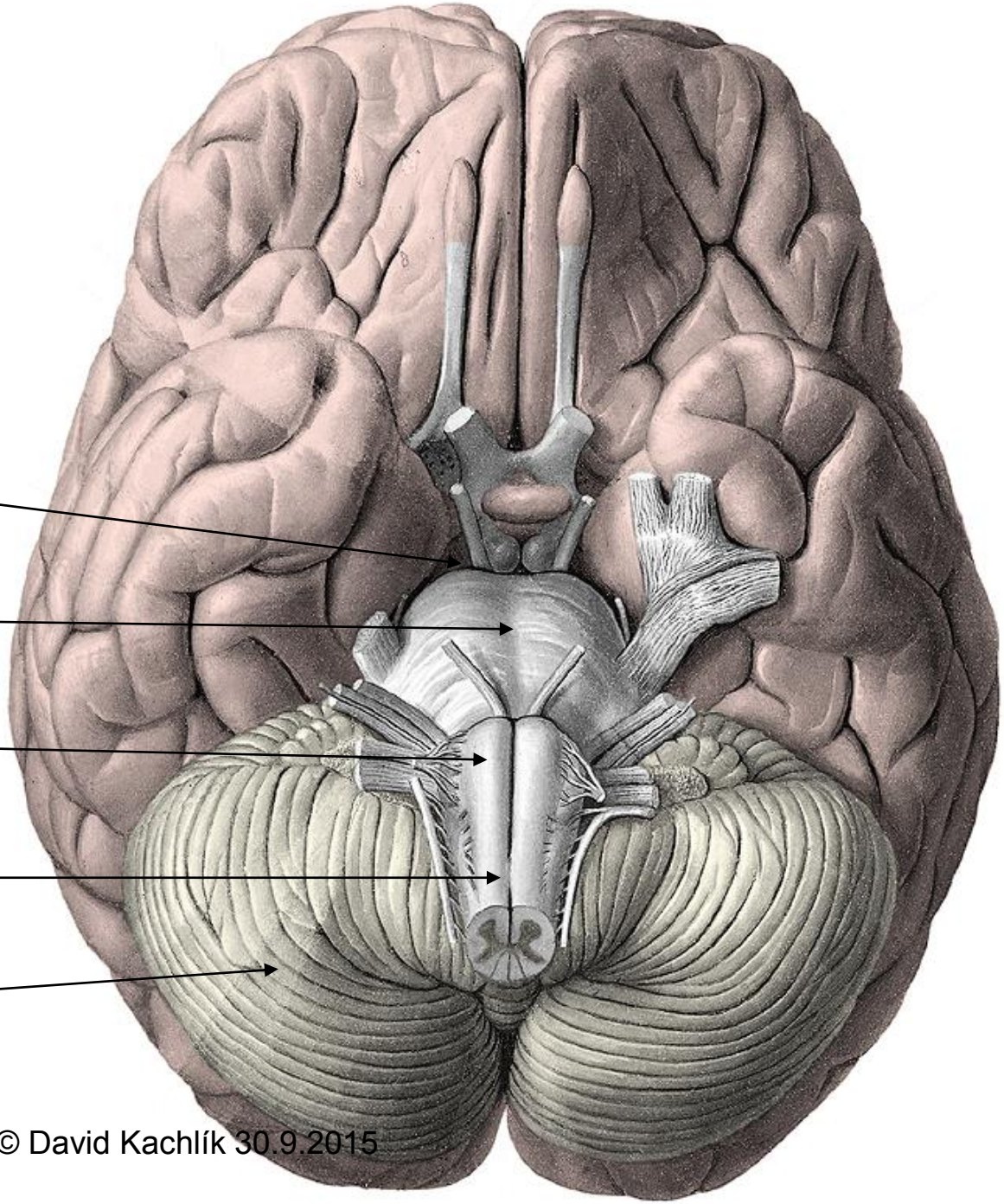
Cerebellum

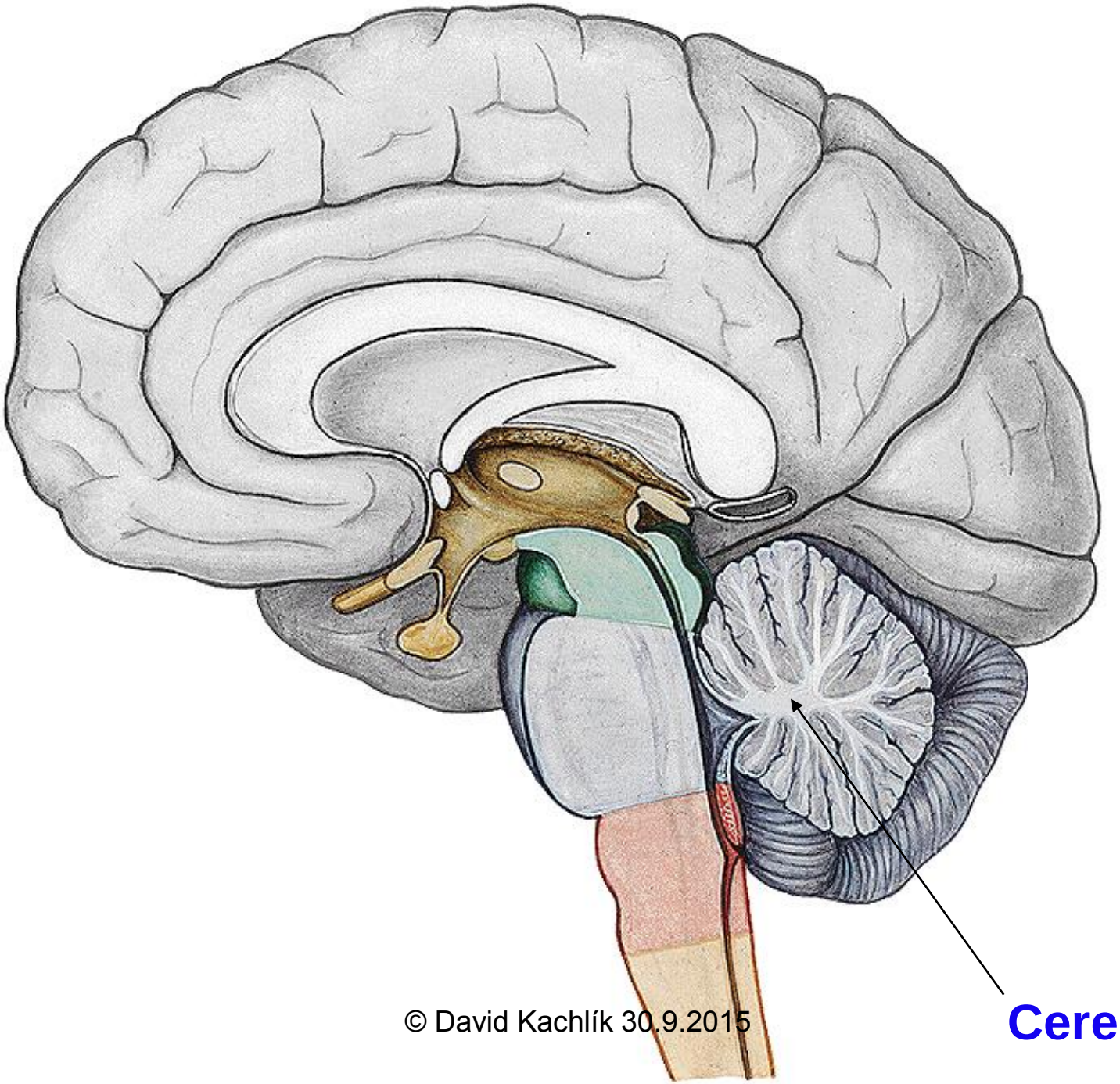
Small brain = Cerebellum

10 % weight of whole brain

More than ½ neurons of whole brain

¼ - ¾ area of whole brain





Cerebellum – parcellation

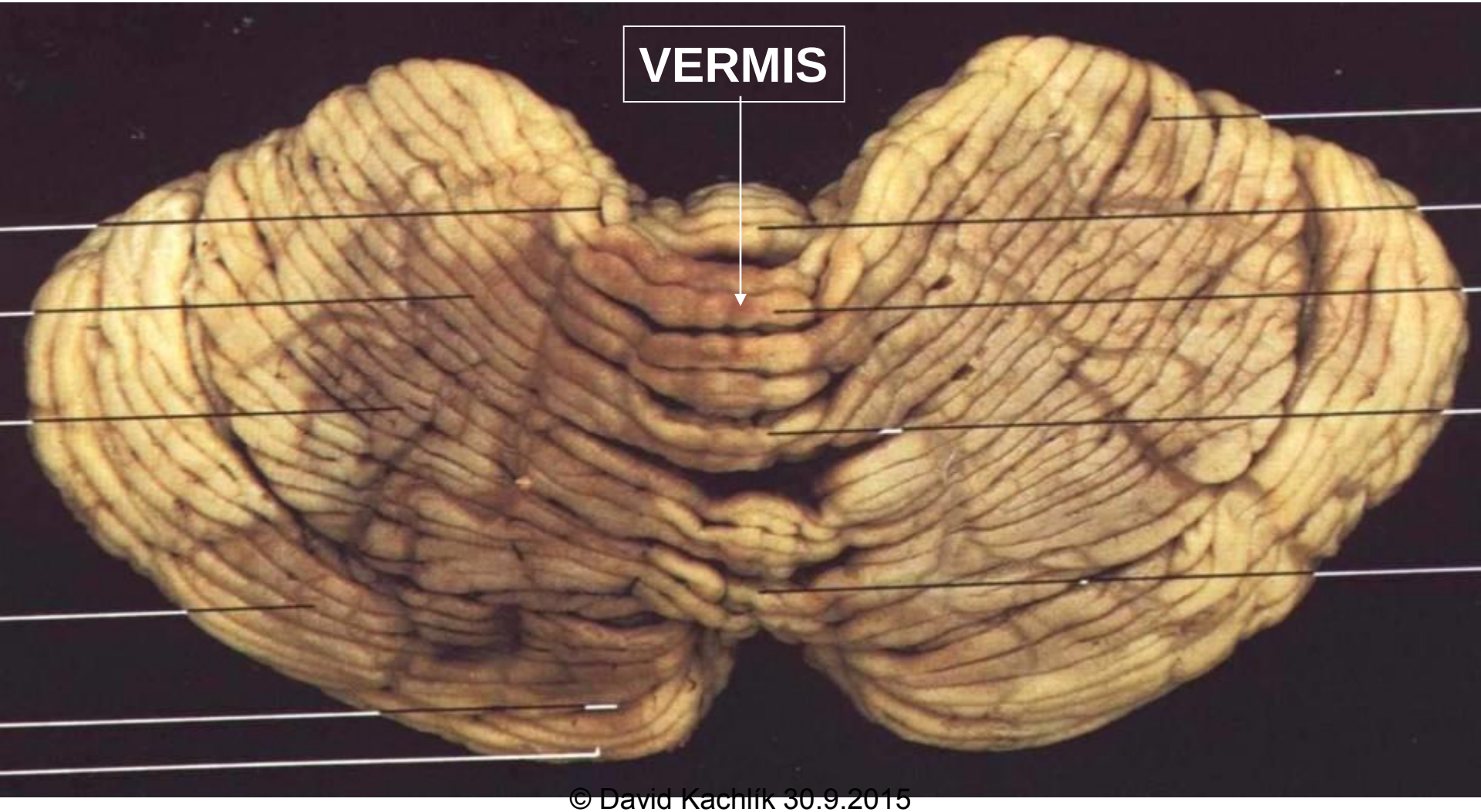
- developmentally:
  - archicerebellum
  - paleocerebellum
  - neocerebellum
- function:
  - vestibulocerebellum
  - spinocerebellum
  - cerebrocerebellum (= pontocerebellum)
- Functional placement:
  - vermis a l. floculonodularis
  - paravermální (intermediální) zóna
  - hemisféry (laterální zóna)
- External structure:
  - lobus anterior
  - lobus posterior
  - lobus flocculonodularis

Cerebellum – description

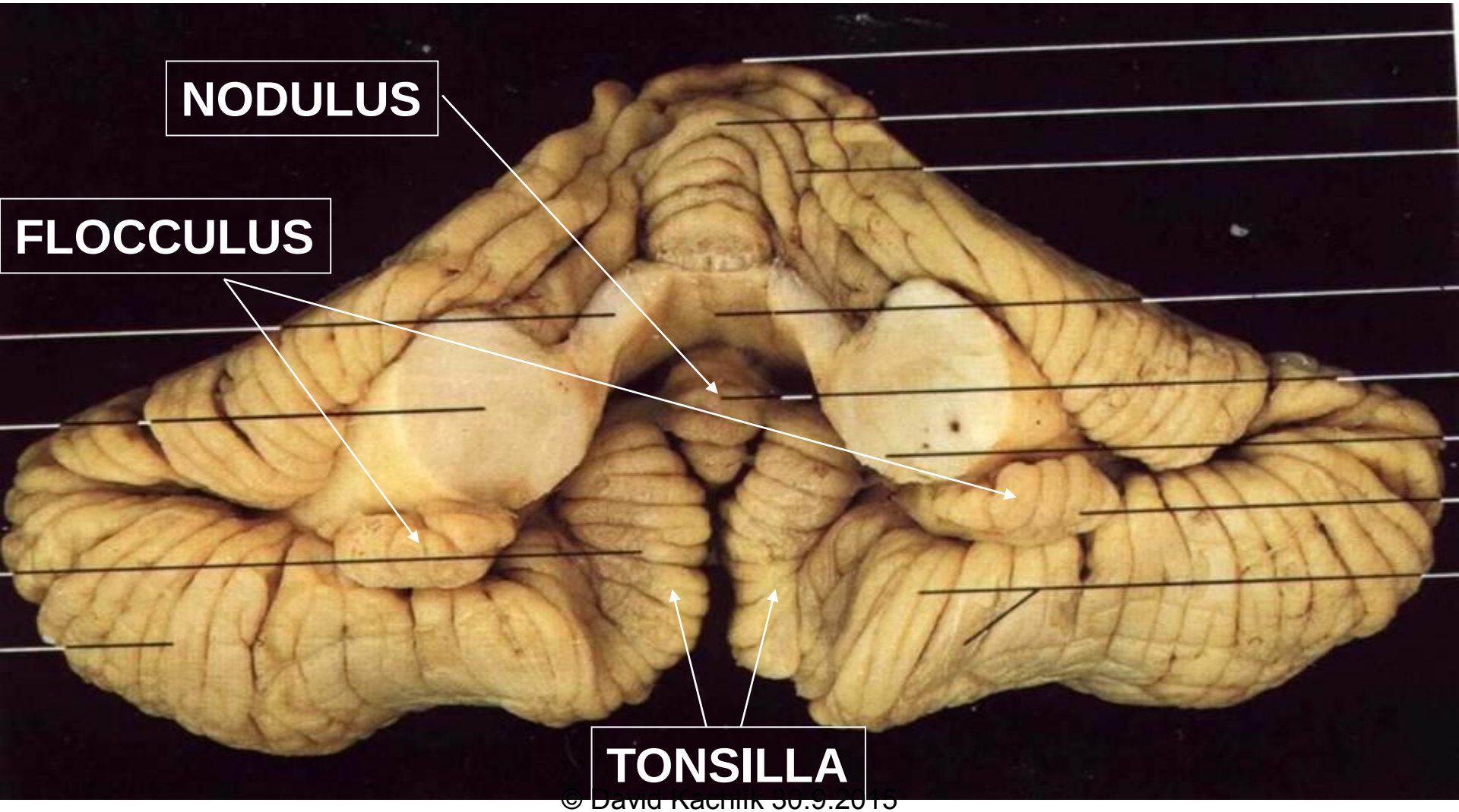
- **folia** cerebelli (*leaves*)
- **fissurae** cerebelli (*crack)*
- **vermis (*červ)*** – *non paired in middle*
- **hemispheria** – paired
- **3 lobi (*lobes*)**
  - Small parts
    - 10 in vermis [I - X] – expample nodulus
    - 9 in hemispheres [H II - H X]

  - **tonsilla** – when edema it goes into foramen magnum and it compresses stem
  - flocculus

