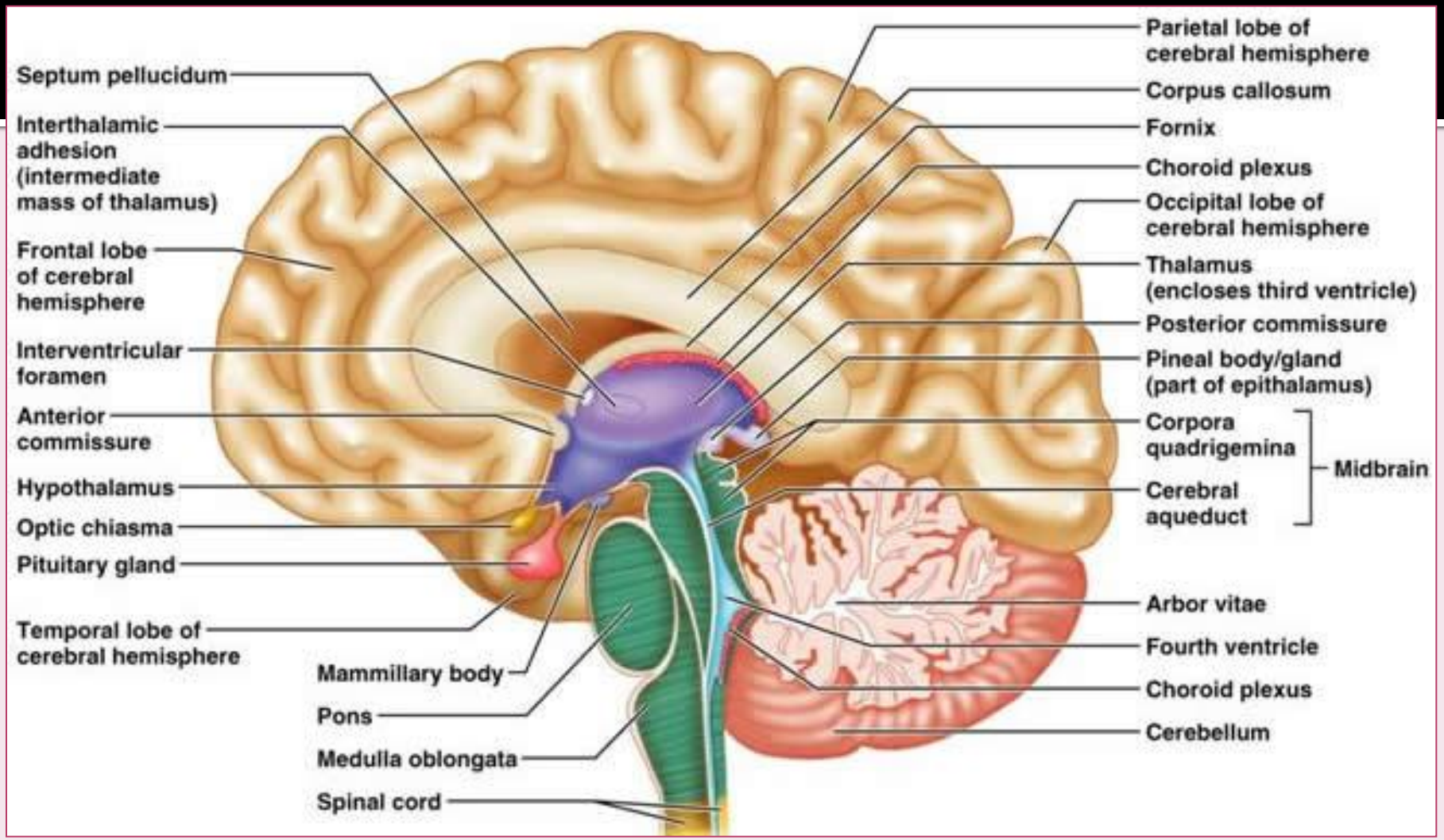
