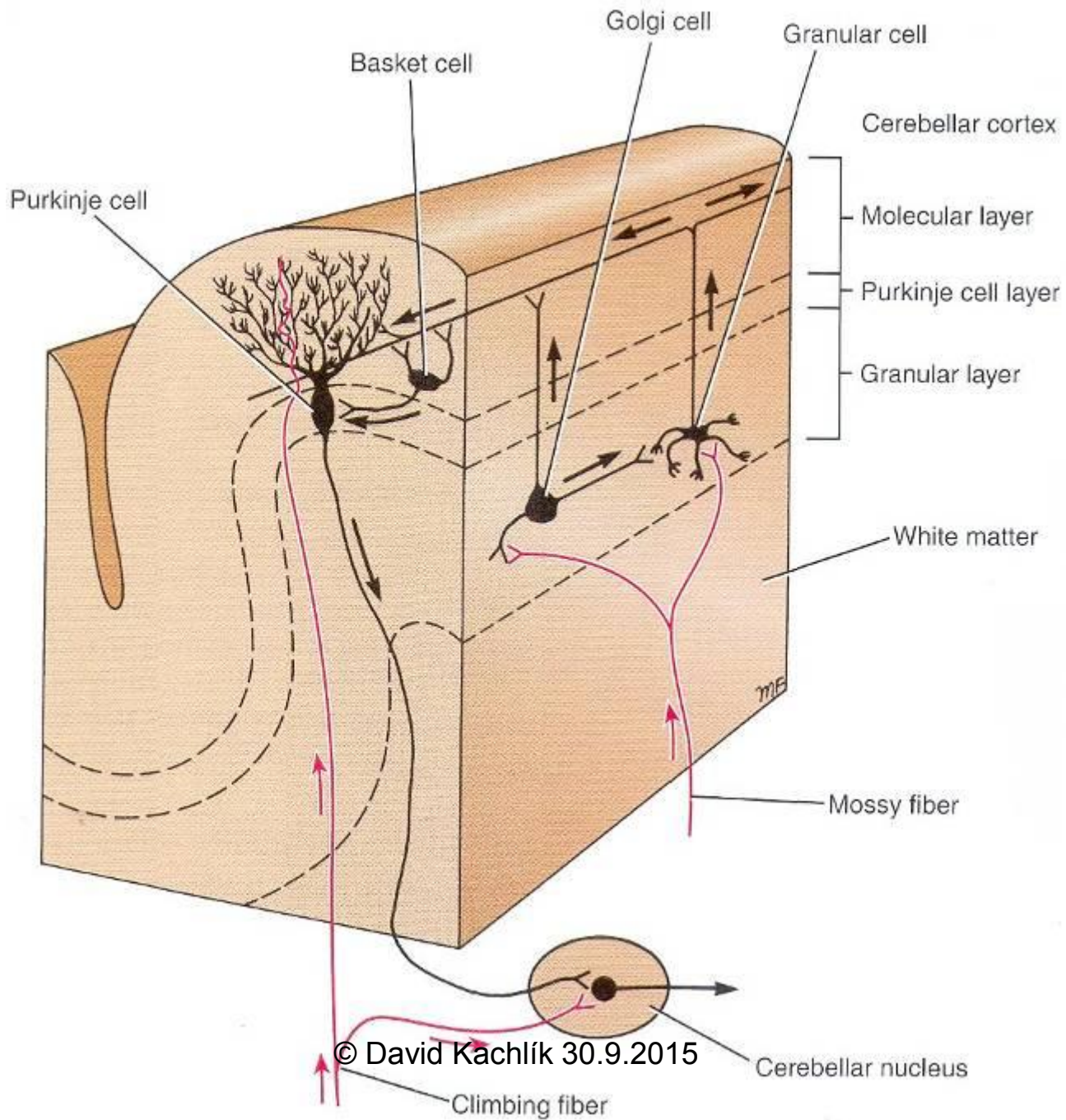
- stratum moleculare
  - neuron stellatum (**hvězdicová buňka**)
  - neuron corbiforme (**košičová buňka**)
  - neurofibra paralela (**souběžné/paralelní vlákno**) – axony zrníčkových buněk
- stratum purkinjese

(= *dříve* stratum neurium piriformium; stratum gaglionicum)

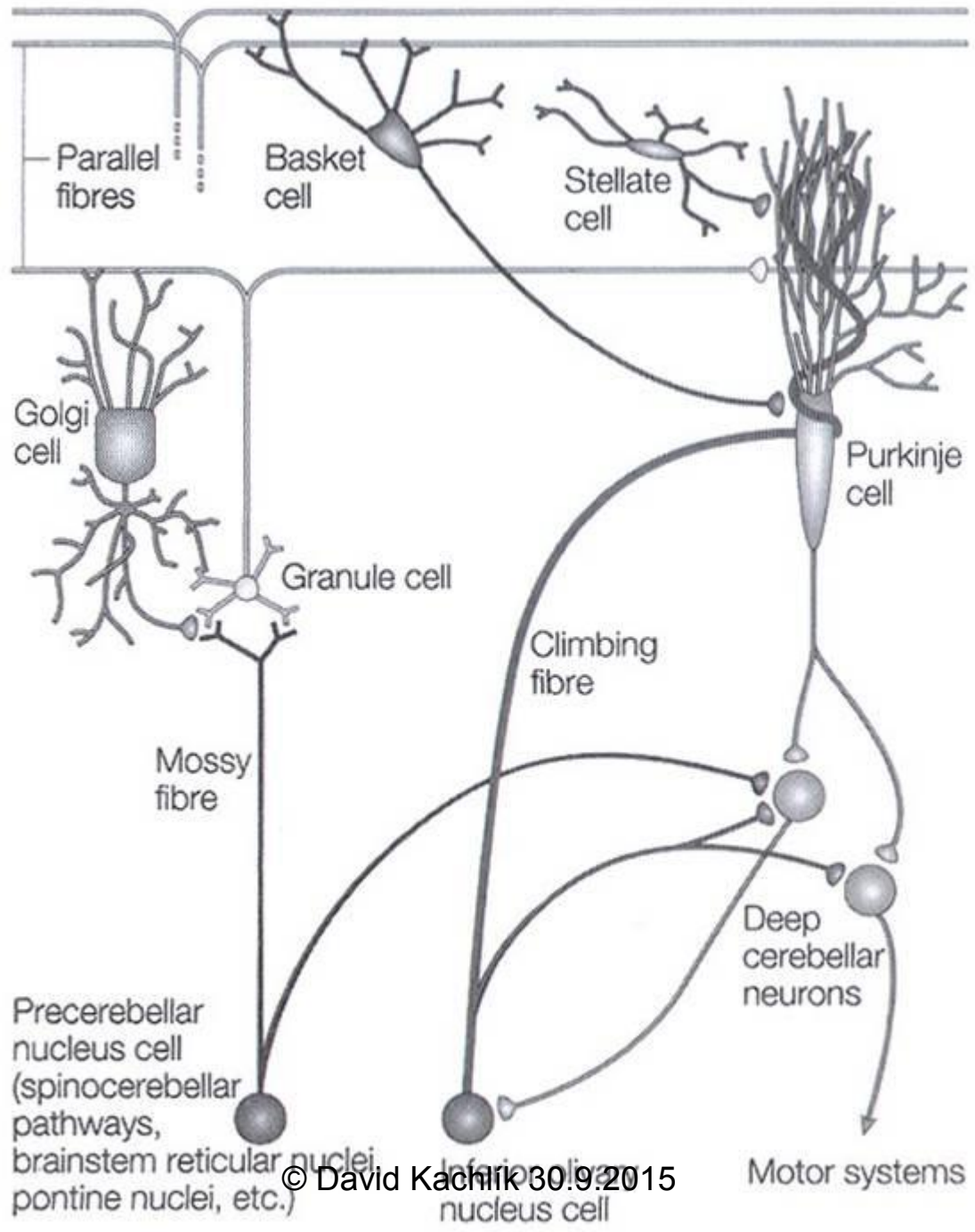
  - neuron purkinjese (**Purkyňova buňka**)
    - corbis neurofibrarum (bohaté větvení do stratum moleculare)
    - axony k jádrům mozečku
- stratum granulare
  - neuron granulosum (**zrníčková/granulární buňka**)
  - neuron stellatum magnum Golghi (**Golgiho buňka**)
  - další 3 typy buněk
  - glomerulus cerebelli
  - aferentní vlákna: neurofibra muscosa (**mechové vlákno - Glu**) + ascendens (**šplhavé vlákno Asp**)

