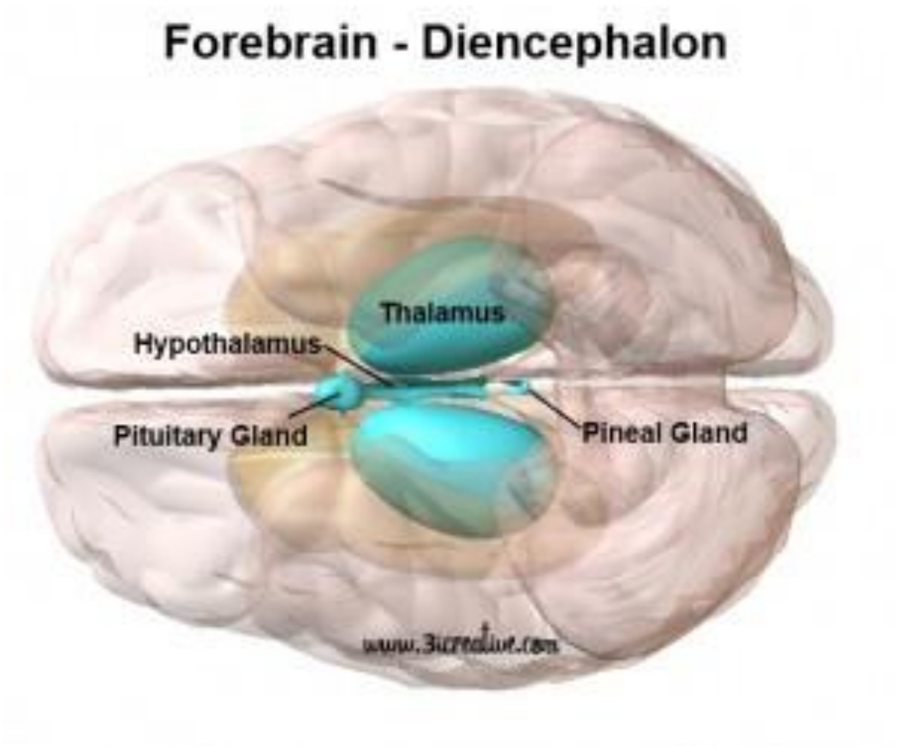
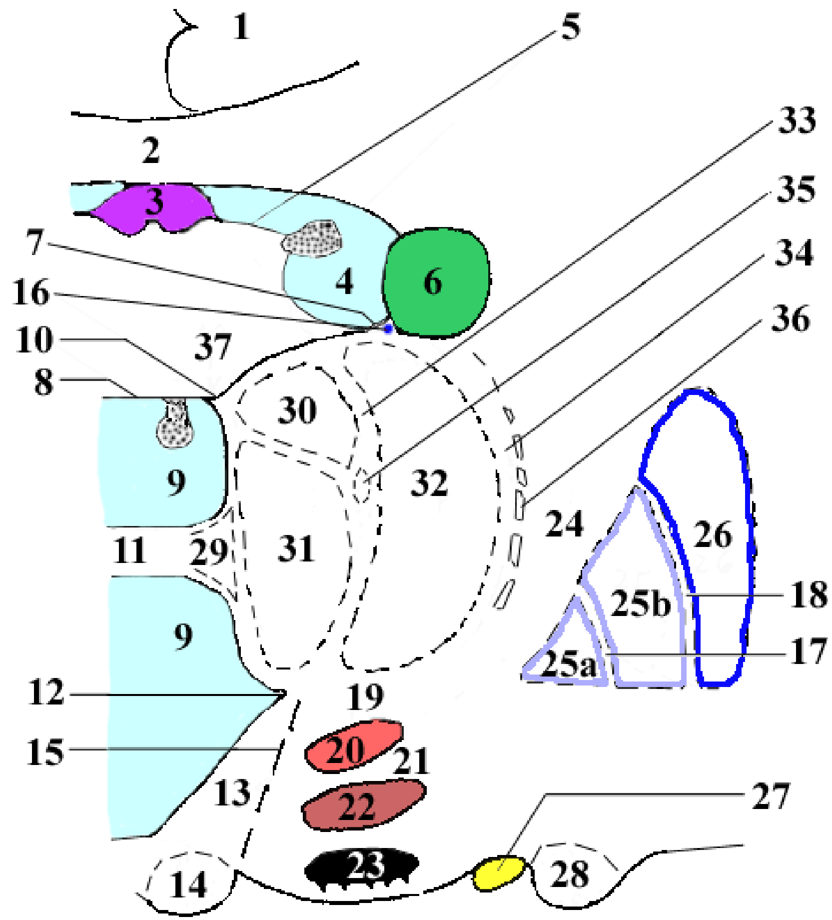
DIENCEPHALON

diencephalon

- epithalamus
- subthalamus
- thalamus
- metathalamus
- hypothalamus
- thalamus opticus



FRONTÁLNÍ ŘEZ DIENCEPHALEM



1 - gyrus cinguli
2 - corpus callosum
3 - corpus fornicis cerebri
4 - ventriculus lateralis
5 - tela choroidea ventriculi lateralis
6 - caput nuclei caudati
7 - lamina affixa thalami
8 - tela choroidea ventriculi tertii
9 - ventriculus tertius
10 - stria medullaris thalami
11 - adhesio interthalamica
12 - sulcus hypothalamicus
13 - hypothalamus
14 - corpus mamillare
15 - hranice hypo- a subthalamu
16 - vena thalamostriata superior
17 - lamina medullaris med. nuclei lentiformis
18 - lamina medullaris lat. nuclei lentiformis
19 - *Forelovo políčko* H1
(fasciculus thalamicus + nucleus campi dorsalis)
20 - zona incerta
21 - *Forelovo políčko* H2
(fasciculus lenticularis + nucleus campi ventralis)
22 - nucleus subthalamicus /*Luys*/
23 - substantia nigra
24 - capsula interna
25a - globus pallidus medialis
25b - globus pallidus lateralis
26 - putamen
27 - tractus opticus
28 - corpus geniculatum laterale
29 - nuclei mediani thalami
30 - nuclei anteriores thalami
31 - nuclei mediales thalami
32 - nuclei ventrales, dorsales et posteriores thalami
33 - lamina medullaris medialis thalami
34 - lamina medullaris lateralis thalami
35 - nuclei intralaminares thalami
36 - nucleus reticularis thalami
37 - fissura telodiencephalica

diencephalon - development

Alar plate → thalamus, subthalamus

Bazal plate → hypothalamus

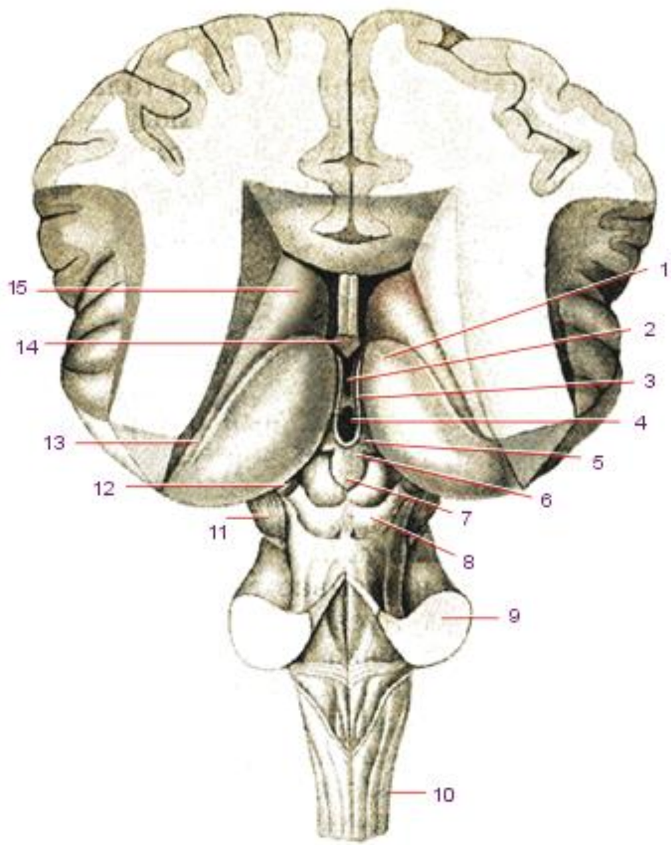
canalis centralis → 3rd ventricle

fissura telodiencephalica

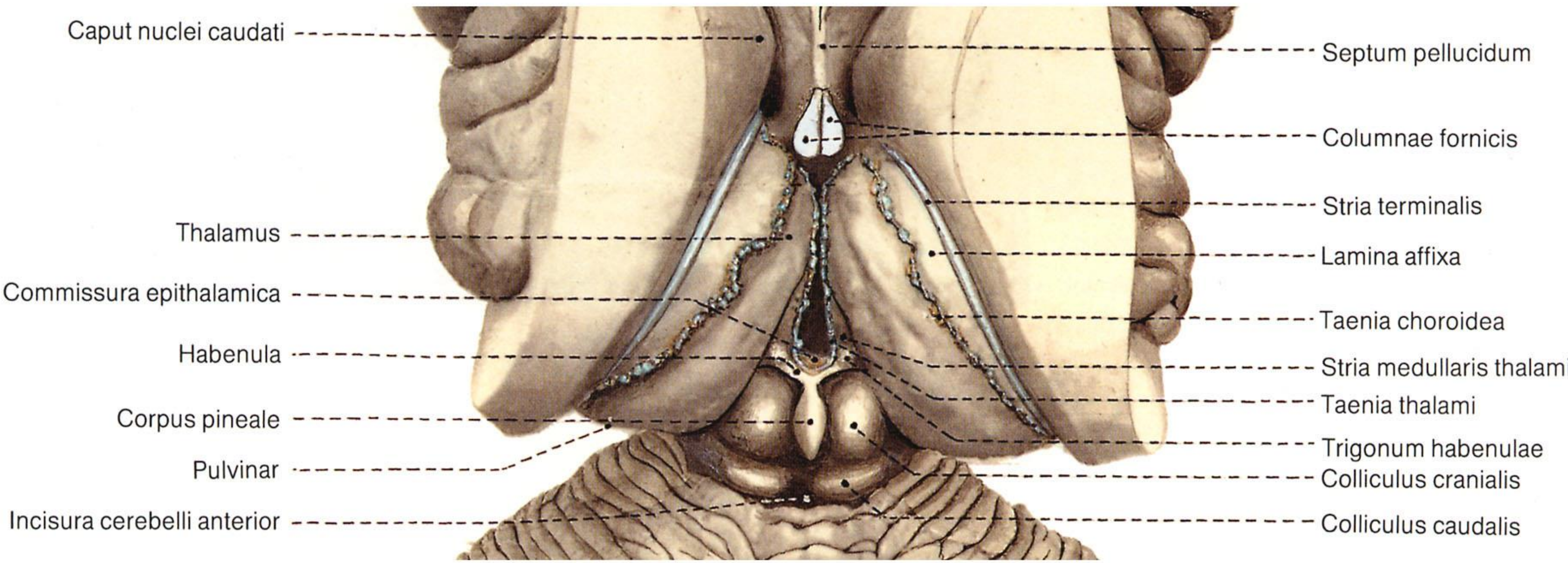
sulcus hypothalamicus

Epithalamus

- **habenula (trigonum habenulare)**
  - **ncl. habenularis med. + lat.**
- **commissura habenularum**
- **commissura posterior**
  - Commisural fibers
    - Posterior thalamic nuclei, colliculi sup., ncll. pretectales
  - Non commissural fibers
    - ncl. interstitialis *Cajali* + ncl. commissurae posterioris *Darkschewitzi* → fasciculus longitudinalis medialis from other side

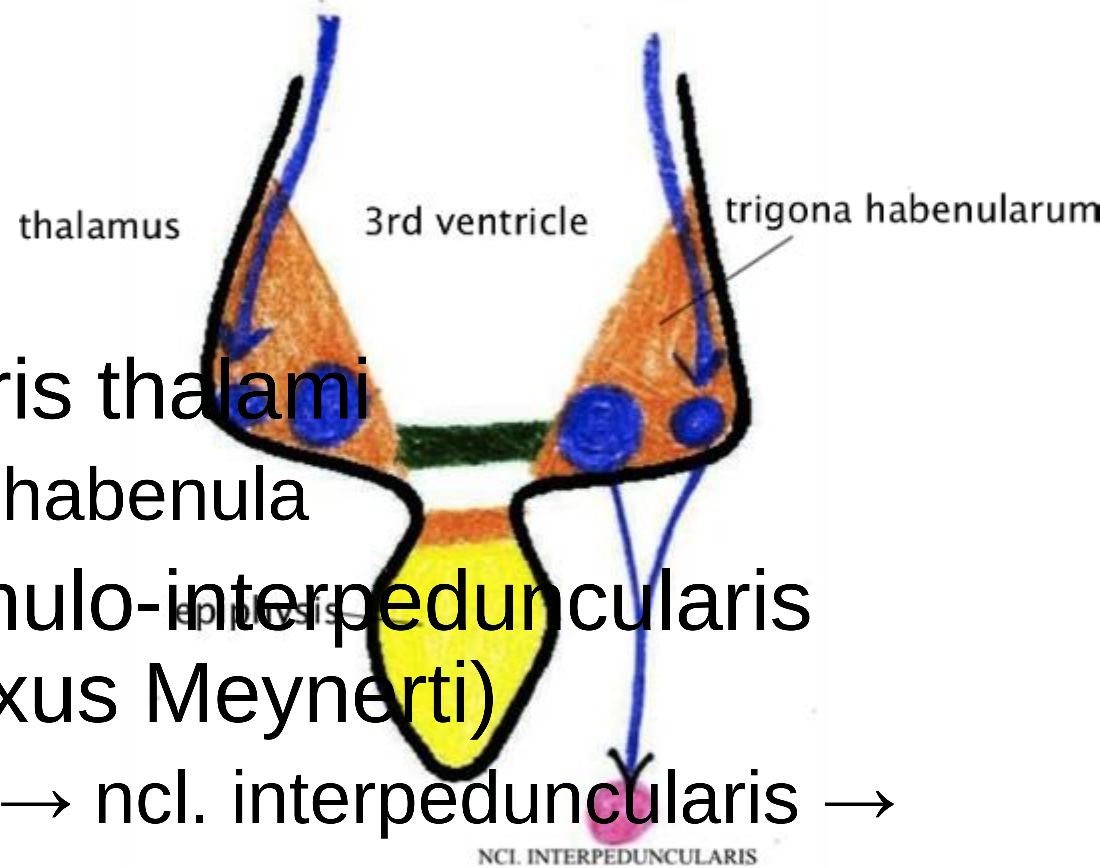


Epithalamus



Epithalamus

Habenulae connections

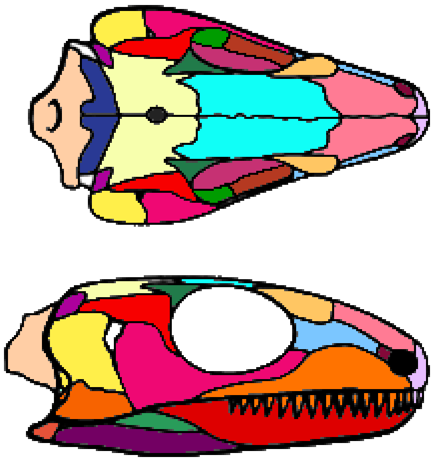


- AF: stria medullaris thalami
  - septum verum → habenula
- EF: tractus habenulo-interpeduncularis (fasciculus retroflexus Meynerti)
  - ncll. habenulares → ncl. interpeduncularis → stem

commissura habenularum

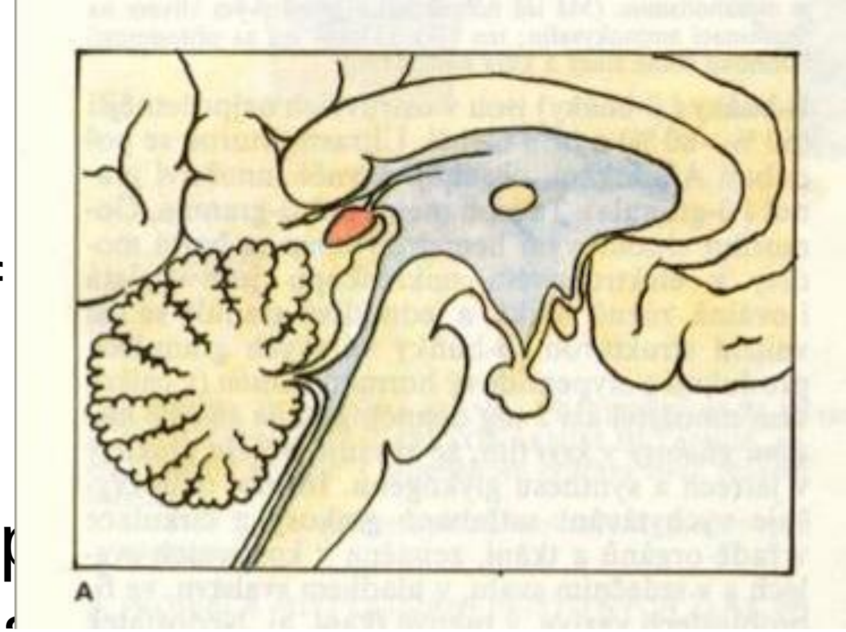
Glandula pinealis; Corpus pineale
„Epiphysis;“

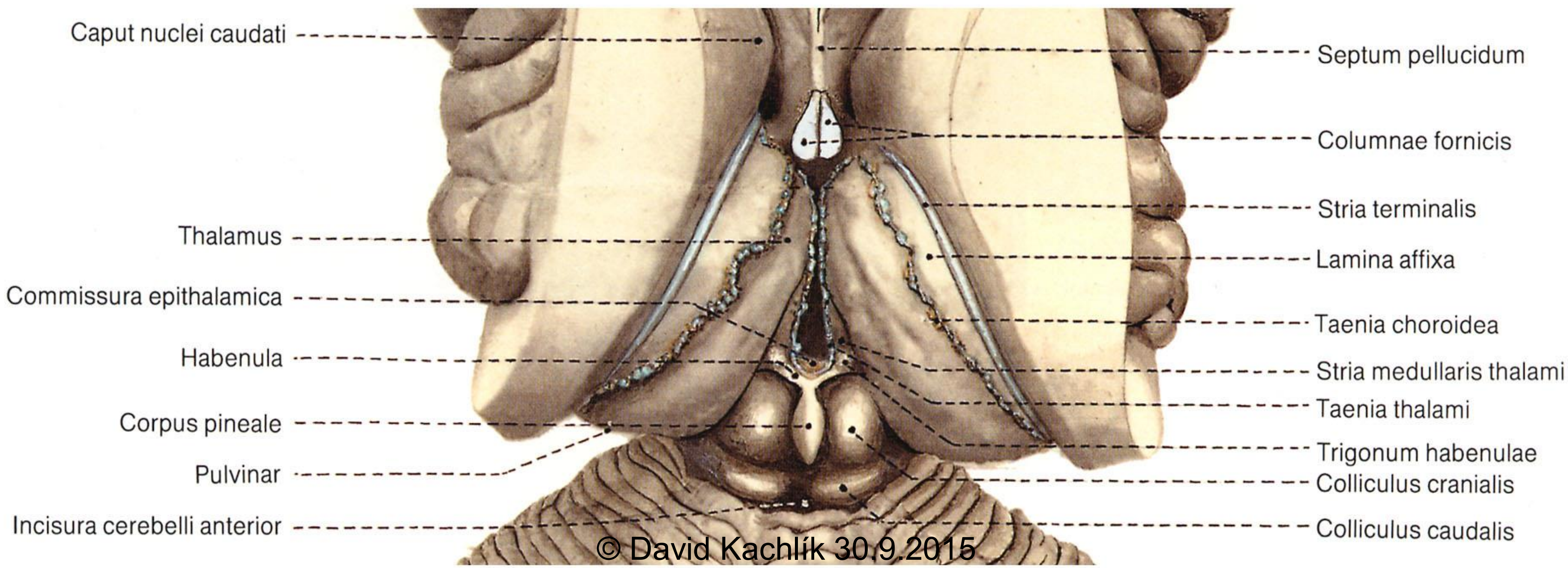
- Developmental relation to parietal eye
- Hateria New Zealand (*Sphenodon punctatus*)
- Reaction to polarized light (monthly biorhytms)