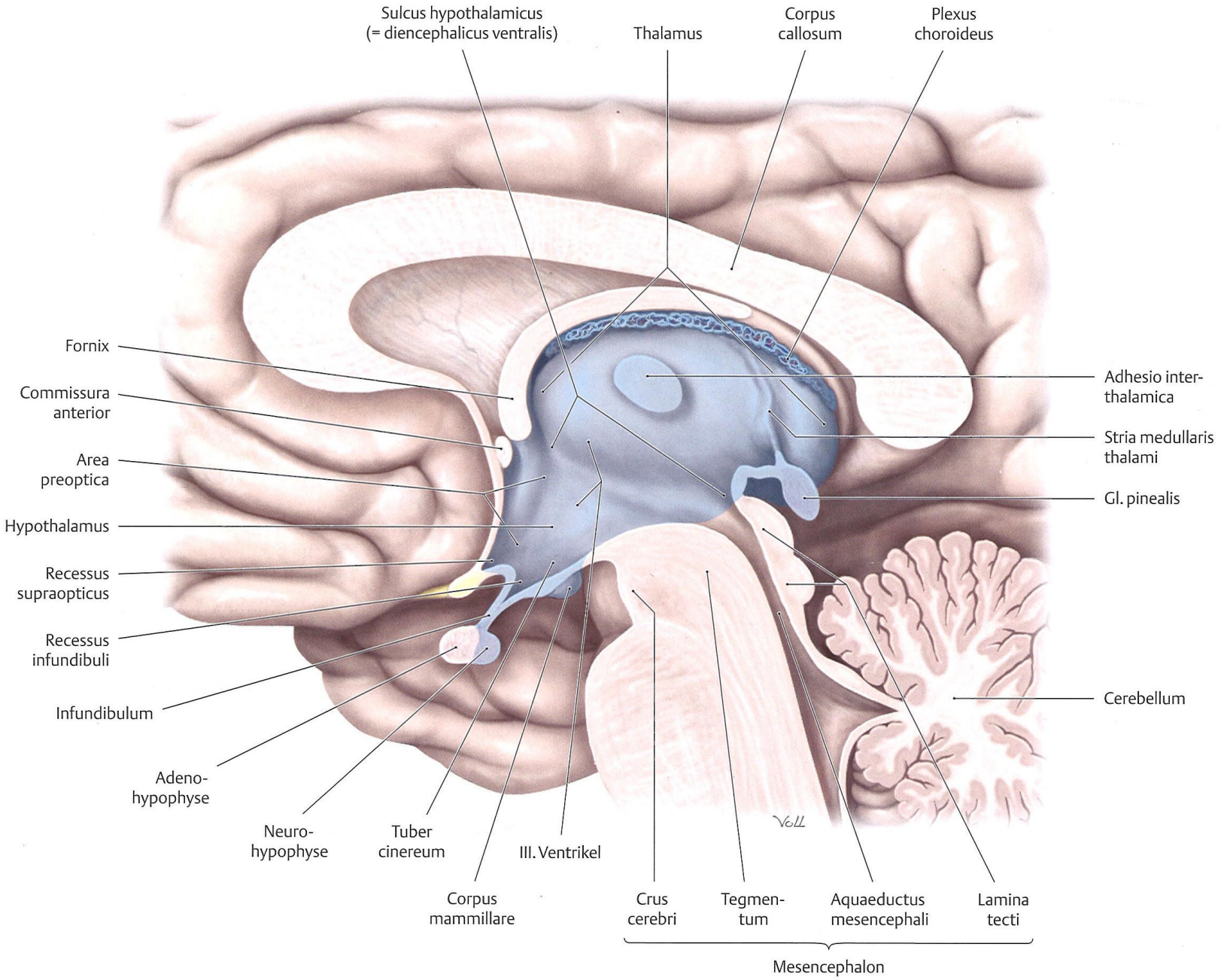
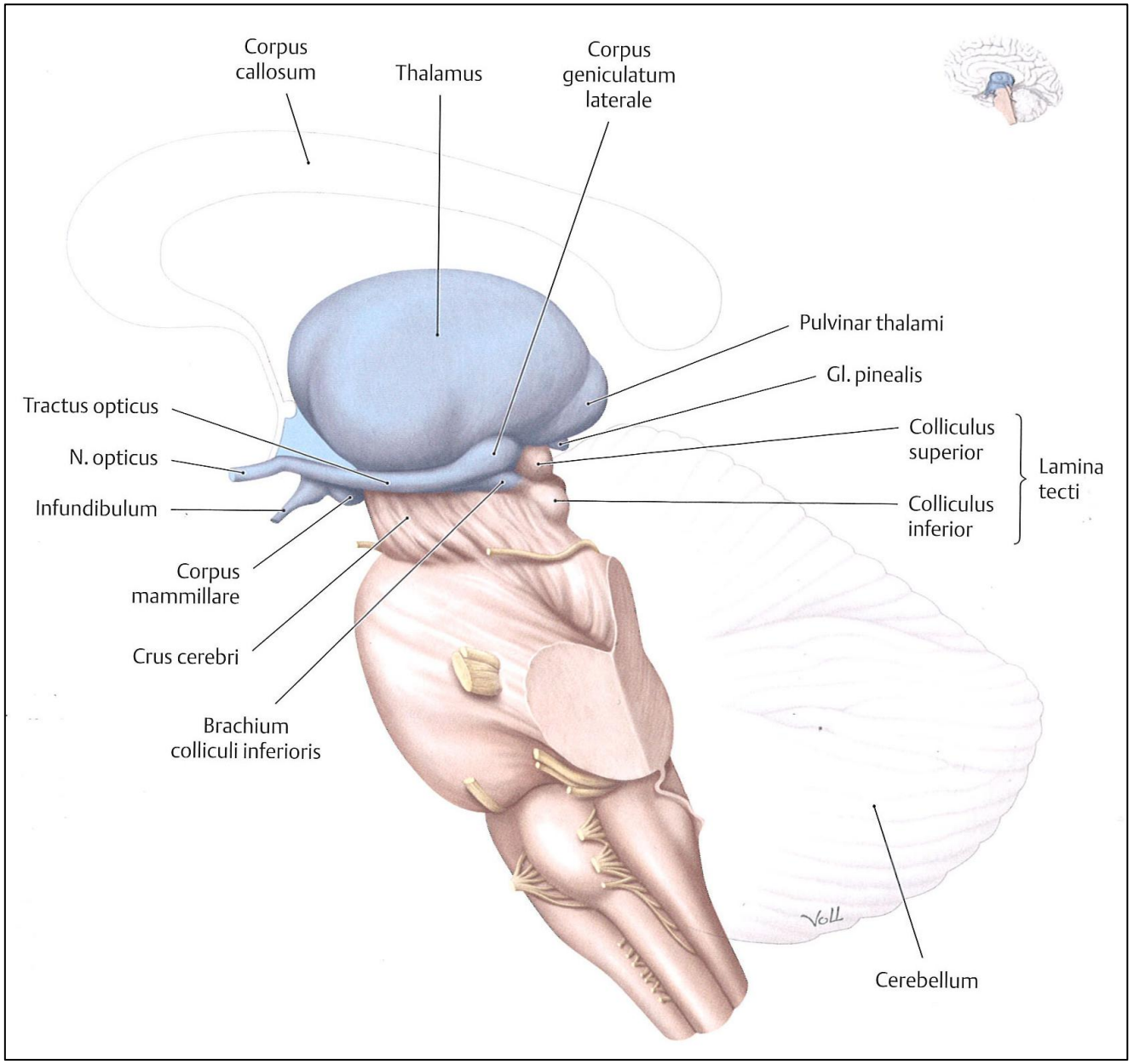