# Glomerulus cerebelli

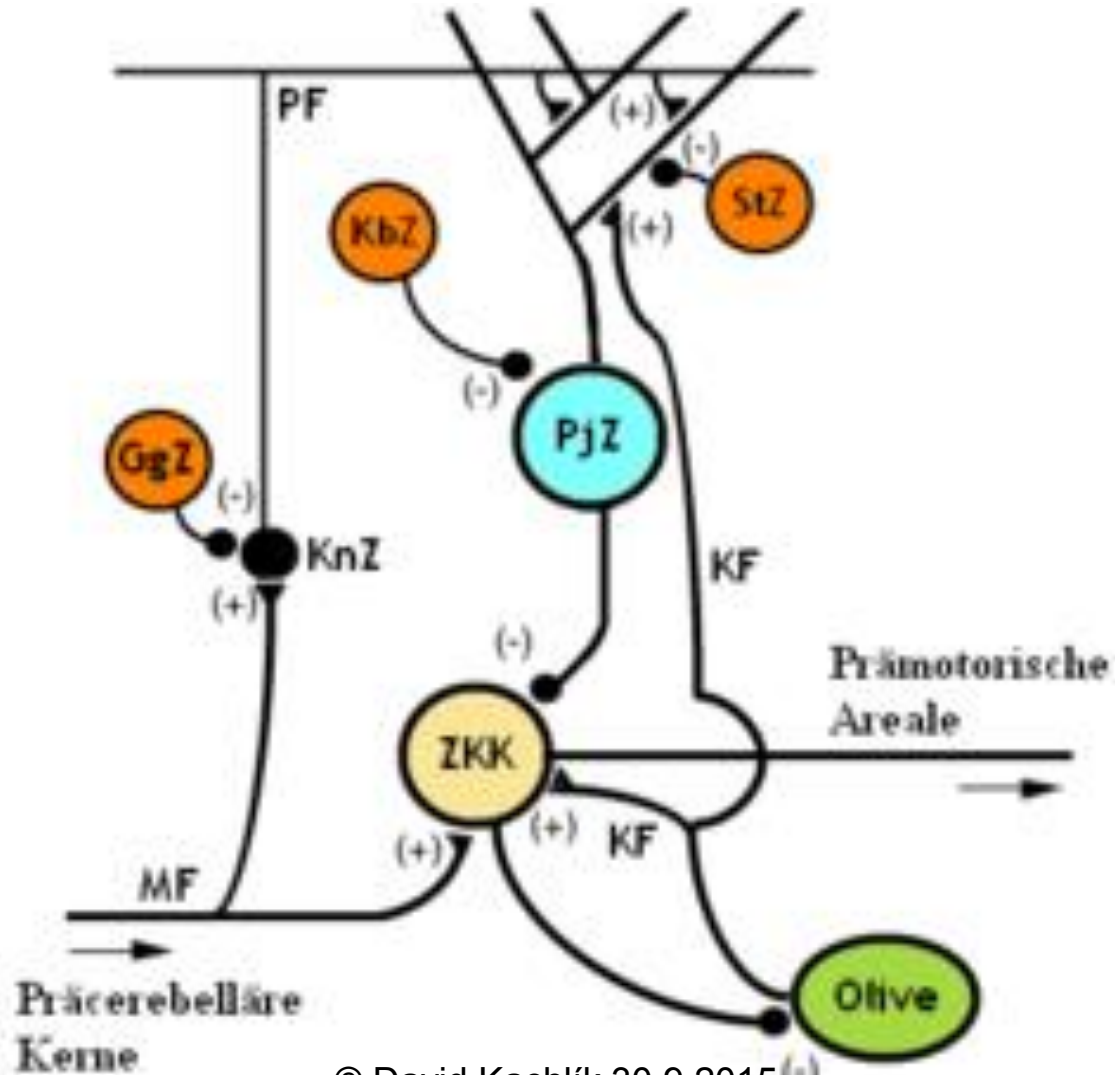








# Zapojení buněk



## Cerebellum: 3 layered cortex

**Climbing fibers:** excite the Purkinje cells

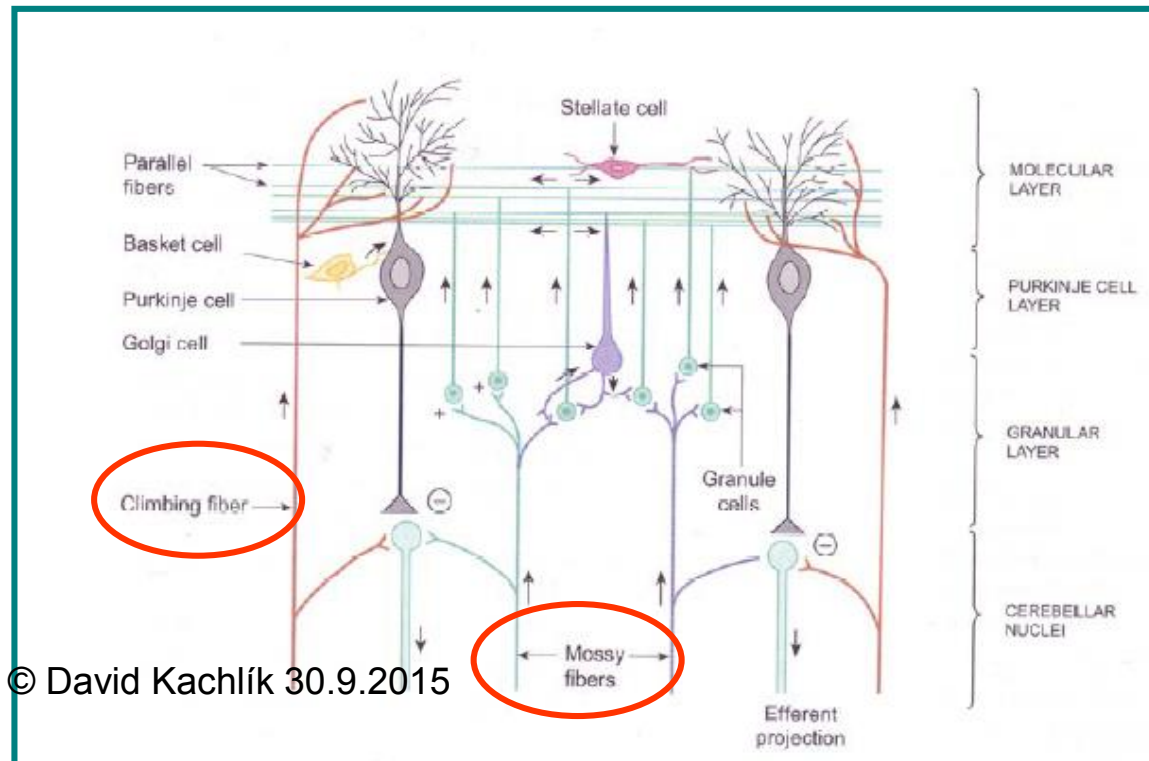
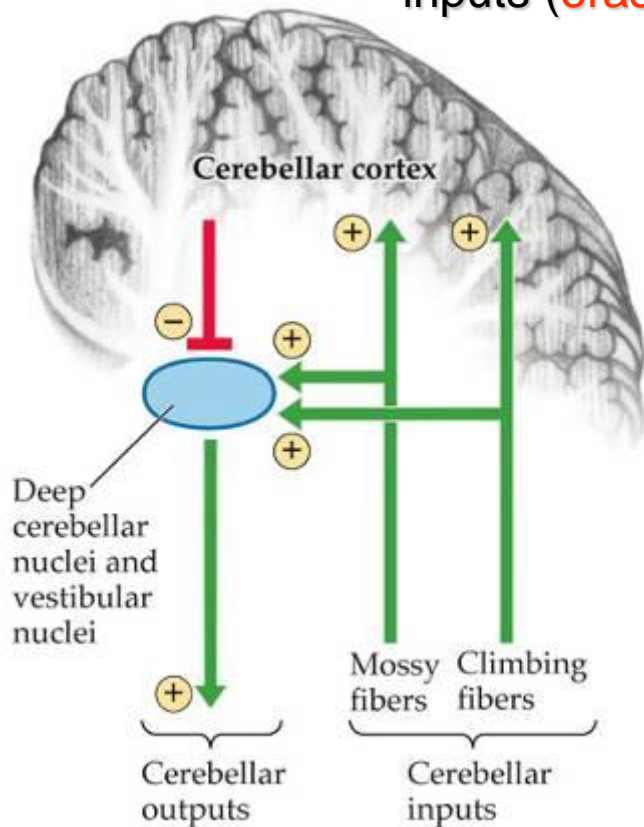
**Mossy fibers:** excite the granule cells

**Granule cells:** make excitatory contact with the Purkinje cells

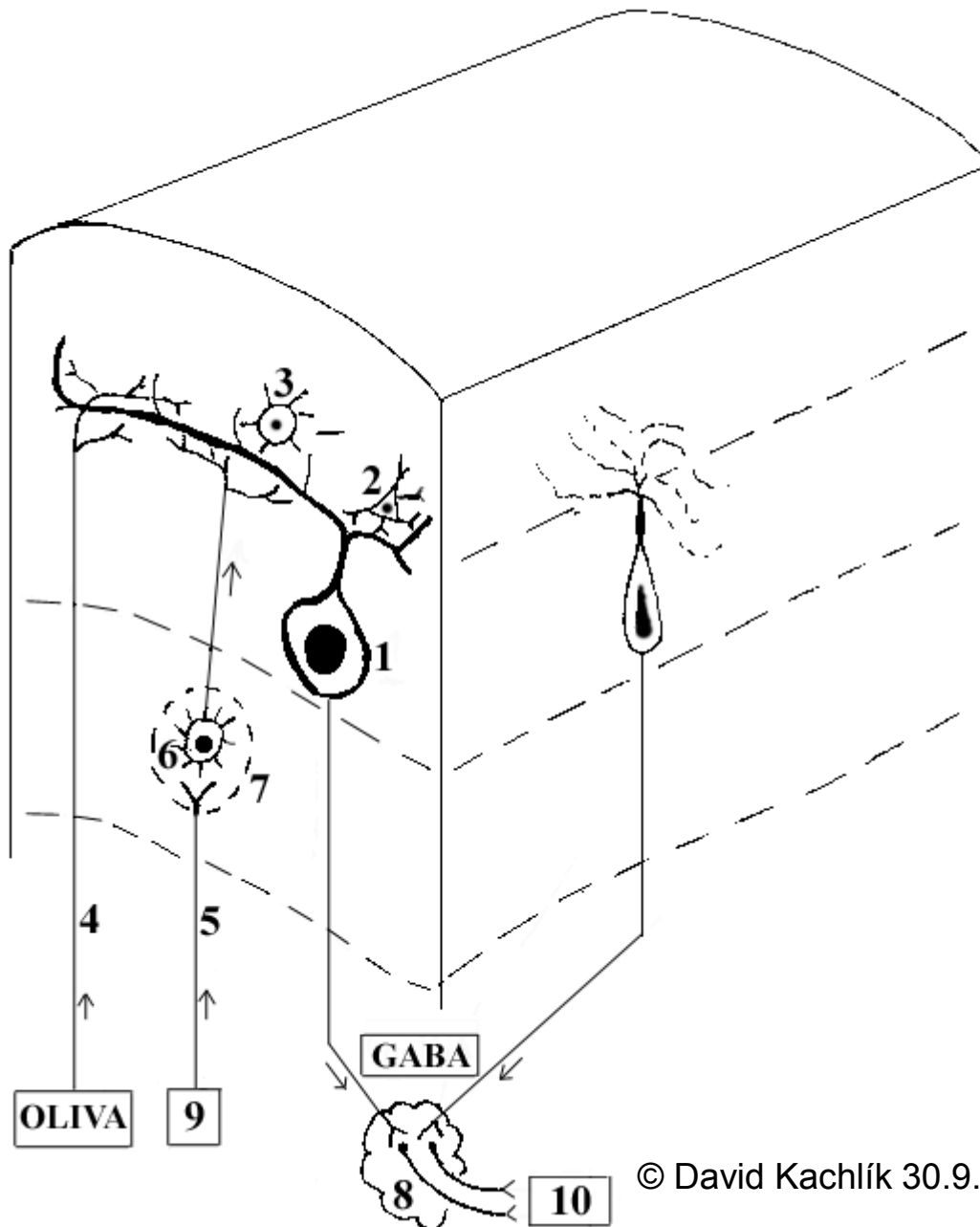
**Purkinje cells:** Tonic inhibition on the activity of the neurons of the cerebellar nuclei

=> All excitatory inputs will be converted to the inhibition

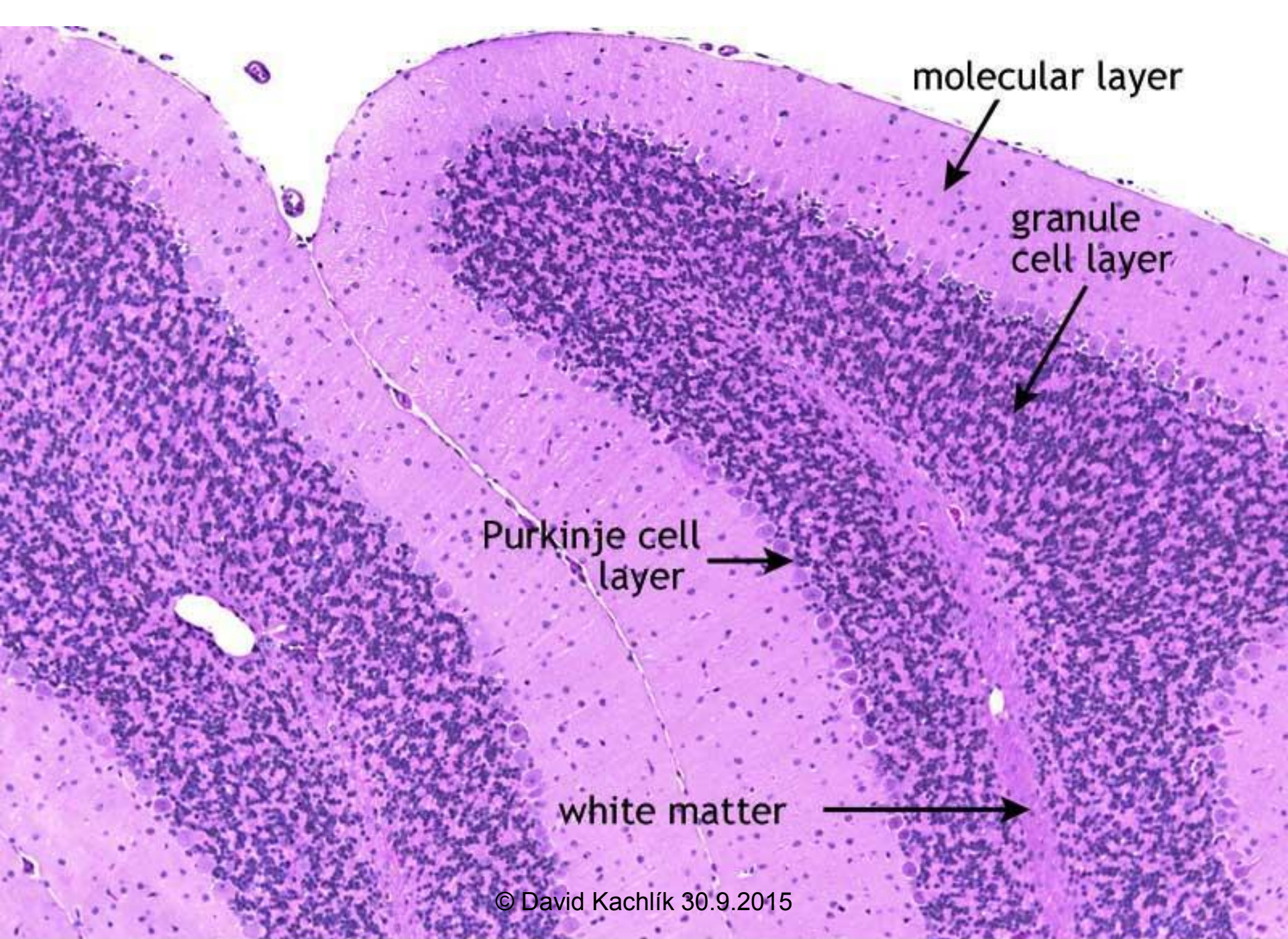
=> Removing the excitatory influence of the cerebellar inputs (**erasing**)