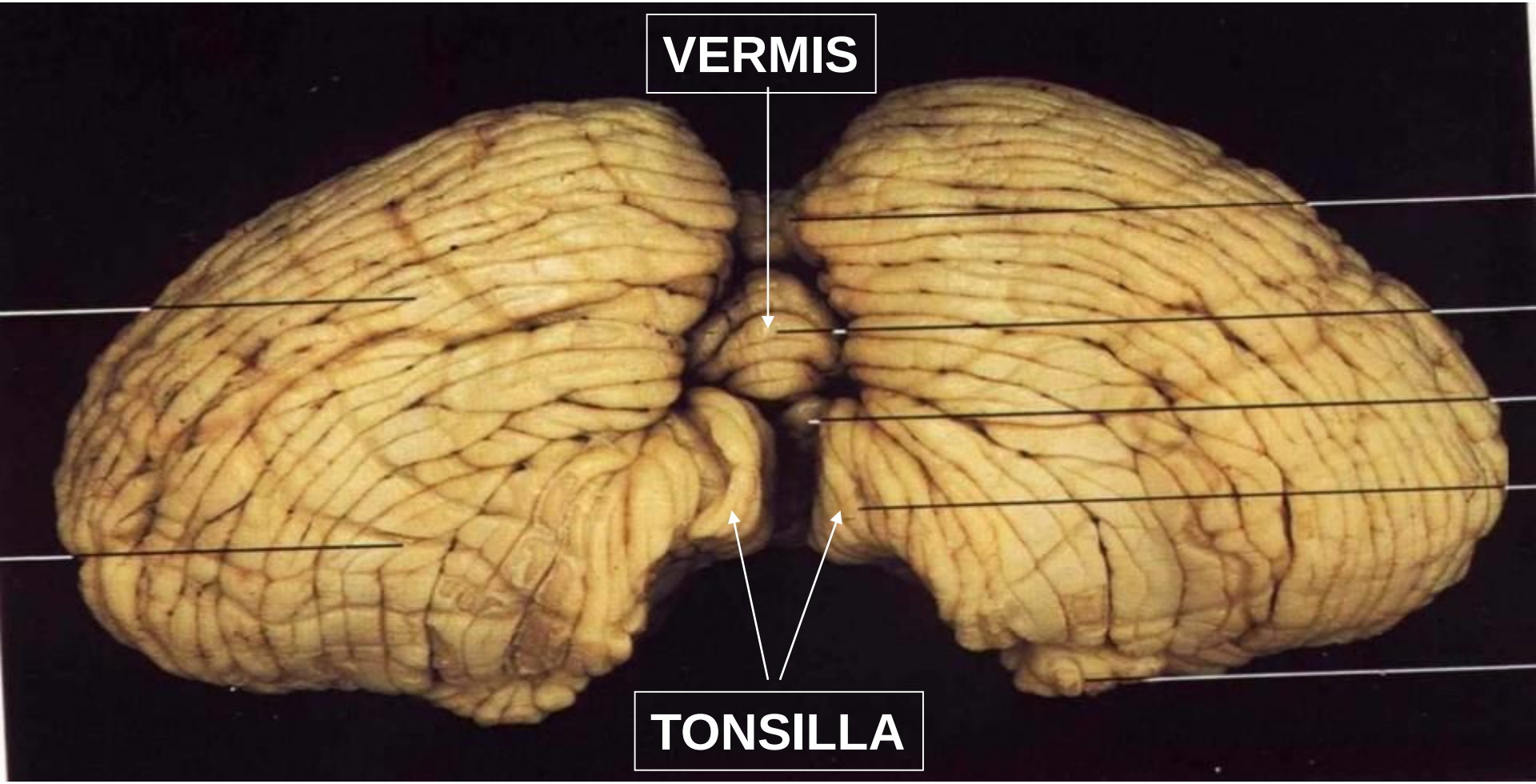
Cerebellum – posterior view



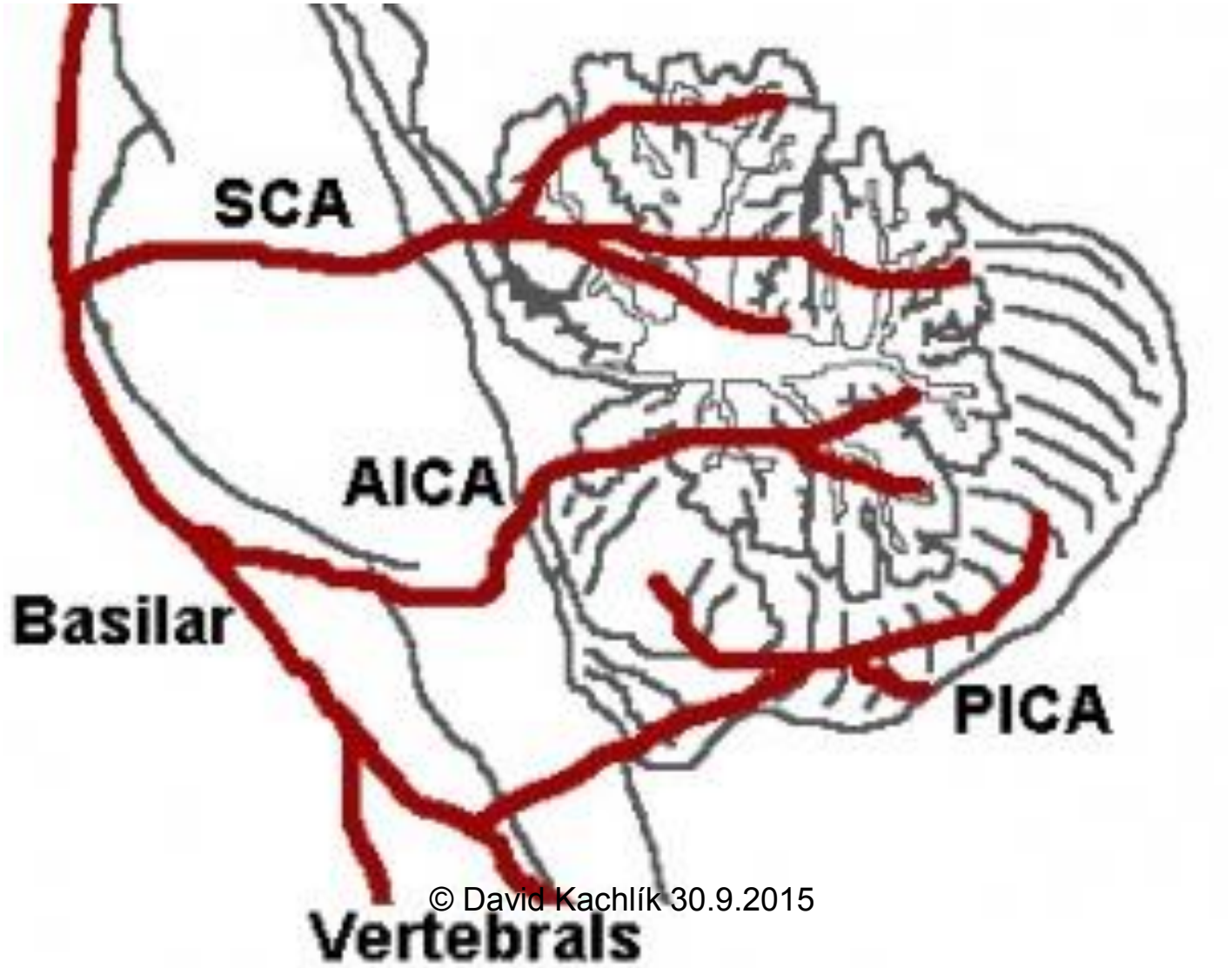
Cerebellum – ventral view



Cerebellum – inferior view



Blood supply



Cerebellum – developmental parts

- 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]

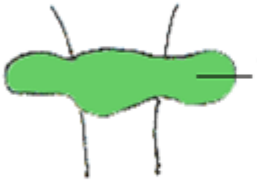
= **vestibulocerebellum = archicerebellum**

Development of cerebellum

dorsal view

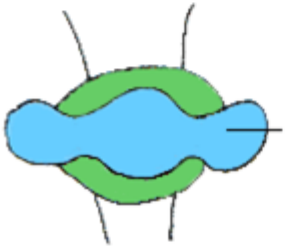
lateral view

Fish



vestibulocerebellum

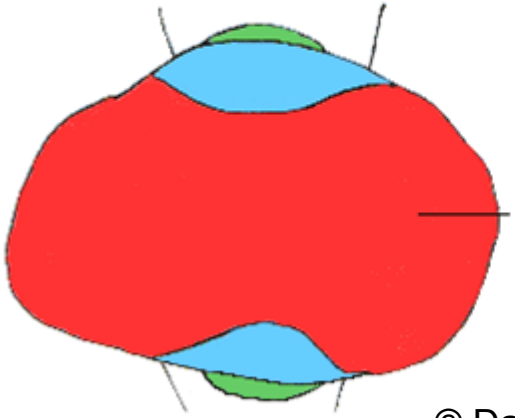
Reptiles



spinocerebellum

brain cortex

mam
mals



neocerebellum

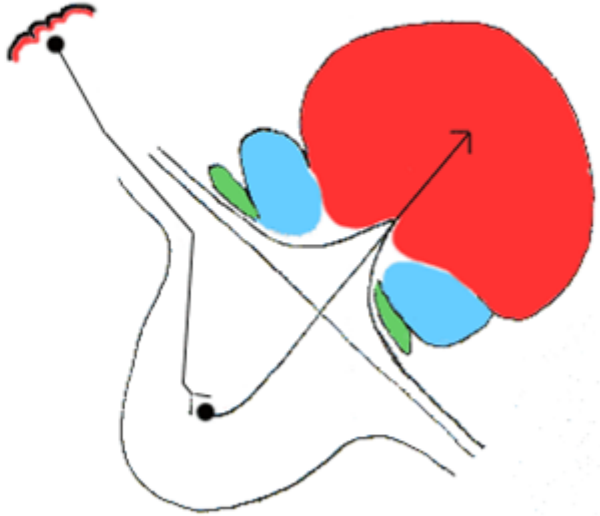
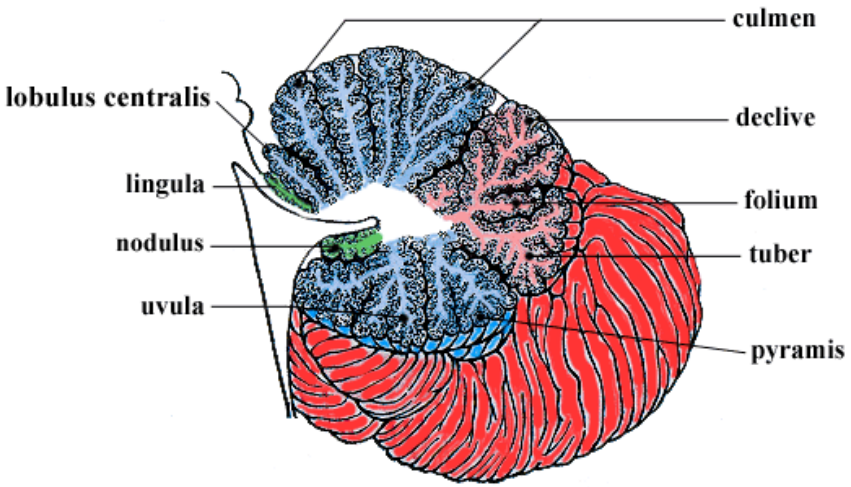


SCHÉMA FYLOGENETICKÉHO VÝVOJE MOZEČKU

pohled na sagitální řez skrz vermis cerebelli

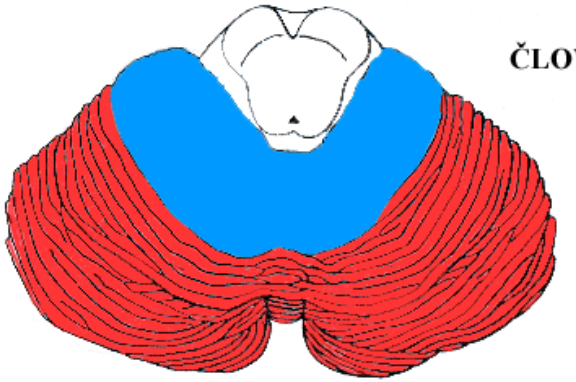


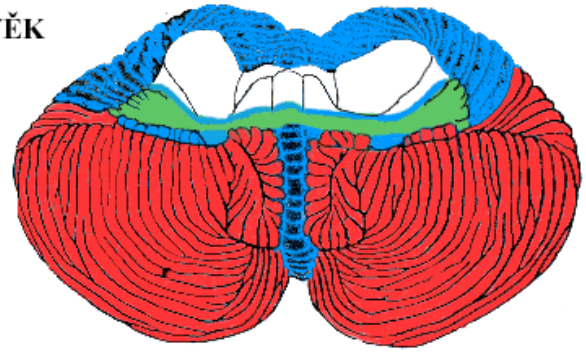
PŮVODNÍ HYPOTETICKÝ STAV

PLAZI

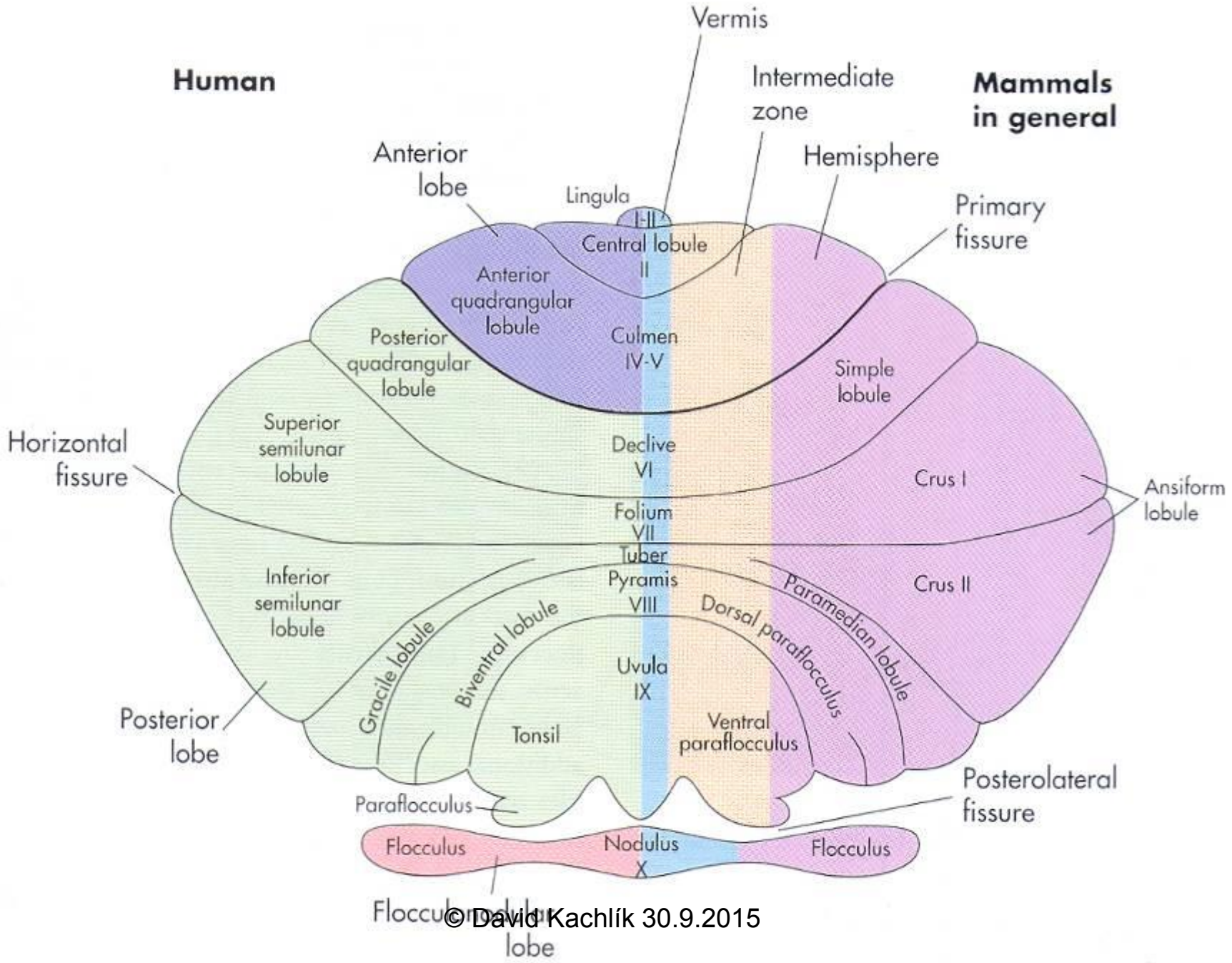
SAVCI

ČLOVĚK



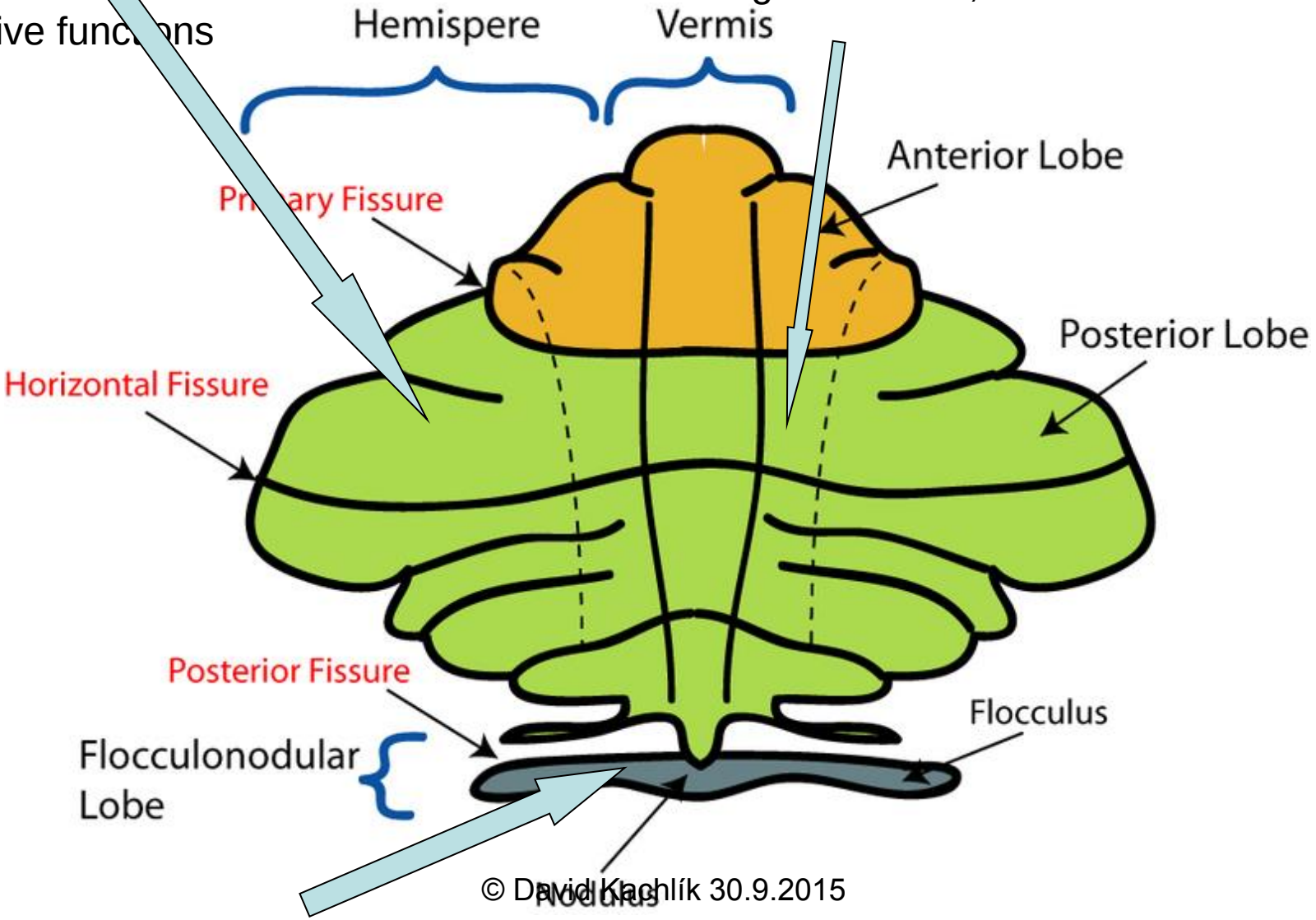


zeleně - vestibulocerebellum
modře - archicerebellum
červeně - neocerebellum

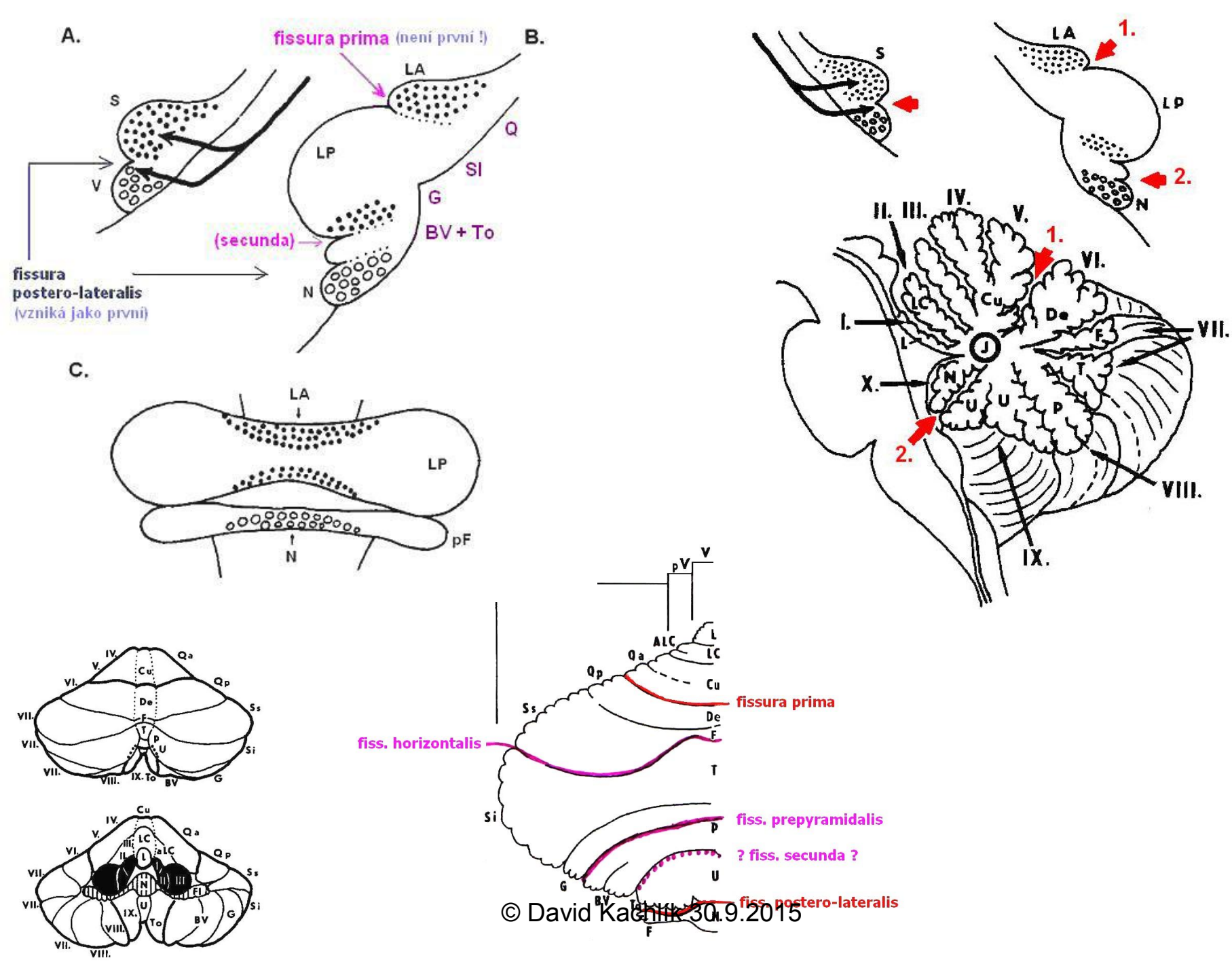


Medial zone of anterior and posterior lobe
=paleocerebellum=spinocerebellum=fine tune body and limb movement