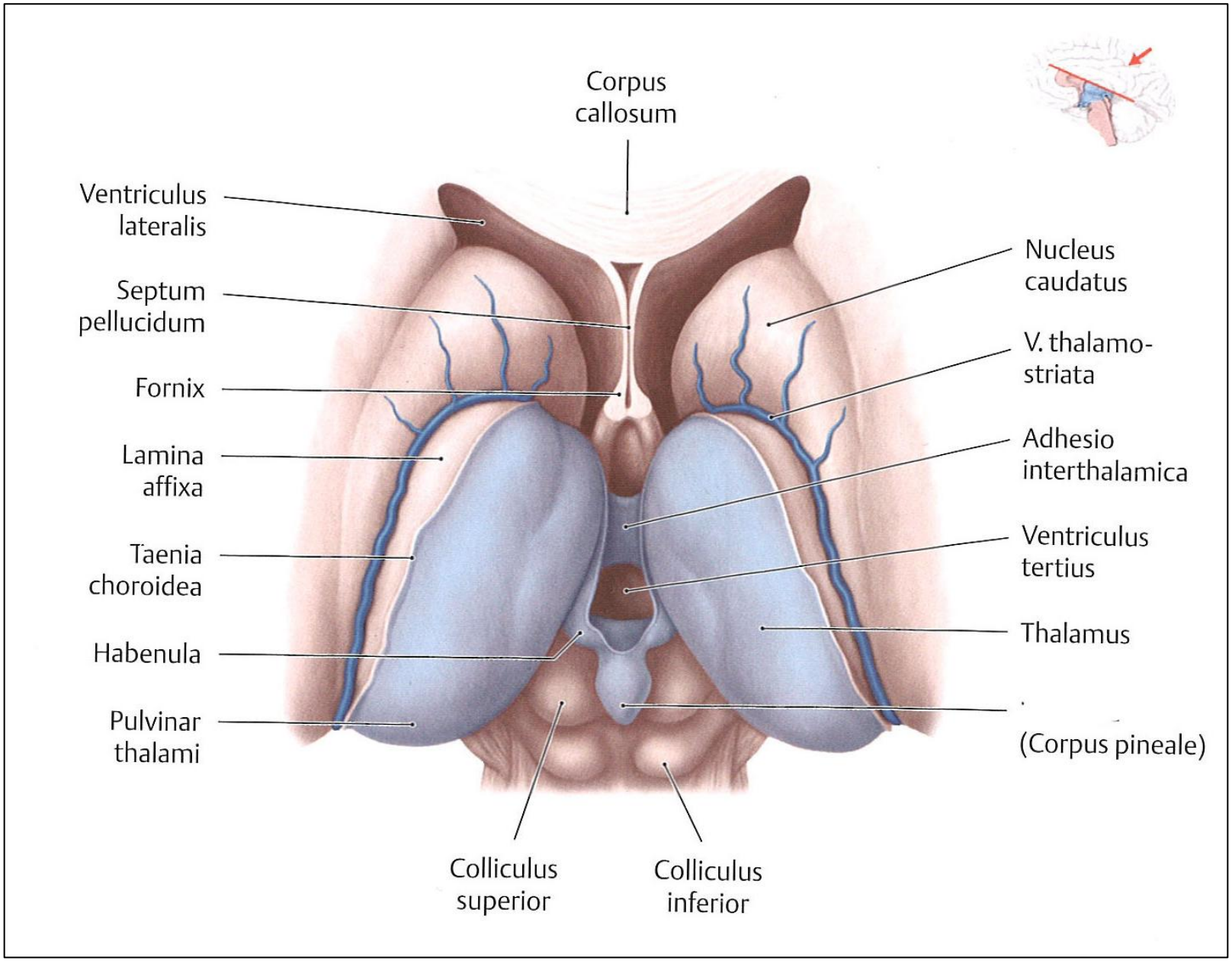
ORGANIZATION OF THE CNS - DIENCEPHALON -

Ivana Pavlinac Dodig, M.D., Ph.D.