# OBEČNÁ STAVBA MOZEČKU - ŘEZ KŮROU



- 1 - Purkyňovy buňky (inhibice mozečkových jader)
  - 2 - košíčkové buňky (inhibice Purkyňových buněk)
  - 3 - hvězdčité buňky (inhibice Purkyňových buněk)
  - 4 - šplhavá vlákna (excitace Purkyňových buněk)
  - 5 - mechová vlákna (excitace Purkyňových buněk)
  - 6 - granulární buňky
  - 7 - mozečkové glomeruly
  - 8 - mozečková jádra
  - 9 - mozečkové aferenty
  - 10 - mozečkové eferenty
- GABA - gama-aminomáselná kyselina



molecular layer

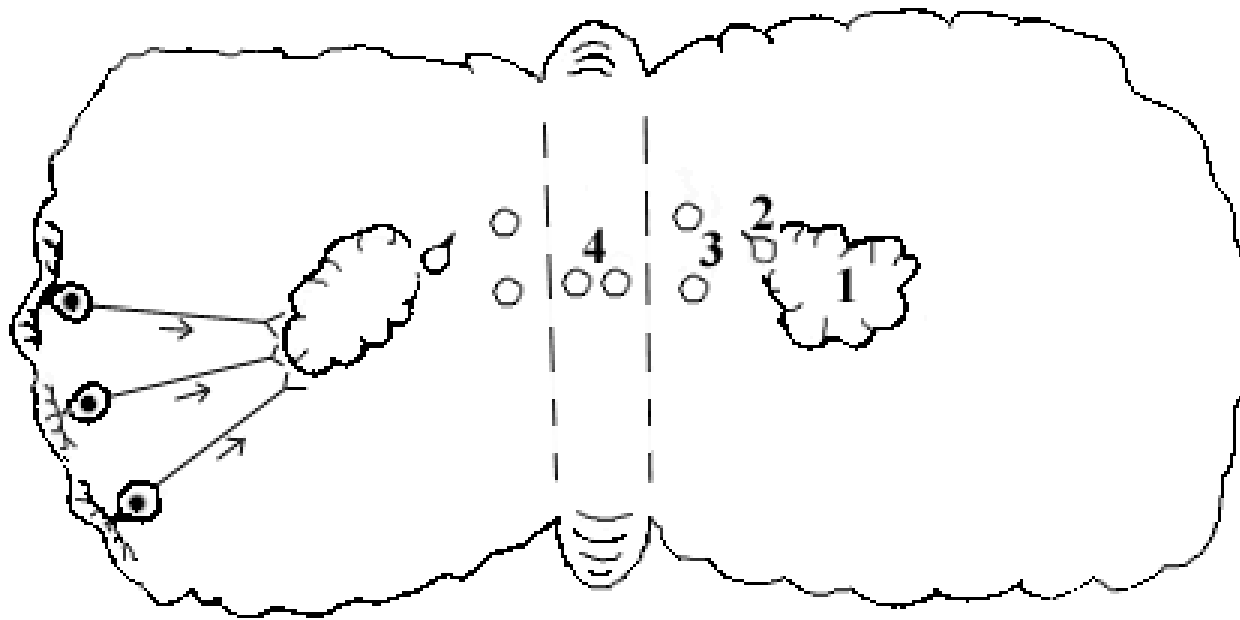
granule cell layer

Purkinje cell layer

white matter

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# Mozeček – jadra



- 1 - nucleus dentatus  
(ncl. lateralis cerebelli)
- 2 - nucleus emboliformis  
(ncl. interpositus anterior)
- 3 - nucleus globosus  
(ncl. interpositus posterior)
- 4 - nucleus fastigii  
(ncl. medialis cerebelli)

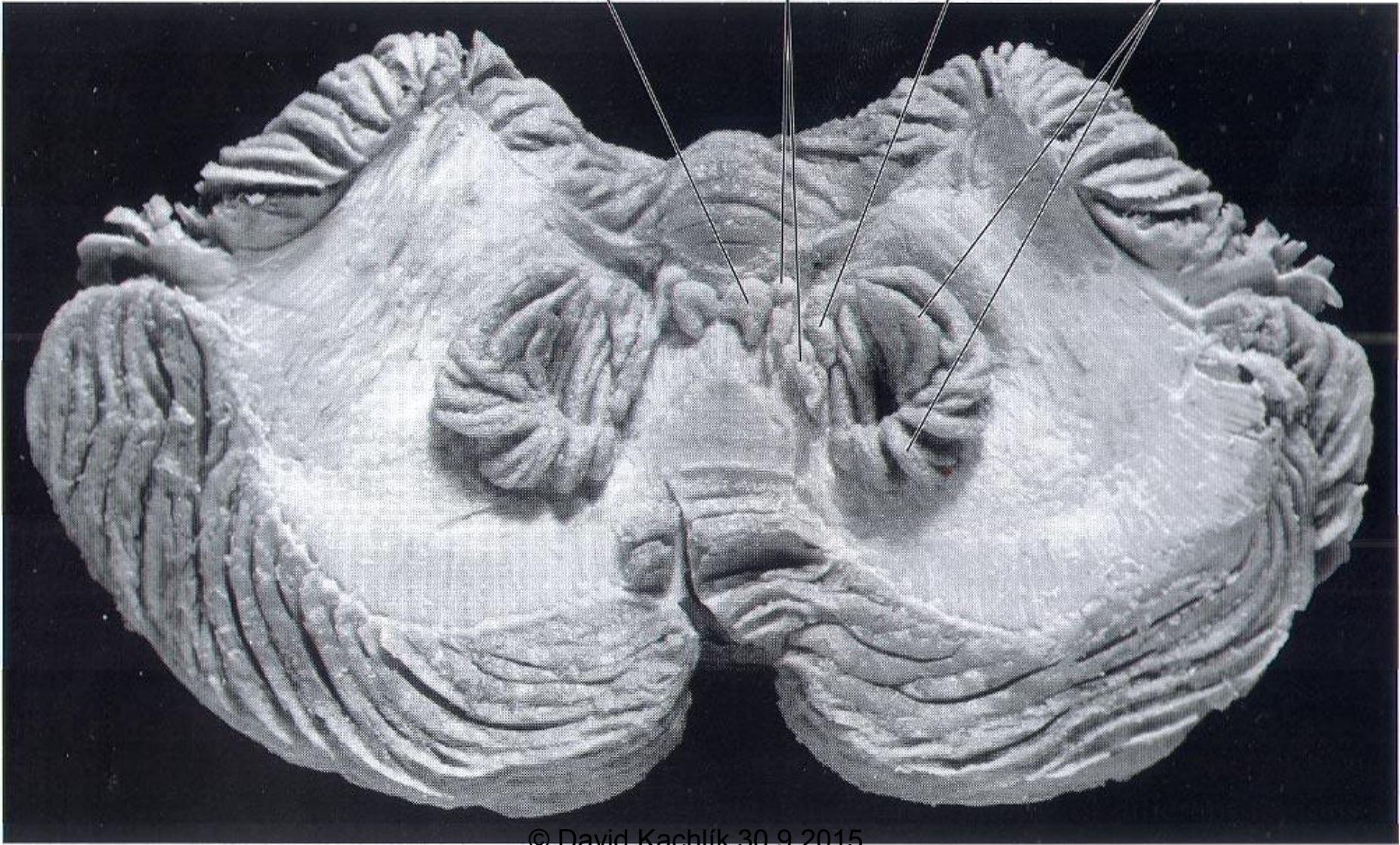
Interposed nucleus:

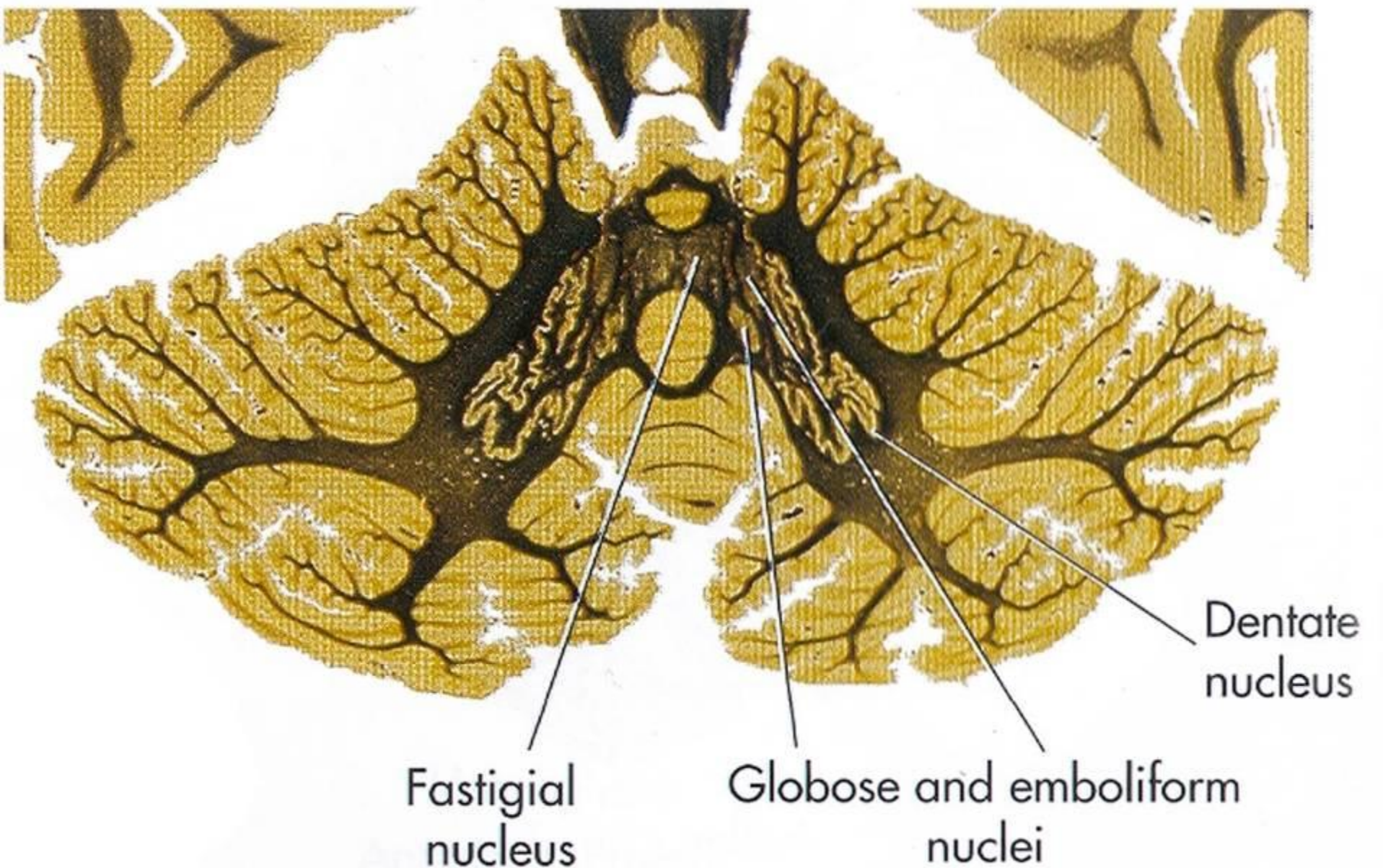
Fastigial  
nucleus

Globose  
nucleus

Emboliform  
nucleus

Dentate  
nucleus





Fastigial  
nucleus

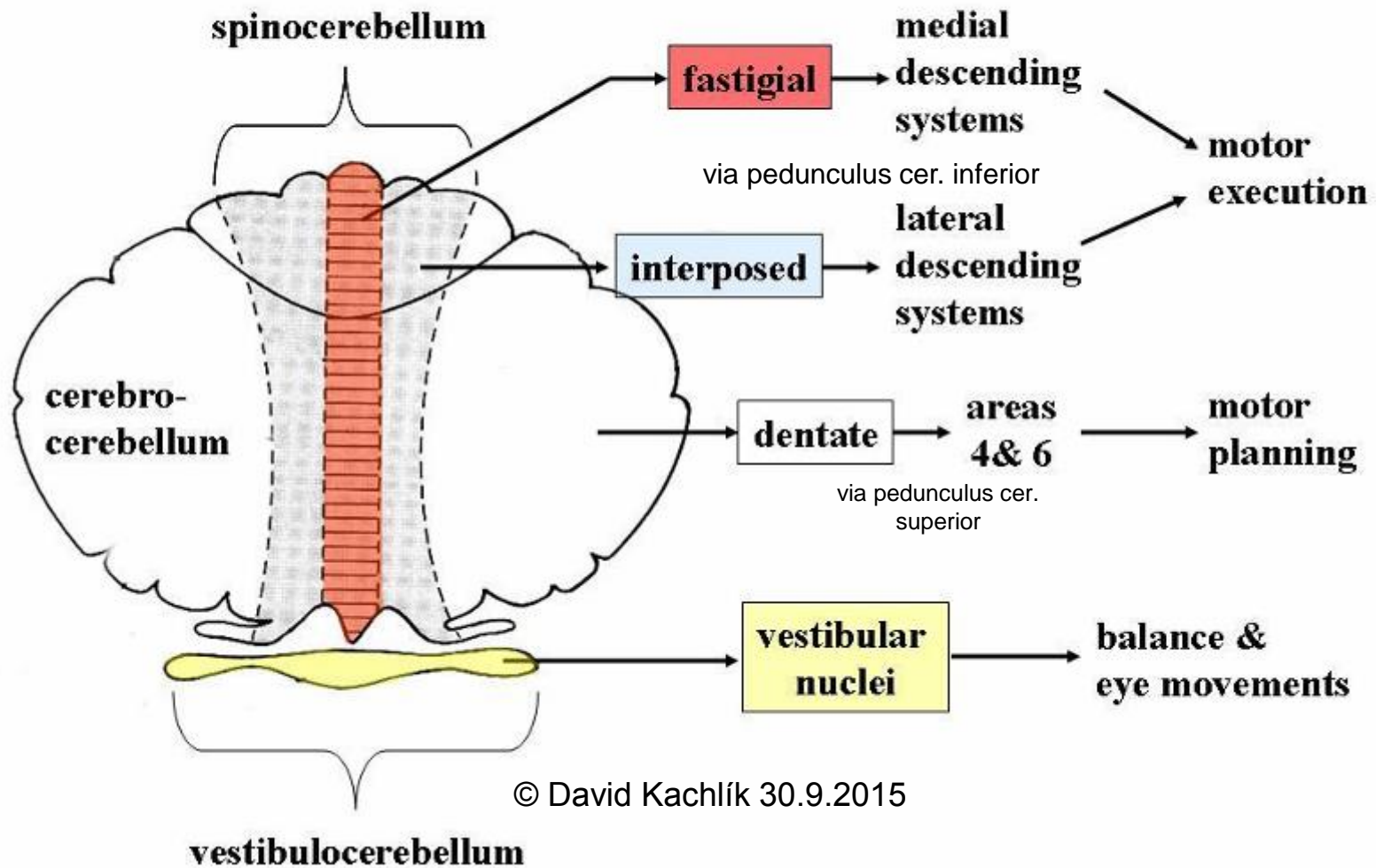
Globose and emboliform  
nuclei

Dentate  
nucleus



# Mozeček – jádra a zapojení

## Cerebellar Output



# Mozeček – aferentace *rovnováha*

- tractus vestibulocerebellaris directus

vestibulum → corpus juxtarestiforme (v PCI) →  
nodulus + uvula (*ipsilat.*)

*míjí ncl. vestibulares a vede přímo do mozečku !*

- tractus vestibulocerebellaris indirectus

vestibulum → ncl. vestibulares → corpus  
juxtarestiforme (v PCI) → lobus  
flocculonodularis + vermis (*bilat.*)

- tractus trigeminocerebellaris

informace z hlavy

# Mozeček – aferentace

## *pasivní propiocepce (polohocit)*

- tractus spinocerebellaris posterior

ncl. thoracicus post. *Stilling-Clarke*

→ medulla oblongata → pedunculus cer. inf.

→ vermis + paravermální kůra (*ipsilaterální*)

**polohocit z trupu a DK**

- tractus cuneocerebellaris

dráha zadních provazců → nucleus cuneatus  
accessorius

**polohocit z HK a hrudníku**

# Mozeček – aferentace

## *aktivní propriocepce (pohybocit)*

- tractus spinocerebellaris anterior

ncl. thoracicus post. *Stilling-Clarke* → křížení na míšní úrovni → mesencephalon → pedunculus cer. superior → křížení v mozečkové kůře → vermis + paravermální kůra (*ipsilaterální*) – **DK**

- tractus spinocerebellaris rostralis

ncl. thoracicus post. *Stilling-Clarke* → pedunculus cer. inferior → vermis + paravermální kůra (*ipsilaterální*) – **HK**

- tractus spinoolivaris

– motorické učení

– *např. lezení do schodů, které jsou prudké*

# Mozeček – aferentace z kůry

- **tractus cortico-ponto-cerebellaris** (20.000.000 vláken)

lobus f,p,o,t → capsula interna → ncll. pontis → fibrae pontis transversae → křížení → pedunculus cer. medius → kůra mozečku (*kontralat.*)

- **tractus cortico-olivo-cerebellaris**

lobus f,p,o,t → capsula interna → complexus olivaris inf. (*bilat.*) → křížení → pedunculus cer. inferior → kůra mozečku

- **tractus cortico-reticulo-cerebellaris**

lobus f,p,o,t (hlavně senzomotorická kůra) → capsula interna → RF (*bilat.*) → křížení → pedunculus cer. medius + inf. → kůra mozečku

**volní motorika, příprava pohybu, nastavení správného svalového tonu**

# Mozeček – eferentace

## ncl. fastigii

1. → PCI → RF (*bilat.*) → tr. reticulospinalis
2. → PCI → ncl. vestibularis lat. *Deitersi* (*bilat.*) → tr. vestibulospinalis
3. → hlavové nervy, svalstvo krku

## ncll. interpositi (globosus + emboliformis)

→ PCS → křížení → ncl. ruber (pars magnocellularis) → tractus rubrospinalis → křížení → mícha (*ipsilat.*)

## ncl. dentatus

→ PCS → křížení → ncl. VA+VL thalami → area 4  
→ tr. pyramidalis → křížení → mícha (*ipsilat.*)

# Mozeček – dolní stopky pedunculi cerebellares inferiores

- corpus restiforme

- AF↑: tr. spinocerebellaris posterior + rostralis, tr. cuneocerebellaris, tr. spinoolivaris
- AF↑: tr. spino-reticulo-cerebellaris
- AF↓: tr. cortico-reticulo-cerebellaris, cortico-olivo-cerebellaris, cortico-arcuato-cerebellaris

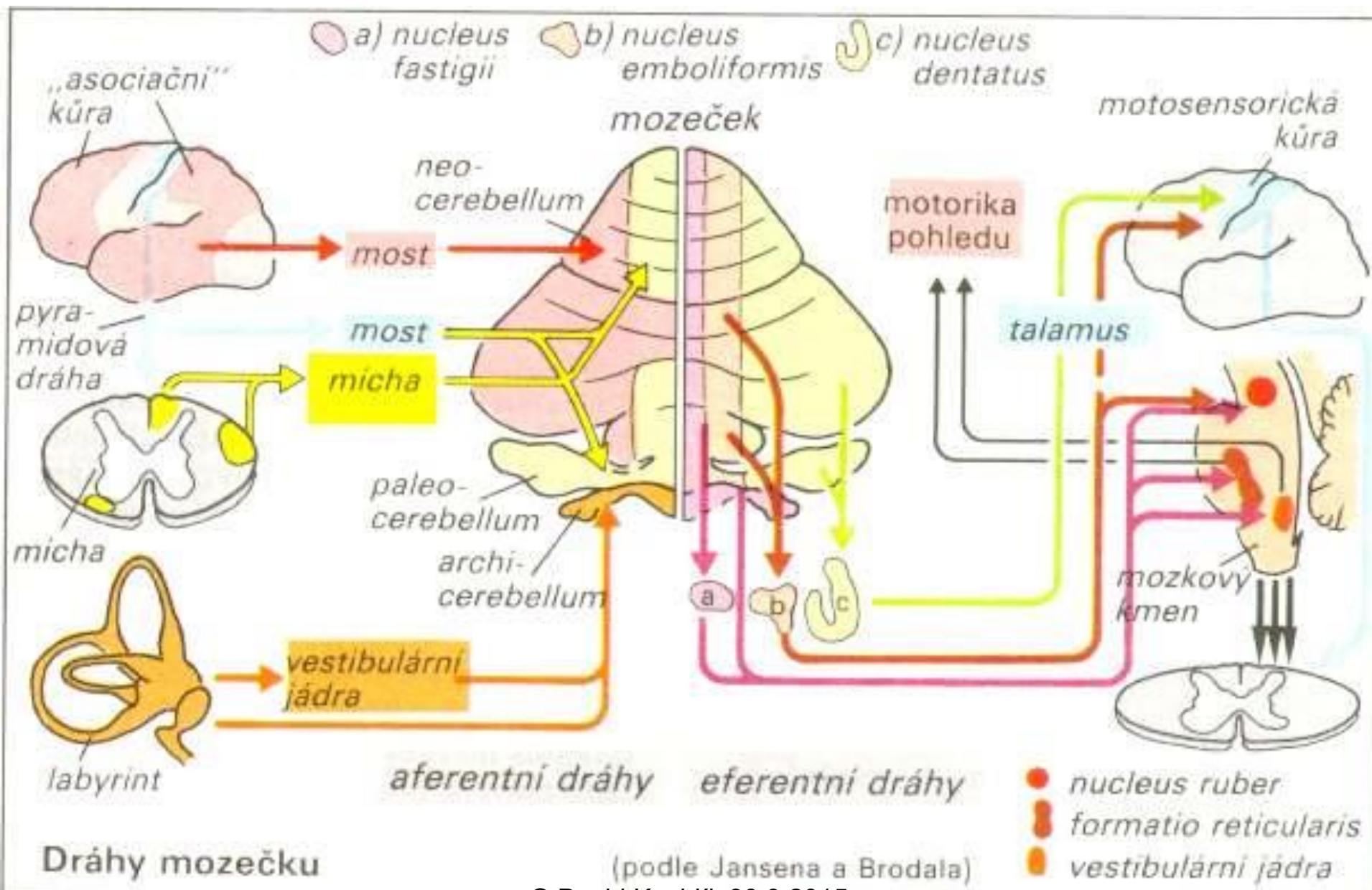
- corpus juxtarestiforme

- AF↑ tr. vestibulocerebellaris directus + indirectus
- EF↓: tr. cerebello-reticulospinalis, - cerebellovestibularis, cerebellospinalis, cerebellonuclearis (vše z *ncl. fastigii*)

# Mozeček – střední a horní stopky pedunculi cerebellares medii et superiores

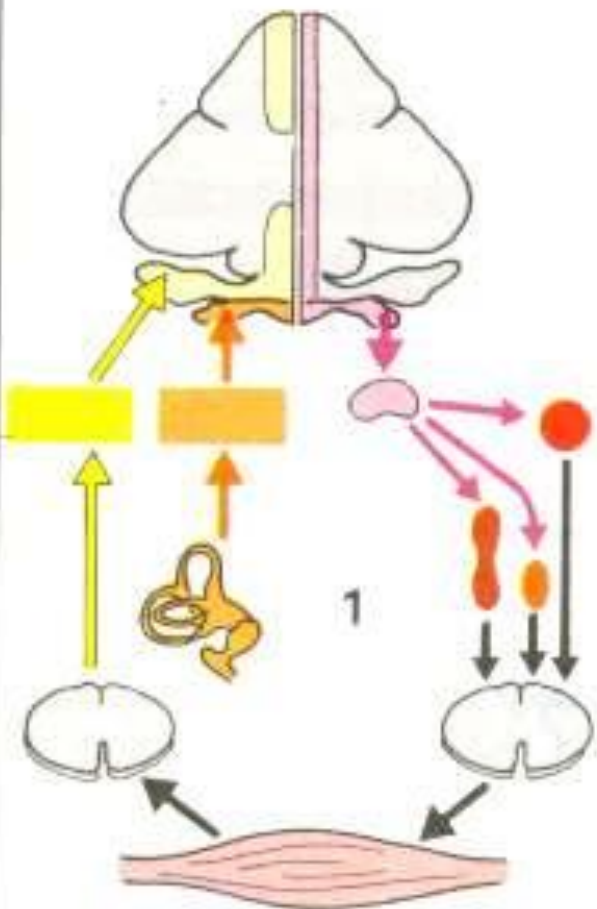
- **pedunculus cerebellaris medius**  
AF↓: tractus cortico-ponto-cerebellaris
- **pedunculus cerebellaris superior**  
AF↑: tr. spinocerebellaris anterior + tectocerebellaris  
EF↓: tr. cerebello-rubro-thalamo-corticalis + tr. cerebello-rubro-spinalis  
EFokruh: tr. cerebello-rubro-olivo-cerebellaris (*Papeziov kontrolní okruh*)