Lateral zone of anterior and posterior lobe =
cerebrocerebellum=neocerebellum = ?? Plannning movement,
cognitive functions



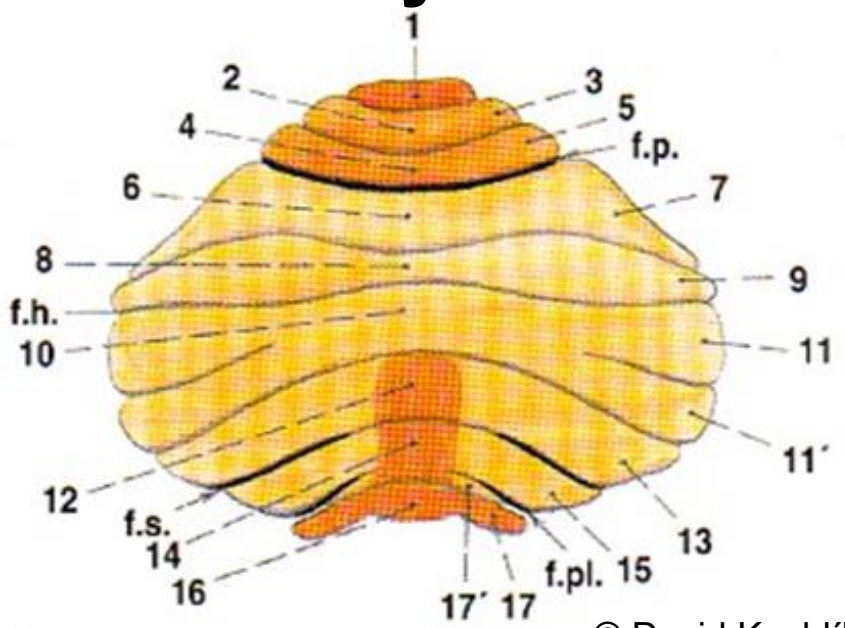
Flocculonodular lobe =vestibulocerebellum=archicerebellum=balance and gait

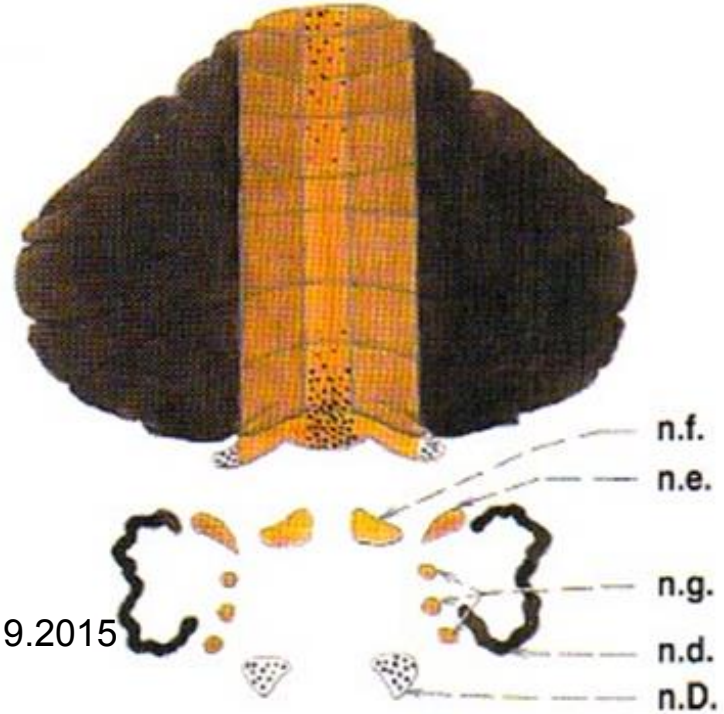


Cerebellum – funkční části

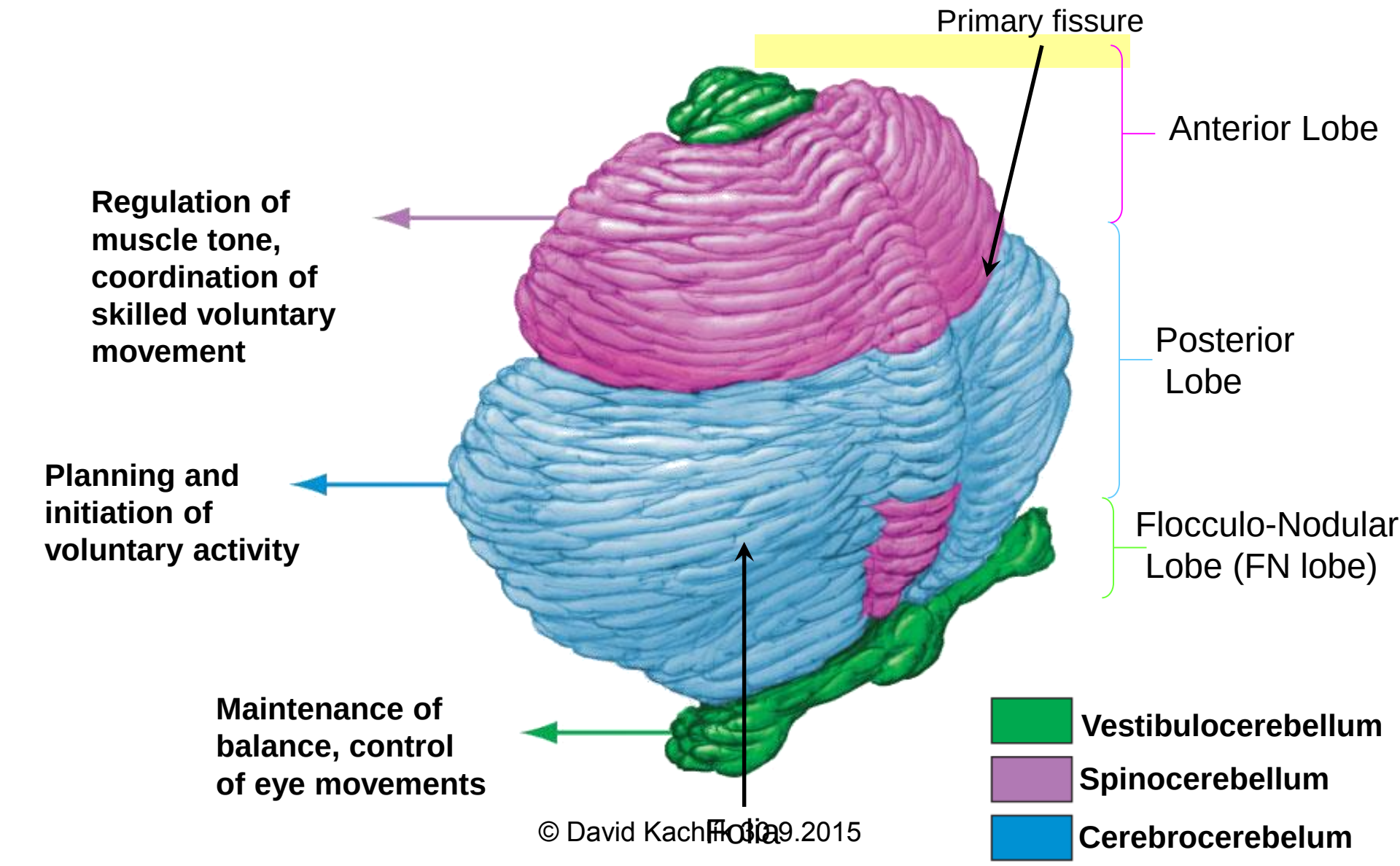
3 podélné zóny

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

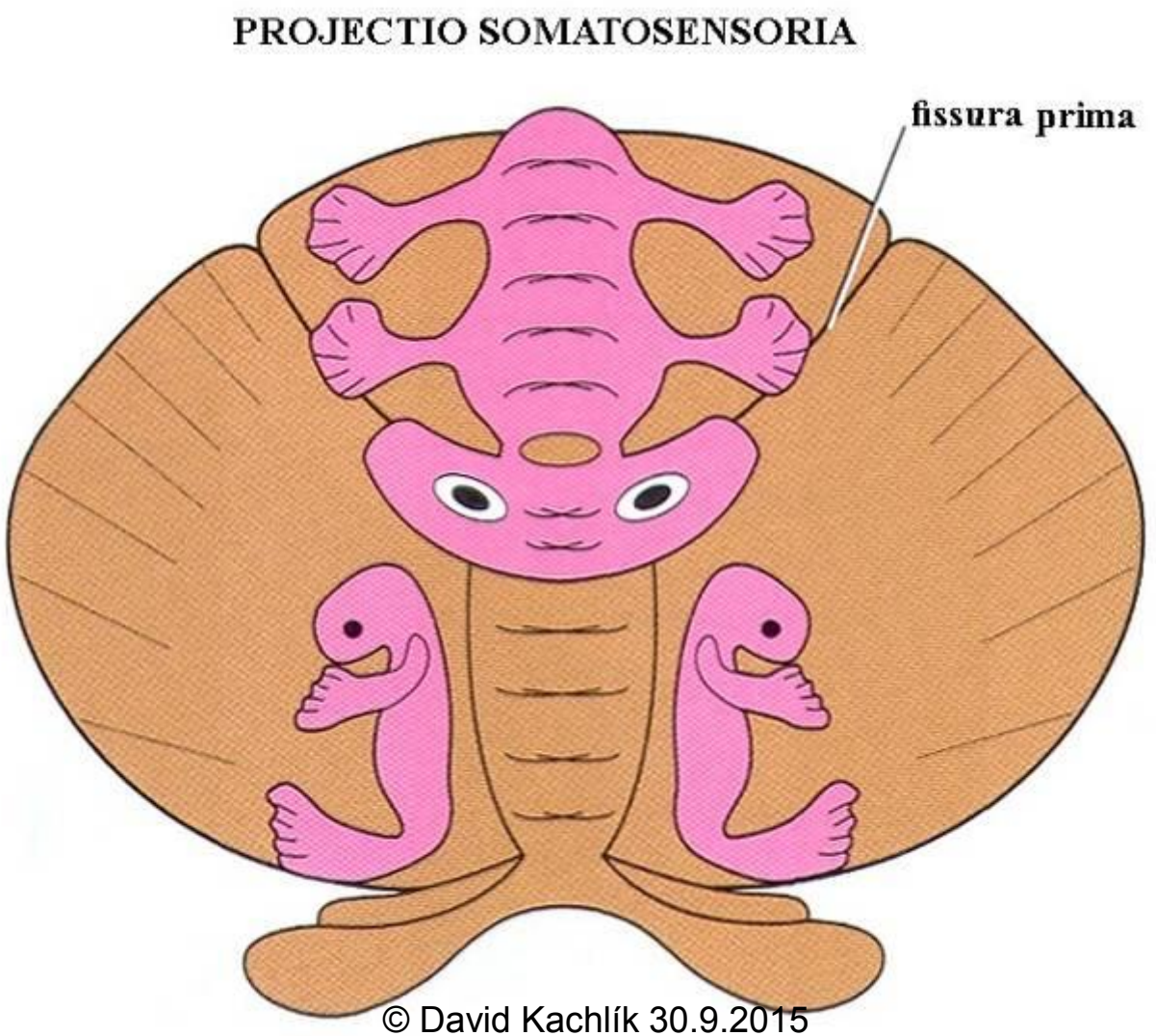




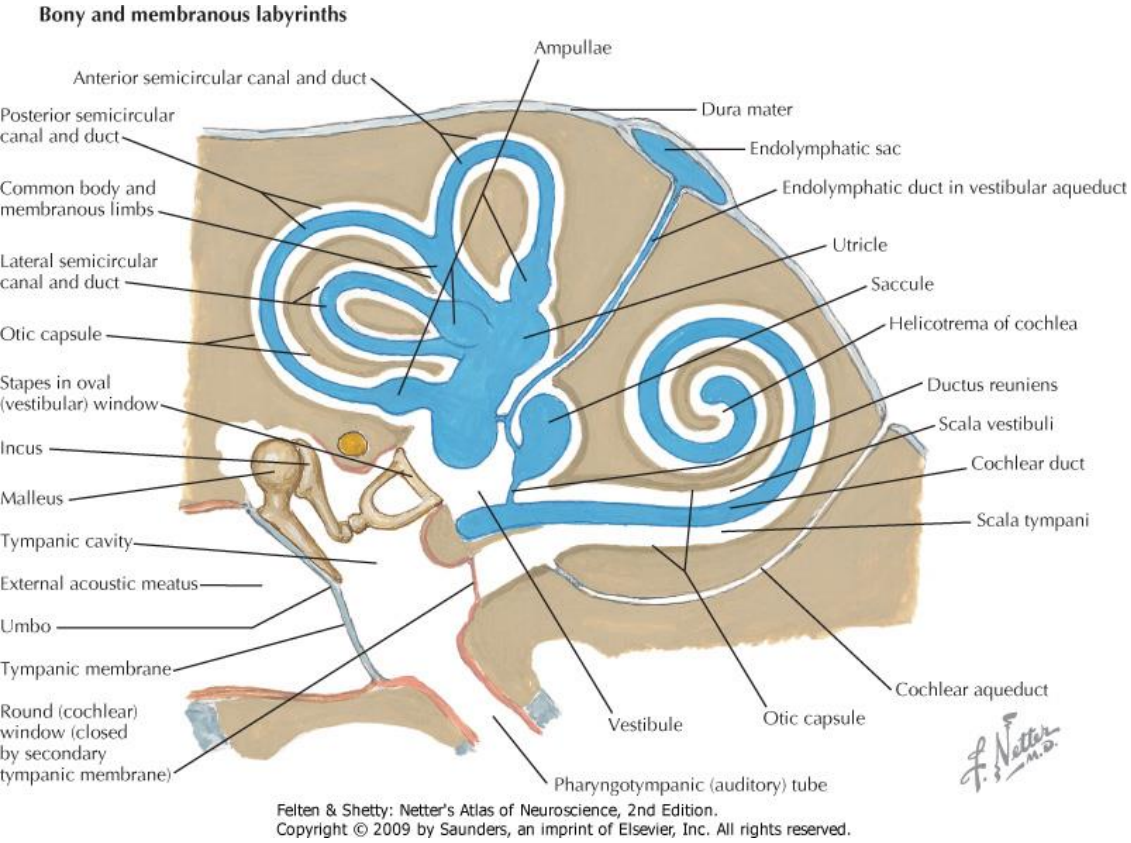
Cerebellum

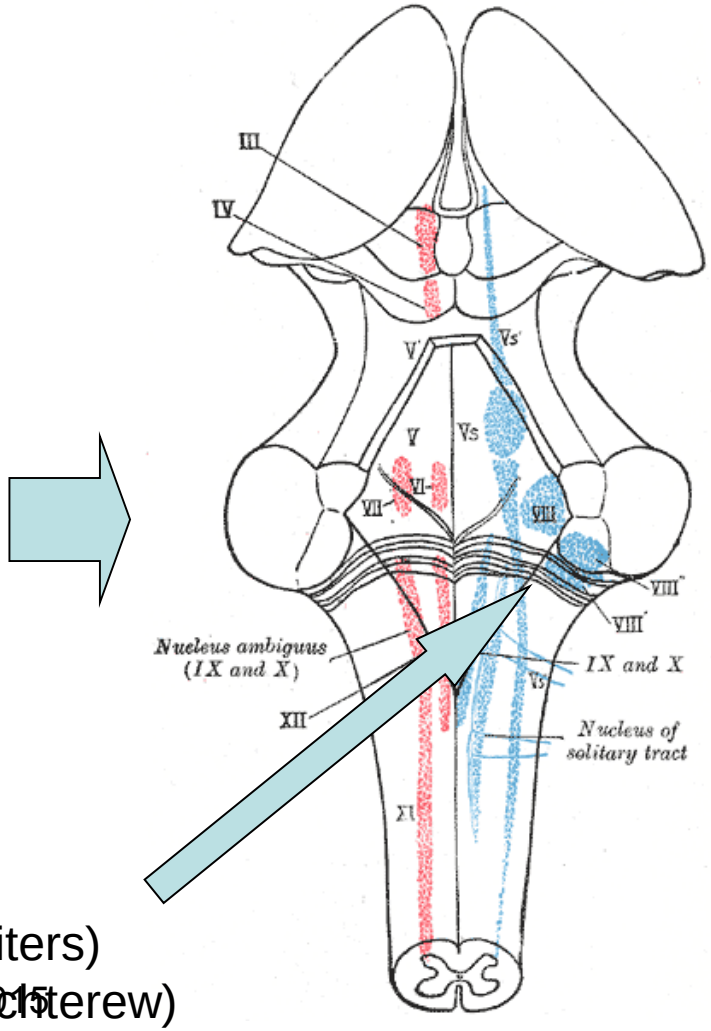


Cerebellar homunkulus



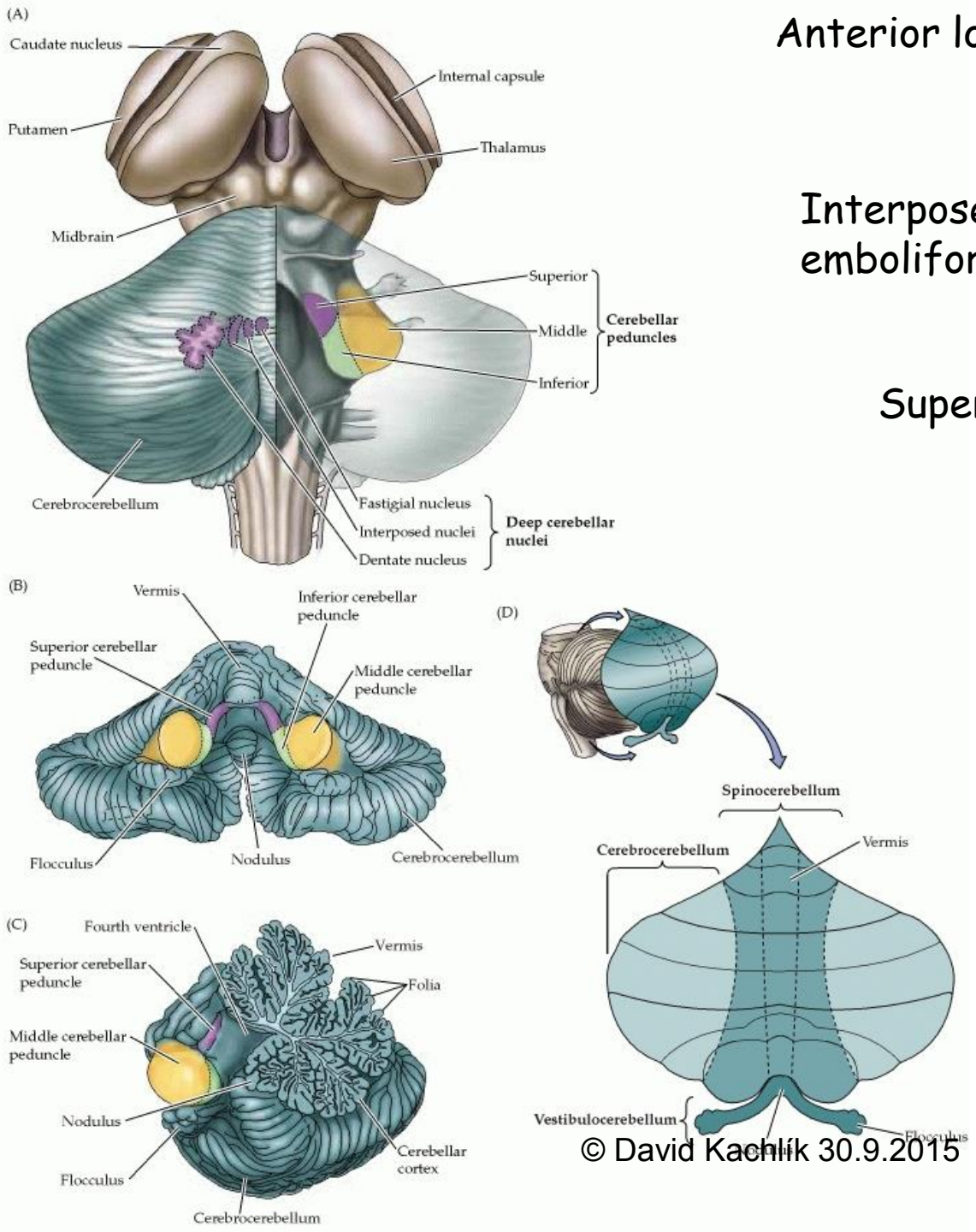
Floculonodular lobe





Does not exit cerebellum via deep cerebellar nuclei!