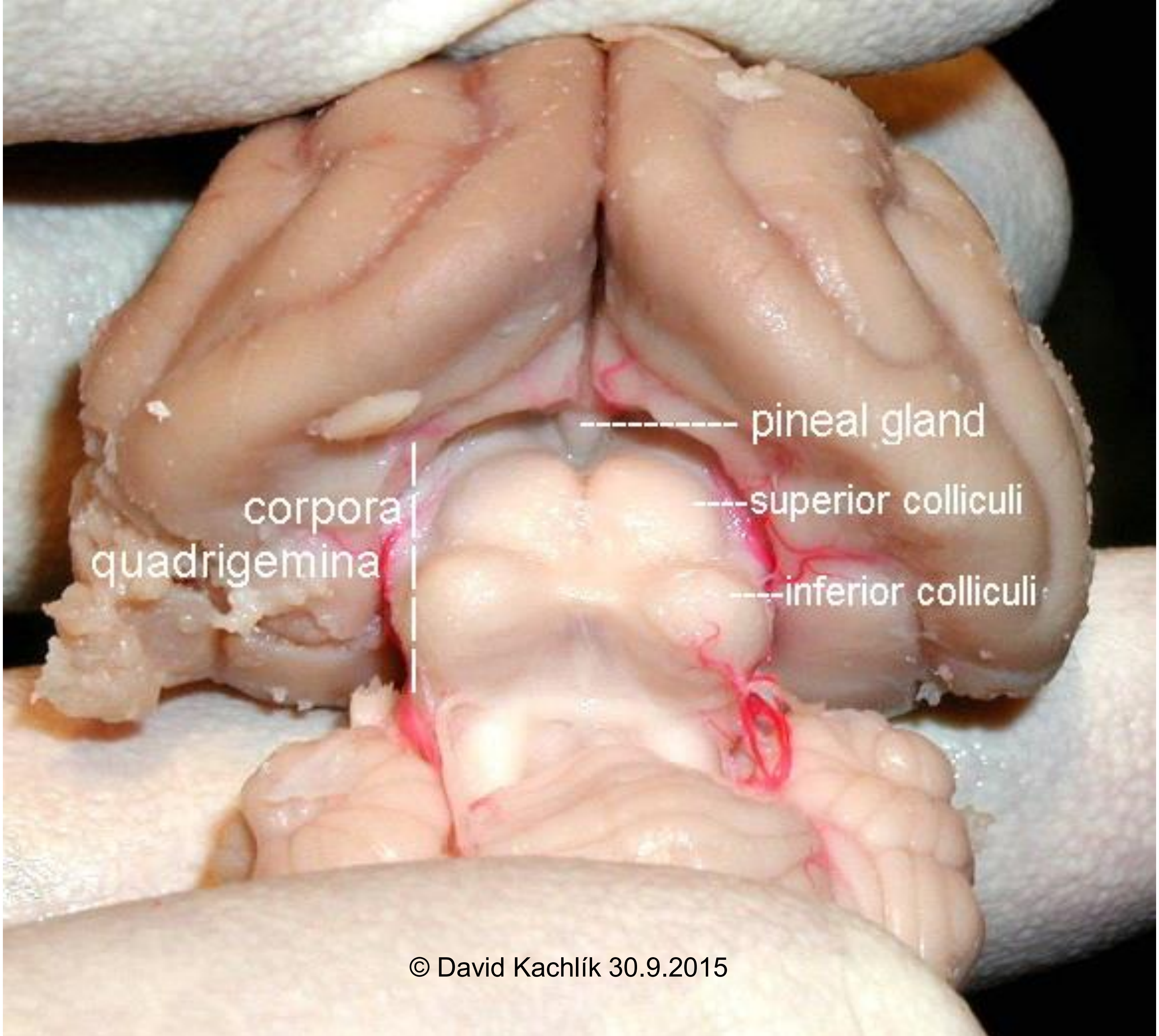


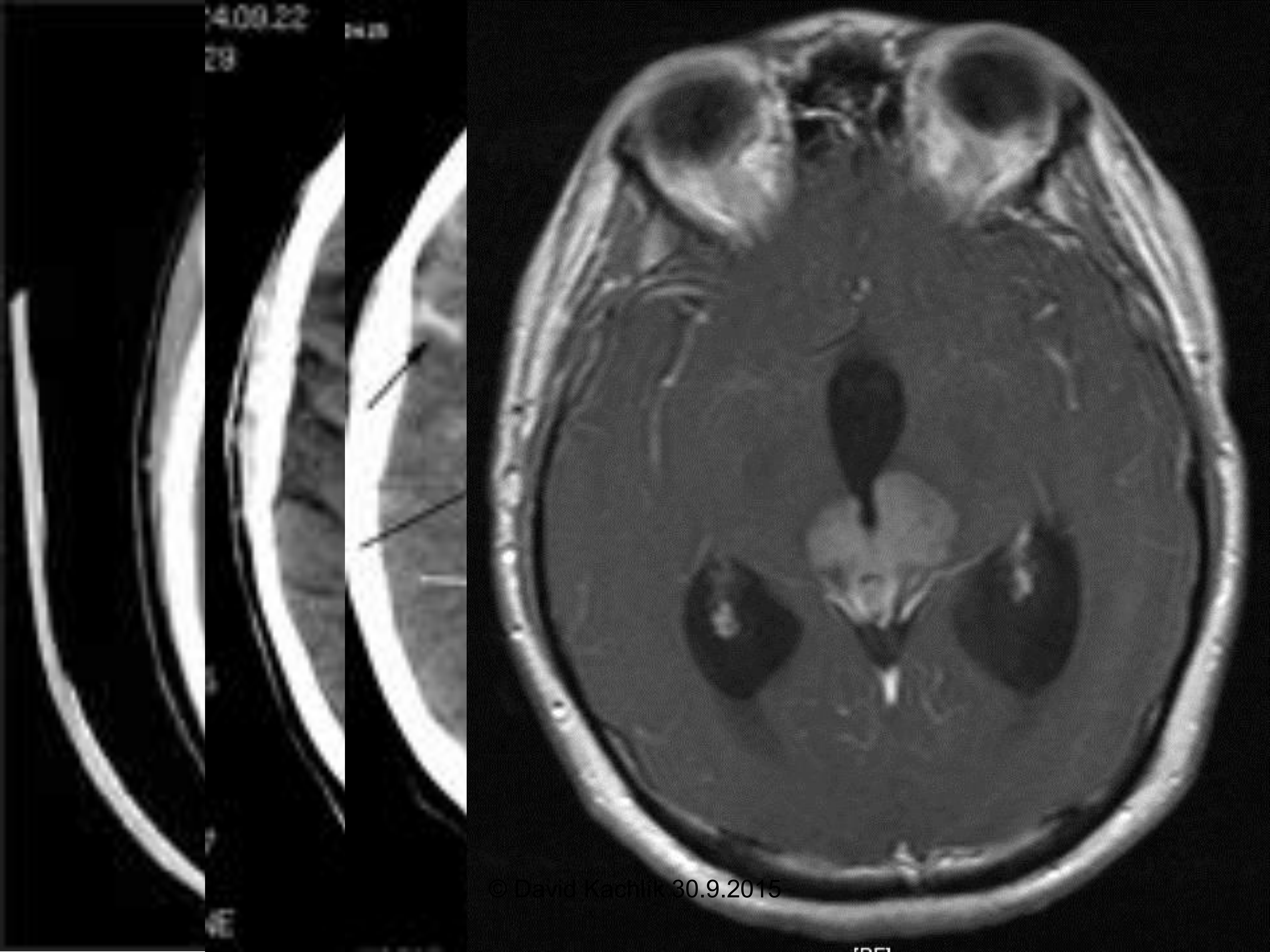
Epiphysis

- Behind upper posterior end of
- Part of epithalamus
- Rudimentary endocrine gland
  on sexual glands → pubertas p
- Dorsally extends above brain






pineal gland
corpora quadrigemina
superior colliculi
inferior colliculi
© David Kachlík 30.9.2015



Subthalamus

- Positioned below thalamus – separated by *Forels field* H1
- Externally to hypothalamus – w/o visible border

- **zona incerta**

- **nucleus subthalamicus (= corpus Luysi)**

- Forels fields = campi perizonales
  = H zone (Haubenfelder)

Subthalamus

- **zona incerta**
  - Composition resembles RF
  - Integration of inputs from cortex and stem
  - GABA inhibits ncll. intralaminares and association nuclei of thalamus (similarly to ncll. reticulares thalami)
- **nucleus subthalamicus (= corpus Luysi)**
  - Connected to basal ganglia system (Glu into globus pallidus)
  - *lesion: hemibalismus (rough non coordinated movements of contralateral cingulum muscles) after CMP, non ketonic hyperglycemia*
- **Forels fields** = campi perizonales

  = H zones (Haubenfelder)
  - H = ansa lenticularis
    - H1 = fasciculus thalamicus
    - H2 = fasciculus lenticularis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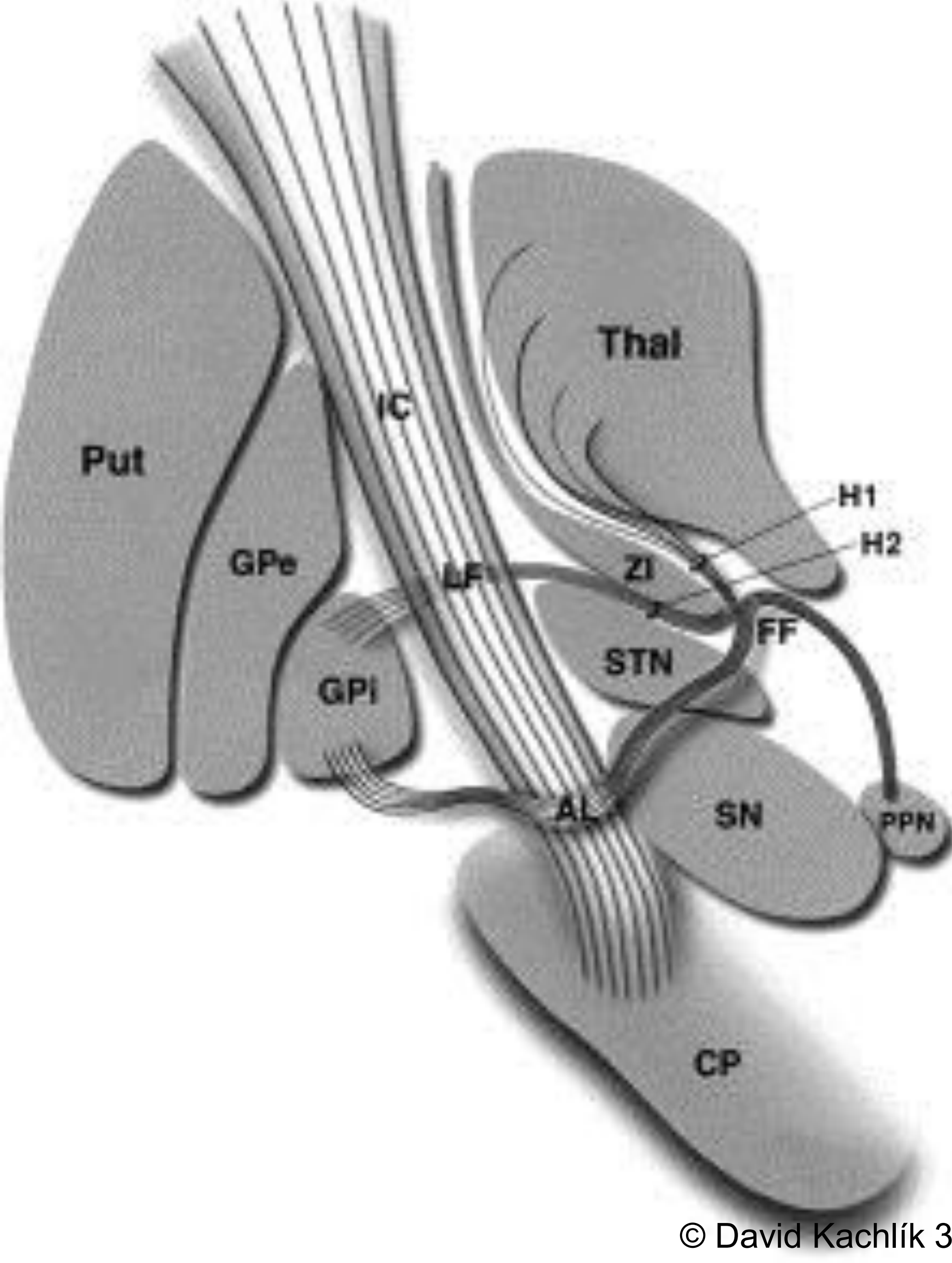
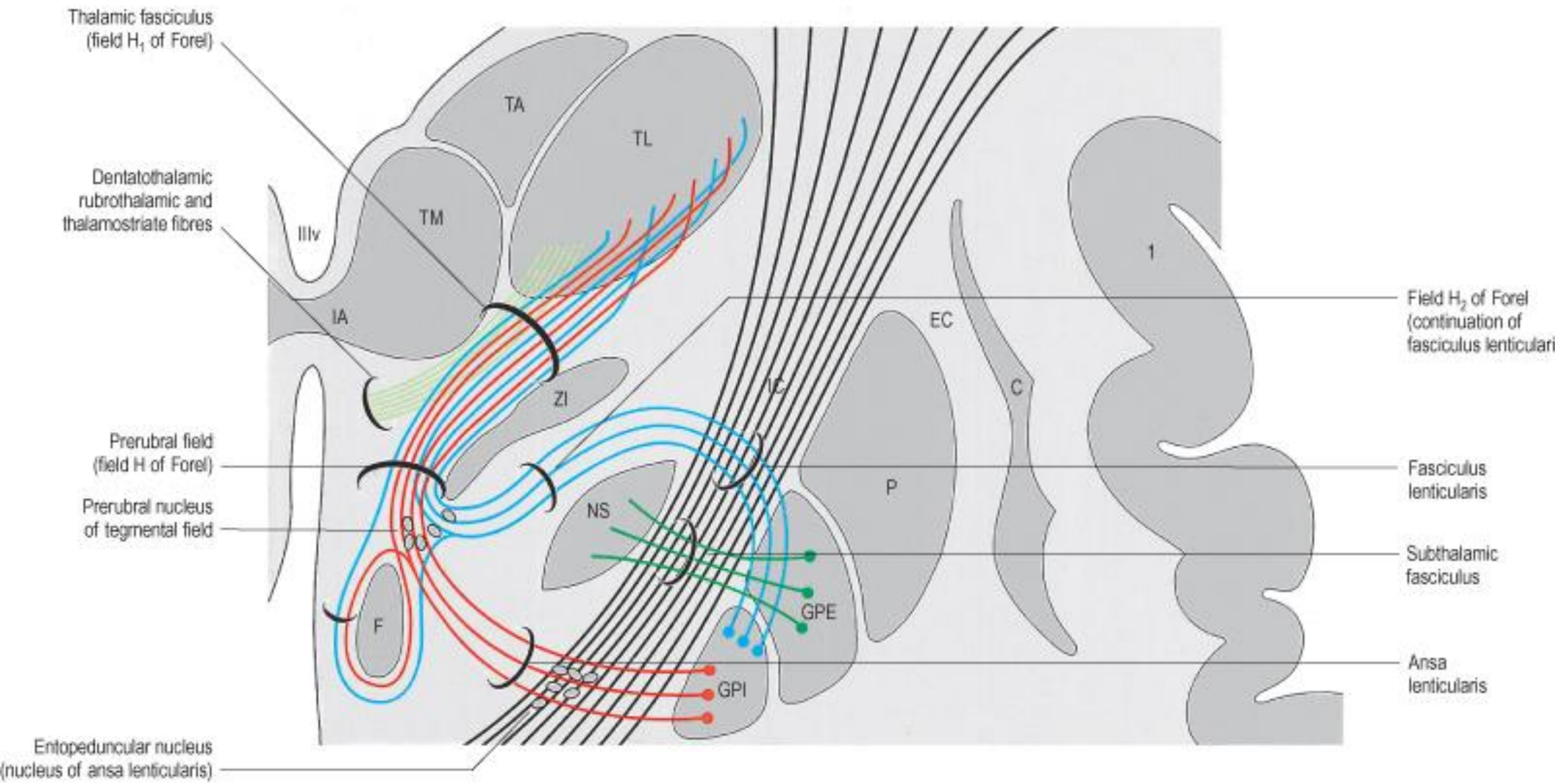
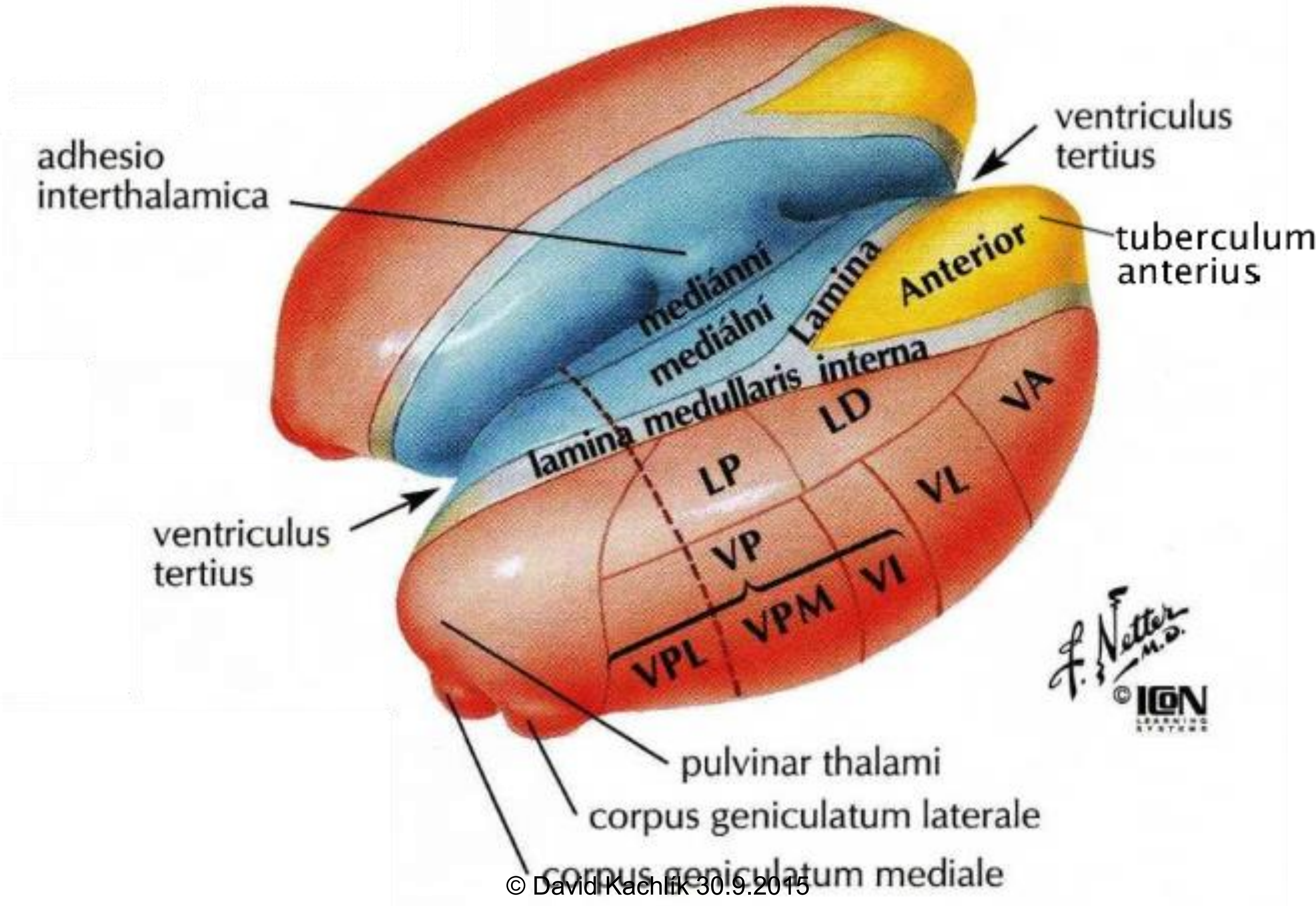


Nuclear groups and fiber tracts associated with the subthalamus include the subthalamic nucleus, zonal incerta, and the fields of Forel and their associated fiber bundles.
AL, ansa lenticularis;
CP, cerebral peduncle;
FF, fields of Forel;
GPe, globus pallidus externus;
GPi, globus pallidus internus;
H1, H1 field of Forel (thalamic fasciculus); IC, internal capsule;
LF, lenticular fasciculus (H2);
PPN, pedunculopontine nucleus;
Put, putamen; SN, substantia nigra;
STN, subthalamic nucleus; Thal, thalamus; ZI, zona incerta. H, corresponding to the nucleus of the medial field is not shown.
Used with permission from Hamani et al., Brain 127:4-20, 2004.