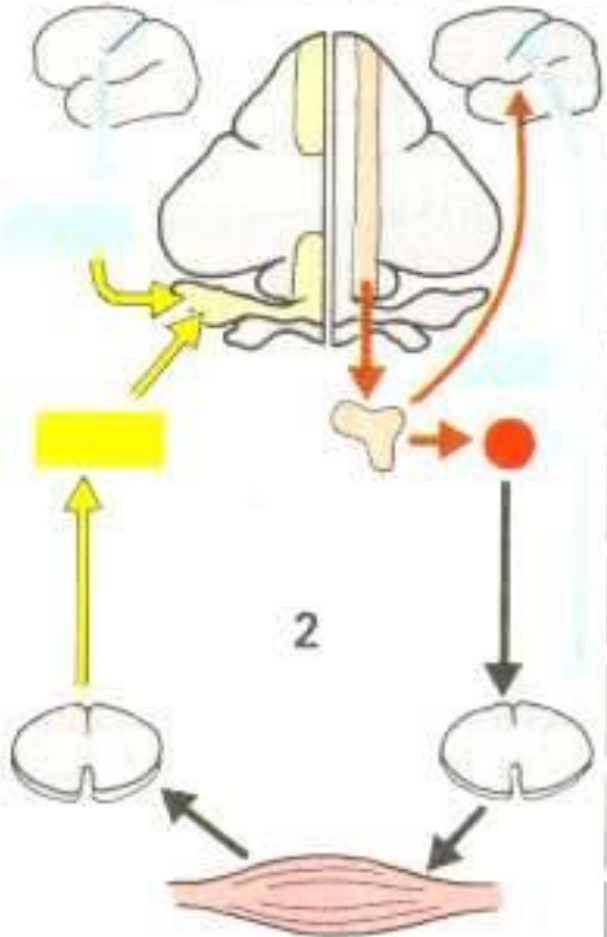
**Dráhy mozečku**

(podle Jansena a Brodala)



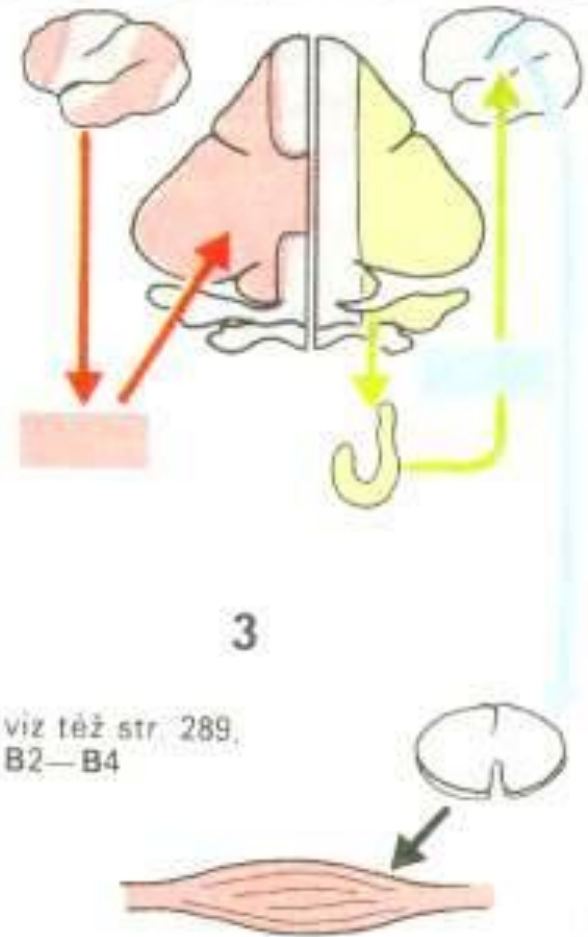
1

optimalizace a korektura opěrné a pohled. motoriky (tonus; držení, rovnováha)



2

koordinace opěrné a cílené motoriky, korektura směru cílené motoriky

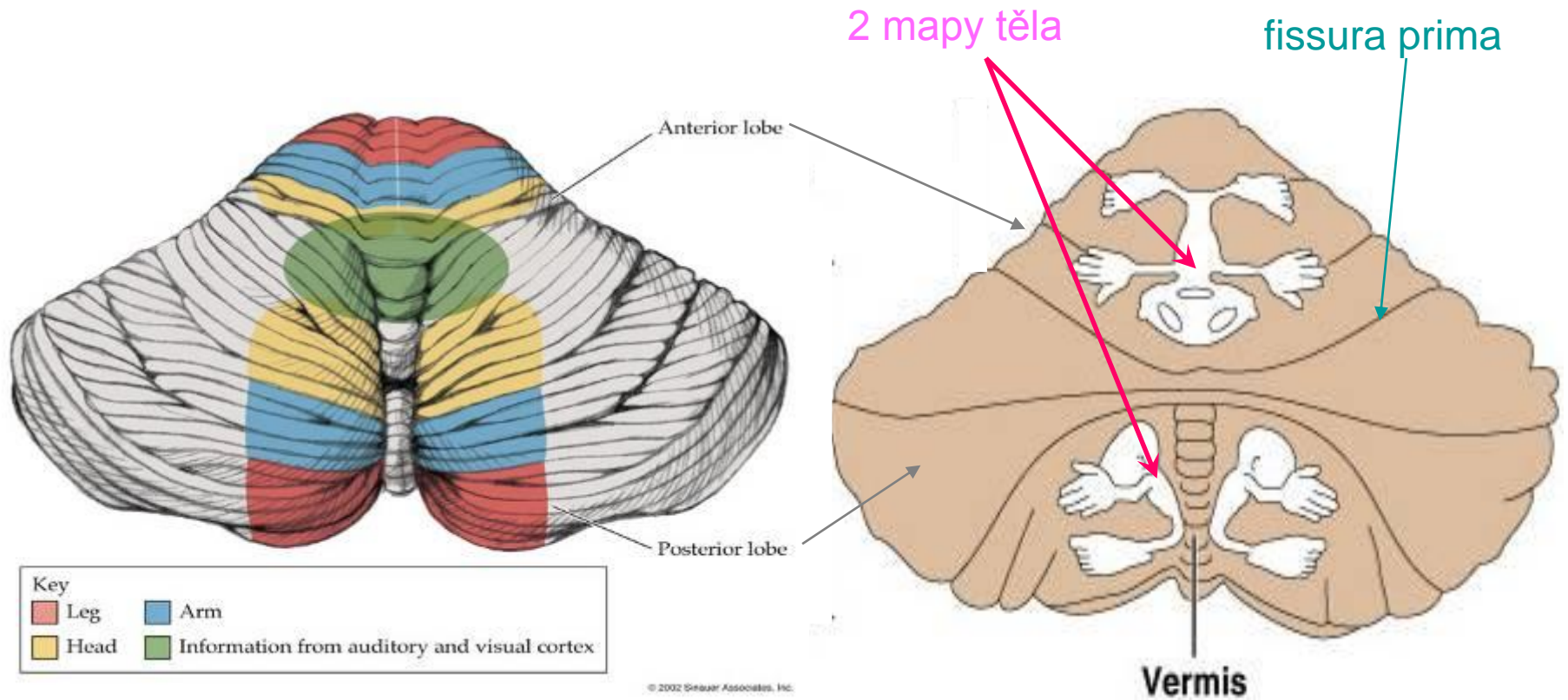


3

viz též str. 289, B2—B4

pohybové programy pro cílenou motoriku (podle R. F. Schmidta)

# Aferentace do mozečku somatotopická organizace



somatosenzorická a motorická projekce z mícha a mozkové kůra je do stejných míst

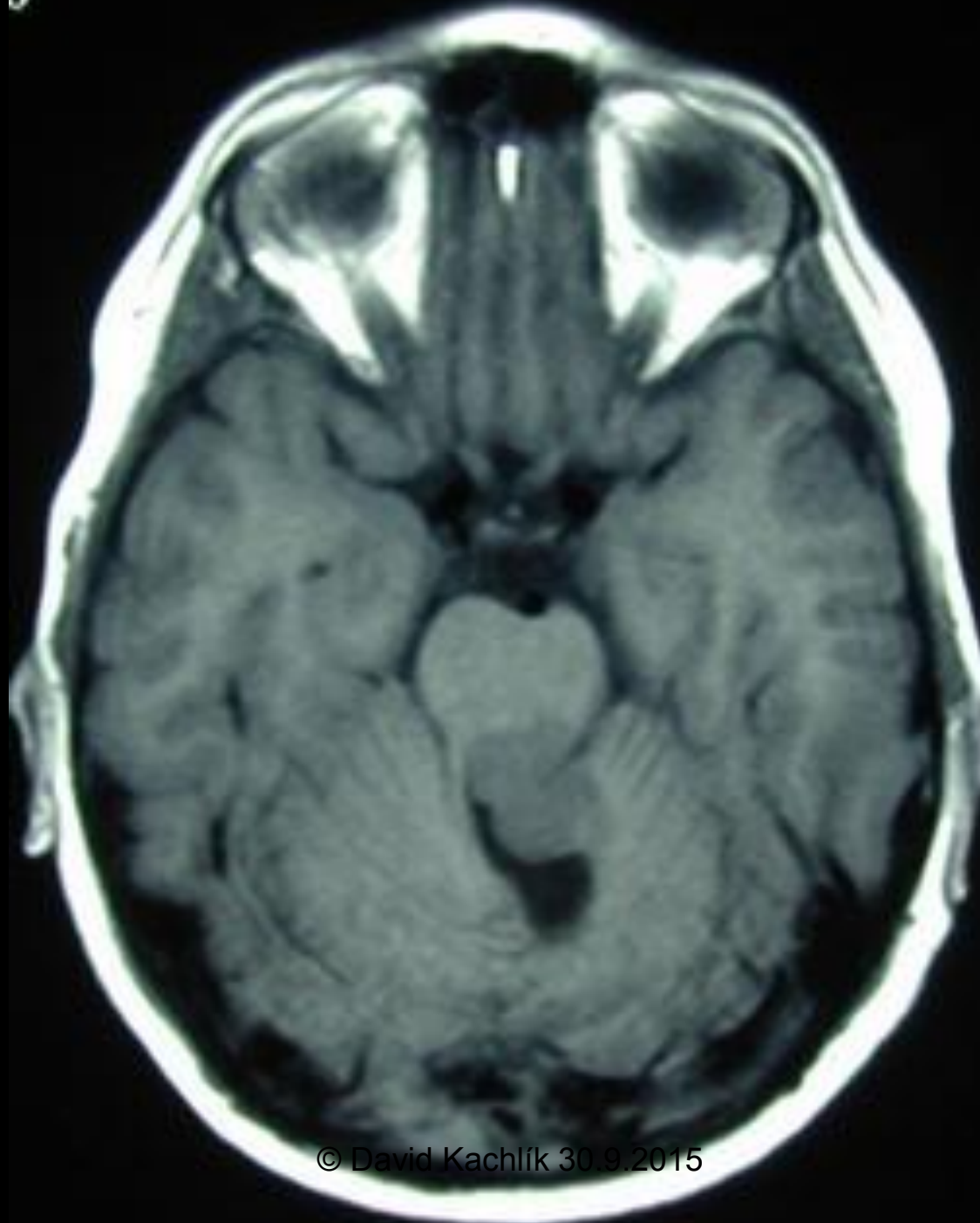
Function	Movement parameters	Visually-guided movements	Working memory
Cortical area	M1	PMv	PFC
Thalamic nucleus	VPLo	X	MD/VLc
Cerebellum	DN Dorsal	DN Lateral	DN Ventral

**Fig. 4 Output channels in the dentate nucleus.** Schematic diagram indicating the cerebello-thalamocortical connections of three output channels in the dentate (DN dorsal, lateral and ventral). It also illustrates the observation that neurons within individual output channels appear to be involved in different aspects of motor and non-motor behavior, consistent with the areas to which they project. (M1, primary motor cortex; MD, medialis dorsalis; PFC, prefrontal cortex; PMv, ventral premotor cortex; VLc, ventralis lateralis pars caudalis; VPLo, ventralis posterior lateralis pars oralis; X, area X.)