Medial
Lateral (Deiters)
Inferior (Bechterew)
Superior



Anterior lobe, spinocerebellum

↓

Interposed nuclei=nc. globosi and nc. emboliformis

↓

Superior cerebellar peduncule

↓

Red nucleus

↓

Distal muscle group

Vermis

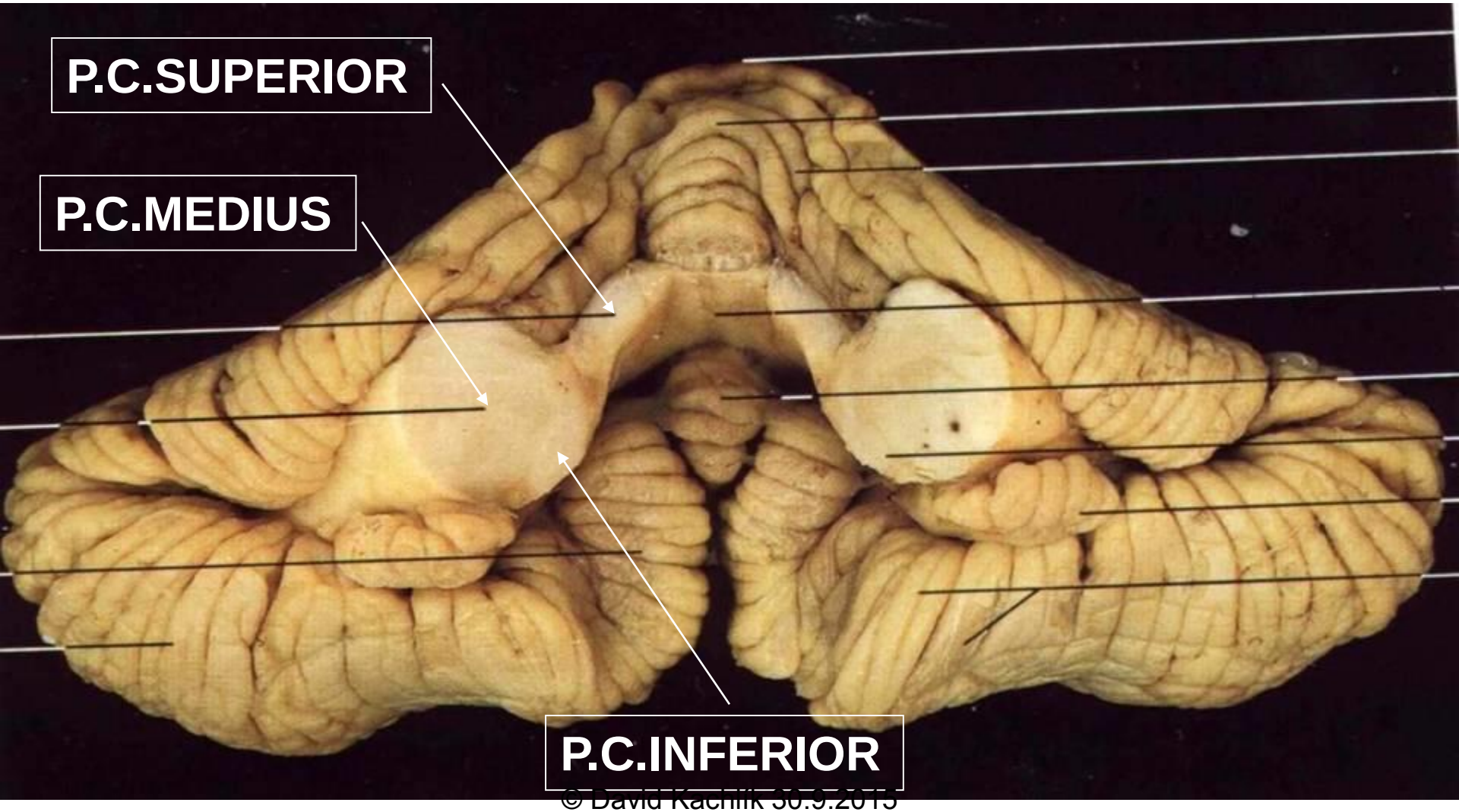
↓

Fastigial nucleus

Cerebellum – pedicles

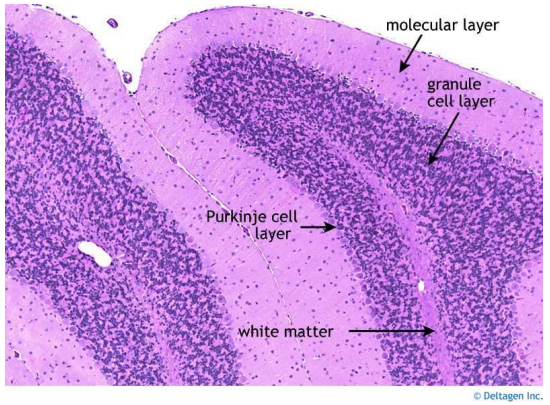
- **pedunculus cerebellaris inferior**
  - corpus restiforme
  - corpus juxtarestiforme
- **pedunculus cerebellaris medius**
  (= brachium pontis)
  - AF: *tractus cortico-ponto-cerebellaris*
- **pedunculus cerebellaris superior**
  (= brachium conjunctivum)

Cerebellum – ventral view

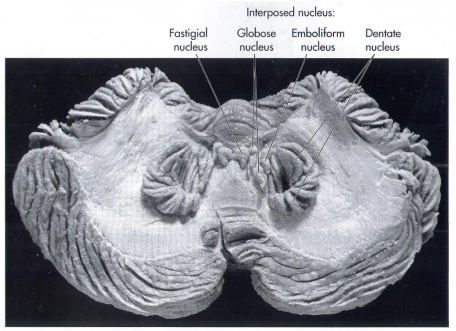


Cerebellum – internal structure

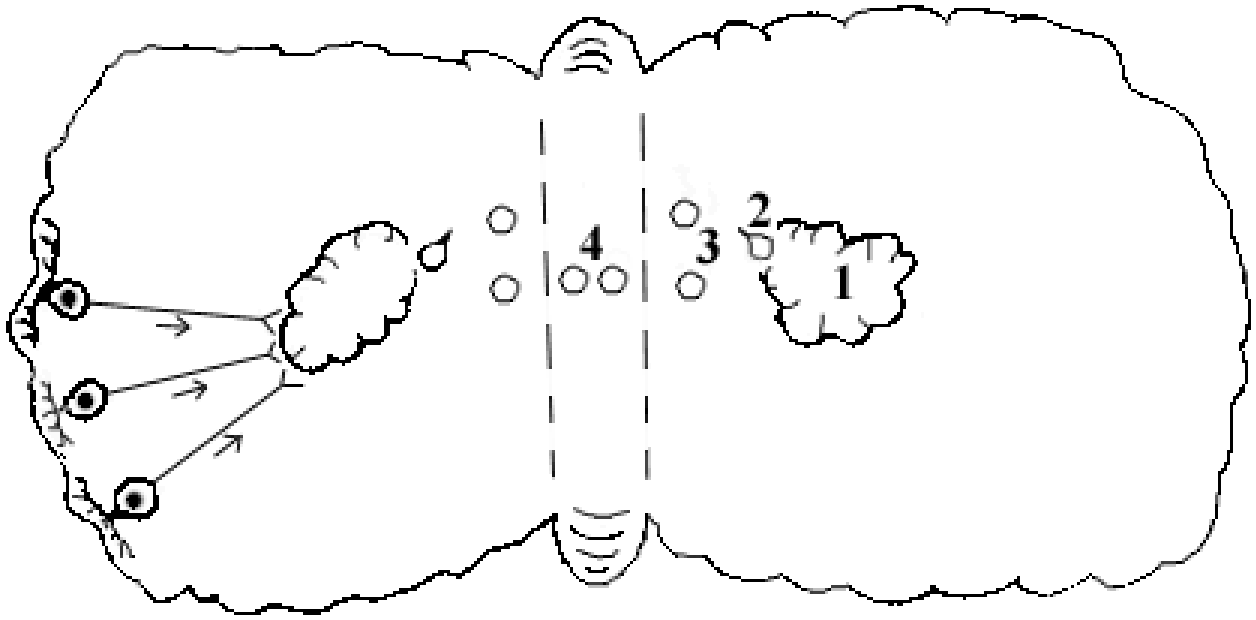
- **cortex cerebelli:** strata (3 layers) – *arbor vitae*
  - stratum moleculare
  - stratum purkinjese
  - stratum granulosum



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

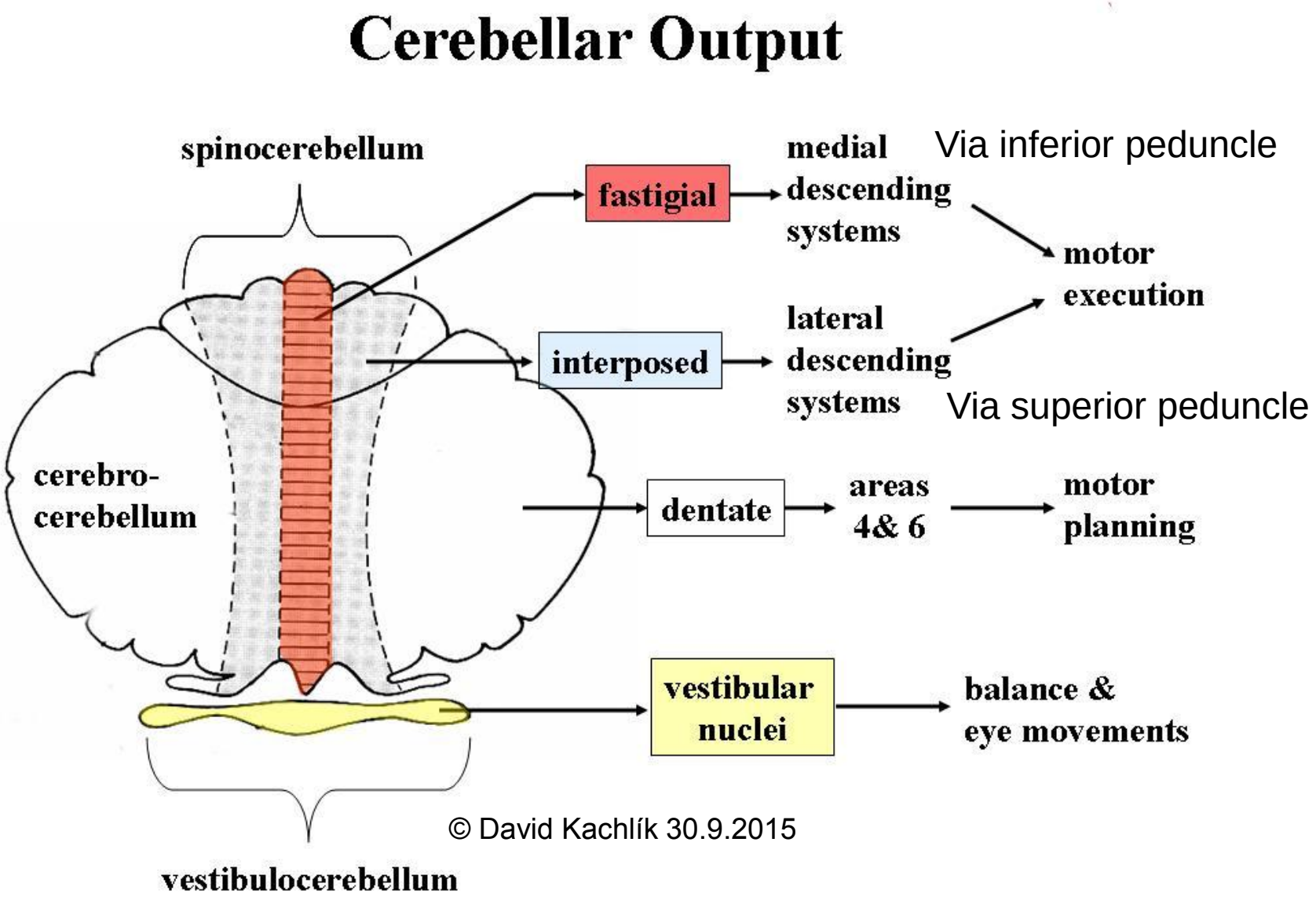


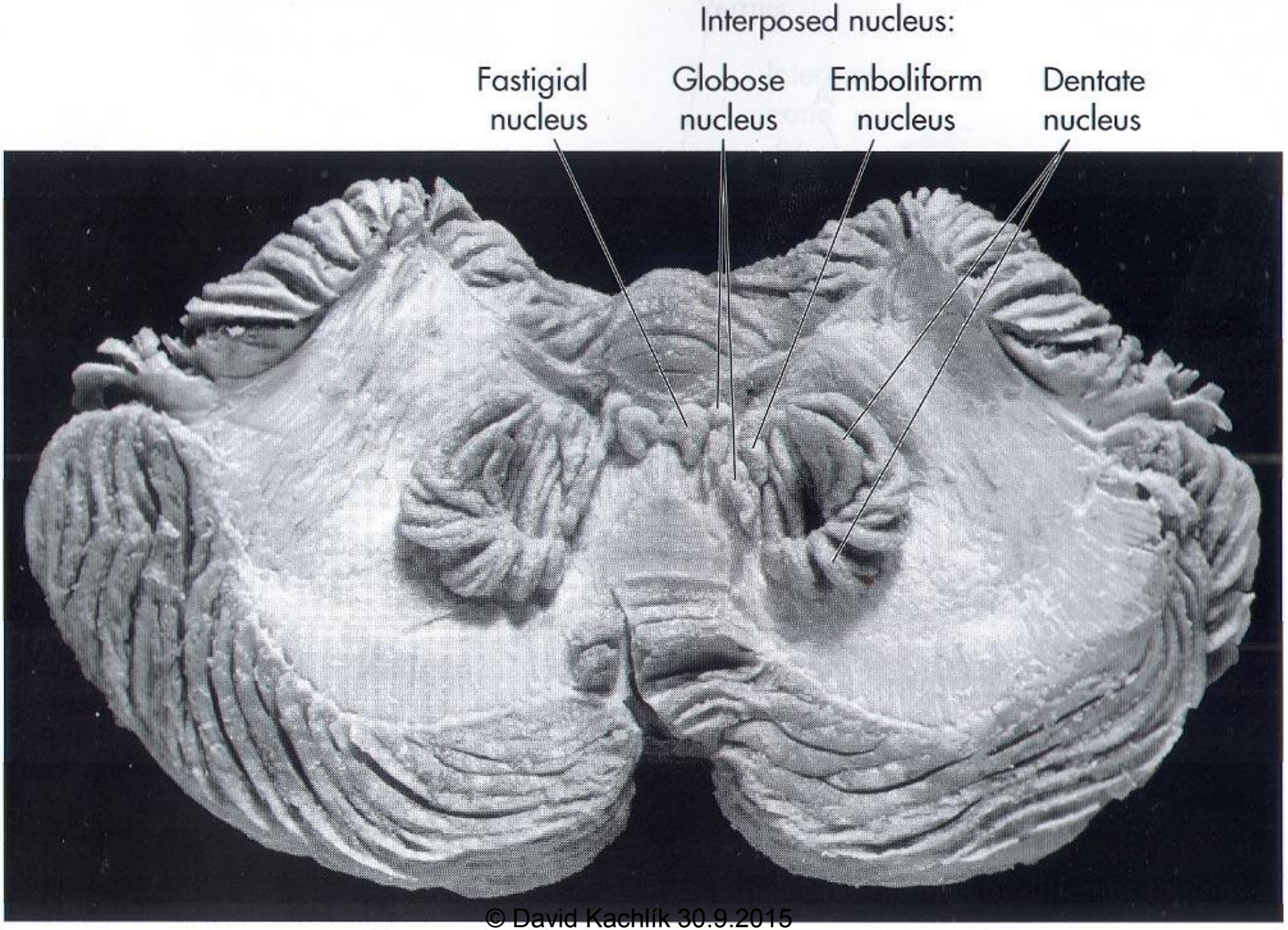
Cerebellum - nuclei

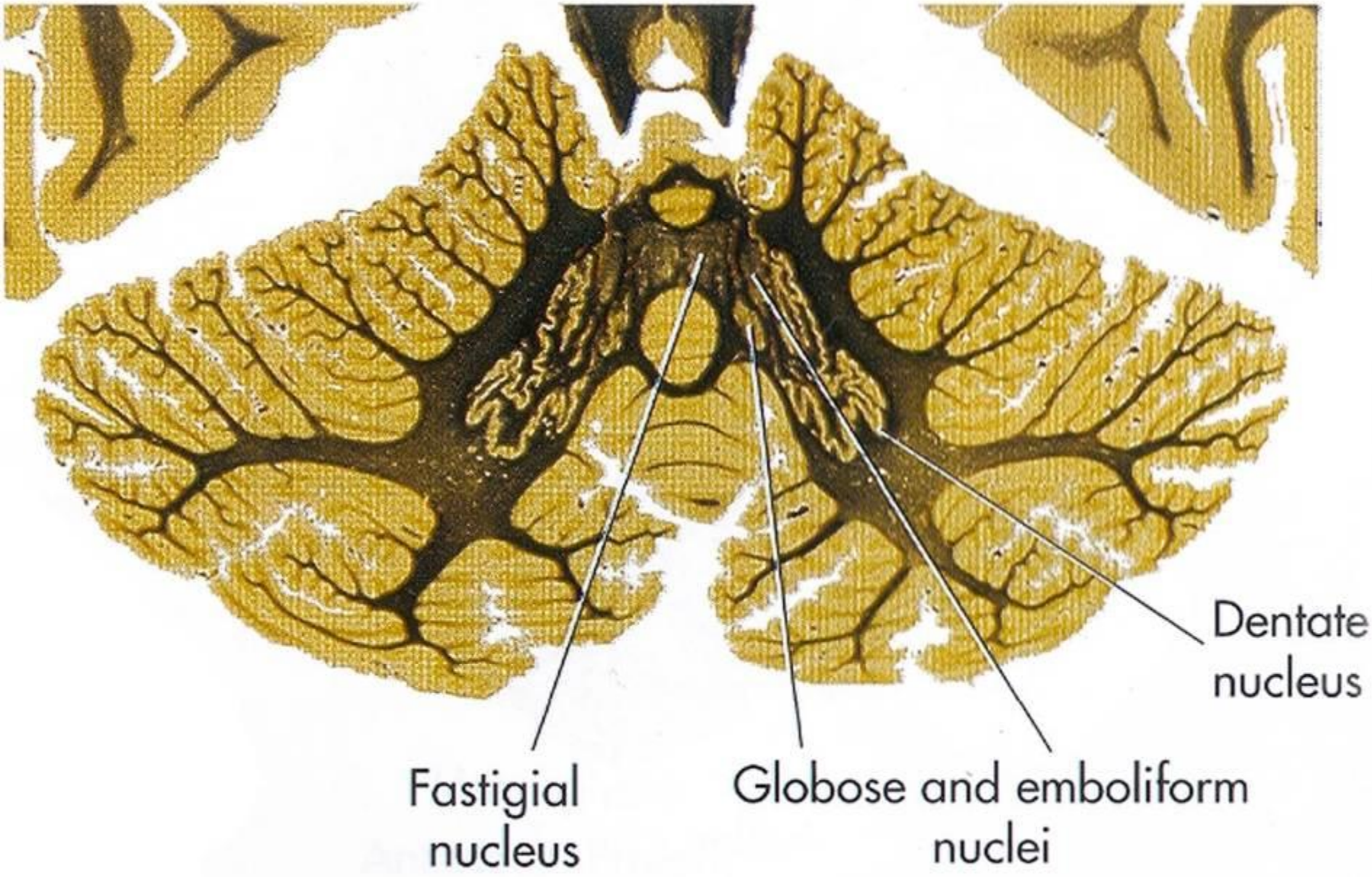


1 - nucleus dentatus
ncl. lateralis cerebelli)
2 - nucleus emboliformis
(ncl. interpositus anterior)
3 - nucleus globosus
(ncl. interpositus posterior)
4 - nucleus fastigii
(ncl. medialis cerebelli)