Thalamic fasciculus (field H_1 of Forel)
Dentatothalamic rubrothalamic and thalamostriate fibres
Prerubral field (field H of Forel)
Prerubral nucleus of tegmental field
Entopeduncular nucleus (nucleus of ansa lenticularis)
TA
TL
TM
IIIv
IA
ZI
NS
F
IC
EC
P
C
1
GPE
GPI
Field H_2 of Forel (continuation of fasciculus lenticularis)
Fasciculus lenticularis
Subthalamic fasciculus
Ansa lenticularis

Thalamus (thalamus dorsalis)

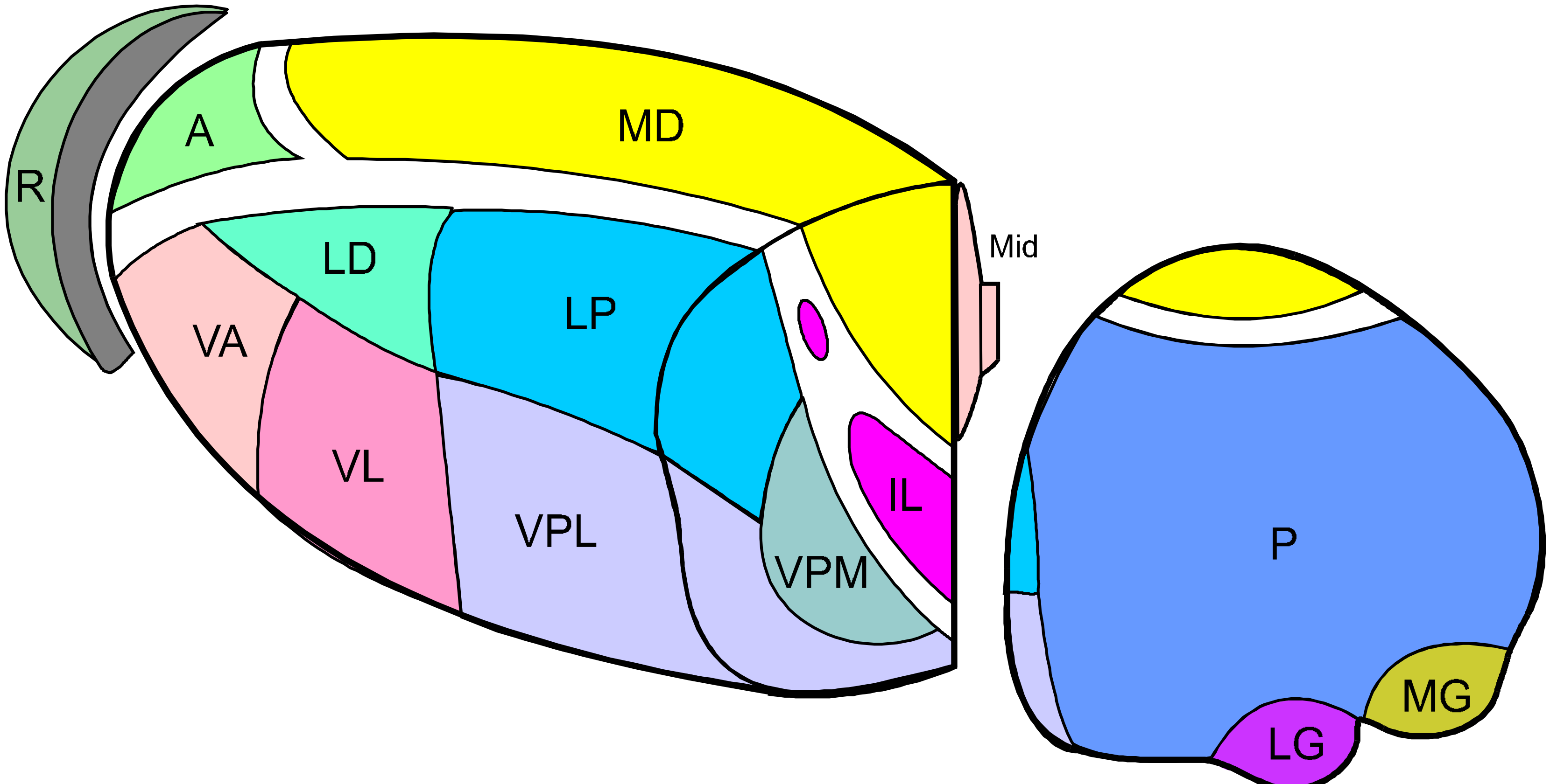
- **„secretary of brain“ ← all except for smell**
- pulvinar (dorsally)
- tuberculum anterius (ventrally)
- lamina medullaris medialis + lateralis thalami
- adhesio interthalamica (80 %) – *w/o notion*
- **Nuclei parcellated according to position** or **connection**
  - nuclei **anteriores, dorsales, intralaminares, mediani, mediales, posteriores, ventrales, reticularis**
  - **specific sensory nuclei**
  - **specific non sensory nuclei**
  - **Non specific nuclei**
  - **Association nuclei**



adhesio interthalamica
ventriculus tertius
tuberculum anterius
mediánní
mediální
Lamina
Anterior
lamina medullaris interna
LD
VA
LP
VL
VP
VI
VPM
VPL
ventriculus tertius
pulvinar thalami
corpus geniculatum laterale
corpus geniculatum mediale

Parcellation of thalamic nuclei acc to position

nuclei **anteriores, dorsales, intralaminares, mediani, mediales, posteriores, ventrales, reticularis**



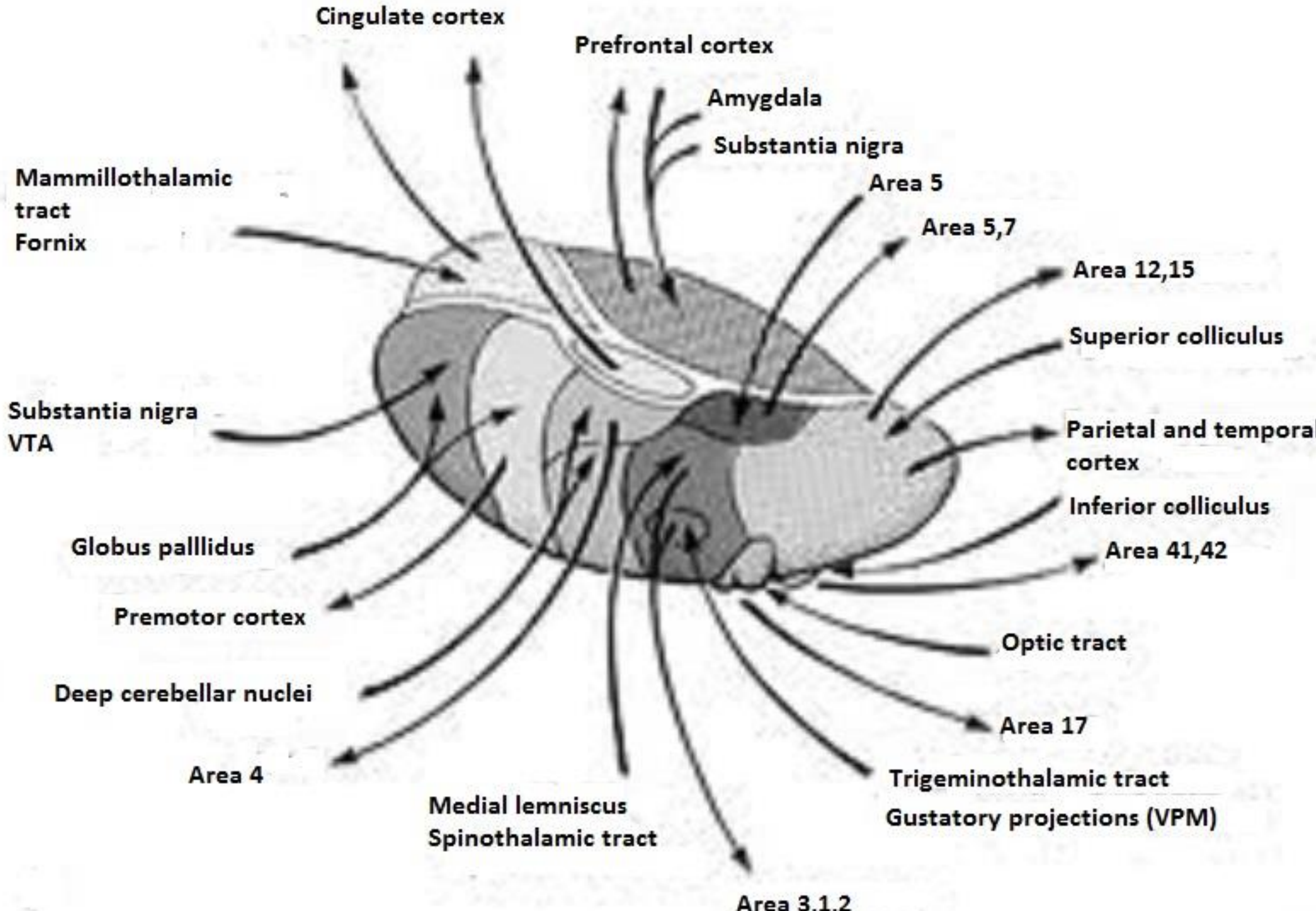
Thalamic connections

AF:

- sensitive and sensory
  - Pain, proprioception, touch, taste, balance, hearing, vision
- motoric
  - cerebellum, BG
- RF - ARAS
- limbic system
  - corpus mammillare, hippocampus

EF: cortex + hypothalamus

Reciprocal connections: BG, RF, cortex, stem, cerebellum, spine



Cingulate cortex
Prefrontal cortex
Amygdala
Substantia nigra
Mammillothalamic
tract
Fornix
Area 5
Area 5,7
Area 12,15
Superior colliculus
Substantia nigra
VTA
Parietal and temporal
cortex
Inferior colliculus
Globus palllidus
Area 41,42
Premotor cortex
Optic tract
Deep cerebellar nuclei
Area 17
Area 4
Trigeminothalamic tract
Gustatory projections (VPM)
Medial lemniscus
Spinothalamic tract
Area 3,1,2

Specific nuclei

- tractus mamillothalamicus → ***ncl. anterior*** → gyrus cinguli
  – *reverberation enforces emotions*
- globus pallidus → ***ncl. VA*** → prefrontal cortex
- globus pallidus → ***ncl. VL*** → supplementary motoric cortex
- nucleus dentatus cerebelli → ***ncl. VL*** → motoric cortex
- lemniscus medialis et spinalis → ***ncl. VPL*** → senz. cortex
- lemniscus trigeminalis → ***ncl. VPM*** → senzitive cortex

Association nuclei

- ***ncl. LD (lat. dors.)*** ➔ area cingularis posterior
- Olfactory and limbic brain ➔ ***ncl. MD (mediodors.)*** ➔ prefrontal cortex (*thinking, reasoning, mood, mind state – integration with sensory inputs*)
- colliculus superior ➔ ***ncl. LP (lat. post.) + pulvinar*** ➔ visual and parietal association cortex (*draws attention to objects on the periphery of visual field*)
- ***ncll. P (pulvinar)*** ➔ frontal, temporal, parietal and occipital association cortex (*integration of visual, auditory, tactile and proprioceptive inputs*)

Non specific nuclei

- ***ncll. intralaminares***
  - Slow pain
  - ARAS
- ***ncll. mediani***
    - Limbic system (according to efferentation)

Ncll. reticulares

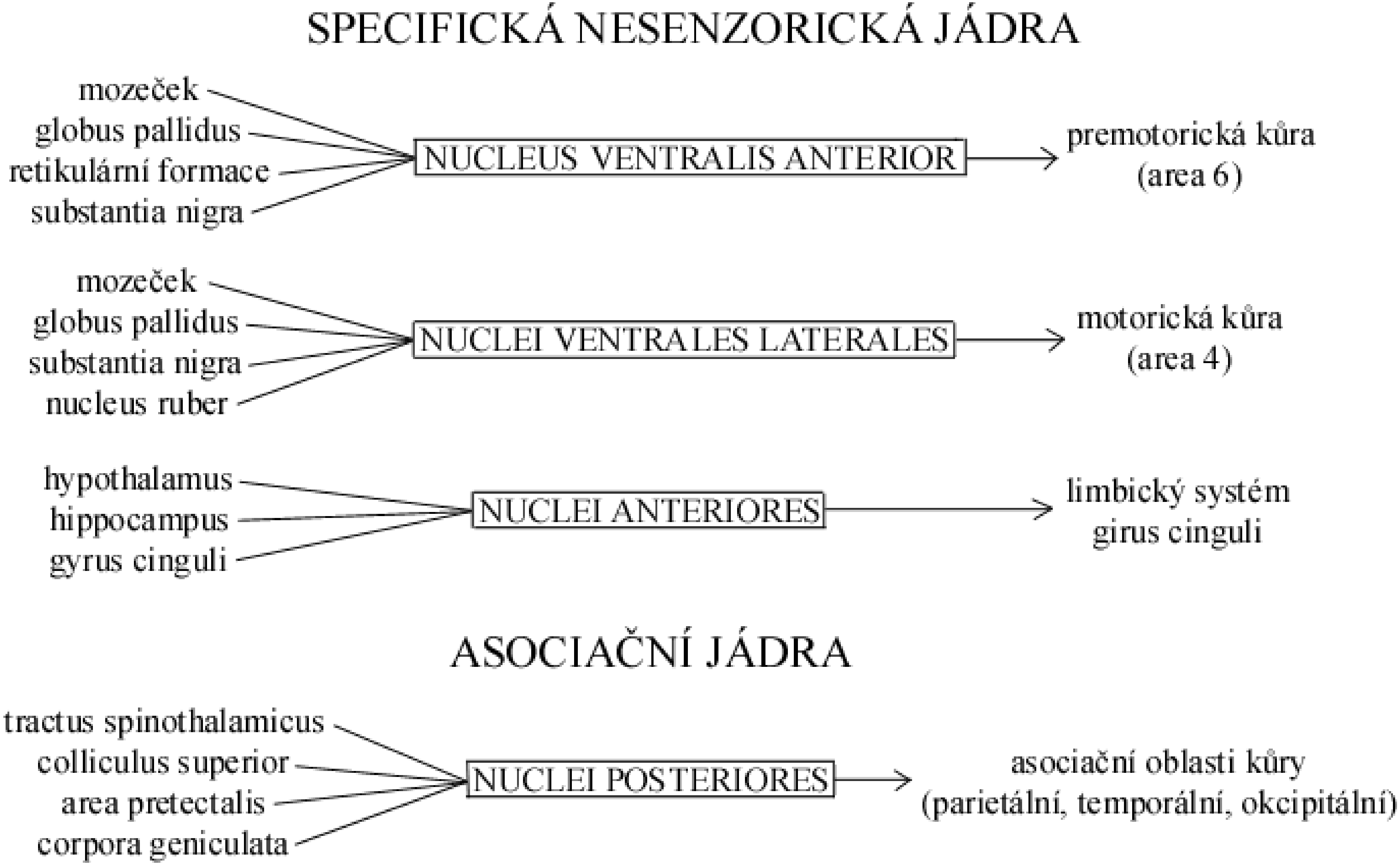
- GABA
- Excitatory collaterals from all specific nuclei of thalamus and cortex
- Inhibitory efferentation back to thalamus
- Similarly as zona incerta
- *Function: labels new inputs and differentiates them from regular inputs from environment*

SPECIFICKÁ SENZORICKÁ JÁDRA

lemniscus medialis tractus spinothalamicus	NUCLEUS VENTRALIS POSTEROLATERALIS	senzitivní kůra (area 3,1,2)
tractus trigeminothalamicus tractus solitarius (chuť)	NUCLEUS VENTRALIS POSTEROMEDIALIS	senzitivní kůra gyrus postcentralis (hlava, krk)
colliculus inferior (sluch)	CORPUS GENICULATUM MEDIALE	nuclei posteriores thalami sluchová kůra (area 41,42)
tractus opticus (zrak)	CORPUS GENICULATUM LATERALE	zraková kůra - sulcus calcarinus (area 17)

NESPECIFICKÁ JÁDRA

hypothalamus	NUCLEI MEDIANI	hypothalamus čichová kůra
retikulární formace mozeček pallidum	NUCLEI INTRALAMINARES	striatum frontální kůra (= ascendentní aktivační systém zajišťující bdělost, pozornost)


SPECIFICKÁ NESENZORICKÁ JÁDRA
mozeček
globus pallidus
retikulární formace
substantia nigra
NUCLEUS VENTRALIS ANTERIOR
premotorická kůra
(area 6)
mozeček
globus pallidus
substantia nigra
nucleus ruber
NUCLEI VENTRALES LATERALES
motorická kůra
(area 4)
hypothalamus
hippocampus
gyrus cinguli
NUCLEI ANTERIORES
limbický systém
girus cinguli
ASOCIAČNÍ JÁDRA
tractus spinothalamicus
colliculus superior
area pretectalis
corpora geniculata
NUCLEI POSTERIORES
asociační oblasti kůry
(parietální, temporální, okcipitální)

Thalamic connection

Cortex

tractus thalamocorticalis ↑

↓ tractus corticothalamicus – strong tract inhibiting thalamus

„cleaning further incoming informations“

Thalamic connection

- **senzitive + sensory inputs**
  - **senzitivity (pain, proprioception, touch)**
  - **Special sensory (taste, balance, hearing, vision)**
- **motoric inputs**
  - **Cerebellum, basal ganglia**
- **Reticular formation**
- **limbic system**
  - **corpus mammillare**
  - **Hippocampal formation**
- ncll. reticulares only do not have efferentation to other thalamic nuclei

Pain – *processing in thalamus*

- fast – acute
  - ncl. VPL + VPM

- slow – chronic
  - nuclei intralaminares

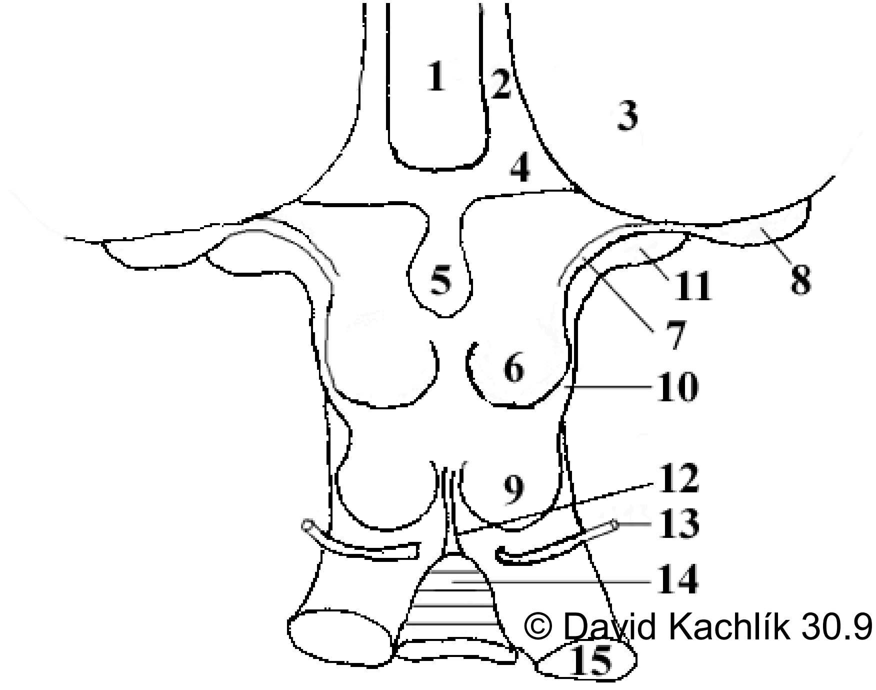
    for example:

    - ncl. centromedianus (CM)
    - ncl. parafascicularis (PF)

Metathalamus

- corpus geniculatum laterale – *visual center*
- corpus geniculatum mediale – *auditory center*

DORSAL VIEW OF MESENCEPHALON



1 - third ventricle
2 - stria medullaris of thalamus
3 - pulvinar
4 - habenular trigone
5 - pineal gland
6 - superior colliculus
7 - brachium of inferior colliculus
8 - lateral geniculate body
9 - inferior colliculus
10 - brachium of superior colliculus
11 - medial geniculate body
12 - frenulum of superior medullary vellum
13 - trochlear nerve
14 - lingula
15 - superior cerebellar peduncle

Corpus geniculatum laterale

Visual center

- *pars magnocellualris: movement, depth and perspective*

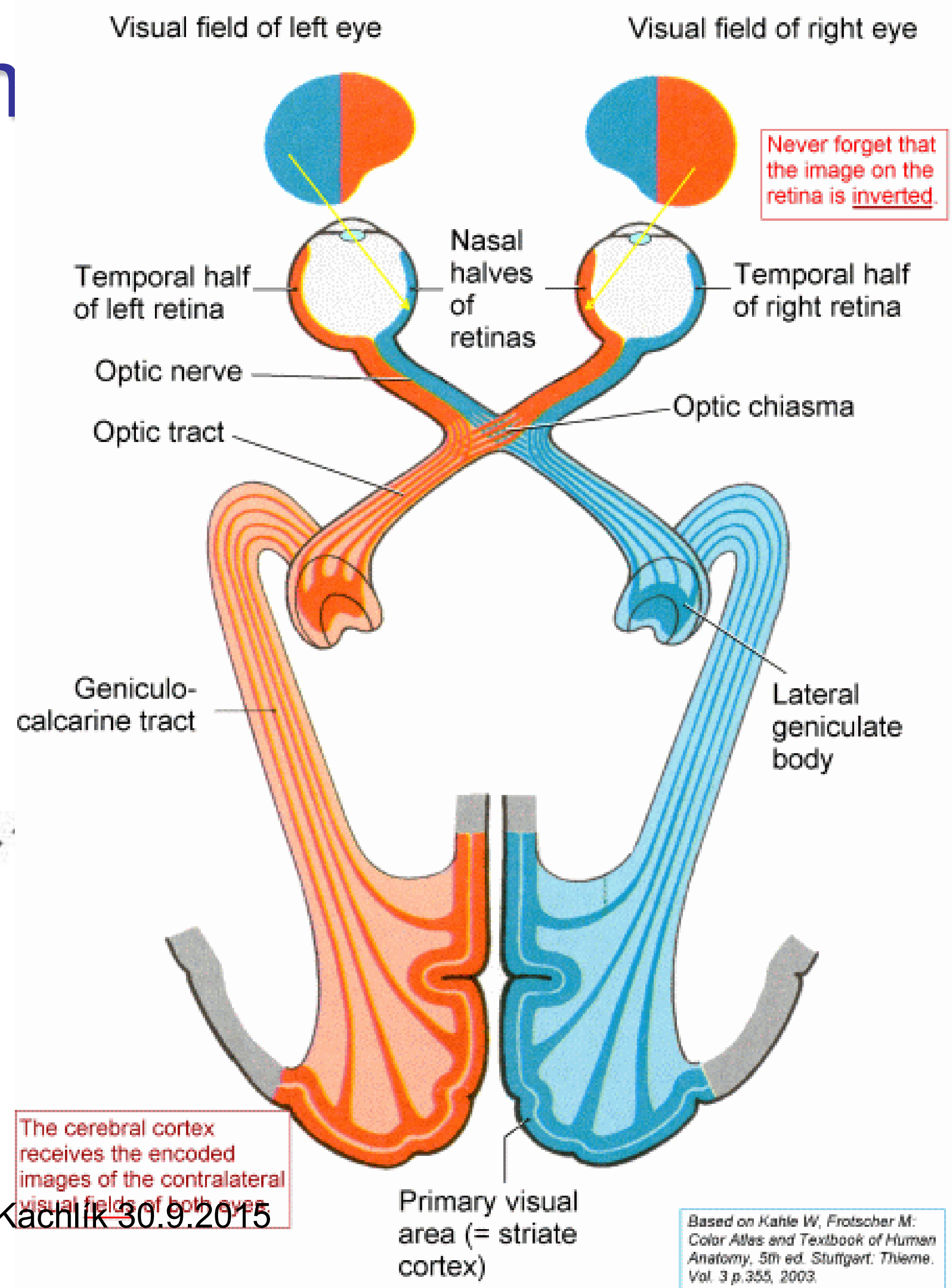
- *pars parvocellularis: diameters, volume, shape and colors*

Thalam

1. nervus opticus
2. chiasma opticum
3. tractus opticus
4. corpus geniculatum laterale

5. radiatio optica
6. Visual cortex

4



Thalamic syndrom „6 hemi“

- hemi**hypestezia** /hemi**anestezia**
- hemi**ataxia** (+ hemi**apraxia**)
- hemi**paresis**
- hemi**algia** (+ hemi**pathia**)
- hyper**kinesis choreatic and athetoid**
- hemi**anopsia homonymous contralateral**
- **Consciousness problems / epilepsy / cataplexy**

Clinical talamic syndromes

posterolateral talamic syndromes

- senzitive and senzoric lesions
- talamic syndrom =

Dejerine-Roussy syndrome

  - ncl. VPL, VPM
  - talamic pain

Joseph Jules Dejerine (1849-1917)

Gustave Roussy (1874-1948)

Clinical thalamic syndromes

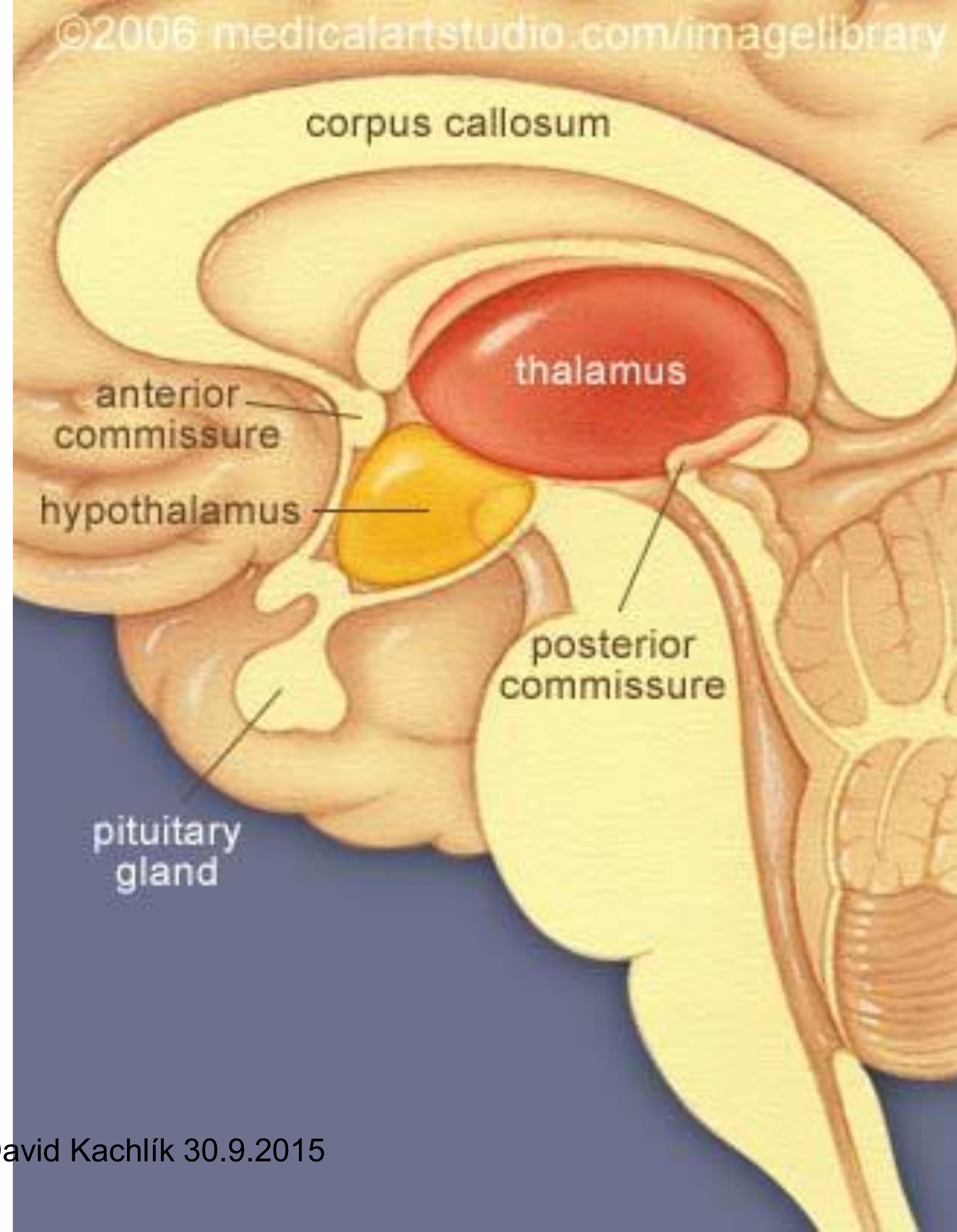
<u>medial talamic syndromes</u>

- Consciousness lesions
- „thalamic neglect“, talamic amnesia, akinetic mutizm

<u>anterolateral talamic syndromes</u>

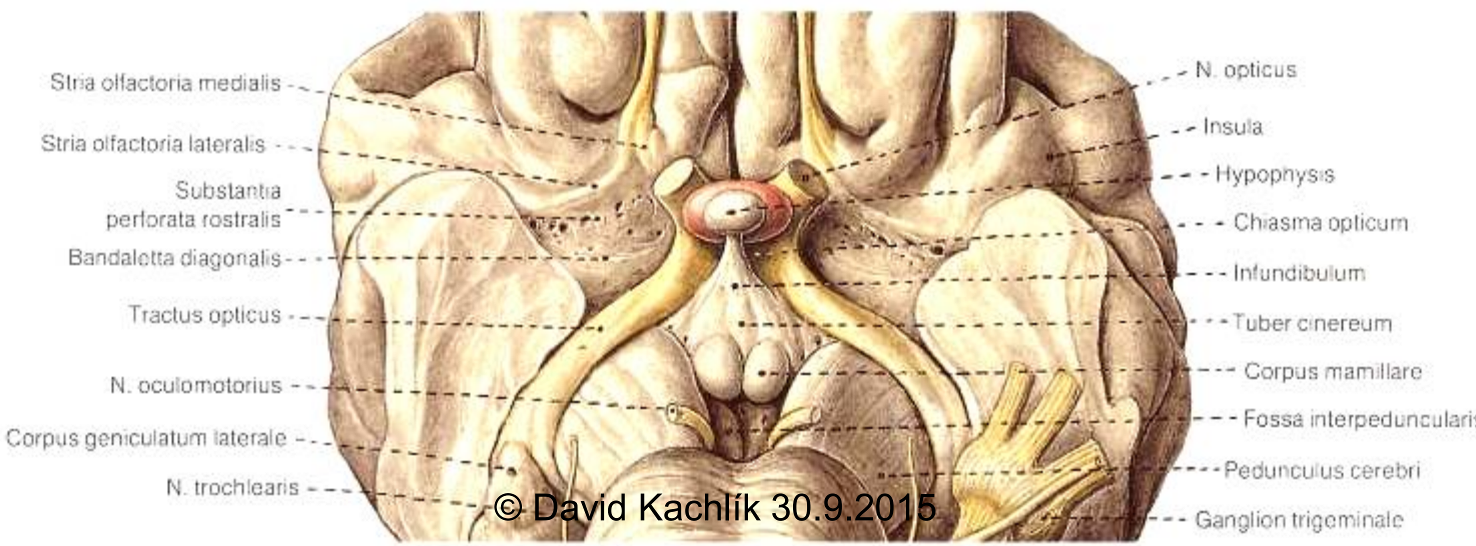
- Motoric lesions
- palsy, ataxia, motoric non coordination, dysfagia

Hypothalamus



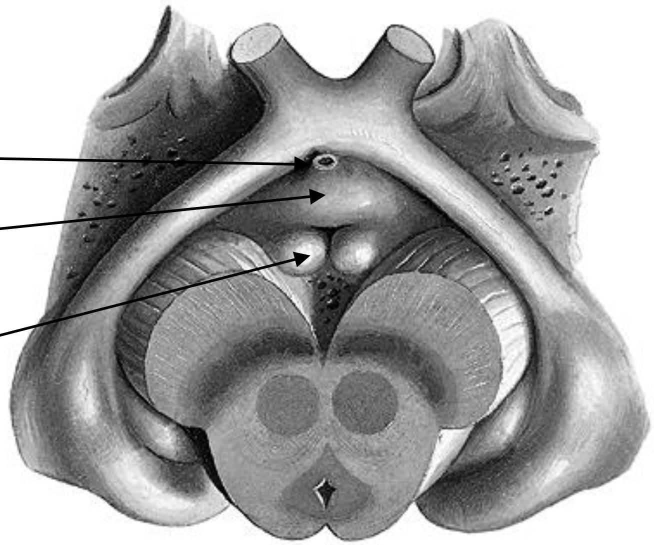
Hypothalamus

- Is derivative of visceromotor zone of basal plate
- Highest autonomous center
- **infundibulum + hypophysis**
- **tuber cinereum (eminentia mediana) + corpus mammillare**
- **area preoptica + chiasma et tractus opticus**

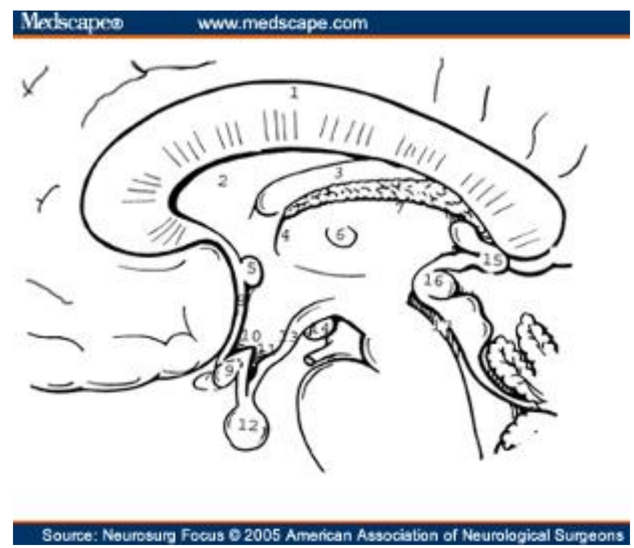


Hypothalamus

- infundibulum
- tuber cinereum
- corpora mammillaria



- *recessus infundibuli*
- *recessus opticus*



Hypothalamus – *borders*

- up: sulcus hypothalamicus
- down: base of brain
- front: lamina terminalis
- back: continues into tegmentum mesencephali
- Medially: 3rd ventricle
- laterally: capsula interna