# Archicerebellum (vestibulocerebellum)

- lobus flocculonodularis + vermis
- rovnováha
- *nystagmus*
- spojení s ncl. vestibulares  
(inferior + medialis)

nejčastější příčina: *meduloblastom*



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# Paleocerebellum (spinocerebellum)

- lobus anterior
- AF: tractus spinocerebellaris anterior + posterior
- polohocit a pohybocit (informace o reflexech)
- kolaterály přímo na mozečková jádra
- EF: činnost antigravitačních svalů, koordinace činnosti agonistů/antagonistů
- postoj (chůze)

# Neocerebellum (cerebrocerebellum)

- lobus posterior
- AF: tractus cortico-ponto-cerebellaris
- kolaterály k mozečkovým jádrům
- EF: motorická kontrola
  - koordinace jemných pohybů končetin
  - zpětnovazebná úprava motorické aktivity
  - společně s mozkovou kůrou plánuje pohyby



# Mozečkový syndrom

- svalová hypotonie (zvýšený rozsah a pasivita pohybů)
- ataxie (porucha koordinace)
  - hypermetrie – dysmetrie
    - makrografie, skandovaná řeč, megafonie, bradylálie
  - adiadochokinéza
  - asynergie („opilecká chůze“)
- intenční tremor
- nystagmus a závratě
- (hyporeflexie elementárních posturálních reflexů)

# Mozečkový kognitivně-afektivní syndrom

- porucha exekutivních funkce
- postižení prostorových úloh
- osobnostní změny
  - oploštění, desinhibice, neadekvátní chování
- jazykové obtíže
  - dysprosodie, agrammatismus, mírná anomie

# Mozečková ataxie

ataxická chůze a  
postoj  
*nádor mozečku  
vlevo*

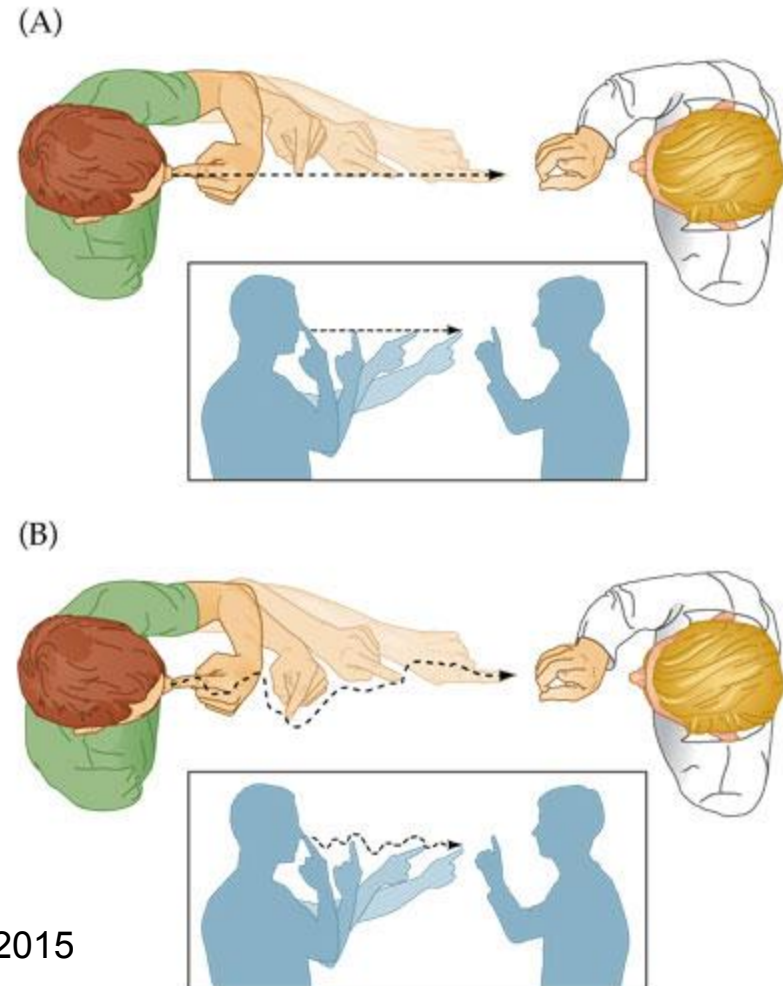
- ve stoje padání  
doprava
- pevný stoji na  
pravé noze
- vratký stoj na  
levé noze
- ataktická  
chůze



## Clinical Findings and Localization of Cerebellar Lesions

Ataxia refers to disordered contractions of agonist and antagonist muscles and lack of coordination between movements at different joints typically seen in patients with cerebellar lesions. Normal movements require coordination of agonist and antagonist muscles at different joints in order for movement to have smooth trajectory. In ataxia movements have irregular, wavering course consisting of continuous overshooting, overcorrecting and then overshooting again around the intended trajectory.

Dysmetria = abnormal undershoot or overshoot during movements toward a target (finger-nose-finger test).



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# Mozeček - hlavní okruhy

- okruh: mozková kůra-mozeček

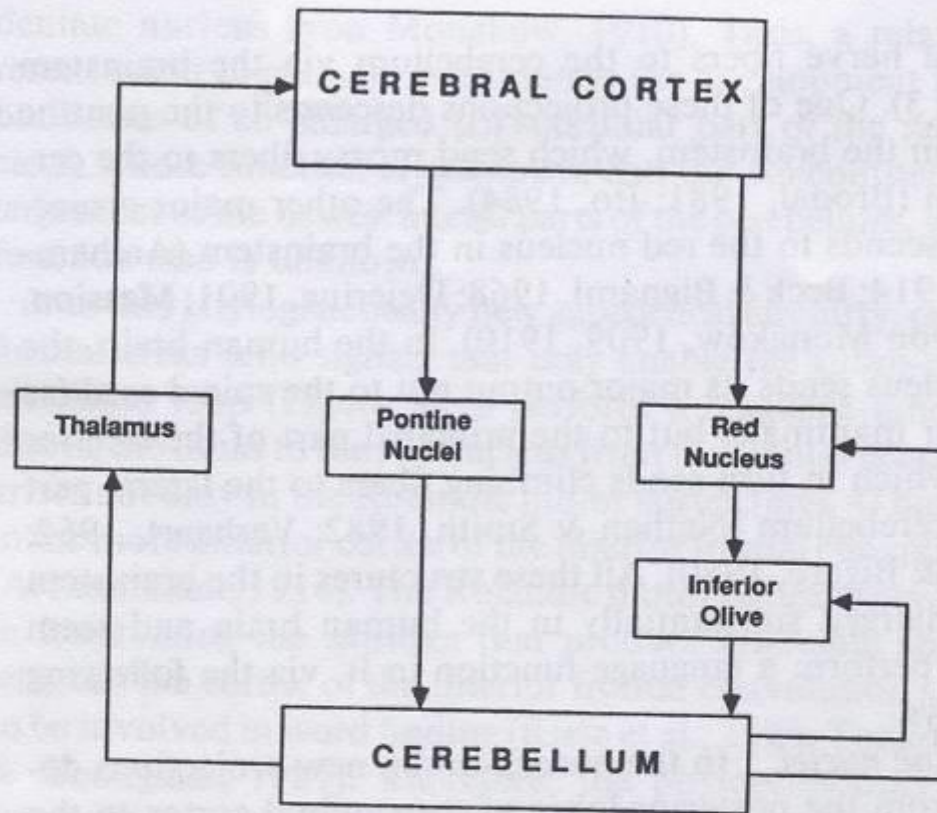
mozková kůra → most / oliva / RF (oliva) – ncl. pontis / complexus olivaris inferior → *křížení* → kůra → ncl. dentatus → *křížení* → thalamus (ncl. VL) → mozková kůra

- Papezův mozečkový kontrolní okruh:

ncl. dentatus → ncl. ruber (pars parvocellularis) → oliva → ncl. dentatus

– učení se nejen motorickým, ale i kognitivním a jazykovým dovednostem

- mozková kůra – mozeček: **vždy kontralaterálně**
- mozeček – tělo: **vždy ipsilaterálně**



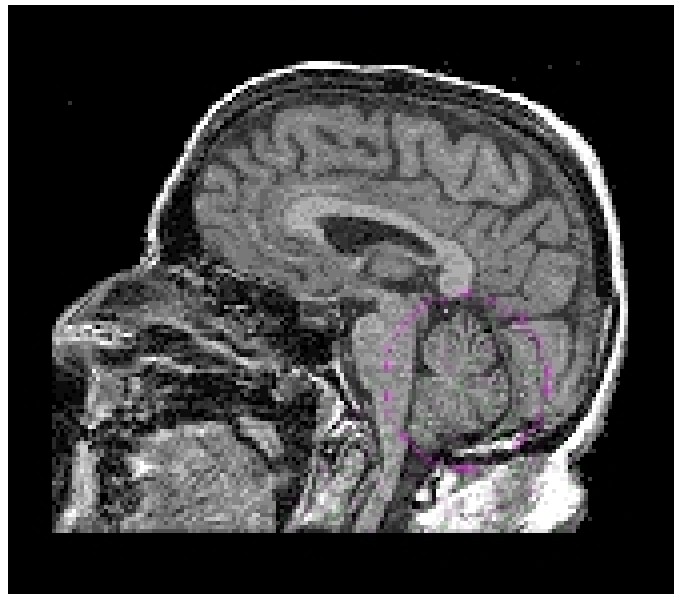
*Figure 3.* Major cerebro-cerebellar loops in the human brain. (From the cerebral cortex, two major sets of projections descend to the cerebellum via enlarged structures in the brainstem, i.e., via pontine nuclei and via rubro-olivary nuclei. The pontine nuclei project mossy fibers to the cerebellum, and the inferior olive projects climbing fibers—a dual input that seems to be a basic pattern of cerebellar organization. The conjunctive activation of mossy fibers and climbing fibers may enable learning to occur in the cerebro-cerebellar loops, leading to the acquisition of new procedural skills, which could include not only motor but also cognitive and language skills.)

# Mozeček - shrnutí

- rovnováha
- převážně motorická funkce
  - tvorba, podpora a udržování svalového napětí
  - součinnost s kůrou při plánování pohybu
  - složité a jemné pohyby: tanec, řeč, psaní
- „komparátor“
- jiné funkce – kognice, senzoričné vnímání

# Alcohol Damages the Cerebellum

Control



Alcoholic



nedostatek thiaminu (B1) způsobuje degeneraci lobus anterior cerebelli

Sullivan et al., *Neuropsychology*, In press



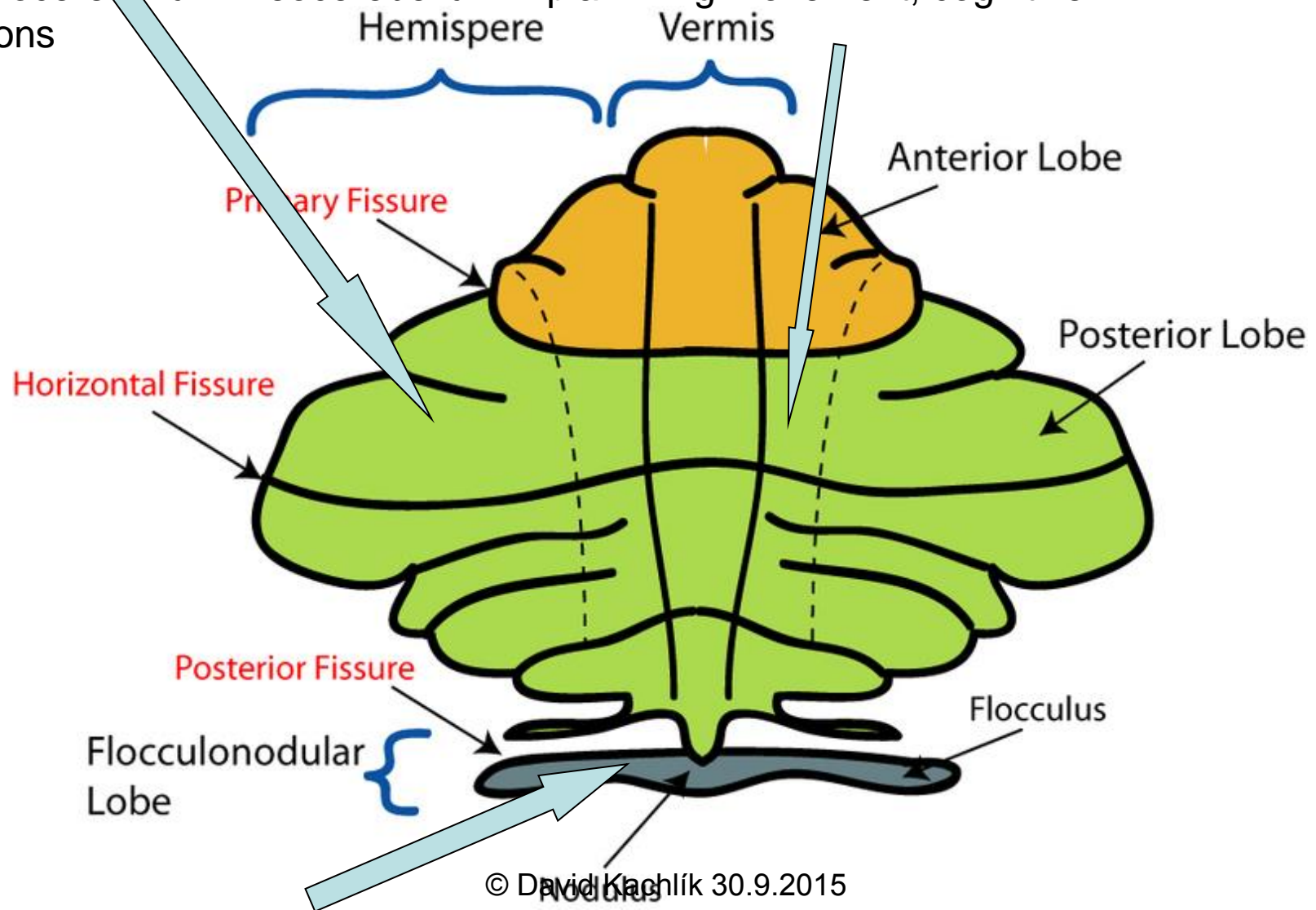
# Take home message

**Medial zone of anterior and posterior lobe**

=paleocerebellum=spinocerebellum=fine tune body and limb movement

**Lateral zone of anterior and posterior lobe =**

cerebrocerebellum=neocerebellum = planning movement, cognitive functions



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**Flocculonodular lobe** = vestibulocerebellum=archicerebellum=balance and gait

# Optional reading: Cerebellar lesions

Petr Zach

# Cerebellar symptoms

- Dysmetria (hypermetria) – invalid targeting and finishing of movements due to delayed or insufficient contraction of antagonists, which normally end movement
- Spontaneous movements are incorrect (cerebellar macrography of Henner – increasing size of letters during writing as opposed to parkinson micrography)
- Bradytelokinesis – ending of movement before reaching target, compensated by cortical atactic spasms

# Cerebellar symptoms

- Dyssynergia (asynergia) – individual muscle groups work independently and complex movement patterns split into particular movements, movement fragments are usually performed with too much/less strength.
- Small asynergia – lesion of cerebellar hemispheres, targeting limb coordination
- Great asynergia – paleocerebellar lesion, deficit of trunk axial muscle – standing, sitting from laying, erecting etc.