Deep cerebellar nuclei



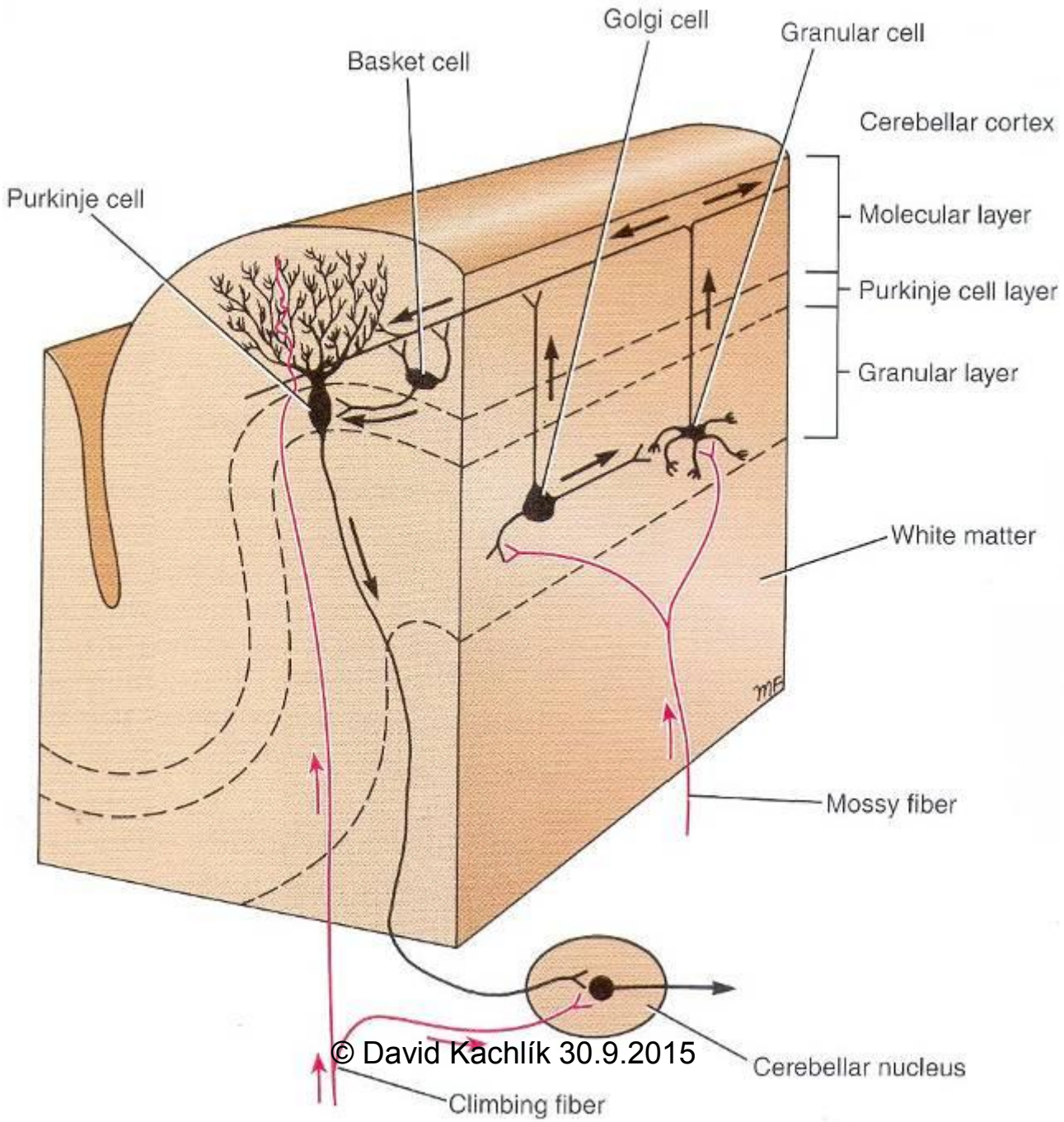


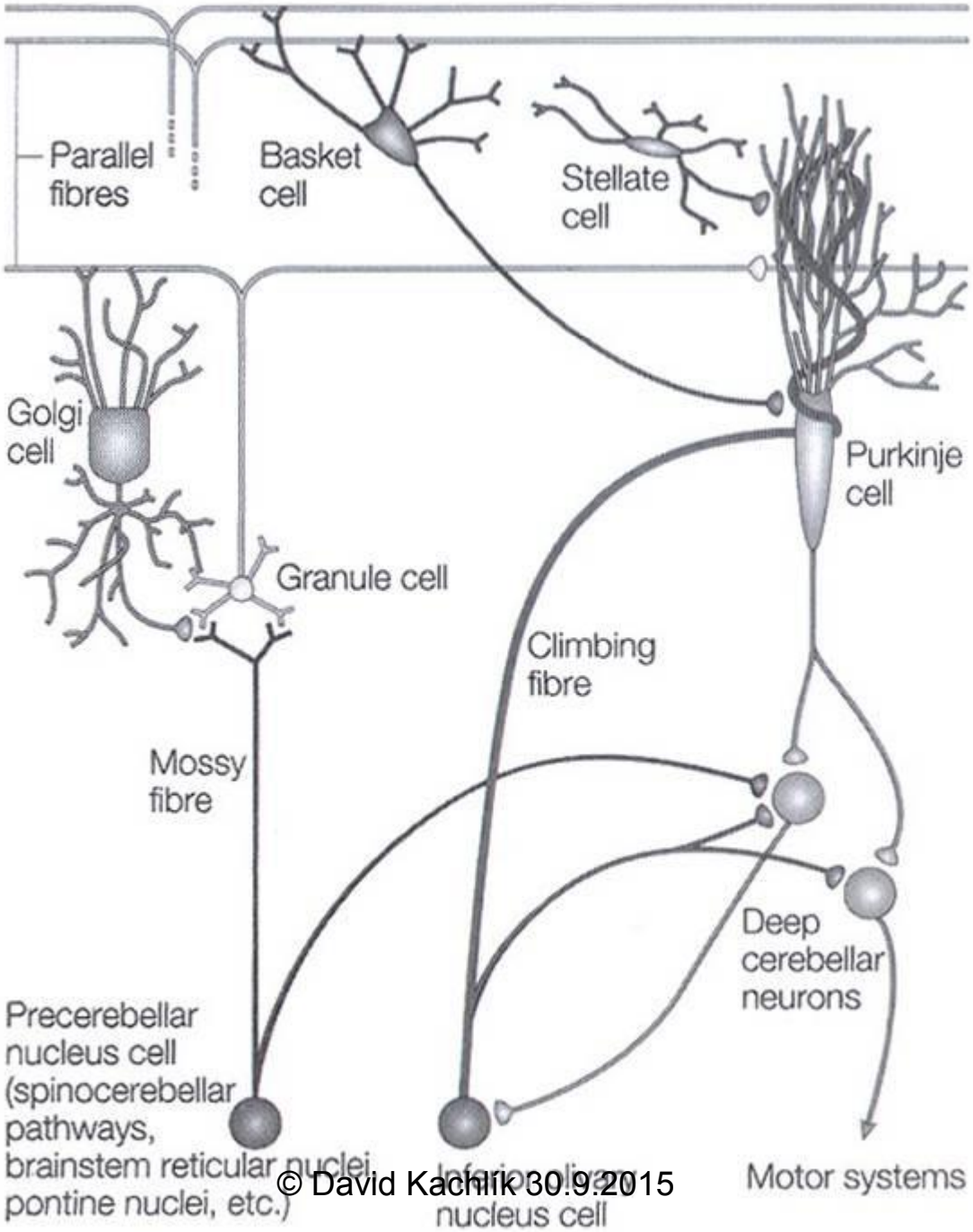


Cerebellum – layers of cortex

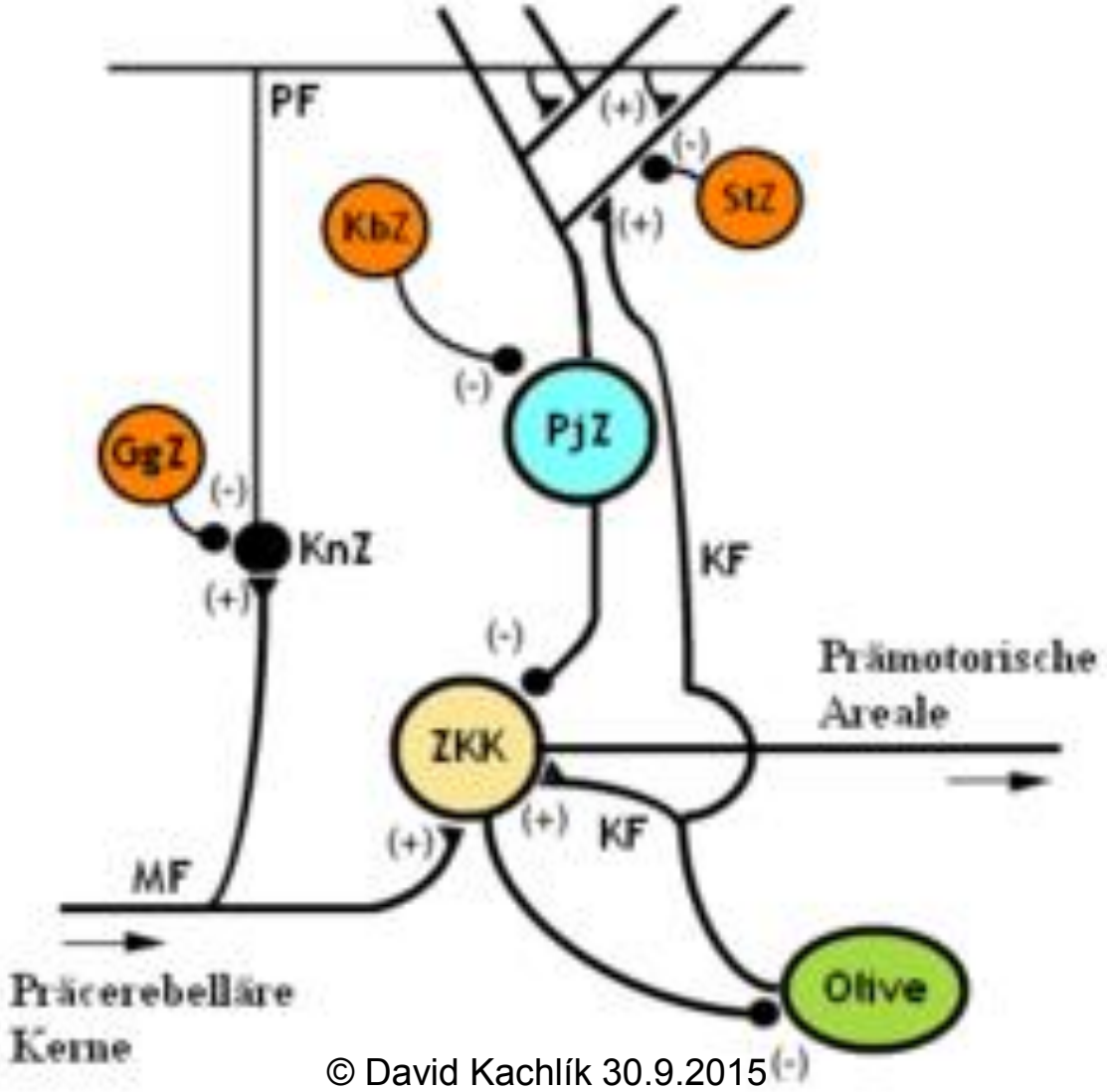
- stratum moleculare
  - neuron stellatum (stellate cells)
  - neuron corbiforme (basket cells)
  - neurofibra parellela (parallel fiber) – axons of granular cells
- stratum purkinjese

  = stratum neurium piriformium; formerly *stratum gaglionicum*
  - neuron purkinjese (***Purkynje cells***)
    - corbis neurofibrarum (rich branching to stratum moleculare)
    - Axons to cerebellar nuclei
- stratum granulare
  - neuron granulosum (***granulr cell***)
  - neuron stellatum magnum Golghi (***Golgi cell***)
  - Next 3 types of cells
  - glomerulus cerebelli
  - Afferent fibers: neurofibra muscosa (mossy fiber **-** ***Glu***) + ascendens (climbing fiber **-** ***Asp***)





Cellular connection

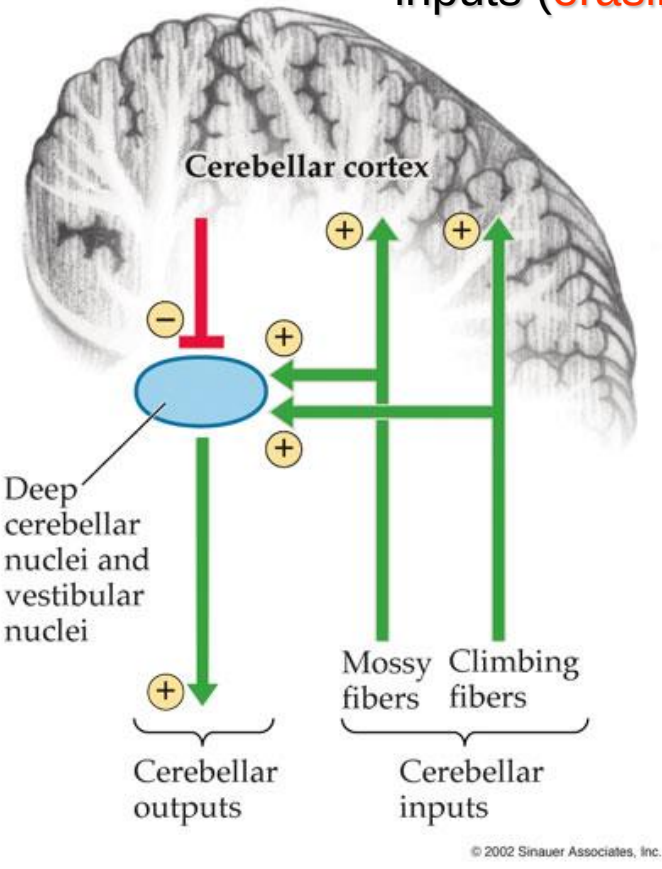


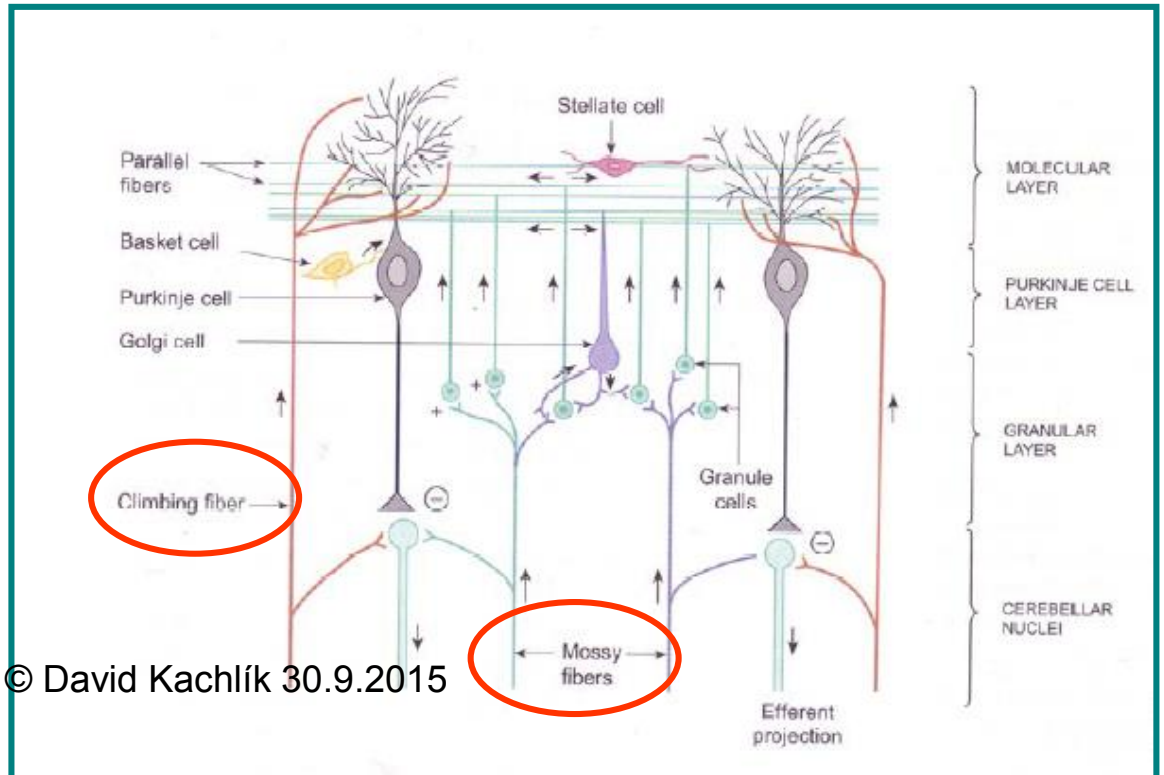
Cerebellum: 3 layered cortex

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

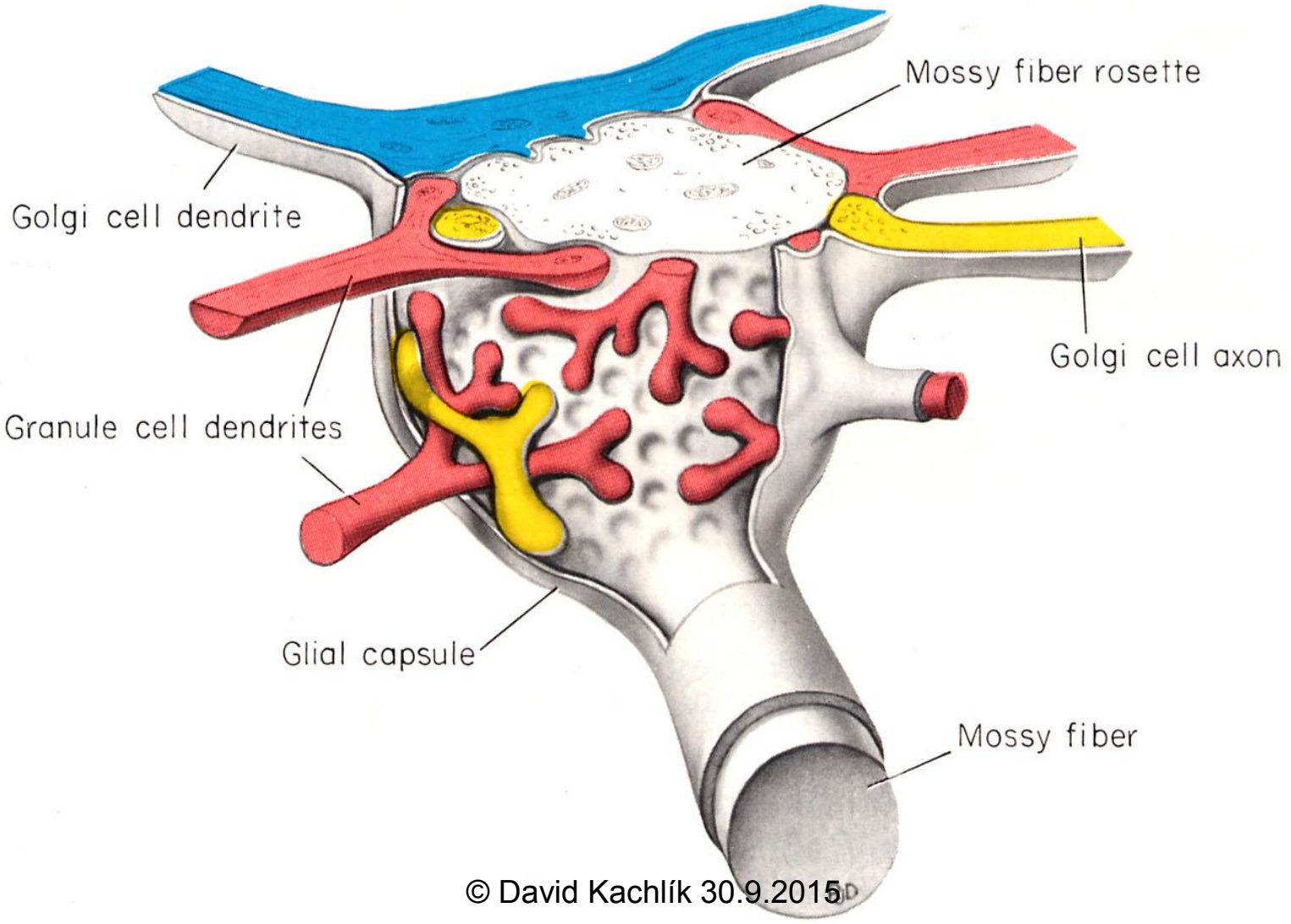
=> All excitatory inputs will be converted to the inhibition