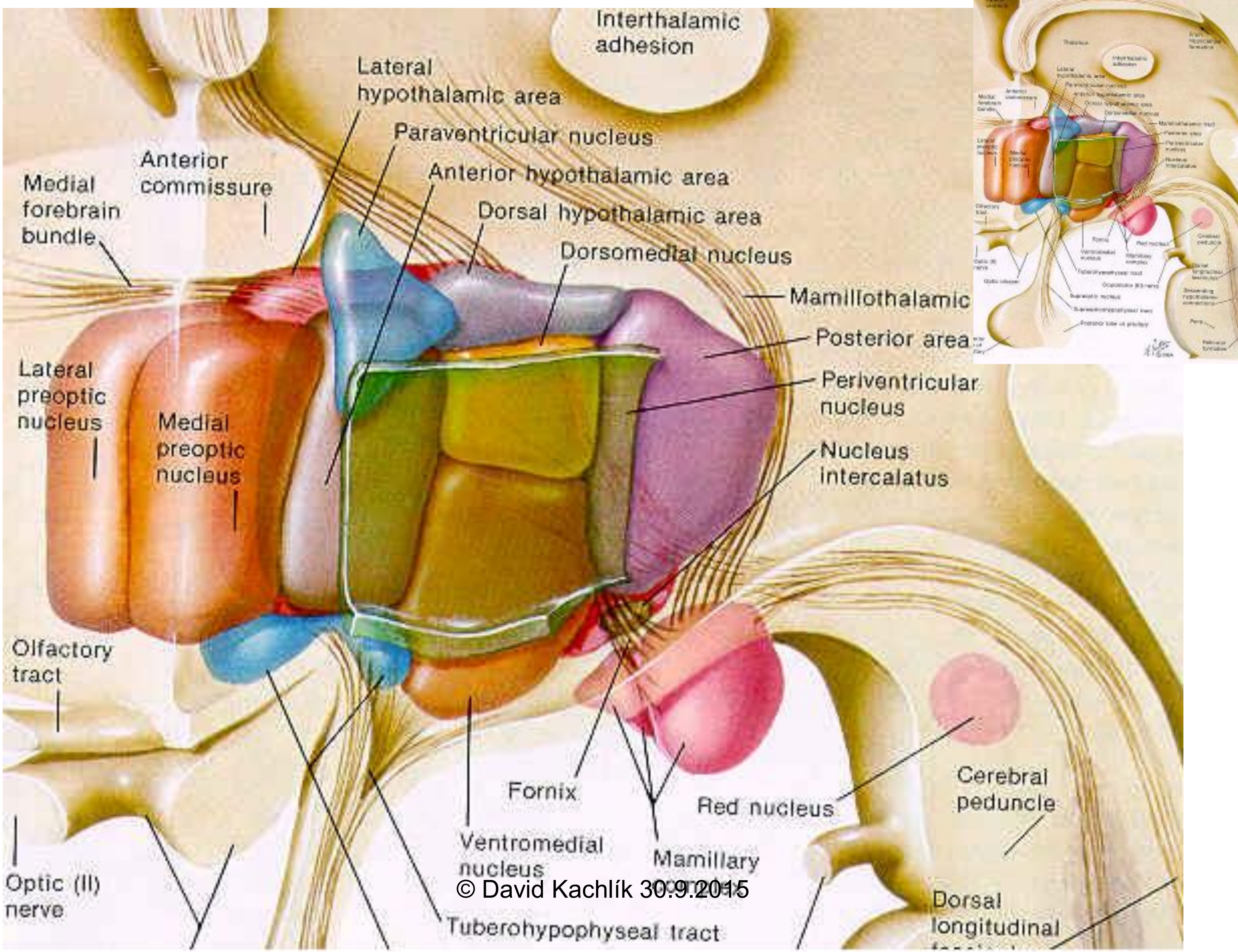
Hypothalamus

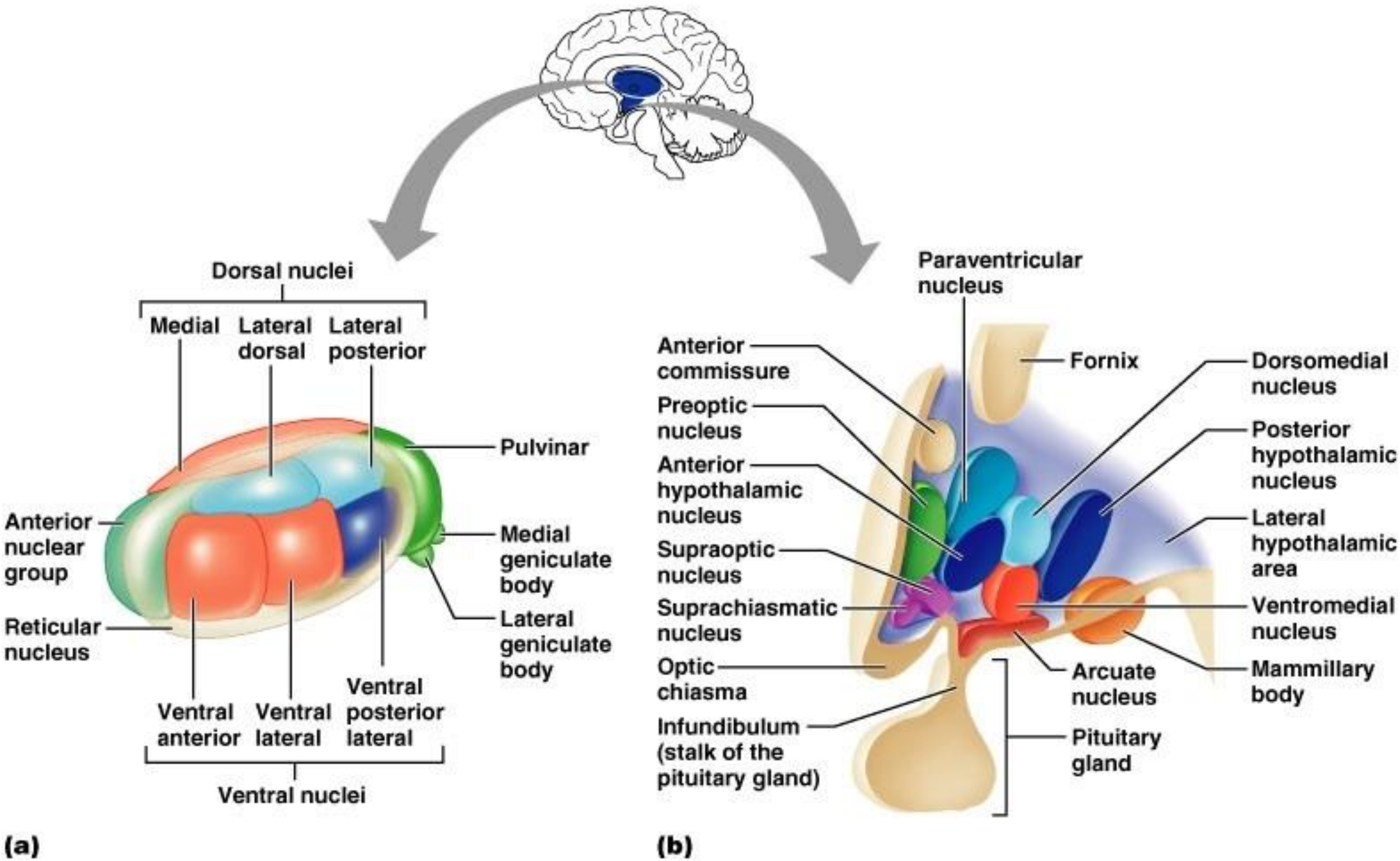
3 longitudinal zones: **periventricular, medial, lateral** zones

3 horizontal zones: **anterior, middle, posterior** hypothalamus

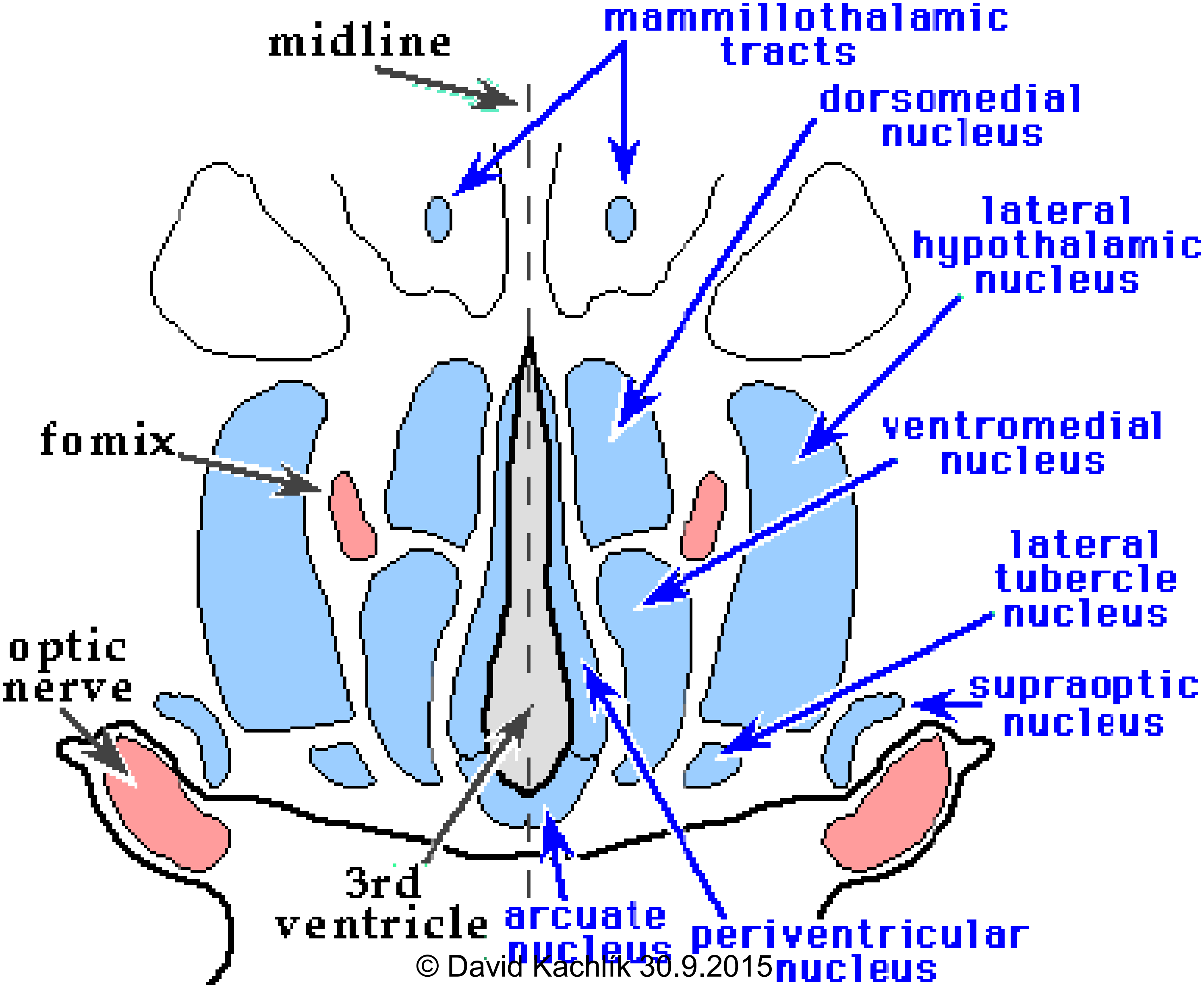
Nuclei

- **ventral** hypothalamus (area hypothalamica rostralis) - **nucleus paraventricularis, supraopticus, suprachiasmaticus**
- **middle** hypothalamus (area hypothalamica intermedia et dorsalis) **nuclei tuberales laterales et ventromediales**
- **posterior** hypothalamus (area hypothalamica posterior) - **nuclei mammillares, nucleus h. posterior, nucleus tberomammillaris**


Interthalamic adhesion
Lateral hypothalamic area
Paraventricular nucleus
Anterior commissure
Anterior hypothalamic area
Medial forebrain bundle
Dorsal hypothalamic area
Dorsomedial nucleus
Mamillothalamic
Posterior area
Lateral preoptic nucleus
Medial preoptic nucleus
Periventricular nucleus
Nucleus intercalatus
Olfactory tract
Fornix
Red nucleus
Cerebral peduncle
Optic (II) nerve
Ventromedial nucleus
Mamillary
Tuberohypophyseal tract
Dorsal longitudinal



Dorsal nuclei
Medial
Lateral dorsal
Lateral posterior
Pulvinar
Anterior nuclear group
Medial geniculate body
Lateral geniculate body
Reticular nucleus
Ventral anterior
Ventral lateral
Ventral posterior lateral
Ventral nuclei
(a)
Paraventricular nucleus
Anterior commissure
Fornix
Dorsomedial nucleus
Preoptic nucleus
Posterior hypothalamic nucleus
Anterior hypothalamic nucleus
Lateral hypothalamic area
Supraoptic nucleus
Suprachiasmatic nucleus
Ventromedial nucleus
Optic chiasma
Arcuate nucleus
Mammillary body
Infundibulum (stalk of the pituitary gland)
Pituitary gland
(b)


midline
mammillothalamic tracts
dorsomedial nucleus
lateral hypothalamic nucleus
ventromedial nucleus
lateral tubercle nucleus
supraoptic nucleus
fomix
optic nerve
3rd ventricle
arcuate nucleus
periventricular nucleus

Hypothalamus – function

Receives inputs from almost all receptors – especially from RF, prefrontal cortex and hippocampus

<u>former hypothesis:</u>

- **anterior** hypothalamus - **parasympaticus**
- **Middle** hypothalamus - **sympaticus**
- **posterior** hypothalamus – **limbic system**

Hypothalamus – *fyziology*

Hormones (blood), nerves, CSF

↓

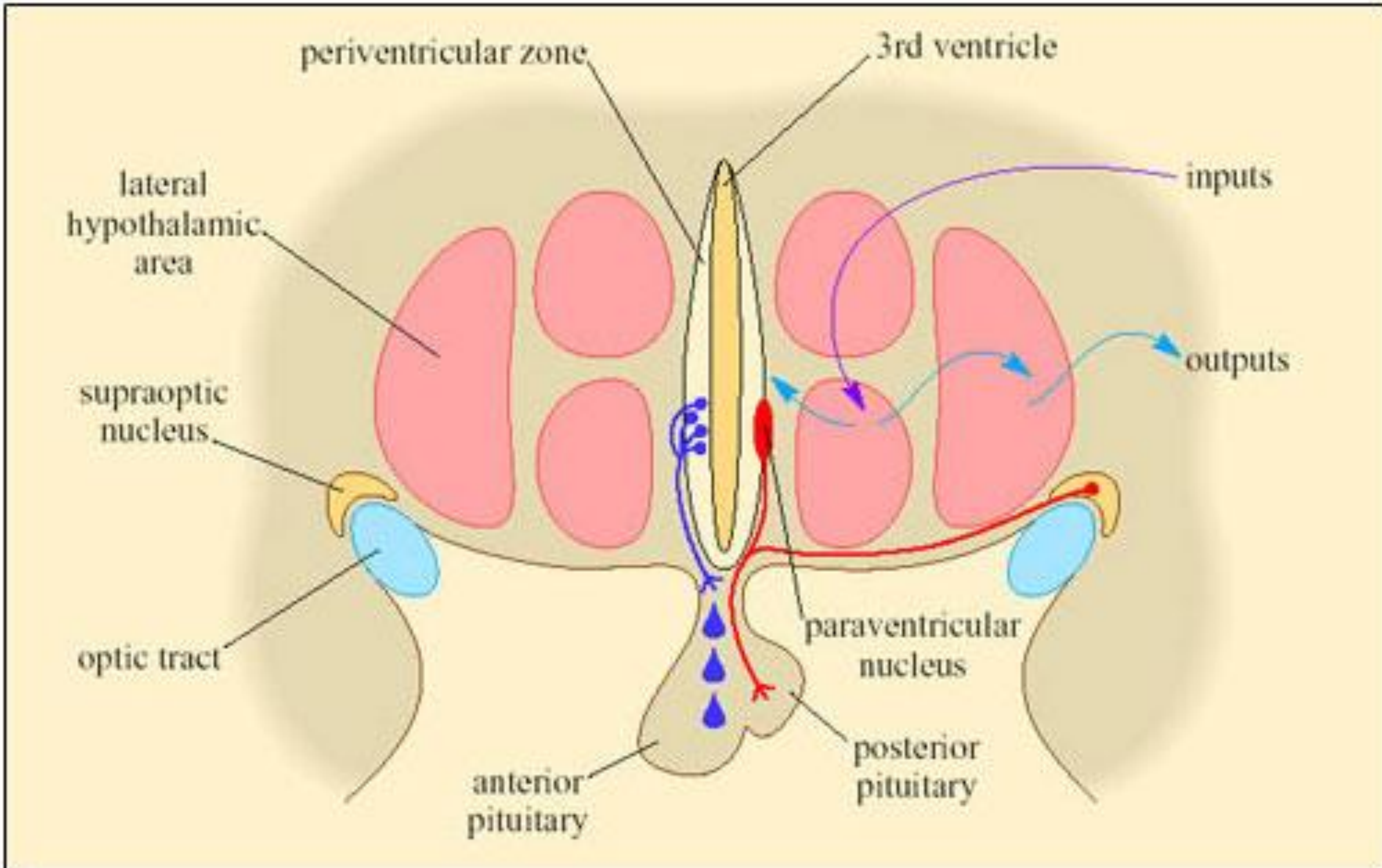
HYPOTHALAMUS

↓

Endocrine + autonomic system

↙ ↘

HOMEOSTASIS *emotions* *(= LIMBIC SYSTEM)*


periventricular zone
3rd ventricle
lateral
hypothalamic
area
inputs
outputs
supraoptic
nucleus
paraventricular
nucleus
optic tract
posterior
pituitary
anterior
pituitary

Hypothalamus – *function*

- termoregulation
  - center **hyperthermia** – anterior h.
  - center **cold** – posterior h.
- lateral h.: center **hunger, thirst and anger**
- medial h.: center **satiety** and **passivity**
- anterior h.: center **sleep and wake**
- sex
  - ♂ *nucleus preopticus*
  - ♀ *nucleus ventromedialis*

Hypothalamus – *function*

- *ncl. suprachiasmaticus*
  - center of circadian rhytms
- *ncl. supraopticus* + *paraventricularis (magnocellular neurons)*
  - ADH (vazopresin) + oxytocin
- *ncl. arcuatus (infundibularis) and around (parvocellular neurons)*
  - statins and liberins
- *ncl. tuberomamillaris*
  - histamine to brain and spine („arousal“)
    - Activated by *orexin from* lat. hypothalamus
    - Lack in narcolepsia

Anterior hypotalamus

- ncl. paraventricularis - *oxytocin, ADH*
- ncl. supraopticus – *oxytocin, ADH*

- ncl. preopticus medialis – *blood pressure down, puls too*
- ncl. hypothalamicus anterior – *termoregulation, swetting, inhibition of TSH*

- ncl. suprachiasmaticus – *circadian rhytm*

Sexually dimorphic areas of anterior hypothalamus

- SDN (sexually dimorphic nucleus) – in area preoptica bigger in males comp to females (?testosterone effect)
- INAH3 in humans, oSDN in sheeps, SDN-POA in rats, AHdc in macaques, POM in quails
- Affects sexual behavior in animals

Middle hypothalamus

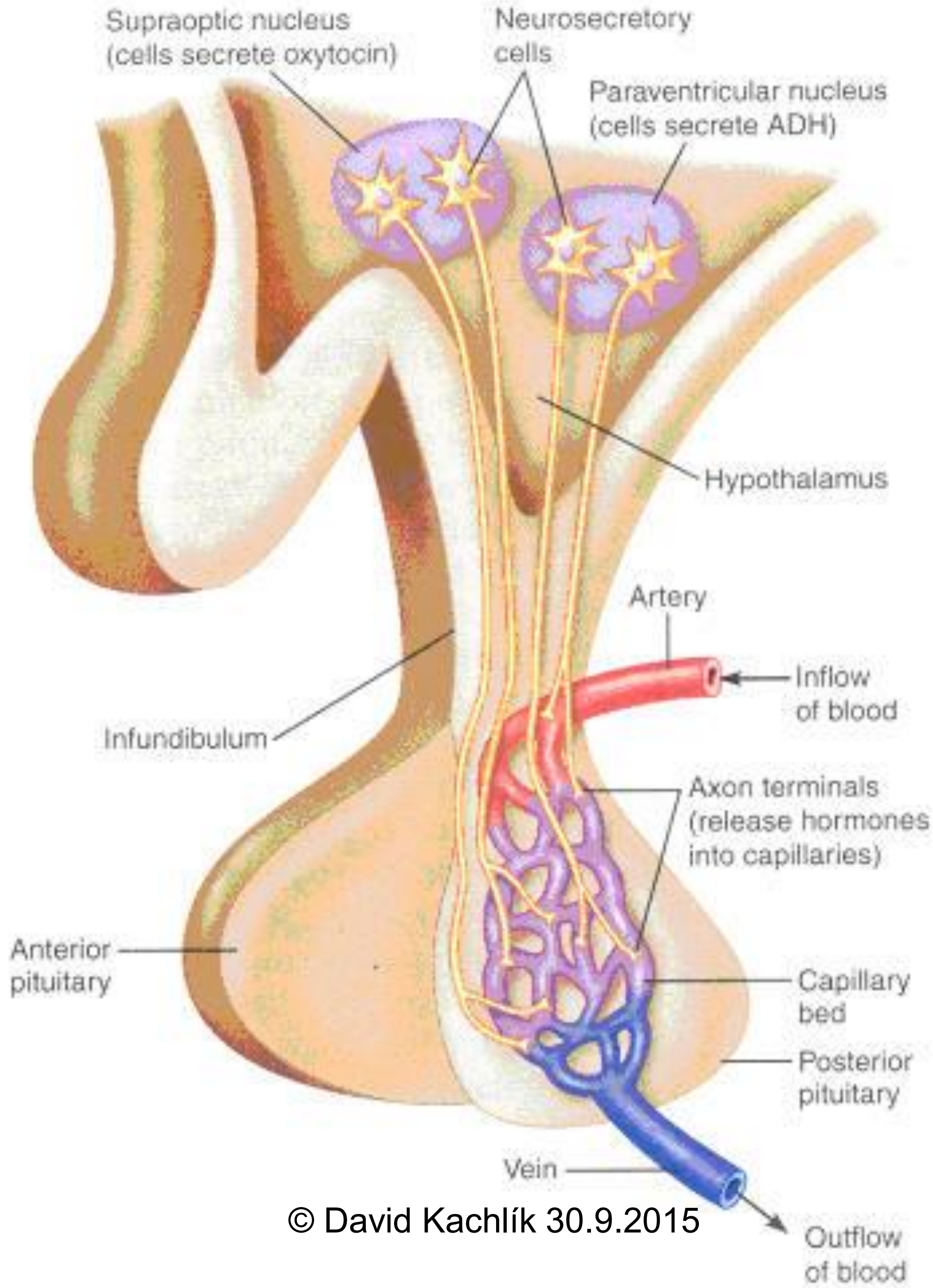
= tuberal hypothalamus (tuber cinereum)

- ncl. infundibularis = ncl. arcuatus – *statins and liberins*
- ncll. tuberales – *hunger and thirst*
- ncl. hypothalamicus ventromedialis - *hunger*
- ncl. hypothalamicus dorsomedialis – *increase of blood pressure and puls*