# Cerebellar symptoms

- Hypotonia (pasivity) – decrease of muscle tonus, increase in movement range in joints, more pronounced in acute then chronic cerebellar lesion

# Cerebellar symptoms

- I. Ataxia
- -uncoordinated voluntary mvmt.
- II. Hypotonia
- III. Cerebellar Gait
- -wide base
- -may veer towards side of lesion
- -will sway standing with feet together eyes open or closed(not a sign of Rhomberg b/c because none of those three senses are causing the patient to lose balance)
- IV. Intention Tremor
- -present when moving, not at rest
- V. Dysdiadochokinesia
- -inability to move rapidly
- VI. Dysmetria
- -can't measure distance, so there is a loss of control of range mvmts. (pastpointing), cant reach out to perform tasks
- VII. Dysarthria
- -slurred (scanning) speech

# Causes of cerebellar lesions

- I. Multiple Sclerosis
- II. Cerebellar Strokes
- III. Tumors
- IV. Degeneration
- V. Wernicke-Korsakoff Syndrome
  - -caused by Thiamine Deficiency, mostly from alcohol abuse
  - -Wernicke's encephalopathy *symptoms are gait ataxia, nystagmus, diplopia, strabismus*
  - -Korsakoff syndrome- severe anterograde and retrograde amnesia
  - -treatment with glucose and no thiamine can result in death
- VI. Alcoholic Cerebellar Degeneration
  - -gait ataxia without limb ataxia
  - -different pathology than Wernicke's
- VII. Cerebellar Hemorrhage
  - -vomiting
  - -ataxia
- VIII. Fredrick's Ataxia
  - -Genetic (triple repeat GAA on Chrm.9)
  - -gradual onset in first 3 decades of life
  - -gait disturbances, dysarthria, sensory loss to extremities



# Cerebellar symptoms

- Tremor
- A) intention tremor during intended movements, worse at the beginning and end of movement, lesion of dentate nc. or mesencephalic pedunculus
- B) Gordon-Holmes tremor when mesencephalic pedunculus without lesion of nc. ruber, rough irregular tremor even in rest (wing-beating tremor)
- C) titubation – tremor of head (3-4 Hz) or upper trunk in ventrodorsal direction, medial cerebellar lesions

# Cerebellar symptoms

- Slurred speech – caused by dyssynergia and dysdiadochokinesis of speech and respiratory muscles, speech tempo slowing down, changes of articulation, words expressed with first syllable accentation (similar to limbs hypermetria)
- Cerebellar dysarthria – blurred pronunciation, slow speech (like drunkard speech)

# Cerebellar symptoms

- Eyeball problems – usually when vestibulocerebellum (archicerebellum) is damaged or connections with vestibular nuclei, nystagmus (saccadic dysmetria)
- Astasia – damage of standing, nonstable standing on wide basis with fall tendency without direction
- Abasia – „drunkard walking“ when vermis damaged (also paleocerebellar syndrome)

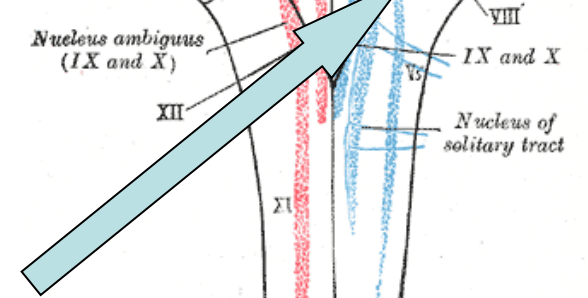
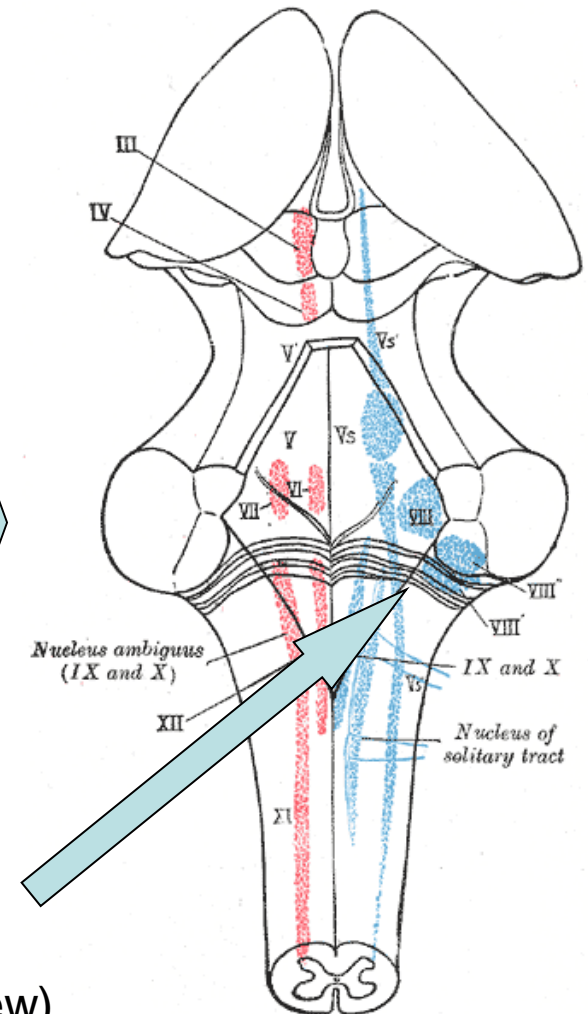
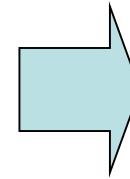
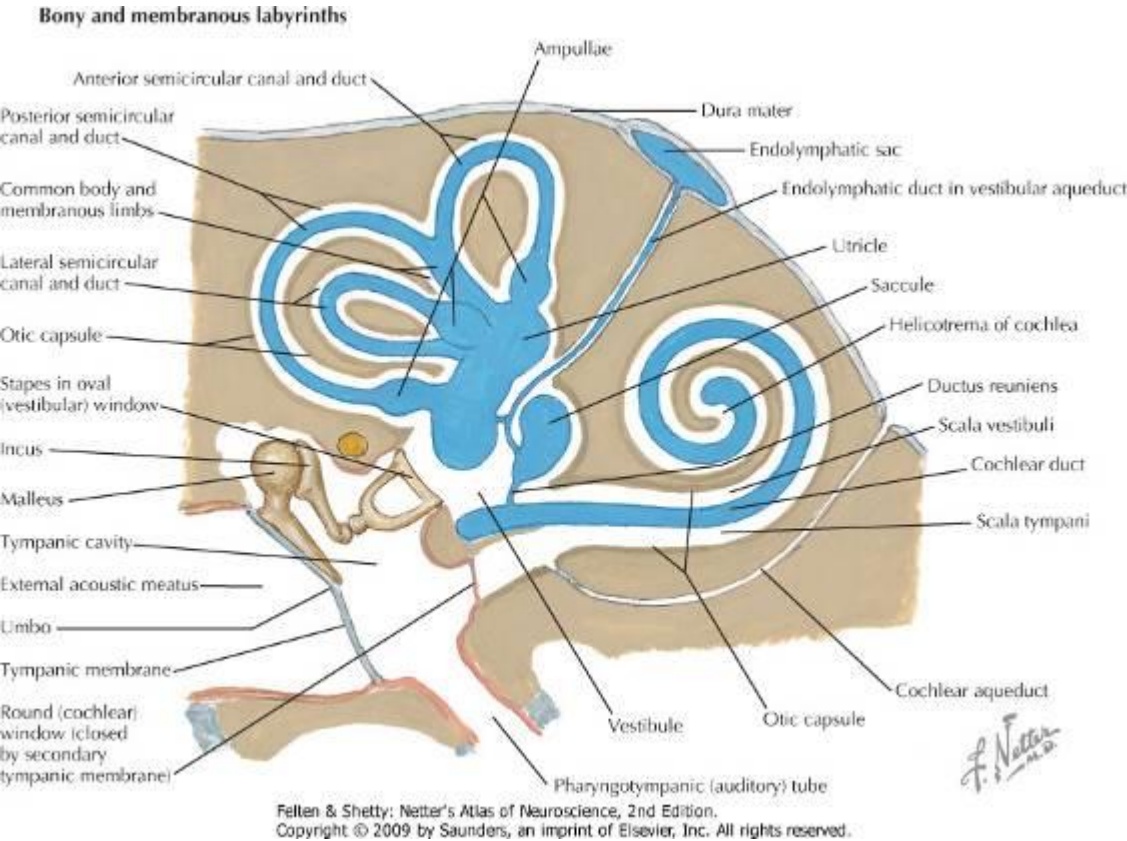
# Cerebellar syndromes

- Paleocerebellar syndrome – astasia, abasia (flocculonodular lobe), rough (big) dyssynergia, axial ataxia (does not get worse with closed eyes – as opposed to posterior fasciculi damage), spontaneous falls
- Neocerebellar syndrome – hypermetria, adiadochokinesis, small asynergia, intention tremor, pasivity, neocerebellar ataxia

# Cerebellar syndromes

- Global cerebellar syndrome – mixed up together other syndromes
- Cerebellar cognitive-affective syndrome – after tumor operation (best described in children Levinson et al., 2000), perseveration, personality changes, memory deficits, prosody, agrammatismus, decrease of intellect