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

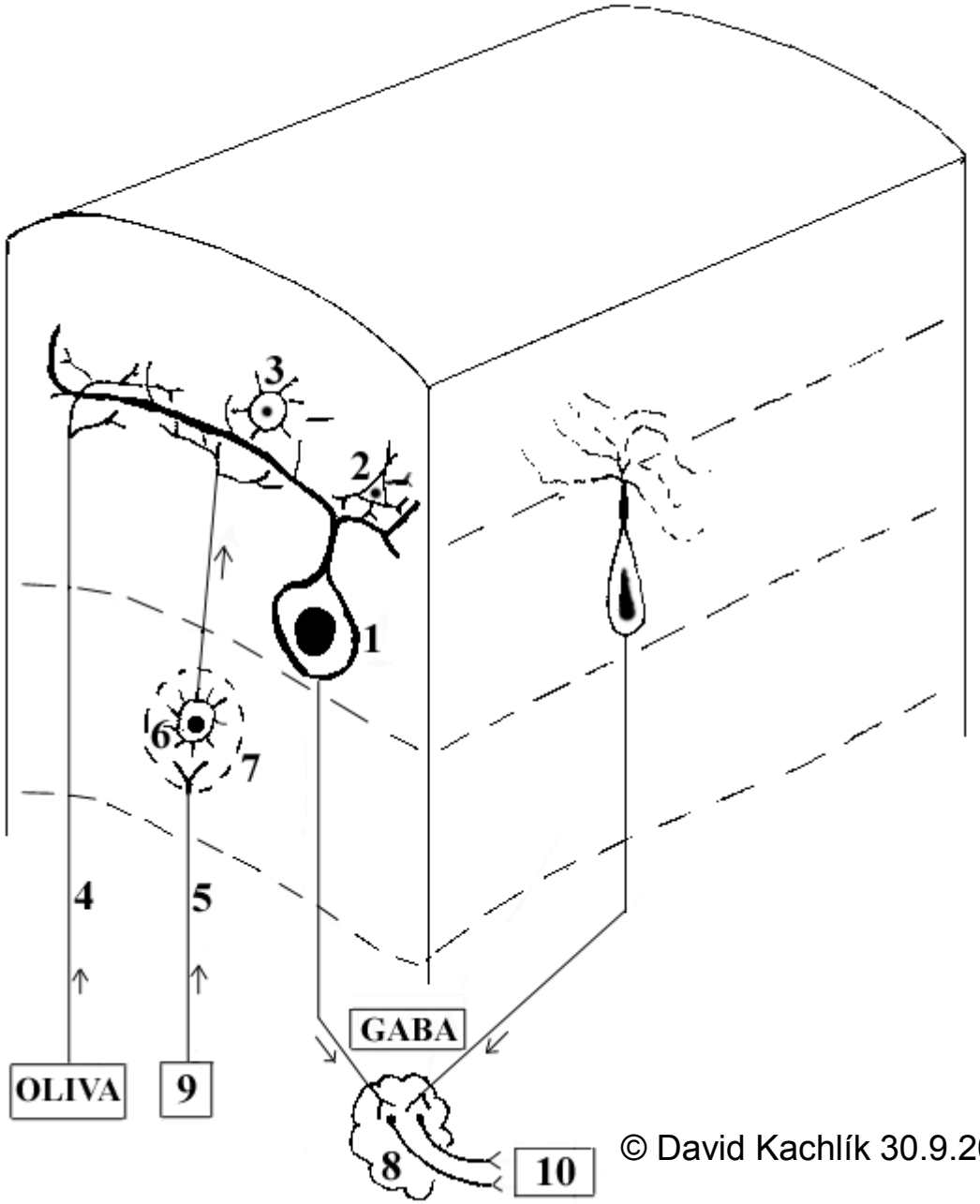




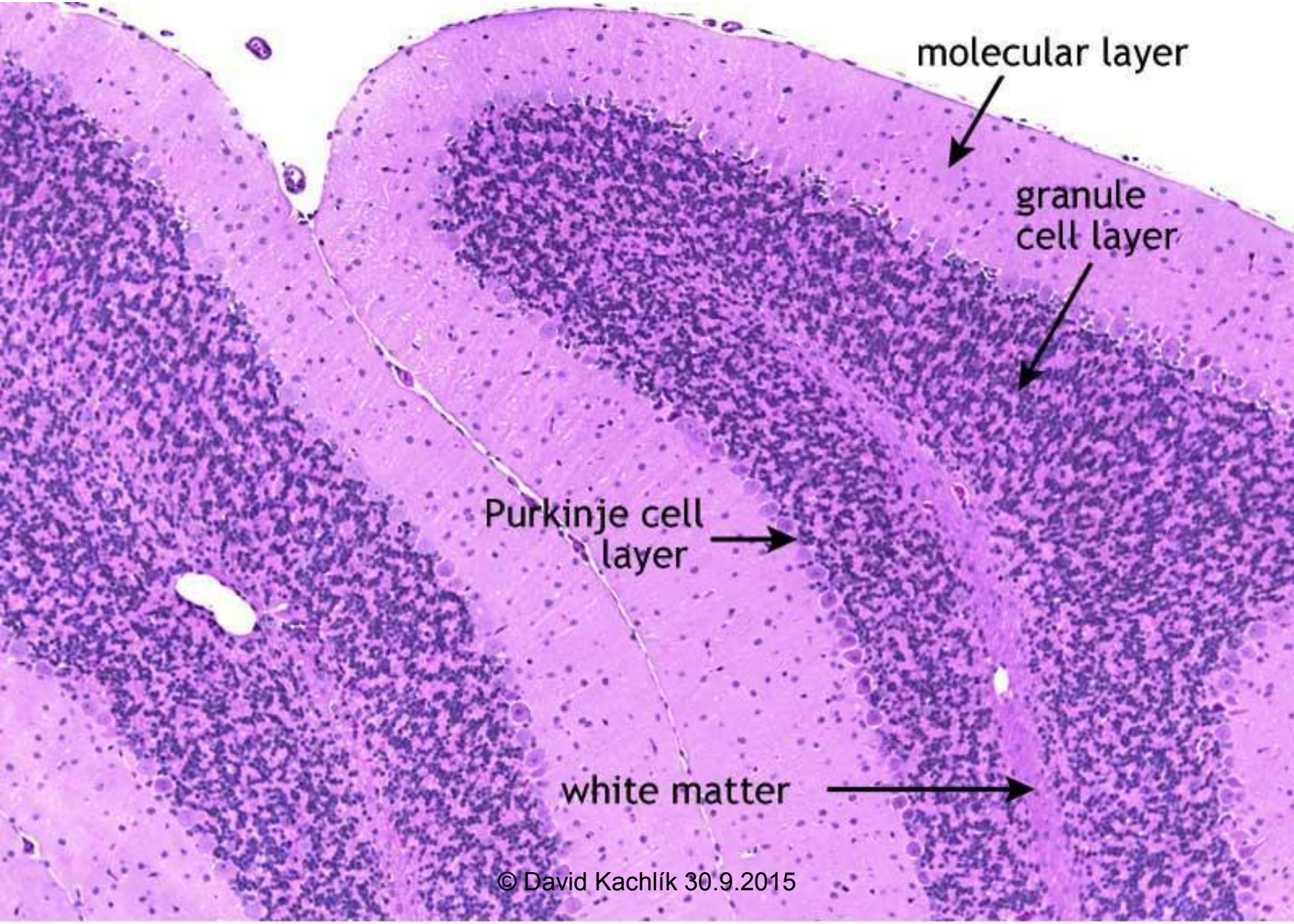
Cerebellar glomerulus



OBECNÁ STAVBA MOZEČKU - ŘEZ KŮROU



1 - Purkyňovy buňky (inhibice mozečkových jader)
2 - košíčkové buňky (inhibice Purkyňových buněk)
3 - hvězdicovité 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



Cerebellum – afferentation *balance*

- **tractus vestibulocerebellaris directus**

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

- **tractus vestibulocerebellaris indirectus**

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

- **tractus trigeminocerebellaris**

Information from head

Cerebellum – afferentation *passive proprioception*

- tractus spinocerebellaris posterior

  ncl. thoracicus post. *Stilling-Clarke*

  ➔ medulla oblongata ➔ pedunculus cer. inf.

  ➔ vermis + paravermal cortex (*ipsilateral*)
  proprioception from trunk and LL

- tractus cuneocerebellaris

  Posterior fascicle tract ➔ nucleus cuneatus accessorius

  Proprioception from UL and thorax

Cerebellum – afferentation *active proprioception*

- **tractus spinocerebellaris anterior**

ncl. thoracicus post. *Stilling-Clarke* ➔ crossing at spinal lvl ➔ mesencephalon ➔ pedunculus cer. superior ➔ crossing in crbl cortex ➔ vermis + paravermal cortex (*ipsilateral*) – **LL**

- **tractus spinocerebellaris rostralis**

ncl. thoracicus post. *Stilling-Clarke* ➔ pedunculus cer. inferior ➔ vermis + paravermal cortex (*ipsilateral*) – **UL**

- **tractus spinoolivaris**
  - motoric learning
  - *for example walking steep steps*

Cerebellum – afferentation form cortex

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

lobus f,p,o,t ➔ capsula interna ➔ ncll. pontis ➔ fibrae pontis transversae ➔ crossing ➔ pedunculus cer. medius ➔ crbl cortex (c*ontralat.*)

- **tractus cortico-olivo-cerebellaris**

lobus f,p,o,t ➔ capsula interna ➔ complexus olivaris inf. (*bilat.)* ➔ crossing ➔ pedunculus cer. inferior ➔ crbl cortex

- tractus **cortico-reticulo-cerebellaris**

lobus f,p,o,t (mostly sensorimotor cortex) ➔ capsula interna ➔ RF (*bilat.*) ➔ crossing ➔ pedunculus cer. medius + inf. ➔ crbl cortex

Will motoric, movement preparation, setting of proper muscle tonus

Cerebellum – efferentation

ncl. fastigii

1. ➔ PCI ➔ RF (*bilat.*) ➔ tr. reticulospinalis
2. ➔ PCI ➔ ncl. vestibularis lat. *Deitersi* (*bilat.*) ➔ tr. vestibulospinalis
3. ➔ cranial nerves, neck muscles

ncll. interpositi (globosus + emboliformis)

➔ PCS ➔ crossing ➔ ncl. ruber (pars magoncellularis) ➔ tractus rubrospinalis ➔ crossing ➔ spine (*ipsilat.*)

ncl. dentatus

➔ PCS ➔ crossing ➔ ncl. VA+VL thalami ➔ area 4 ➔ tr. pyramidalis ➔ crossing ➔ spine (*ipsilat.*)

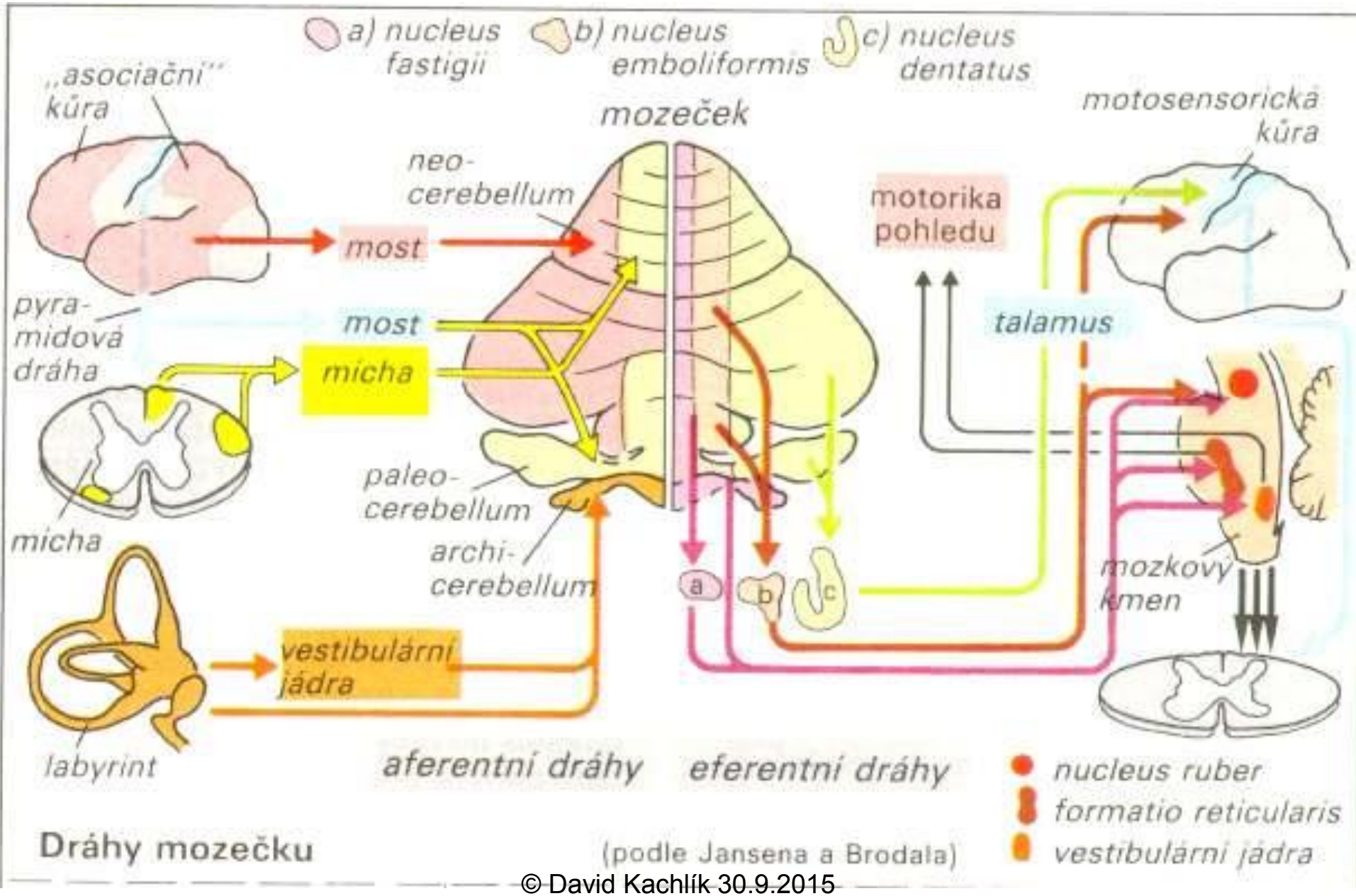
Cerebellum – inferior pedicles pedunculus cerebellaris inferior

- 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. vestibulocerebellerais directus + indirectus
  - EF↓: tr. cerebello-reticulospinalis, -cerebellovestibularis, cerebelospinalis, cerebellonuclearis (all from *z ncl. fastigii*)

Cerebellum – middle and upper pedicles pedunculus cerebellaris medius et superior

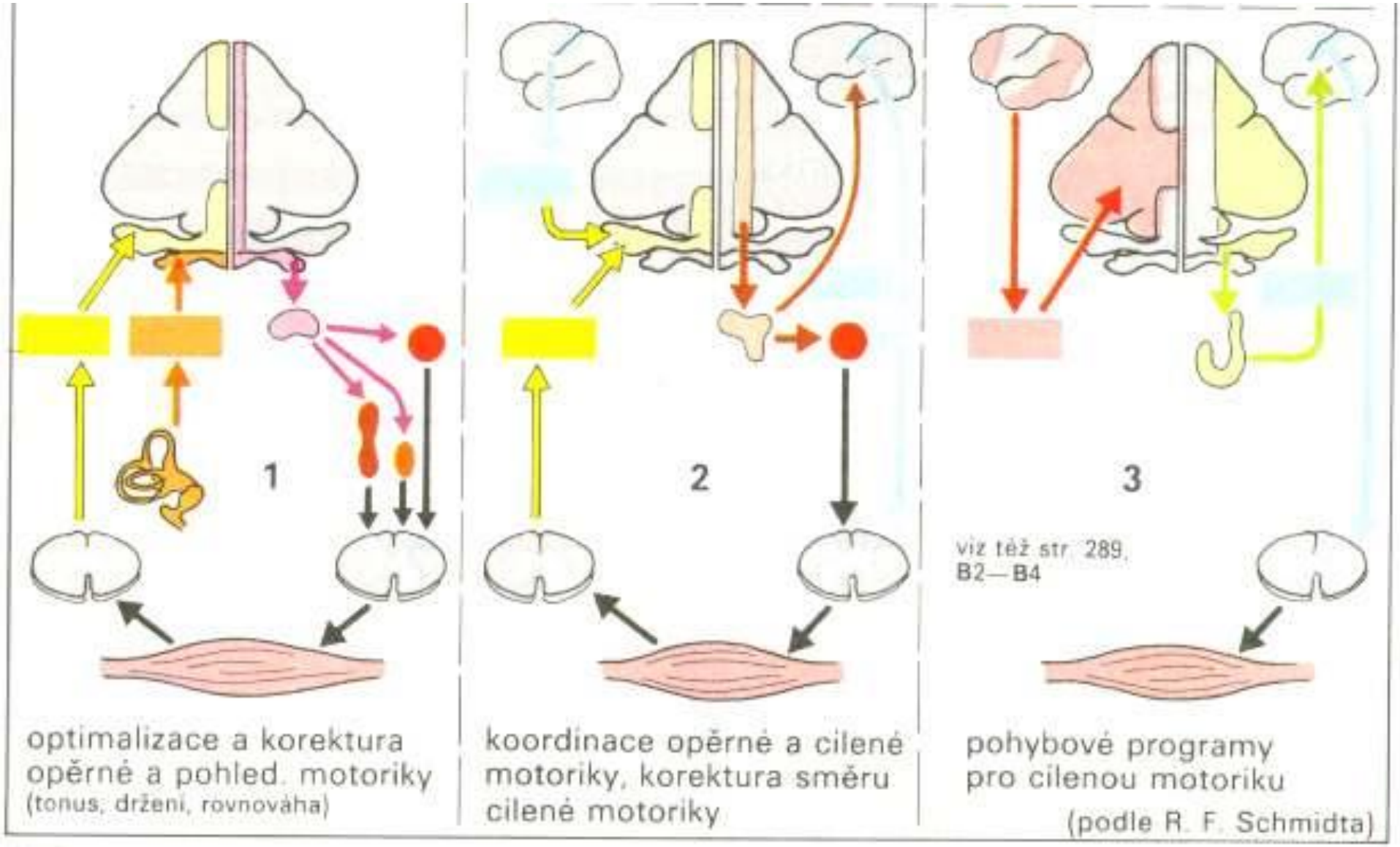
- **pedunculus cerebellaris medius**
  AF↓: tractus cortico-ponto-cerebellaris

- **pedunculus cerebellaris superior**
  AF↑: tr. spinocerebellaris anterior + tectocerebellaris
  EF↓: tr. cerebello-rubro-thalamo-corticalis + tr. cerebello-rubro-spinalis
  EFcircuit: tr. cerebello-rubro-olivo-cerebellaris (*Papezův control circuit*)



Dráhy mozečku

(podle Jansena a Brodala)