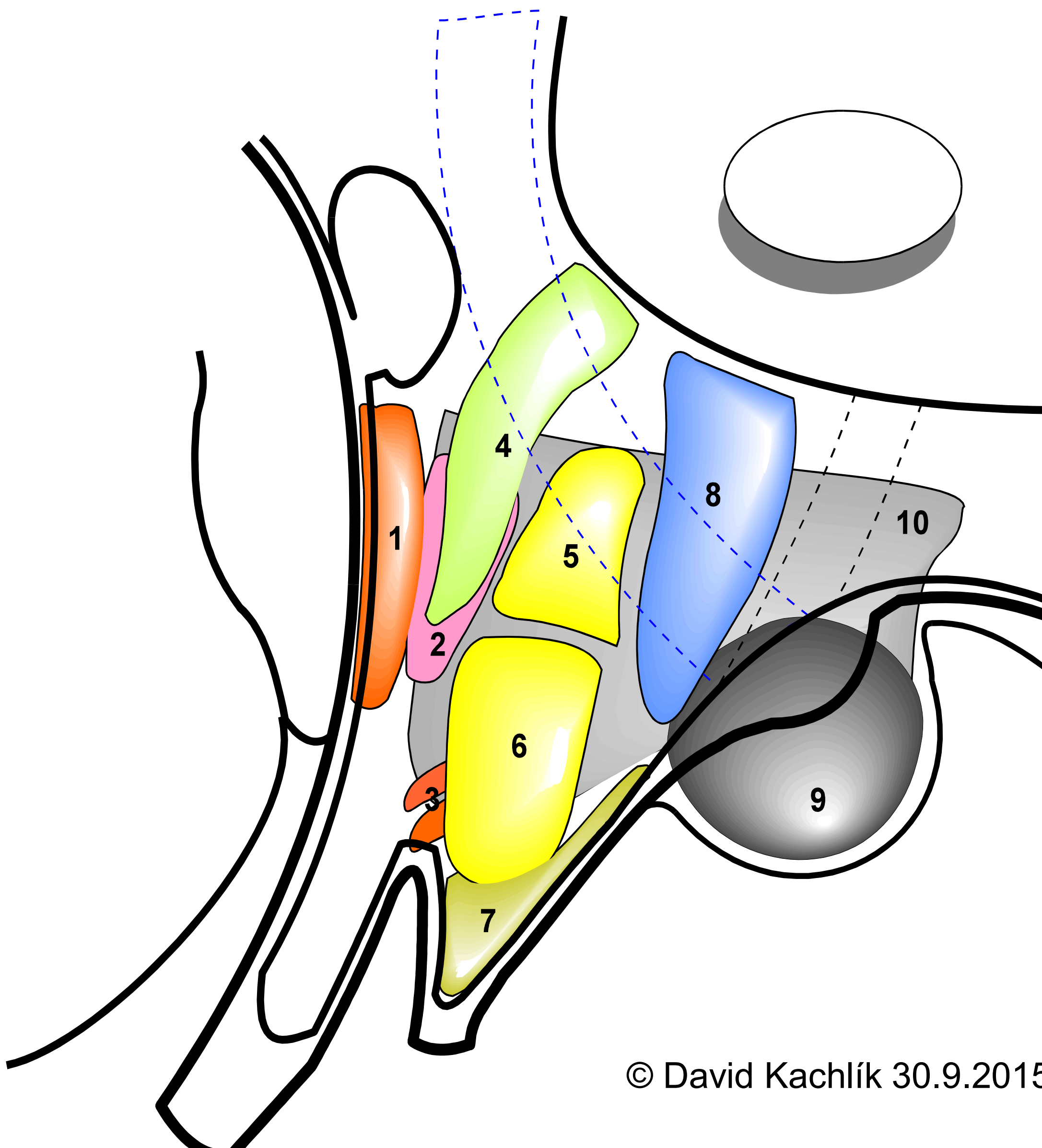
Posterior hypotalamus

- ncll. mammillares
  - *memory, connection to limbic system* (ncl. anterior thalami)

- ncll. hypothalamicus posterior
  - *increase of blood pressure, mydriasis, tremor*


Supraoptic nucleus
(cells secrete oxytocin)
Neurosecretory
cells
Paraventricular nucleus
(cells secrete ADH)
Hypothalamus
Artery
Inflow
of blood
Infundibulum
Axon terminals
(release hormones
into capillaries)
Anterior
pituitary
Capillary
bed
Posterior
pituitary
Vein
Outflow
of blood

Hypothalamus



MEDIAL ZONE

Preoptic Region
1. Preoptic Nucleus

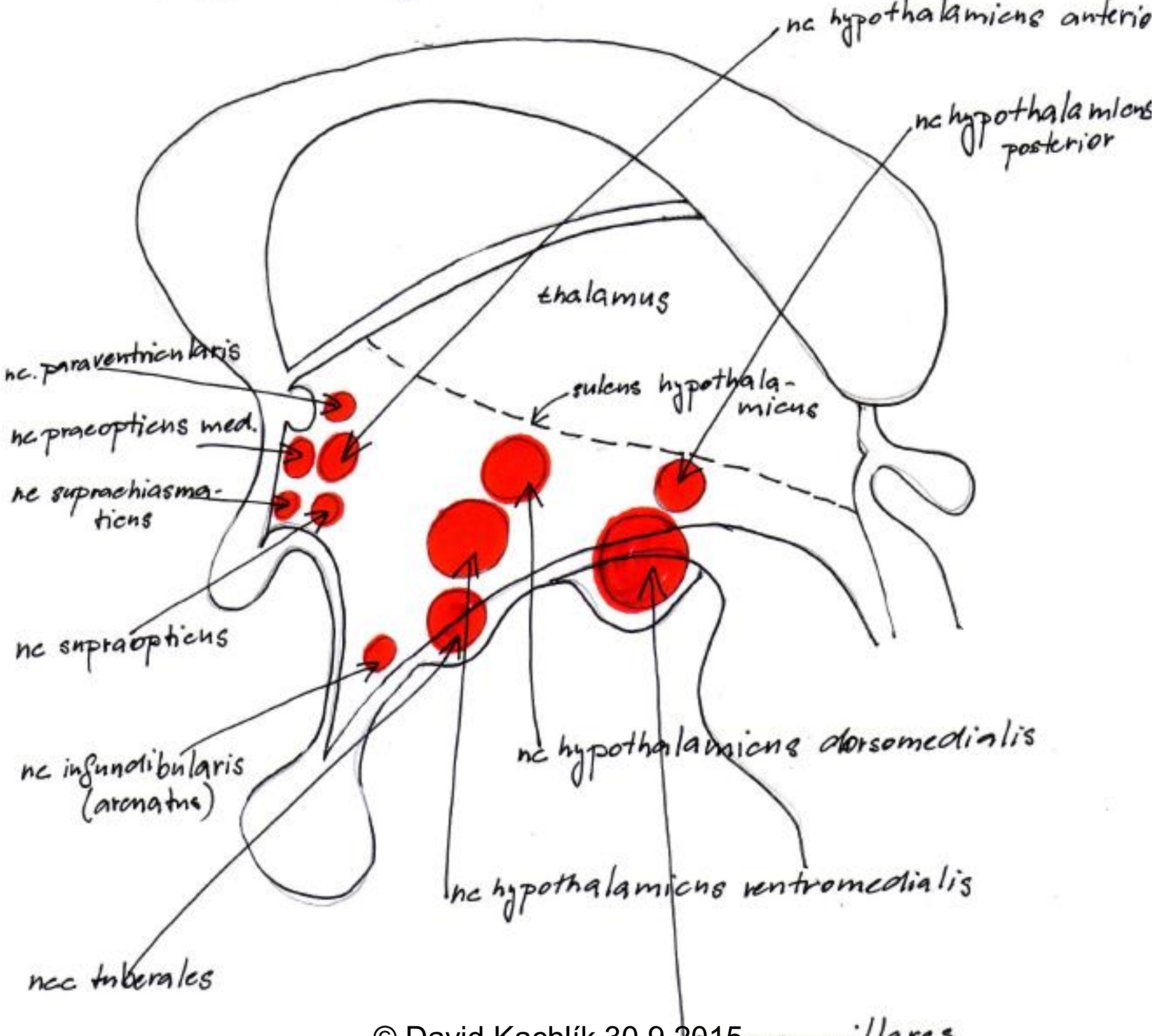
Anterior (Supraoptic) Region
2. Anterior Nucleus
3. Supraoptic Nucleus
4. Paraventricular Nucleus

Intermediate (Tuberal) Region
5. Dorsomedial Nucleus
6. Ventromedial Nucleus
7. Infundibular or Arcuate Nucleus

Posterior Region
8. Posterior Nucleus
9. Mammillary Nucleus

LATERAL ZONE
10. Lateral Hypothalamic Nucleus

HYPOTHALAMUS



Hypothalamus – *white matter*

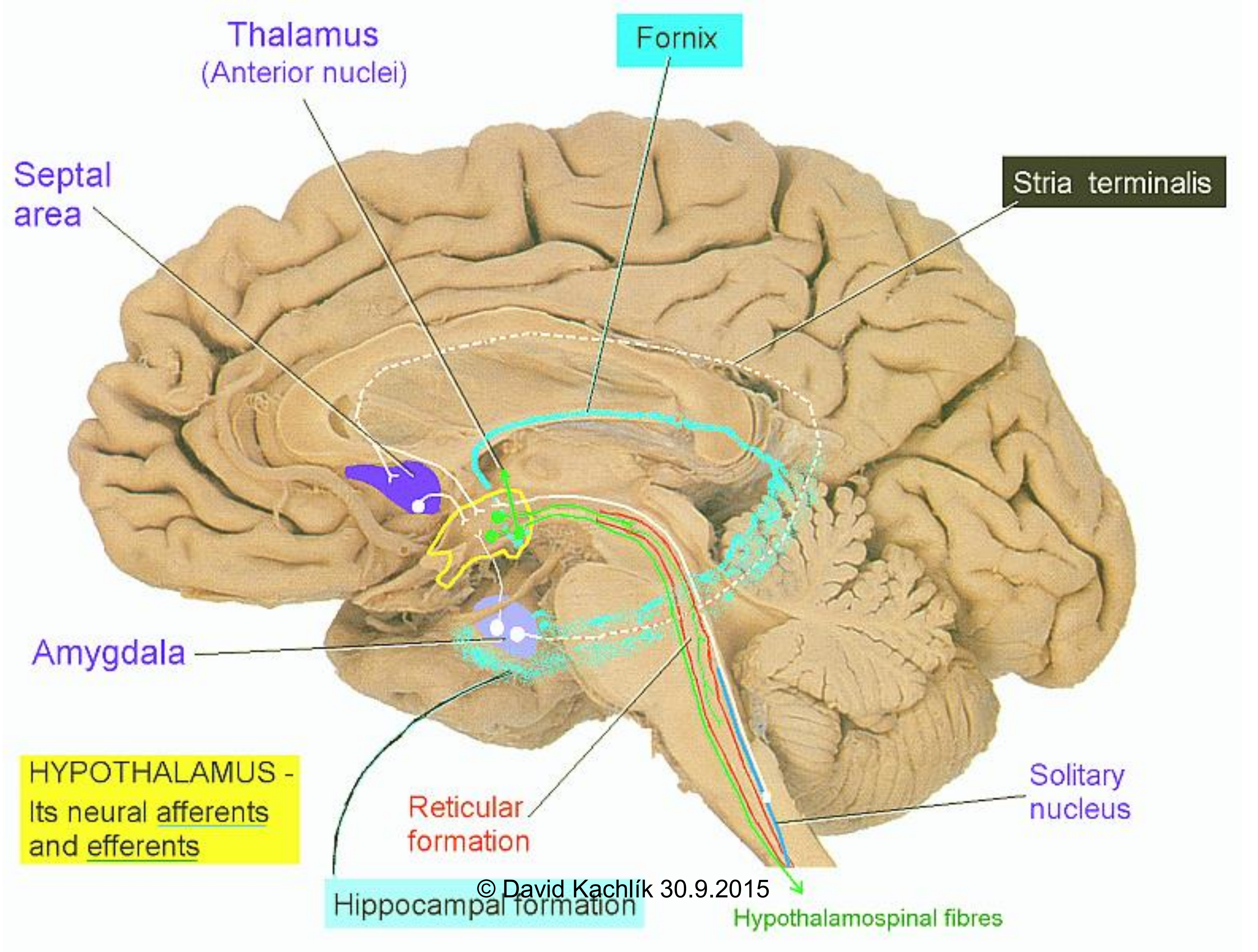
- **fornix** → corpus mammillare (nuclei corporis mammillaris) → tractus mammillaris princeps /splits into/

  → tractus mamillothalamicus → ncl. anteriores thalami

  → tractus mammillotegmentalis → RF of stem (ncl. *Guddeni*)
- **stria terminalis**

  corpus amygdaloideum → hypothalamus
- **stria medullaris thalami**

  hypothalamus → habenula


Thalamus
(Anterior nuclei)
Fornix
Septal area
Stria terminalis
Amygdala
HYPOTHALAMUS -
Its neural afferents and efferents
Reticular formation
Solitary nucleus
Hippocampal formation
Hypothalamospinal fibres

Hypothalamus – *white matter*

- **fasciculus medialis telencephali**

  = fasciculus prosencephalicus medialis = medial forebrain bundle (**MFB)**

  – between medial and laterl zone of nuclei – connects hypotalamus with cortical limbic system + limbic system of brain stem (+ RF)

- **pedunculus mammillaris**

  - connects corpora mammillaria and nucleus dorsalis tegmenti *Guddeni* (in RF of mid brain) and **fasciculus longitudinalis posterior *Schützi***

  ncl. in medial zone of hypotalamus → autonomic nuclei, nuclei of cranial nerves (eventually into spine)

Hypophysis (pituitary gland)

- **adenohypophysis (= lobus anterior)**
  - Development from *Rathke pouch* from roof of pharynx
  - hormones (**ACTH, TSH, FSH, LH, STH, MSH**)
  - Influenced by hypotalamic **releasing and inhibiting hormones**
  - transport from ncl. arcuatus via tractus tuberoinfundibularis (= neurokrinie) → *hypotalamo-hypofyzoportal system*
  - *Sheehan syndrome*
- **neurohypophysis (= lobus posterior)**
  - Development as diencephalic pouch
  - nucleus supraopticus (vazopressin = ADH)
  - ncl. paraventricularis (oxytocin)
  - axonal transport from hypotalamus
  - Reacts to changes of osmolality via *organum subfornicale*

Hypotalamus – *summary*

- Part of limbic system = preserve of species and individual
  - reproduction
  - Growth and metabolism
  - Intake of food and water
  - Attack and defense
  - termoregulation
  - Cycle of wake - sleep
  - memory

Optional reading
Neuroanatomy of sleep cycle

Why sleep?

- You need almost as much sleep after a day of sitting around the house as after a day of intense physical or mental activity (Horne and Minard, 1985, Shapiro et al., 1981).
- You feel tired at the end of the day because inhibitory processes in your brain force you to become less aroused and less alert.

Functions of sleep

- Rest our muscles
- Decrease metabolism
- Rebuild proteins in the brain
- Reorganize synapses
- Strenghten memories

Why sleep?

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Why sleep?

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Search for primary reason

- All species sleep, not just vertebrates with big brain and complex memories
- Bacteria have circadian rhytms
- Conservation theory:
- -Simple way of conserving energy
- NASA´s Rover built to explore Mars had mechanisms to make it „sleep" at night to conserve its batteries.

Conservation theory

- We might not guess original function for which it was evolved.
- Consider computer analogy:
- Important functions today include writing papers, sending e-mail, searching Internet, playing games, storing photographs, playing movies etc.
- Previously served for mathematical operations

Search for primary reason

- Sleep conserves energy during the inefficient time
- Mammal´s body temperature is decreased by 1°C or 2°C during sleep
- Animals increase sleep duration during food shortages
- **Sleep** is therefore analogous to **hibernation**

Hibernation

- Hibernating animals decrease their body temperature to that of the environment (but do not let it drop to freeze ☺)
- Hamsters sometimes hibernate, if you let your favorite pet during winter in cold place, make sure it is not hibernating before you bury it ☺
- Hibernating animals come out of hibernation for few hours every few days, raising temperature to normal

Hibernation

- Hibernating retards the ageing process
- Hibernation is also a period of relative invulnerability to infection and trauma. Procedures that would ordinarily damage brain, such as inserting a needle into it, produce little if any harm (Zhou et al.,2001)
- Na-K dependent ATPase on cell membrane

Hibernation

- Herbivores graze many hours per day – sleep is briefer and often interrupted
- Dolphins and other aquatic mammals have asleep one hemisphere at time, other is awake and control swimming and breathing
- Birds during migration decrease need for sleep – in primates drugs exciting glutamate receptor can decrease sleep need
- Even if you keep migratory bird in cage during migratory period, it does not sleep

Hibernation

- The fact that it is possible to decrease the need for sleep argues that sleep is not necessary for repair and restoration, or at least that sleep usually last longer than required for repair and restoration

Hazel dormouse hibernating

Swift example

Swift example

- Question: when a baby swift first takes off from its nest, how long would you guess its first flight lasts, until it lands again?
- Answer: up to 2 years!
- It spends both night and days in the air, except huge storms
- Perhaps it switches brain hemispheres, but we do not know – EEG during flight is problem

Other functions of sleep

- Restorative functions
- Sleep and memory
- 600 hrs of REM per year
- REM – eyeball movement for cornea to get enough oxygen by shaking eyeballs
- Strenghtening consolidation of different type of memory

Biology of dreaming

- Activation-synthesis hypothesis – dreams begin with periodic bursts of spontaneous activity in the pons – the PGO waves, which partly activates many but not all parts of the cortex. Cortex combines this haphazard input with whatever other activity was already occuring and does its best to synthetize a story that makes sense of all this informations

Biology of dreaming

- Because activity is supressed in the primary visual cortex and somatosensory cortex, normal sensory information cannot compete with the self generated stimulation and hallucinations result
- Input from pons usually activates amygdala – emotional processing
- Prefrontal cortex is inactive during PGO waves, memory is weak

Biology of dreaming

- Patients with pons lesion still have dreams, eventhough they do not move eyeballs and other features of REM
- Paradox: brain produces dreams, but do not percieve them as self-produced. Some people can tickle themselves and actually feel it as a tickling sensation, at least slightly

Biology of dreaming

- Clinico-anatomical hypothesis
- Similar to activation-synthesis theory
- Inferior part of parietal cortex is active during dreaming – patients with damage have no dreams

- www.dreamresearch.net

Variation in sleep

- Cats and bats eat rich food and face little threat – they sleep many hours per day

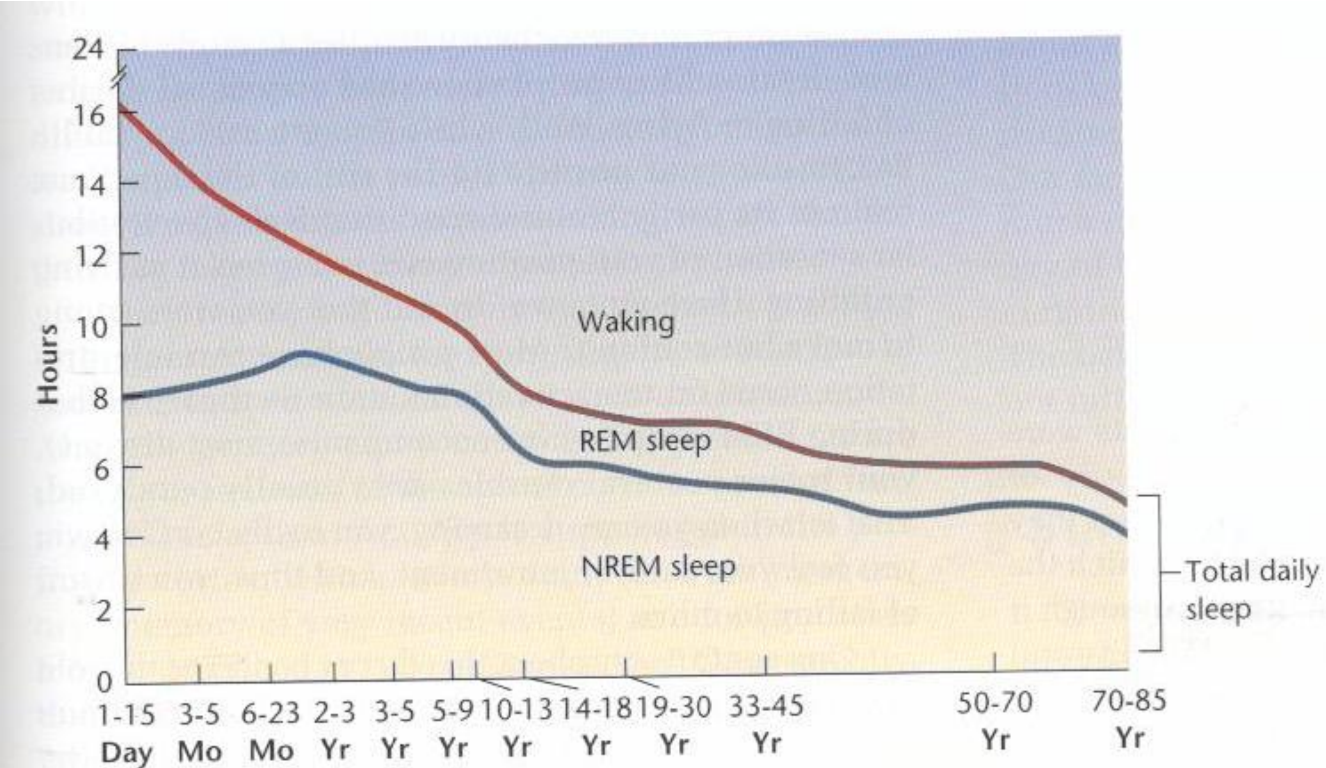


Figure 9.18 Time spent by people of different ages in waking, REM sleep, and NREM sleep
REM sleep occupies about 8 hours a day in newborns but less than 2 hours in most adults. The sleep of infants is not quite like that of adults, however, and the criteria for identifying REM sleep are not the same. *(Source: From "Ontogenetic development of human sleep-dream cycle," by H. P. Roffwarg, J. N. Muzio, and W. C. Dement, Science, 152, 1966, 604–609. Copyright 1966 AAAS. Reprinted by permission.)*