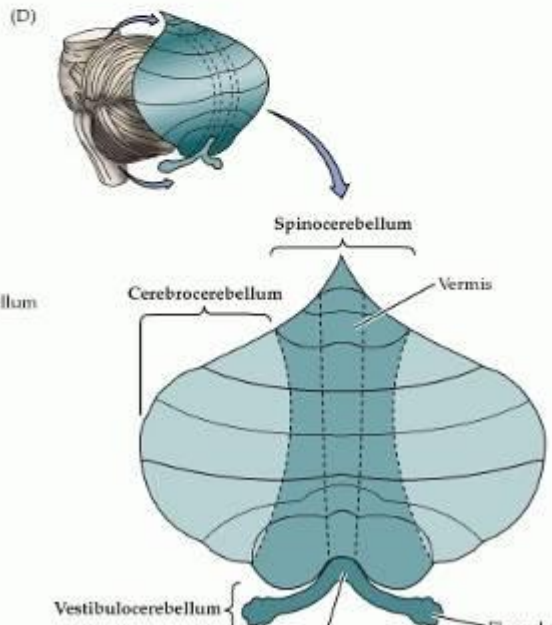
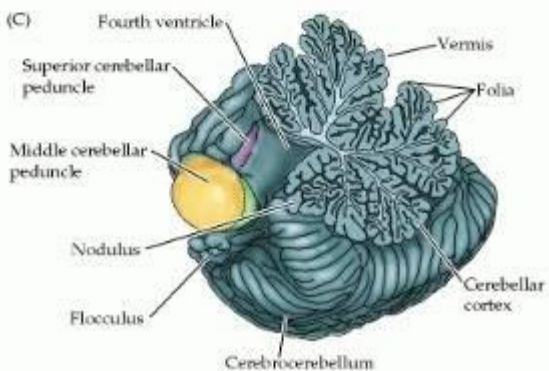
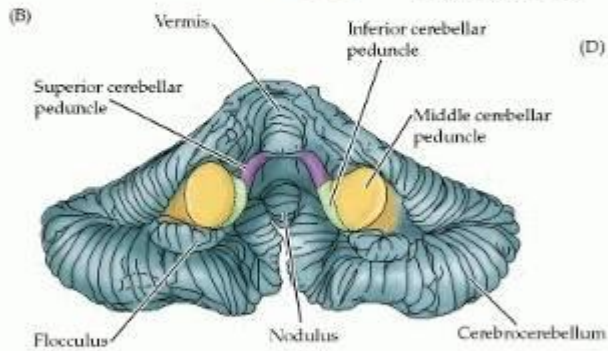
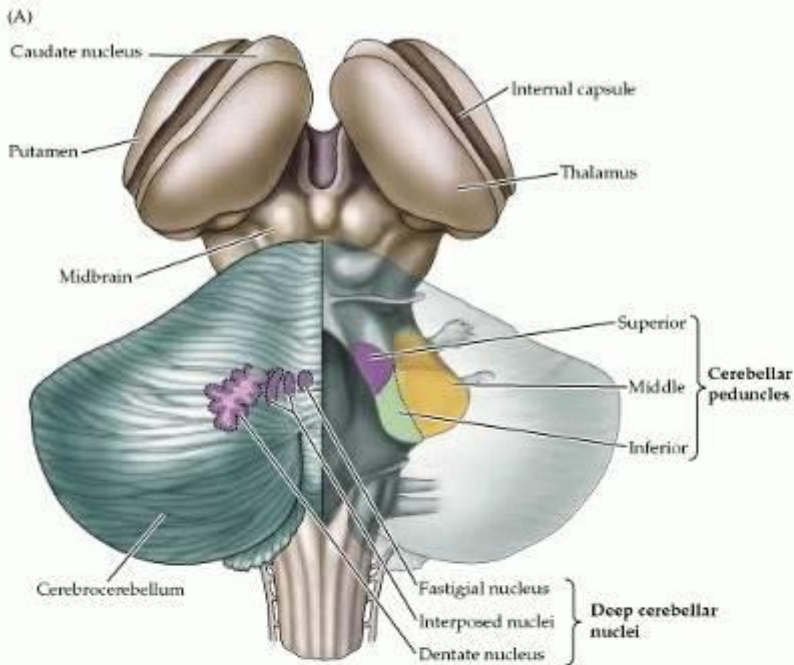
# Floculonodular lobe



Medial  
Lateral (Deiters)  
Superior

© David Keffer (Bachterew)

Does not exit cerebellum via deep cerebellar nuclei!



Anterior lobe, spinocerebellum



Interposed nuclei=nc. globosi and nc. emboliformis



Superior cerebellar peduncle

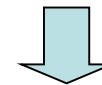


Red nucleus



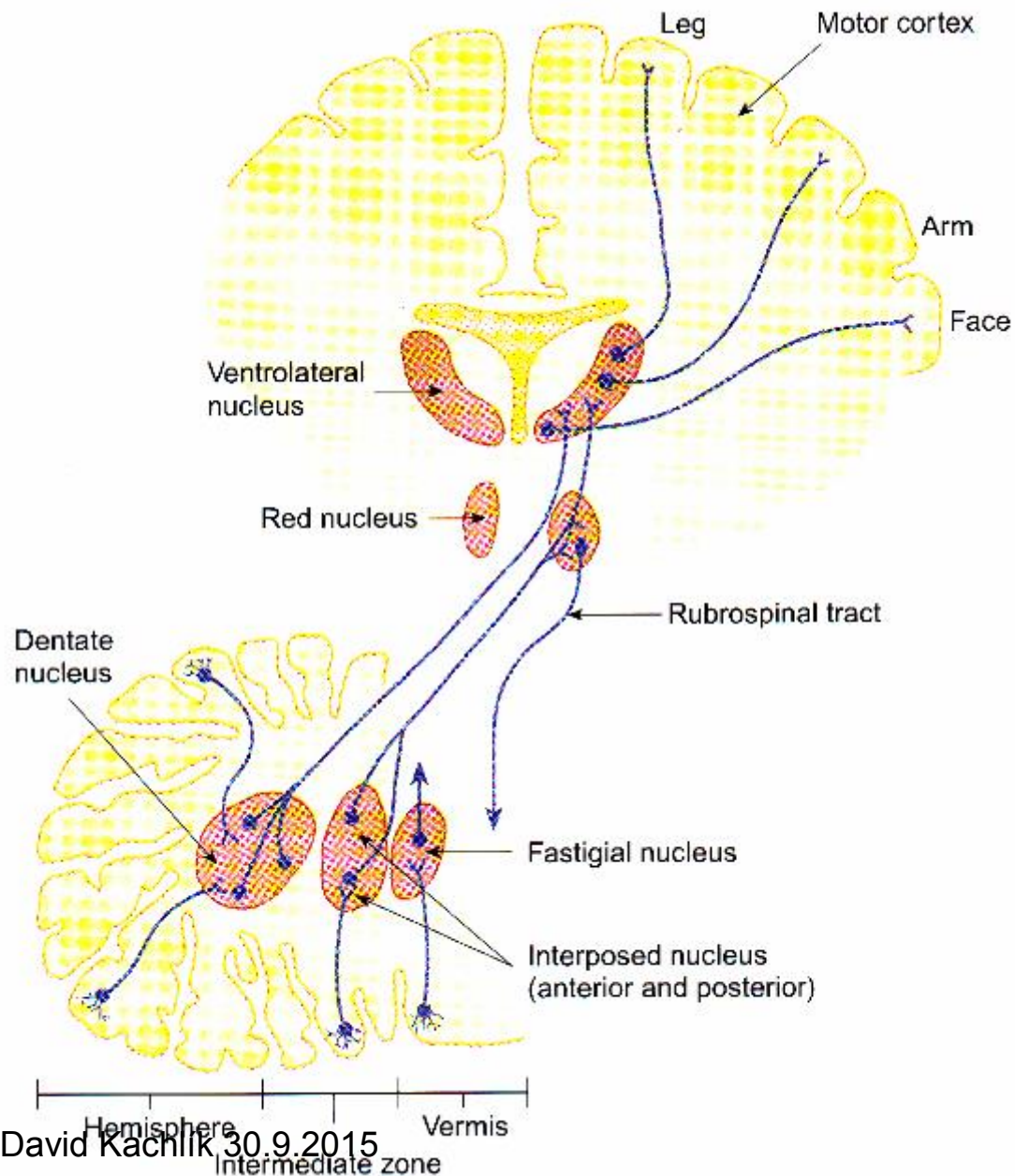
Distal muscle group

Vermis



Fastigial nucleus

Dentate nuclei: project contralaterally through the superior cerebellar peduncle to neurons in the contralateral thalamus & from thalamus to motor cortex  
 Func.: influence planning and initiation of voluntary movement  
Emboliform & Globose nuclei: project mainly to the contralateral red nuclei & a small group is projected to the motor cortex  
 Red Nuclei → Rubrospinal Tract control of proximal limb muscles  
Fastigial nuclei: project to the vestibular nuclei & to the pontine and medullary reticular formation  
 Vestibulospinal & Reticulospinal tracts





# Inputs and outputs of the Cerebellum

## Inputs

Somatosensory and kinesthetic information from spinal cord

Red nucleus, motor cortex, somatosensory information from spinal cord

Motor and association cortex via pons

## Outputs

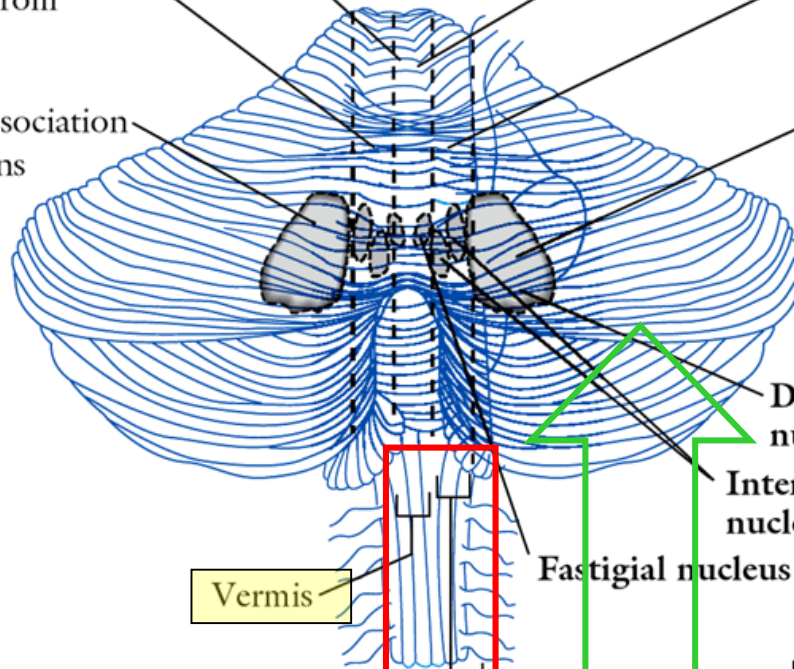
Ventromedial tracts

Corticospinal tracts

To motor and premotor cortices

Motor execution

Motor planning



Vermis

Dentate nucleus

Interpositus nucleus

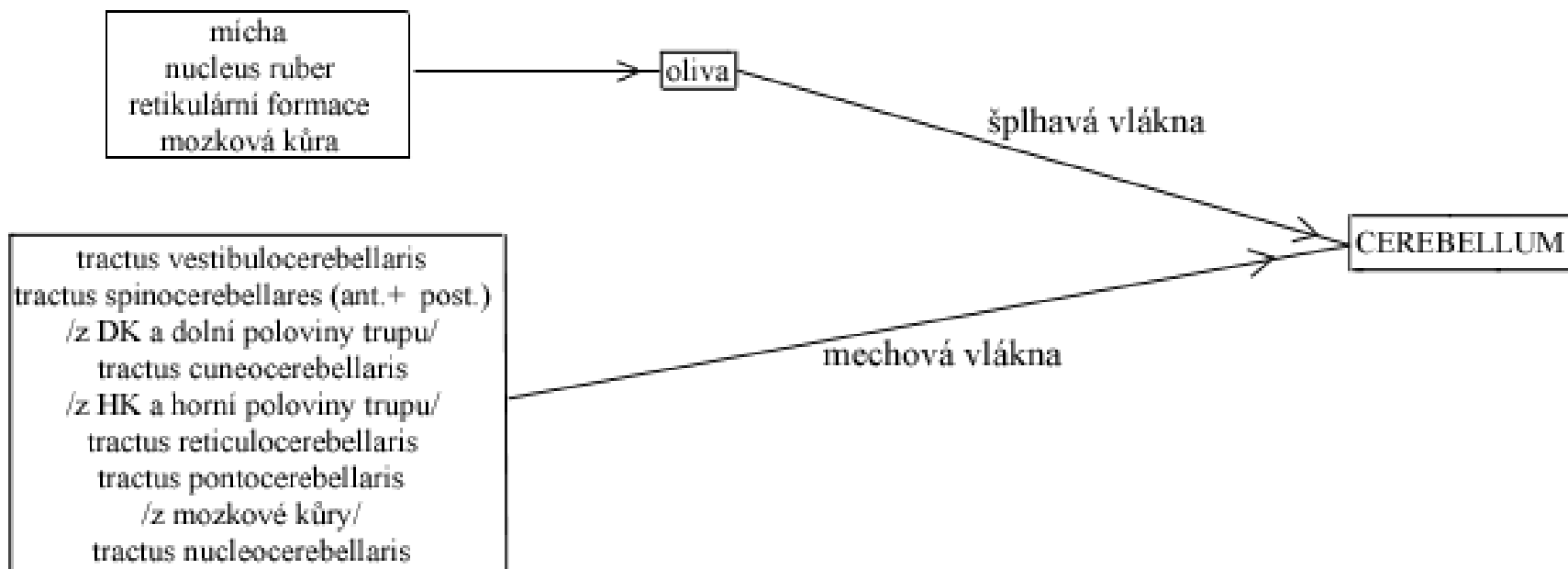
Fastigial nucleus

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zone

Lateral zone

## AFERENTY MOZEČKU



## EFERENTY MOZEČKU

**VERMIS** → nuclei fastigii → nuclei vestibulares → extenzory končetin a trupu

**PARAVERMÁLNÍ KŮRA** → nuclei emboliformis et globosus → retikulární formace, nucleus ruber → proximální svaly končetin

**HEMISFÉRY** → nucleus dentatus → thalamus → mozková kůra /area 4/ → tractus corticospinalis → distální svaly končetin