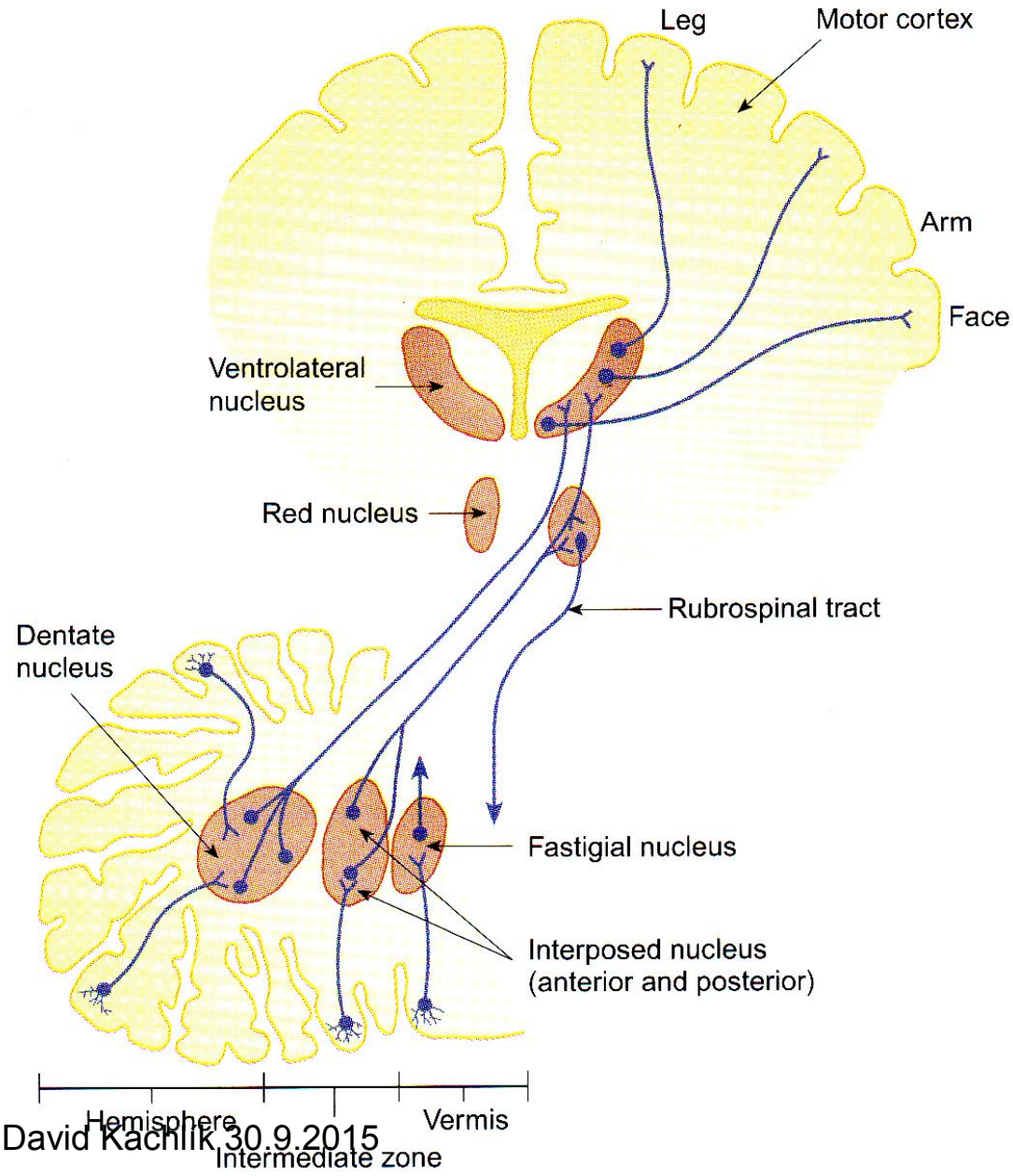
optimalizace a korektura opěrné a pohled. motoriky (tonus, držení, rovnováha)

koordinace opěrné a cílené motoriky, korektura směru cílené motoriky

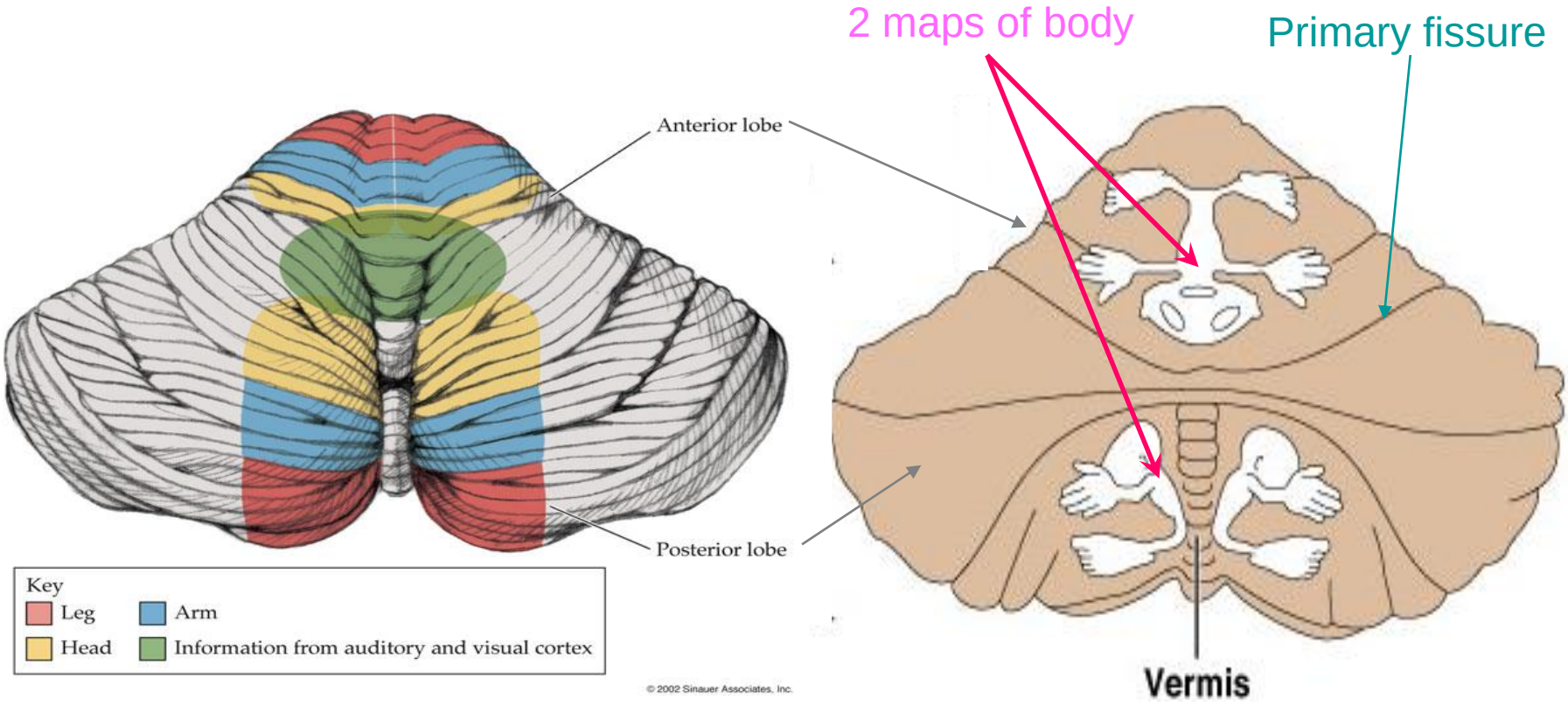
pohybové programy pro cílenou motoriku

(podle R. F. Schmidta)

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

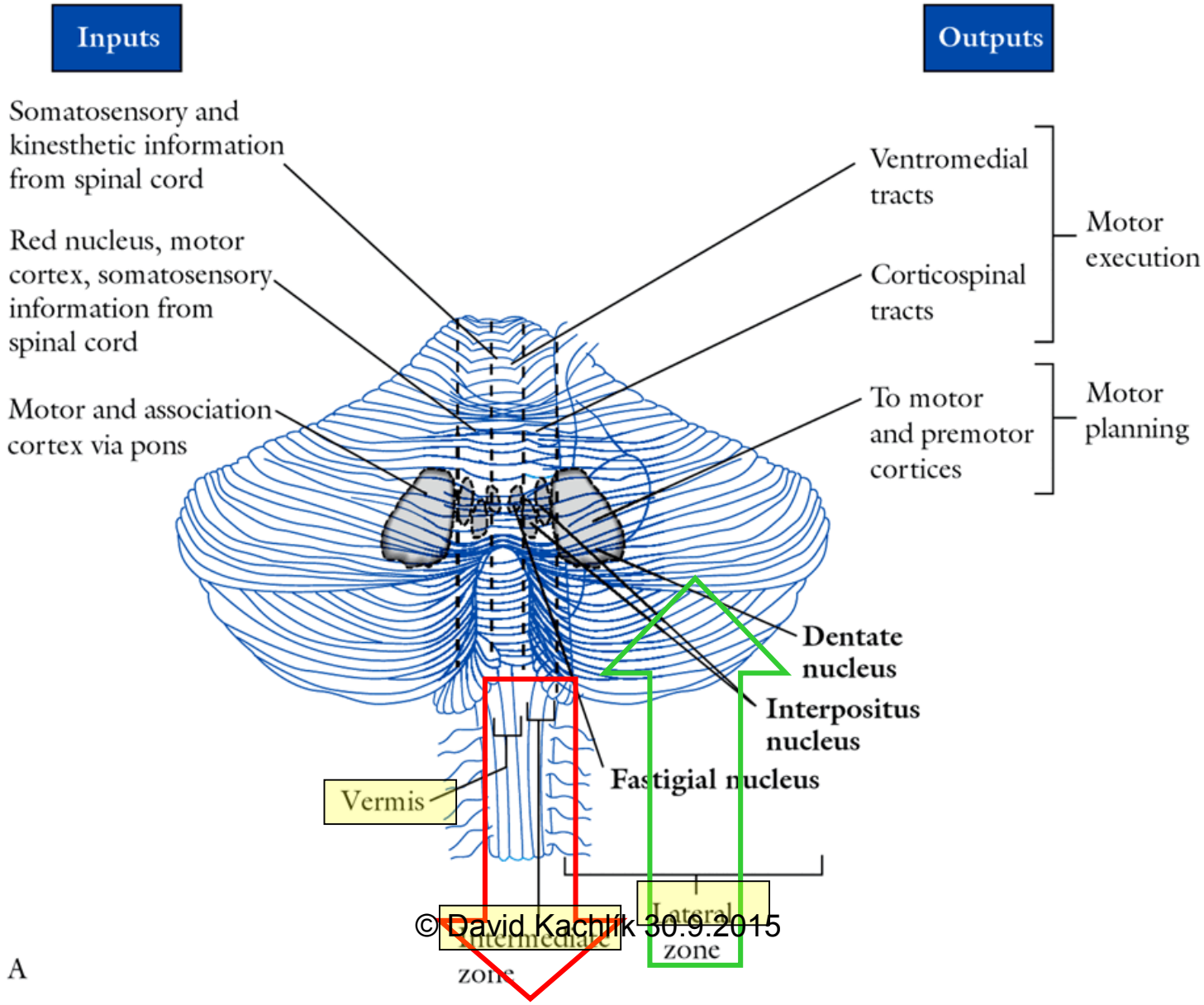


Inputs to cerebellum from spinocerebellar tracts have a somatotopic organization.

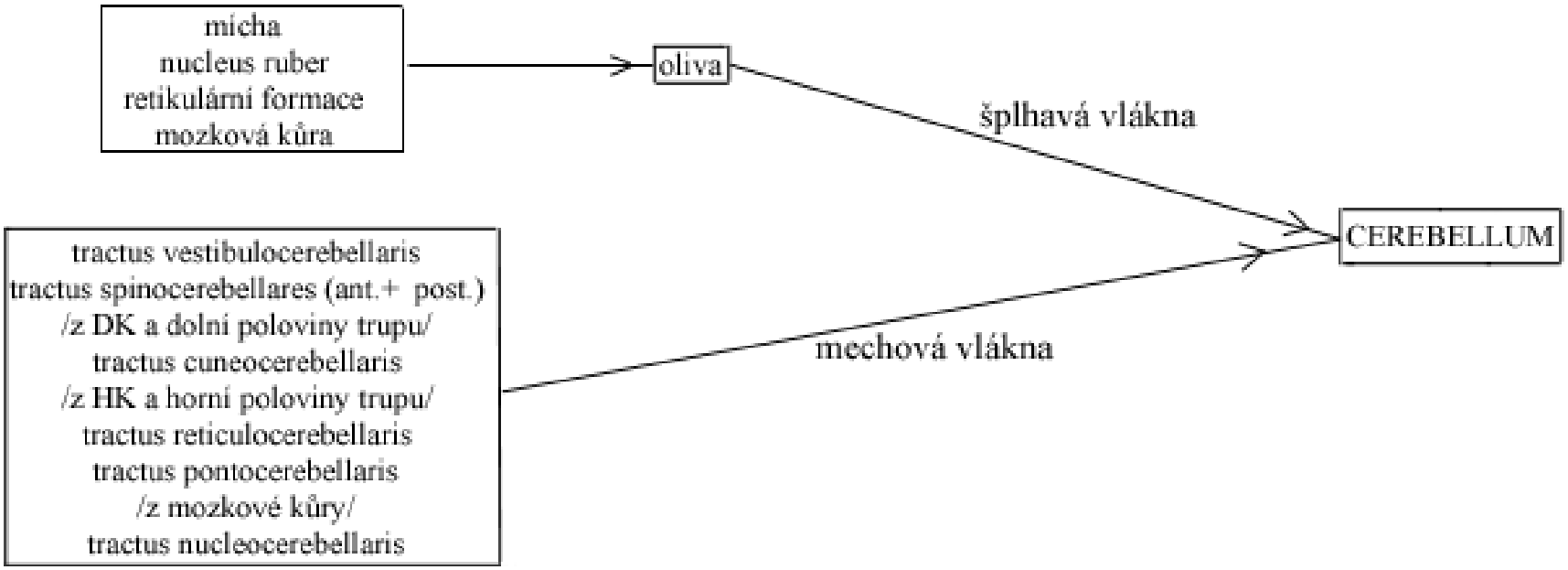


Signals from the motor cortex, which is also arranged somatotopically, project to corresponding points in the sensory maps of the cerebellum.