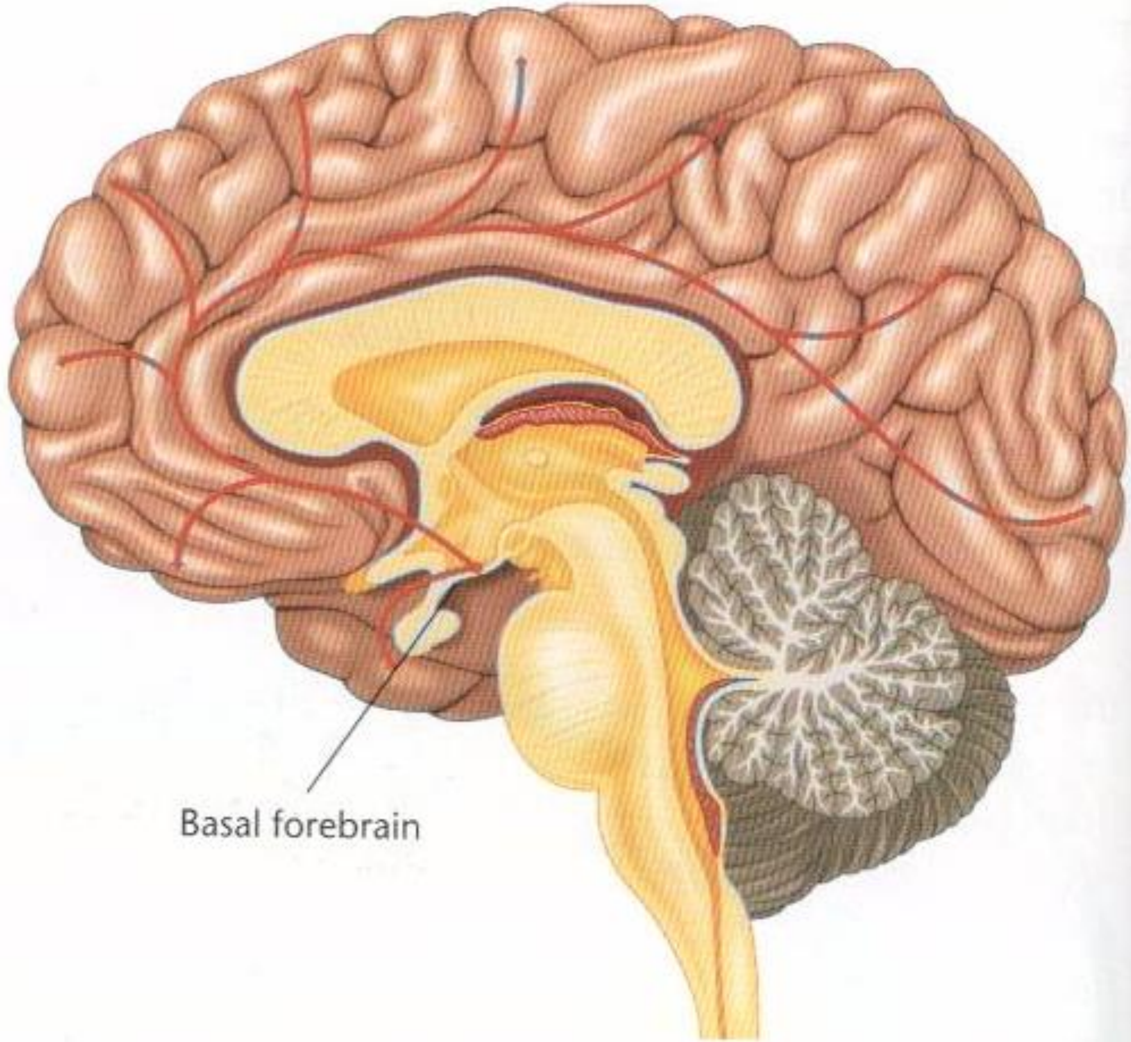


Figure 9.12 Basal forebrain
The basal forebrain is the source of many excitatory axons (releasing acetylcholine) and inhibitory axons (releasing GABA) that regulate arousal of the cerebral cortex.

Table 9.1 Brain Structures for Arousal and Sleep

Structure	Neurotransmitter(s) It Releases	Effects on Behavior
Pontomesencephalon	Acetylcholine, glutamate	Increases cortical arousal
Locus coeruleus	Norepinephrine	Increases information storage during wakefulness; suppresses REM sleep
Basal forebrain		
Excitatory cells	Acetylcholine	Excites thalamus and cortex; increases learning, attention; shifts sleep from NREM to REM
Inhibitory cells	GABA	Inhibits thalamus and cortex
Hypothalamus (parts)	Histamine	Increases arousal
	Orexin	Maintains wakefulness
Dorsal raphe and pons	Serotonin	Interrupts REM sleep

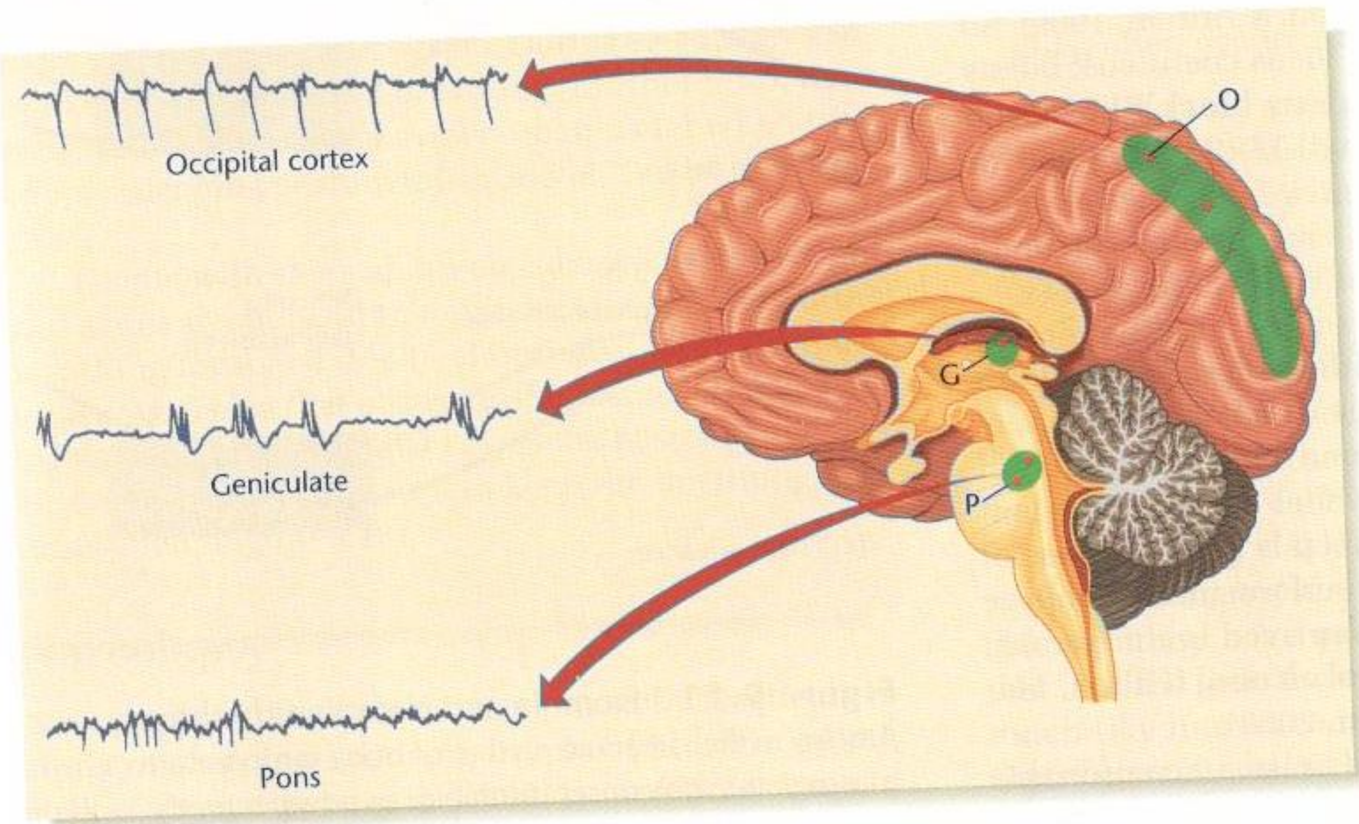


Figure 9.13 PGO waves
PGO waves start in the pons (P) and then show up in the lateral geniculate (G) and the occipital cortex (O). Each PGO wave is synchronized with an eye movement in REM sleep.

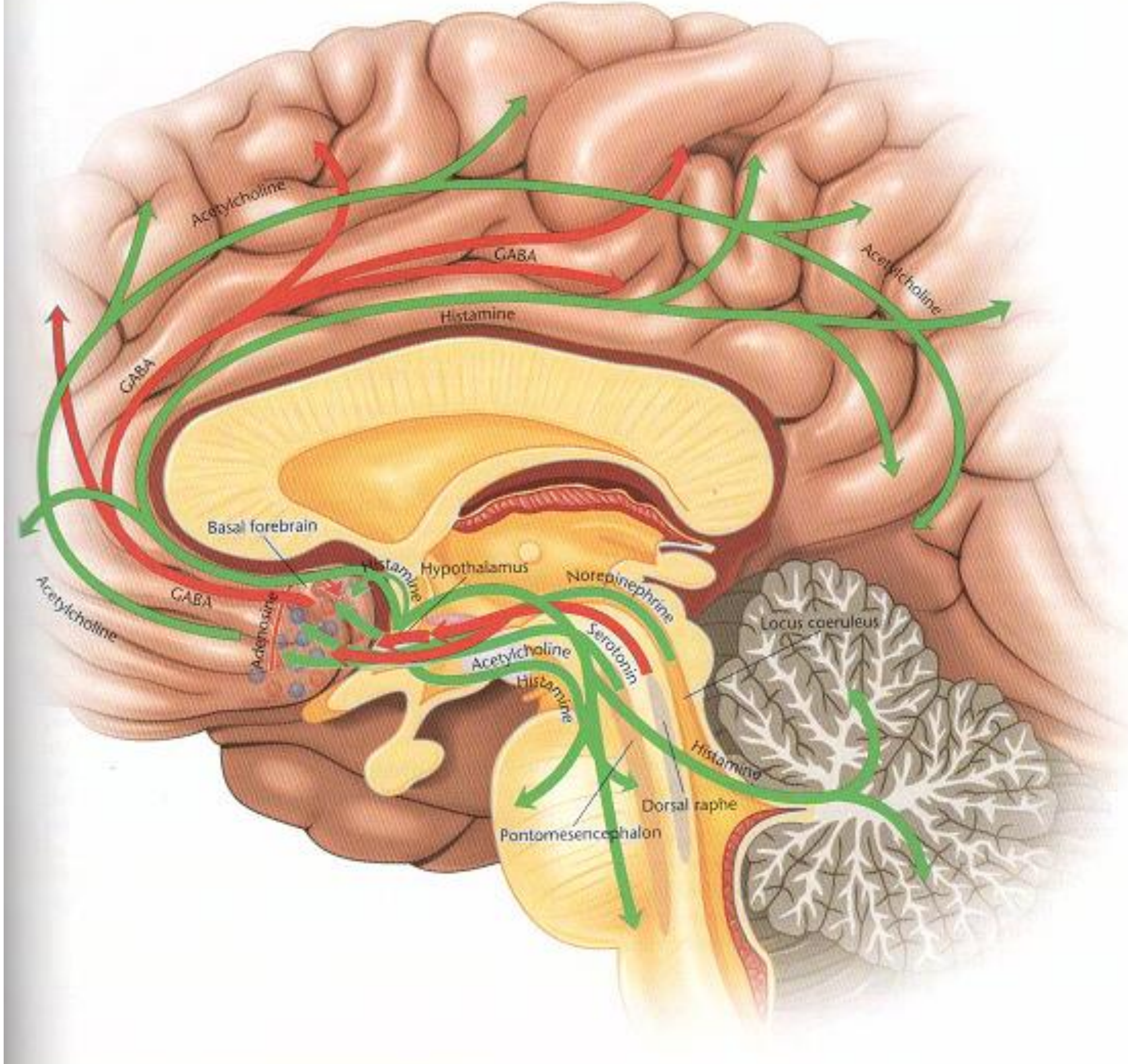


Figure 9.11 Brain mechanisms of sleeping and waking
Green arrows indicate excitatory connections; red arrows indicate inhibitory connections. Neurotransmitters are indicated where they are known. [illegible] small arrow, it is a metabolic product that builds up in the area, not something released by axons.
(Source: Based on Lin, Hou, Sakai, & Jouvet, 1996; Robbins & Everitt, 1995; and Szymusiak, 1995)

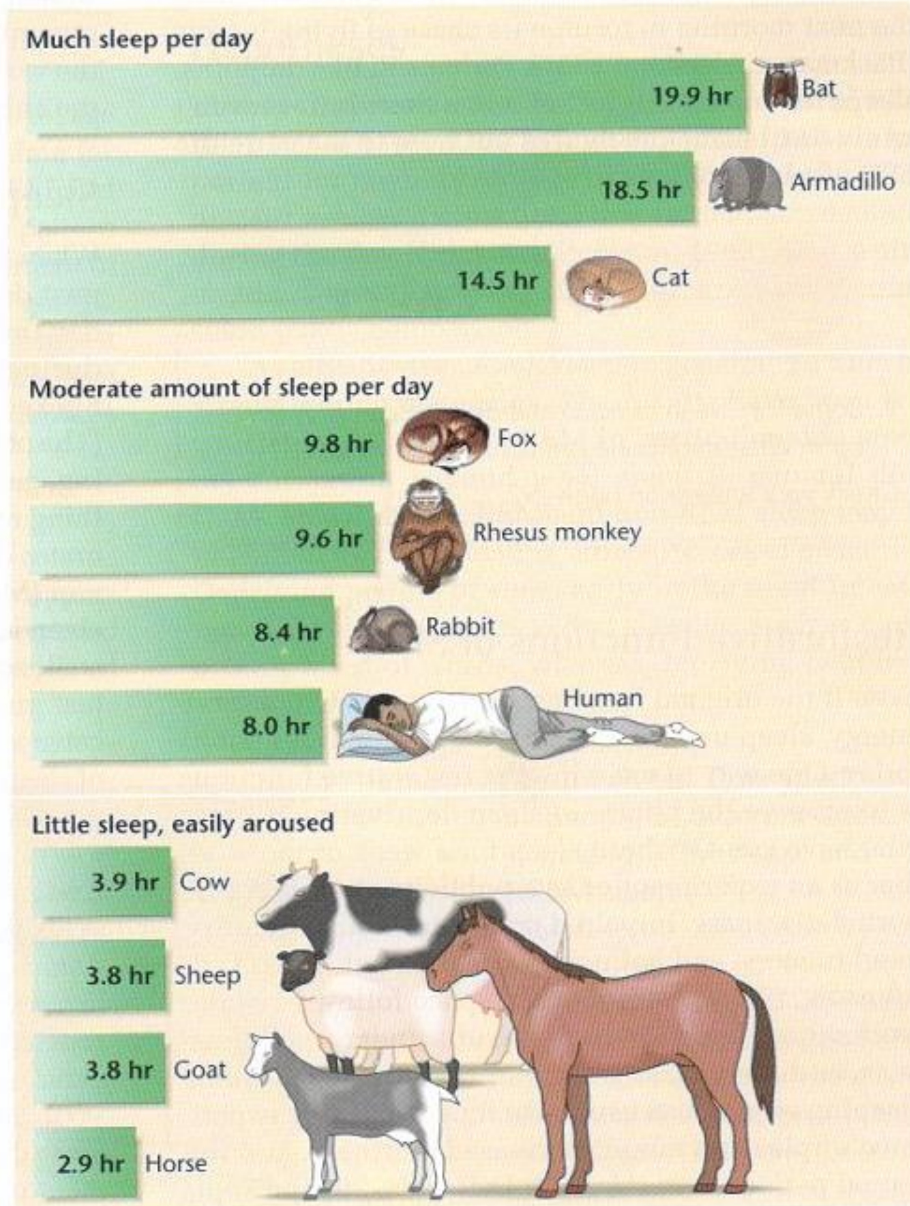
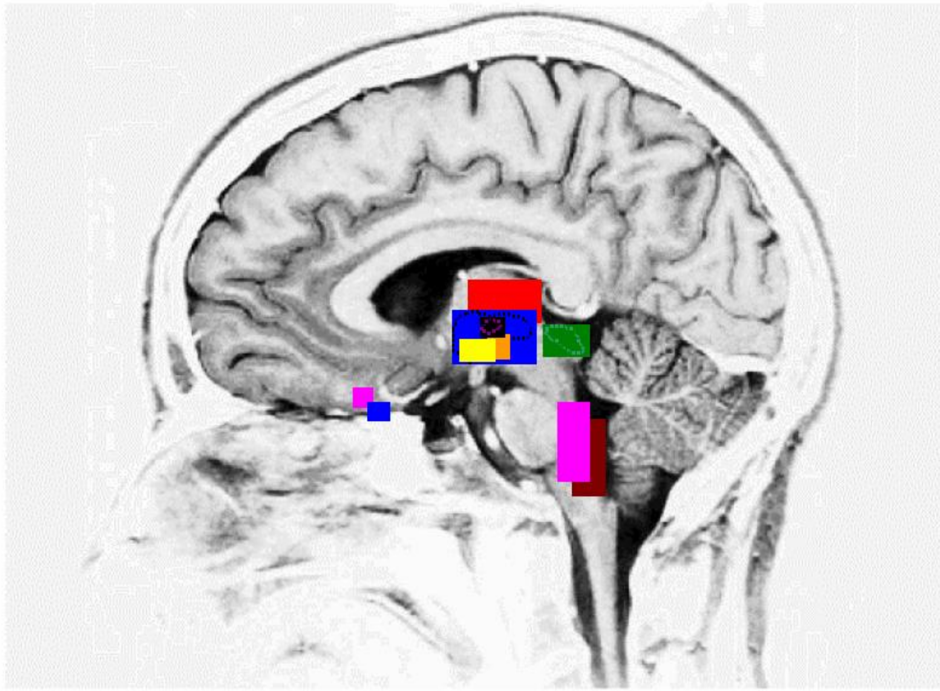


Figure 9.17 Hours of sleep per day for various animal species
Generally, predators and others that are safe when they sleep tend to sleep a great deal; animals in danger of being attacked while they sleep spend less time asleep.

Biological clock

- Richter 1967 introduced idea that the brain generates its own rhythms
- Disruption of BC occurs after damage to hypothalamic area – **suprachiasmatic nucleus**
- After disruption rhythms are less consistent and no longer synchronized to light and dark pattern

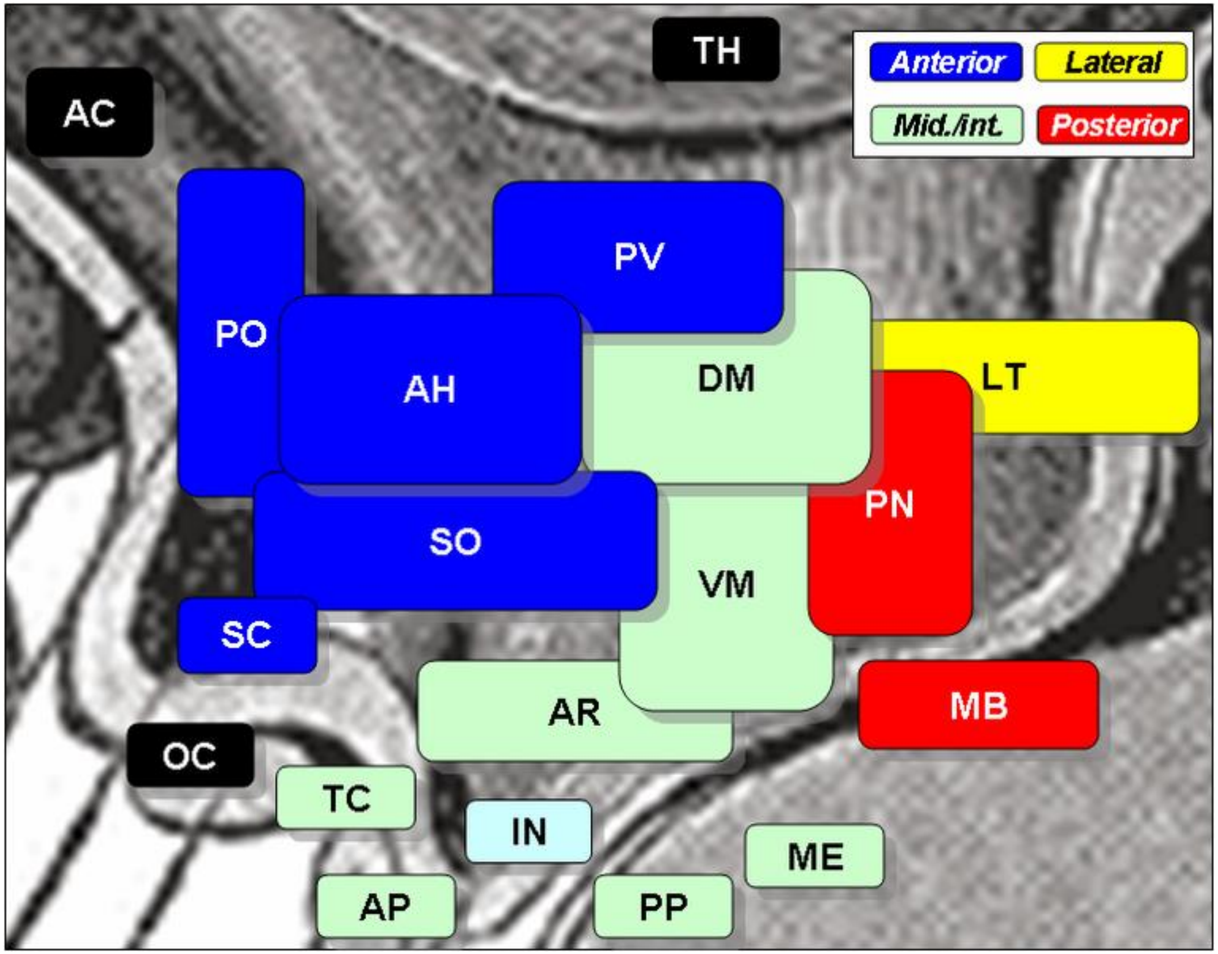
Figure 2



- Suprachiasmatic Nucleus
- Thalamus
- Hypothalamus
- Tuberomammillary Nucleus
- Raphé Nucleus
- Locus Coeruleus
- Perifornical Lateral Hypothalamus
- Ventrolateral Pre-optic Nucleus
- Median Pre-optic Nucleus
- Pineal Gland

Sleep-related structures in the brain as discussed in the neural mechanism section. Notice that some structures like the Tuberomammillary Nucleus are located within another structure, the hypothalamus. The positions indicated are strictly meant to be relative and will vary from one organism to another.

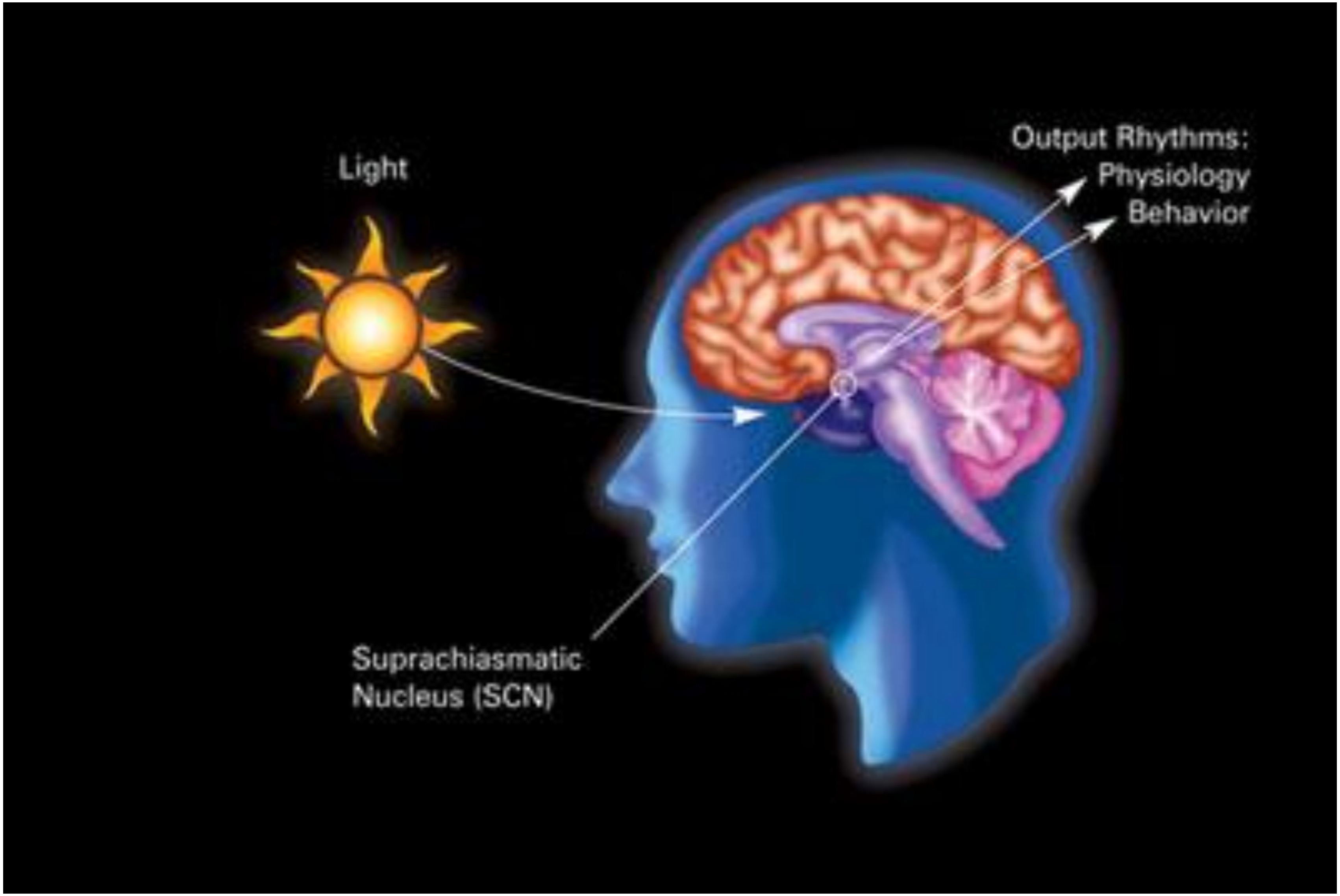
Suprachiasmatic nucleus



Suprachiasmatic nucleus

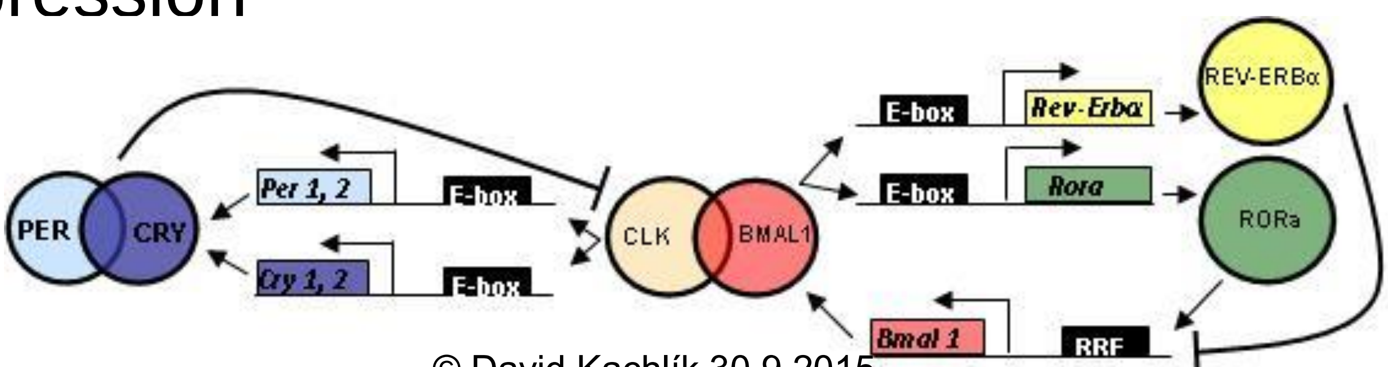
- It generates rhythm in a genetically controlled, unlearned manner
- From Drosophilla – isolated genes *period* (per) and *timeless* (tim), producing proteins Per and Tim
- In the morning their levels are low, in the evening high
- Interact with protein Clock to induce sleepiness

SCN


Light
Output Rhythms:
Physiology
Behavior
Suprachiasmatic
Nucleus (SCN)

Suprachiasmatic nucleus

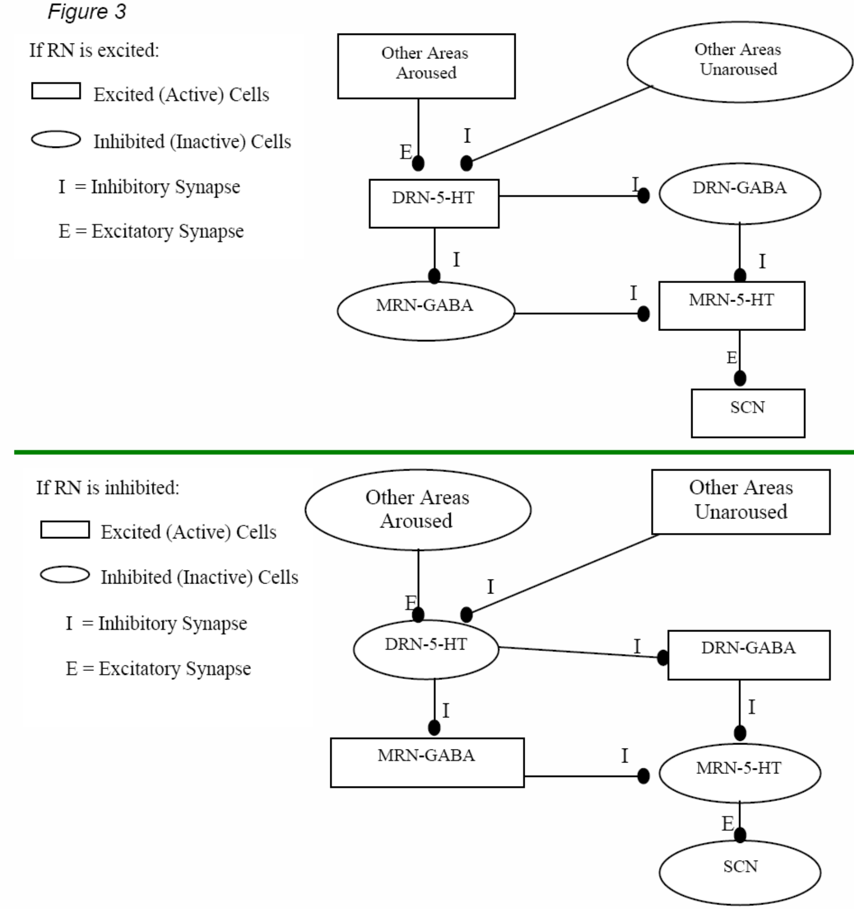
- Pulse of light during night inactivates protein Tim, so extra light during evening resets biological clock
- People having mutation in *per* gene have odd circadian rhythms: run faster
- Mutation in *per* is closely linked to clinical depression



Dorsal raphe nucleus (DRN)

- Sleep antagonist
- Extra DRN path (DRN SC nucleus)
- Intra DRN path (medial and lateral DRN nc.)

Figure 3



The intra-Raphé nucleus pathway as described in the neural mechanism works as a switch. Notice that if the RN is excited by other brain structures, an output to the SCN is observed by inhibiting (I) the MRN- and DRN-GABA cells. When the RN is inhibited by other brain structures, the MRN-GABA and DRN-GABA cells are allowed to fire tonically, thereby suppressing the output of the RN to the SCN.

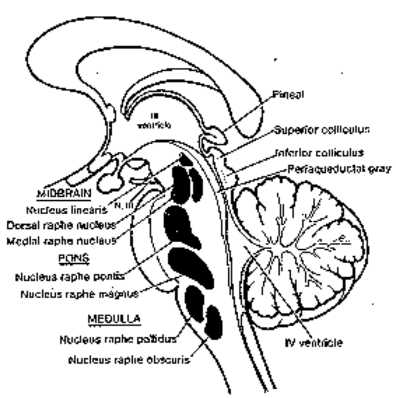


Fig. 5. The midsagittal section of the brain stem indicating the position of the raphe nuclei.

Locus coerulaeus (LC)

- Does not communicate with SC nc. as DRN, but through *dorsal medial hypothalamus*
- The only adrenergic nucleus involved in sleep
- Arousal function, but according to some also most decreased firing rate during REM phase sleep

Tuberomammillary nucleus (TMN)

- Histamine neurotransmission (the only place in brain, where histamine is produced)
- Maximum firing rate during waking state

Perifornical lateral hypothalamus

- Source of Hypocretin (Orexin)
- Hypocretin causes arousal
- Hypocretin has effect on LC and TMN, but not with SCN

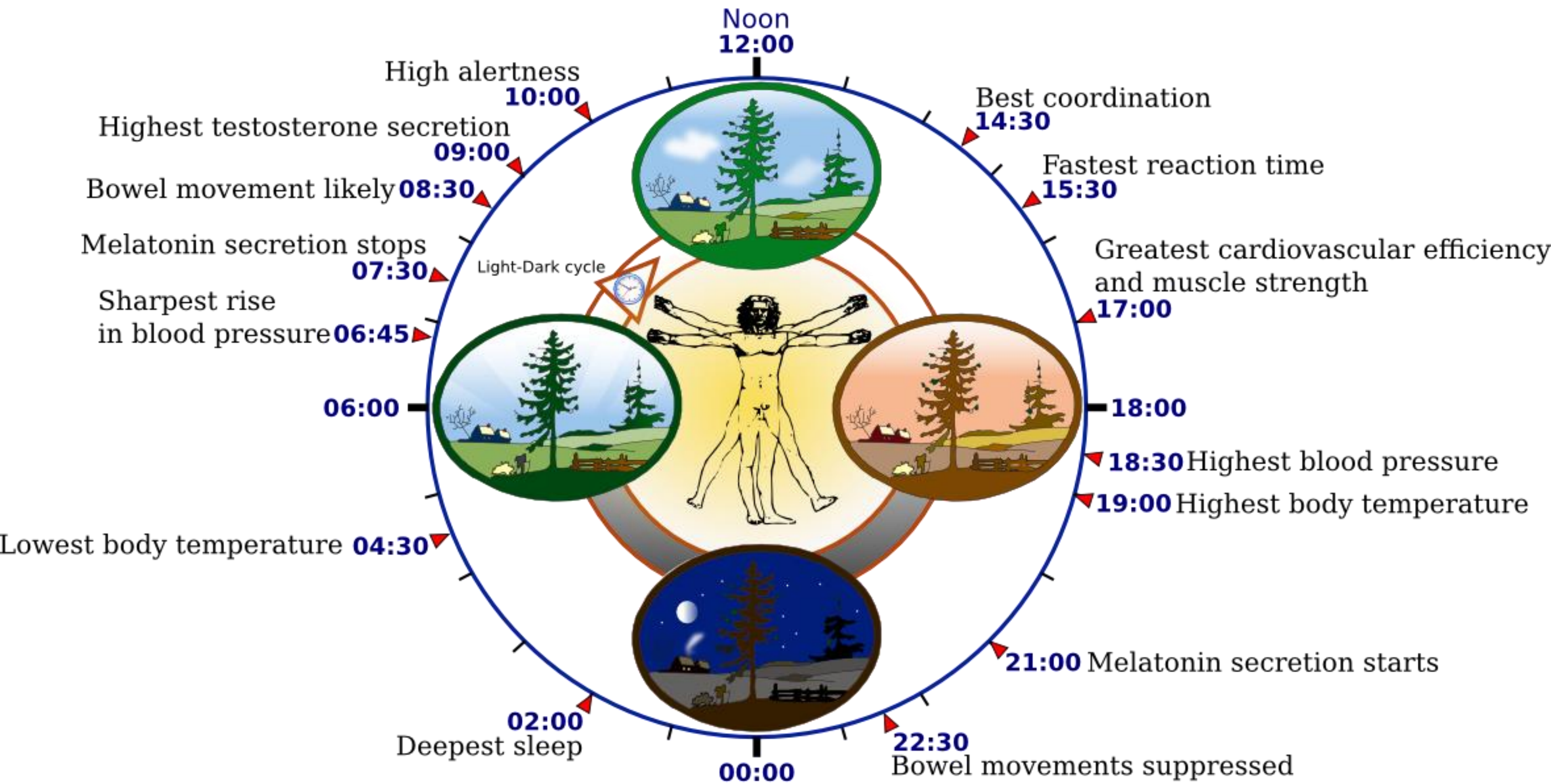
Melatonin

- Melatonin is produced by pineal gland (*is outside blood barrier*) and increases sleepiness
- Tumor of pineal gland – sleepiness
- Melatonin secretion starts usually 2-3 hours prior to bedtime
- Moderate dose of melatonin in the afternoon phase-advances the clock
- Single dose in the morning has little effect

Melatonin

- Dim-Light Melatonin Onset (DLMO)
- Anti Alzheimer disease
- Anti ageing factor
- Prolonging REM phase of sleep
- Its level with ageing decreases
- Scavenger function
- Drowsiness and hypothermia = circadian r.

Biological clock



Triggers

- Light is dominant „zeitgeber“ for land animals
- Retinohypothalamic path – from special population of retinal ganglion cells, having its own photopigment – melanopsin, unlike the ones found in rods and cones
- These cells respond directly to light and do not require any input from rods and cones

Jet lag

- Disruption of circadian rhythms due to crossing time zones
- Going west we stay awake later at night – phase-delay
- Going east we have to go to sleep earlier and awake earlier – phase-advance
- Adjusting to jet lag - ↑ cortisol levels – hippocampal shrinkage

Jet lag memory loss

- Female flight attendants – 5 years on Chicago-Italy route with less than 6 days interval – smaller hippocampal volume and memory impairments (Cho, 2001)
- To treat the jet lag, the recommended dose of melatonin is 0.3–0.5 mg, to be taken the first day of traveling

Sleep disorders

- Dyssomnias (insomnia, hypersomnia, narcolepsia…)
- Parasomnias (Bruxism, sleep sex, sleep enuresis, pavor nocturnus, somnambulism, exploding head syndrome…)