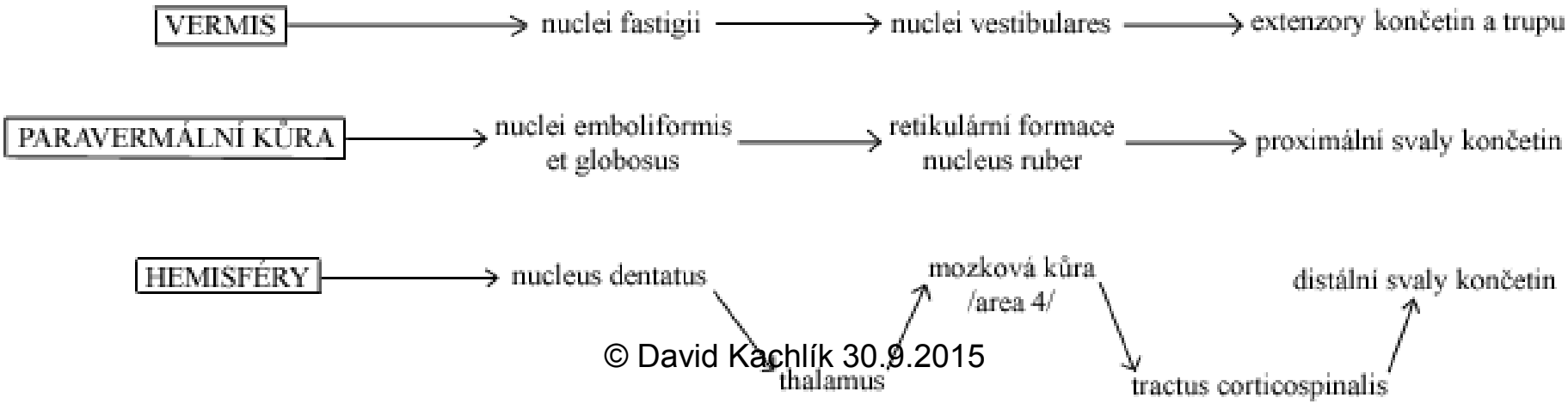
Inputs and outputs of the Cerebellum



AFERENTY MOZEČKU



EFERENTY MOZEČKU



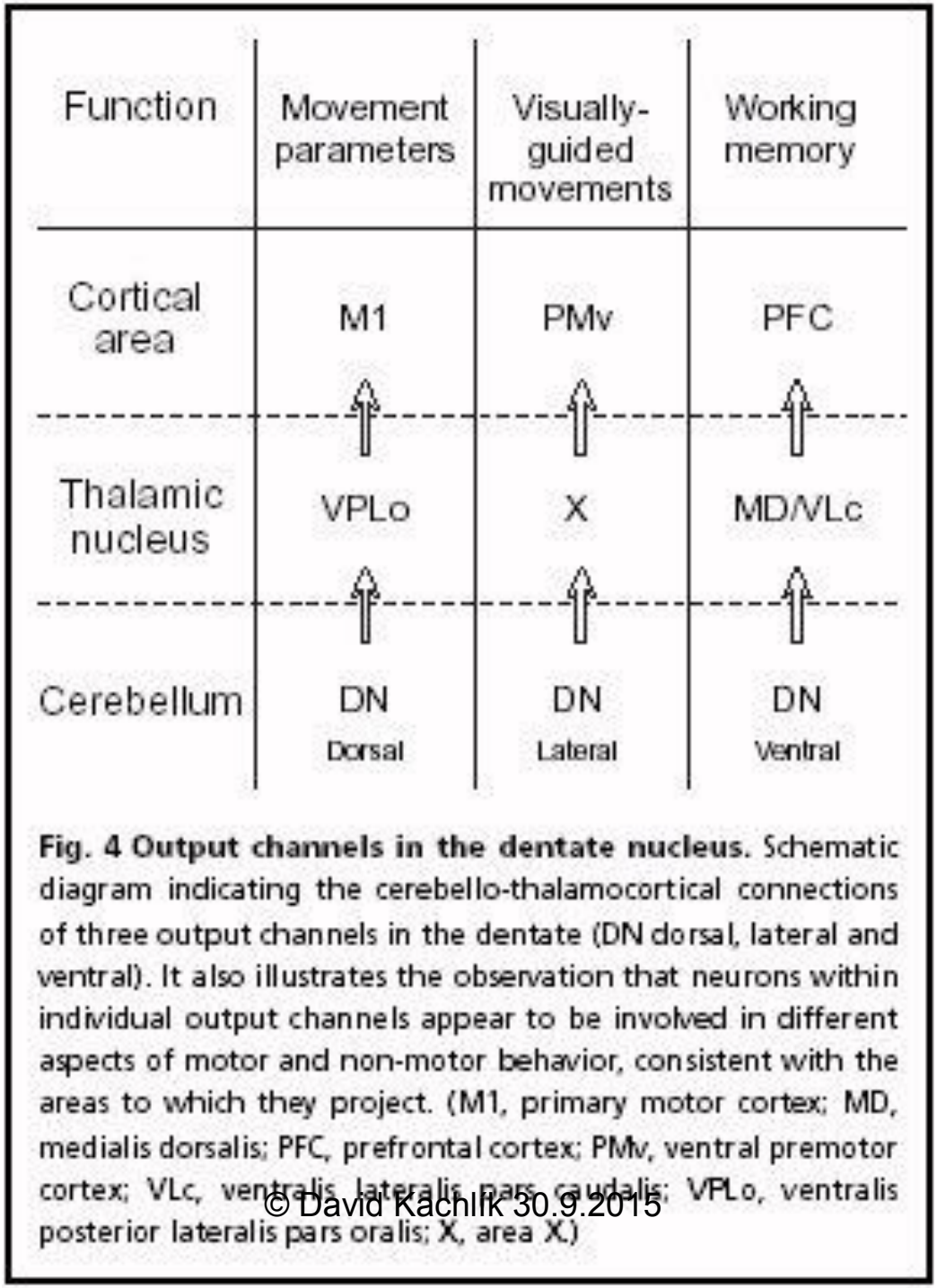
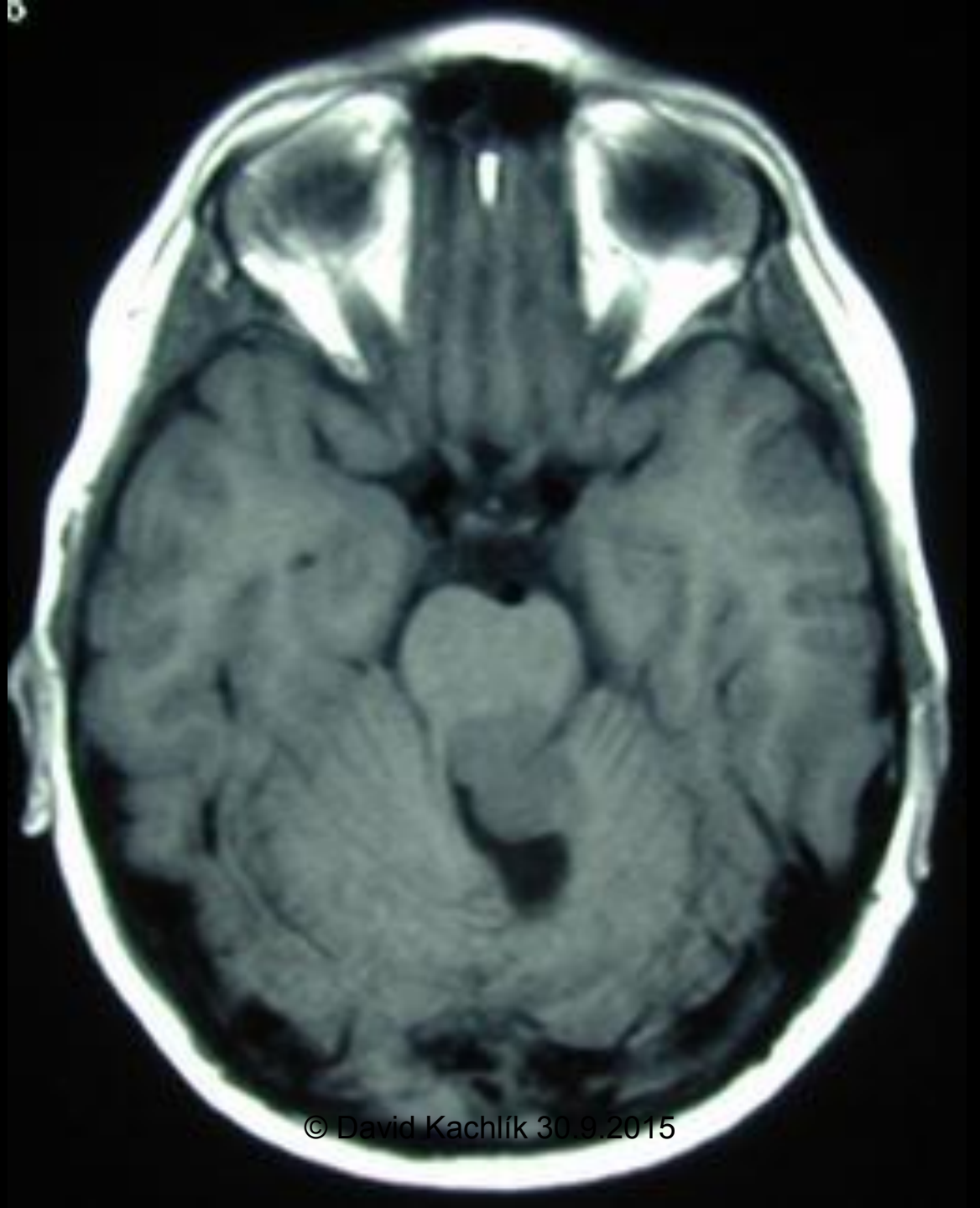


Fig. 4 Output channels in the dentate nucleus. Schematic diagram indicating the cerebello-thalamocortical connections of three output channels in the dentate (DN dorsal, lateral and ventral). It also illustrates the observation that neurons within individual output channels appear to be involved in different 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
- balance
- *nystagmus*
- Connection with ncll. vestibulares (inferior + medialis)

Common reason: *meduloblastoma*



Paleocerebellum (spinocerebellum)

- lobus anterior
- AF: tractus spinocerebellaris anterior + posterior
- Proprioception (passive and active) (information about reflexes)
- Collaterals to cerebellar nuclei
- EF: action of anti gravitatory muscles, coordination of agonists/antagonists
- gait (walk)

Neocerebellum (cerebrocerebellum)

- lobus posterior
- AF: tractus cortico-ponto-cerebellaris
- Collaterals to cerebellar nuclei
- EF: motoric control
  - Coordination of subtle limbs movements
  - Loop sided trim of motor activity
  - Together with cortex plans movements

Cerebellar syndrome

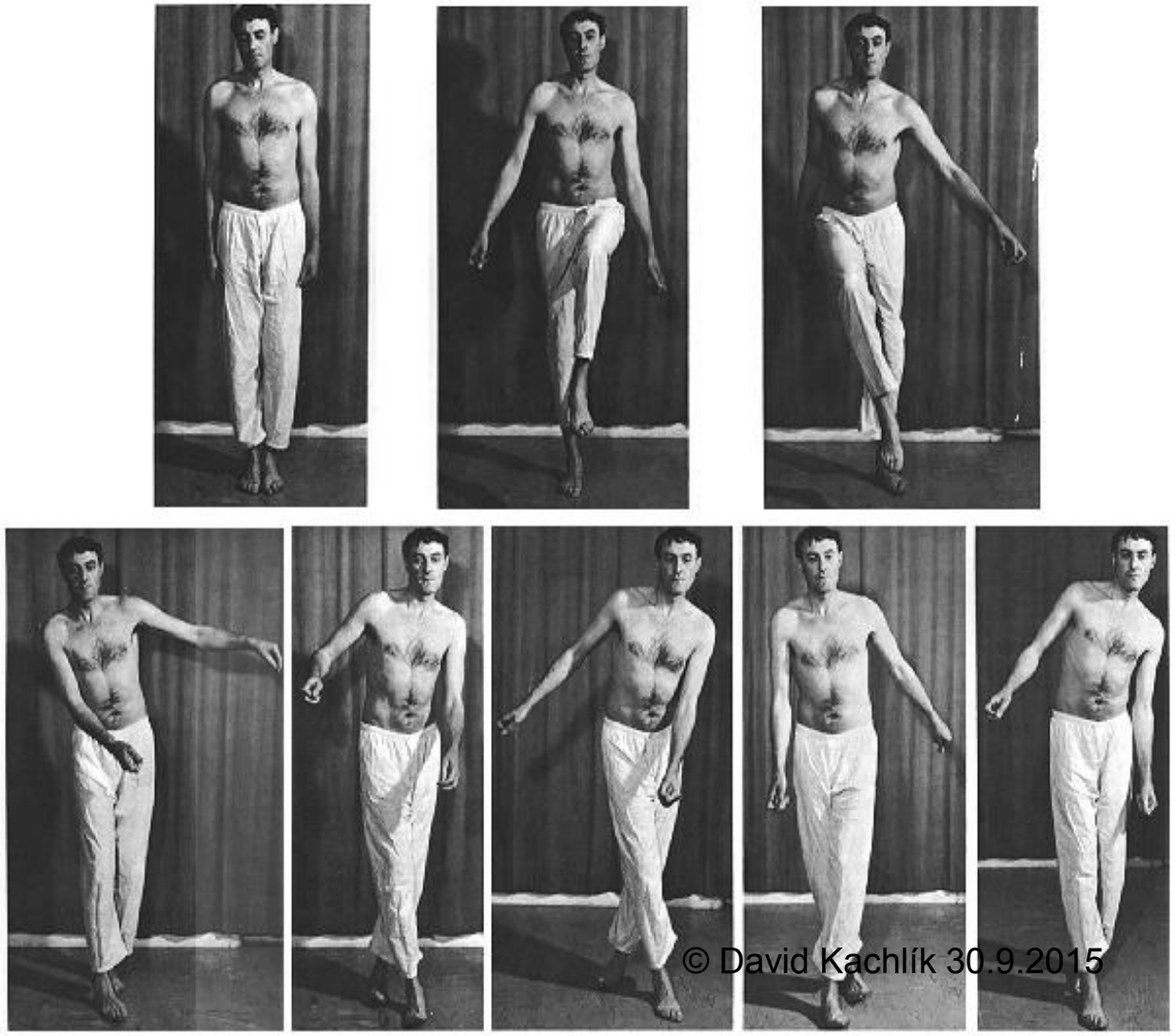
- Muscular hypotonia (increased interval and pasivity of movements)
- ataxia (loss of coordination)
  - hypermetria – dysmetria
    - makrografia, saccadic speech, megafonia, bradylalia
  - adiadochokinesis
  - asynergia („drunken sailor walk“)
- Intention tremor
- nystagmus and vertigo
- (hyporeflexia of elementar postural reflexes)

Cerebellar cognitive-affective syndrome

- Deficit of executive functions
- Impairment of spatial tasks
- Personality changes
  - Flattening, desinhibition, non adequate behavior
- Language problems
  - dysprosodia (melody, temp, rhytm), agrammatismus, light anomia (wrong social behavior)

(Schmahmann a Sherman, 1998)

Cerebellar ataxia



Ataxic gait and position:
Left cerebellar tumor

a. Sways to the right in standing position

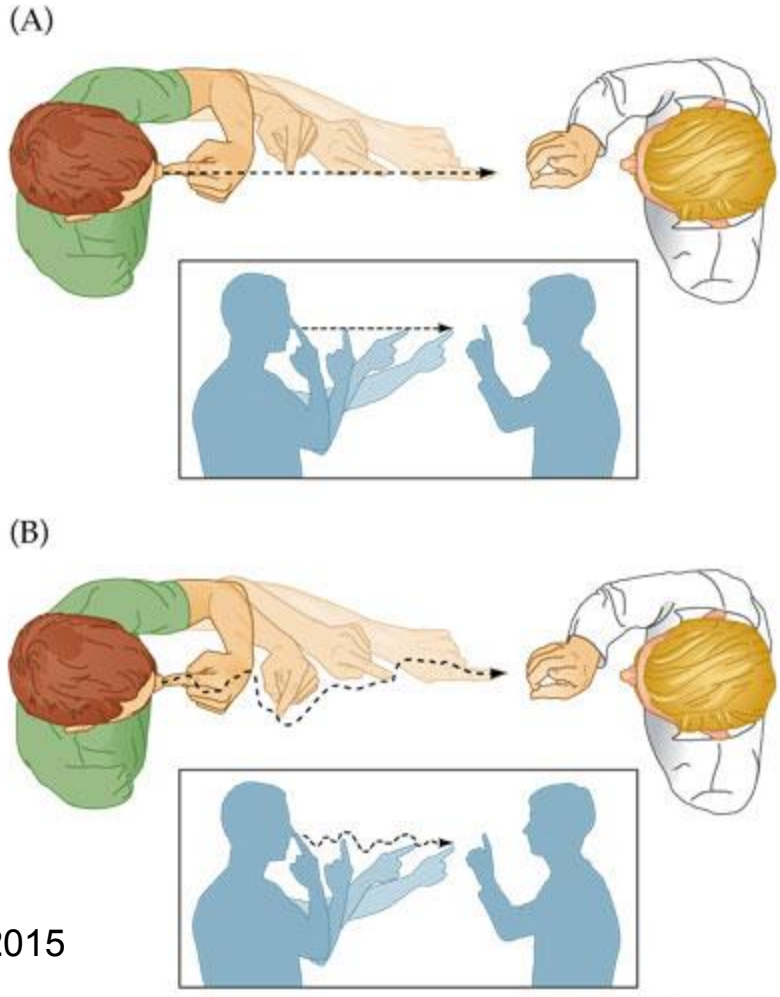
b. Steady on the right leg

c. Unsteady on the left leg

d. ataxic gait

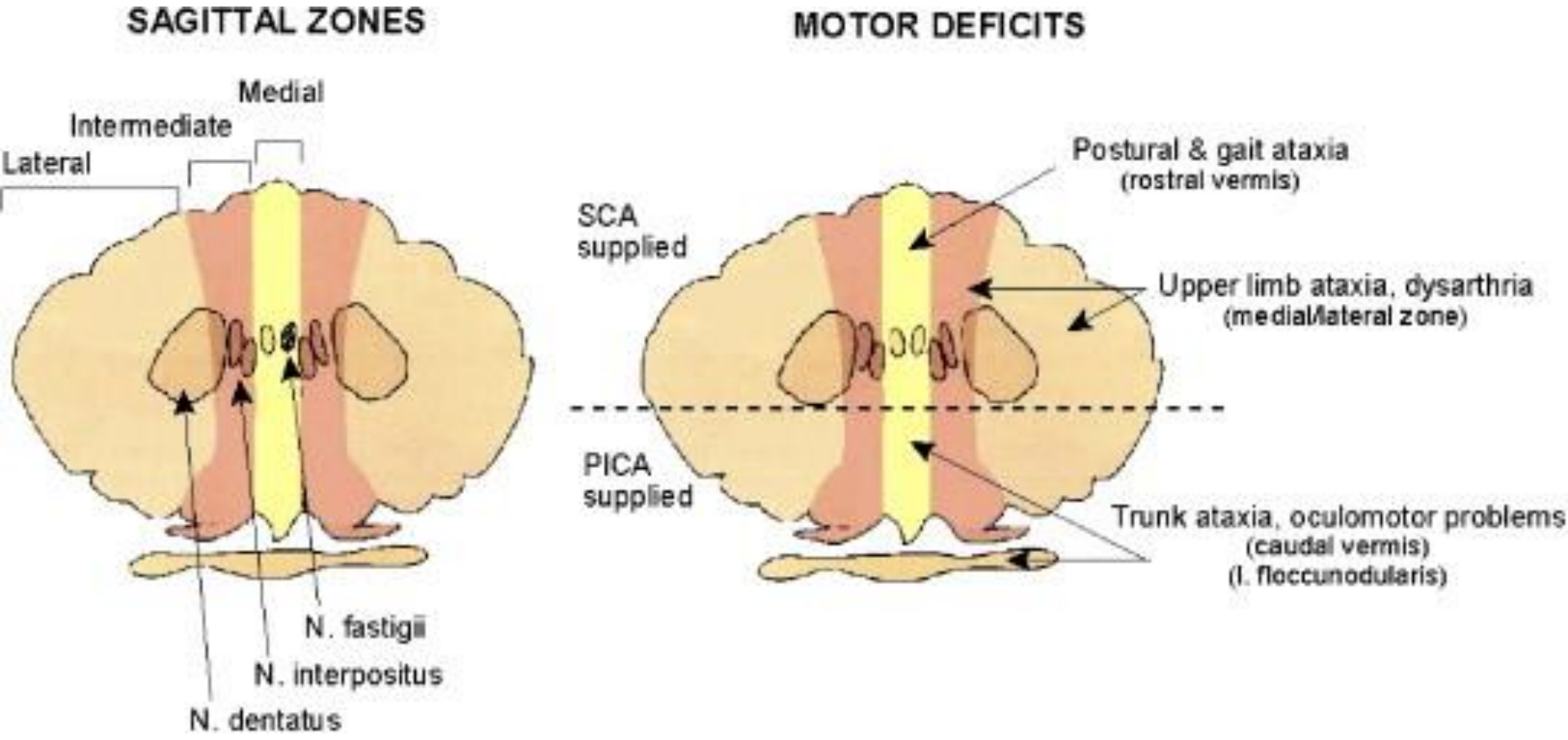
Clinical Findings and Localization of Cerebellar Lesions

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).

Cerebellar lesions



Cerebellum – principal circuits

- circuit: cortex-cerebellum

cortex → pons / oliva / RF (oliva) – ncll. pontis / complexus olivaris inferior → *crossing* → cortex → ncl. dentatus → *crossing* → thalamus (ncl. VL) → cortex

- Papez cerebellar control circuit:

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

  - Learning of motor, cognitive and language skills

- cortex – cerebellum: **always contralaterally**
- cerebellum – body: **always ipsilaterally**

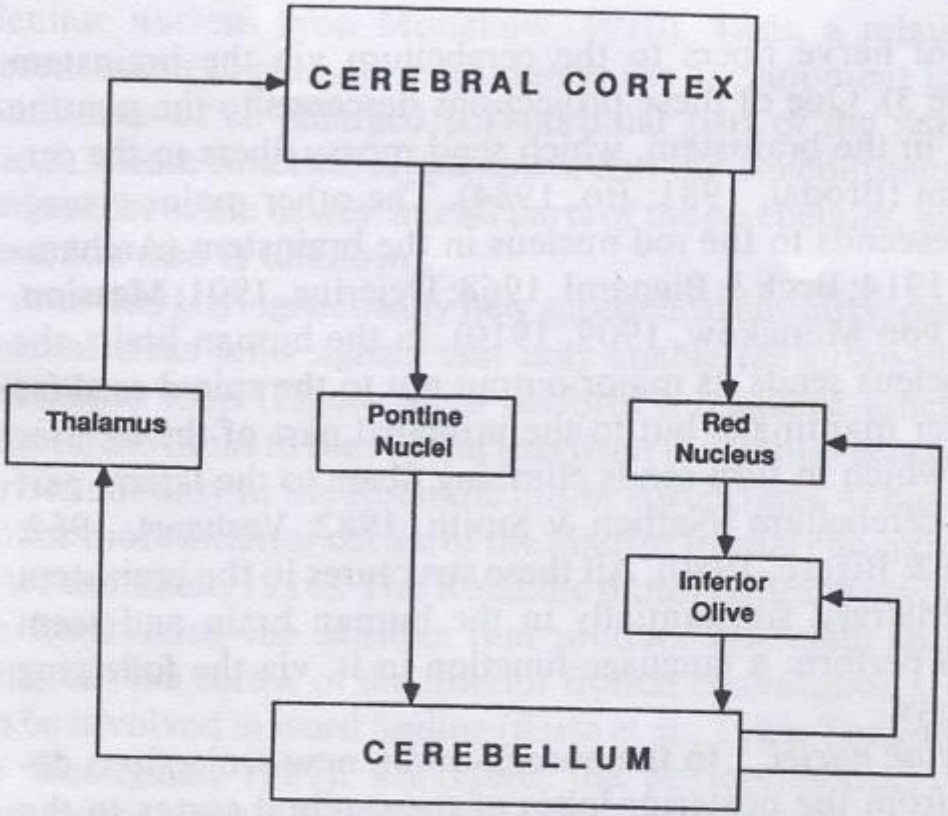


Figure 3. Major cerebro-cerebellar loops in the human brain. (From the cerebral cortex, two major sets of projections descend to the cerebellum via enlarged structures in the brainstem, i.e., via pontine nuclei and via rubro-olivary nuclei. The pontine nuclei project mossy fibers to the cerebellum, and 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.)

Cerebellum - summary

- balance
- Mostly motoric functions
  - Creation, support and maintenance of muscle tonus
  - Planning of movement with cortex
  - Complicated and subtle movements: dance, speech, writing
- „comparator“
- Other functions – cognition, sensory perception

Alcohol Damages the Cerebellum

Control

Alcoholic

Lack of thiamin (B1) causes degeneration of lobus anterior cerebelli

Sullivan et al., Neuropsychology, In press

Optional reading: Cerebellar lesions

Cerebellar symptomes

- 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 symptomes

- 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 – palleocerebellar lesion, deficit of trunk axial muscle – standing, sitting from laying, erecting etc.

Cerebellar symptomes

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

Cerebellar symptomes

- 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 loose
- 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 Thyamine Deficiency, mostly from alcohol abuse
- -Wernicke's encephalopathy *symptoms are gait ataxia, nystagmus, diplopia,*
- strabismus
- -Korsakoff syndrome- sever 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 symptomes

- 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 symptomes

- 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 symptomes

- Eyeball problems – usually when vestibulocerebellum (archicerebellum) is damaged or connections with vestibular nuclei, nystagmus (saccadic dysmetria)
- Astasia – damage of standing, nonstabile 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, agramatismus, decrease of intellect