Septum pellucidum
Interthalamic adhesion (intermediate mass of thalamus)
Frontal lobe of cerebral hemisphere
Interventricular foramen
Anterior commissure
Hypothalamus
Optic chiasma
Pituitary gland
Temporal lobe of cerebral hemisphere
Mammillary body
Pons
Medulla oblongata
Spinal cord
Parietal lobe of cerebral hemisphere
Corpus callosum
Fornix
Choroid plexus
Occipital lobe of cerebral hemisphere
Thalamus (encloses third ventricle)
Posterior commissure
Pineal body/gland (part of epithalamus)
Corpora quadrigemina
Cerebral aqueduct
Midbrain
Arbor vitae
Fourth ventricle
Choroid plexus
Cerebellum

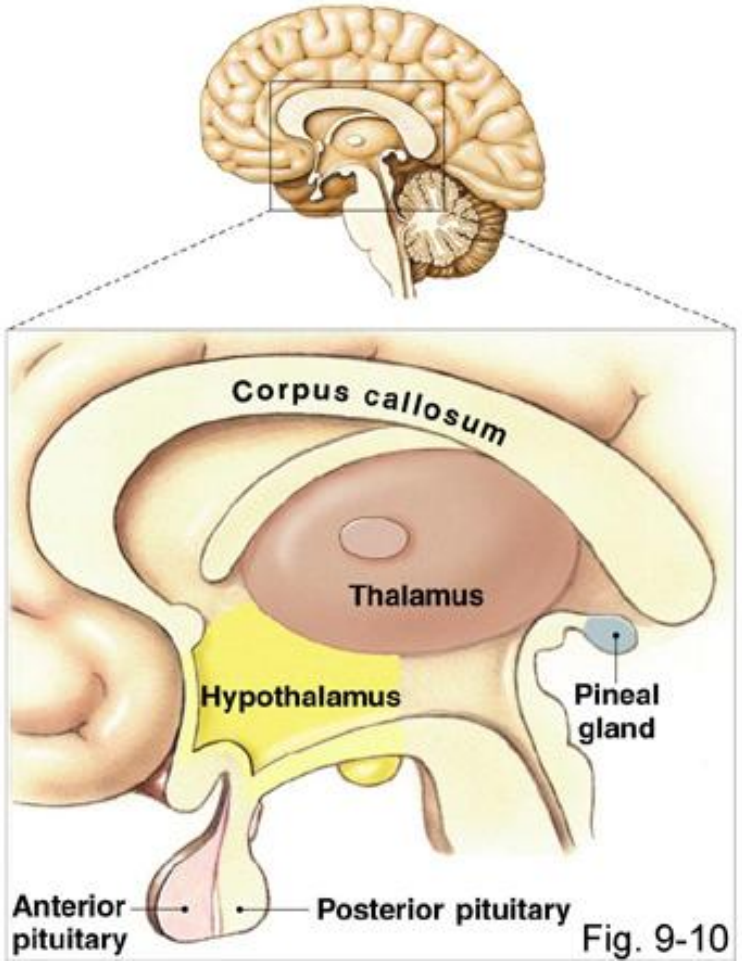

Sulcus hypothalamicus
(= diencephalicus ventralis)
Thalamus
Corpus
callosum
Plexus
choroideus
Fornix
Commissura
anterior
Area
preoptica
Hypothalamus
Recessus
supraopticus
Recessus
infundibuli
Infundibulum
Adeno-
hypophyse
Neuro-
hypophyse
Tuber
cinereum
III. Ventrikel
Corpus
mammillare
Crus
cerebri
Tegmen-
tum
Aquaeductus
mesencephali
Lamina
tecti
Mesencephalon
Adhesio inter-
thalamica
Stria medullaris
thalami
Gl. pinealis
Cerebellum

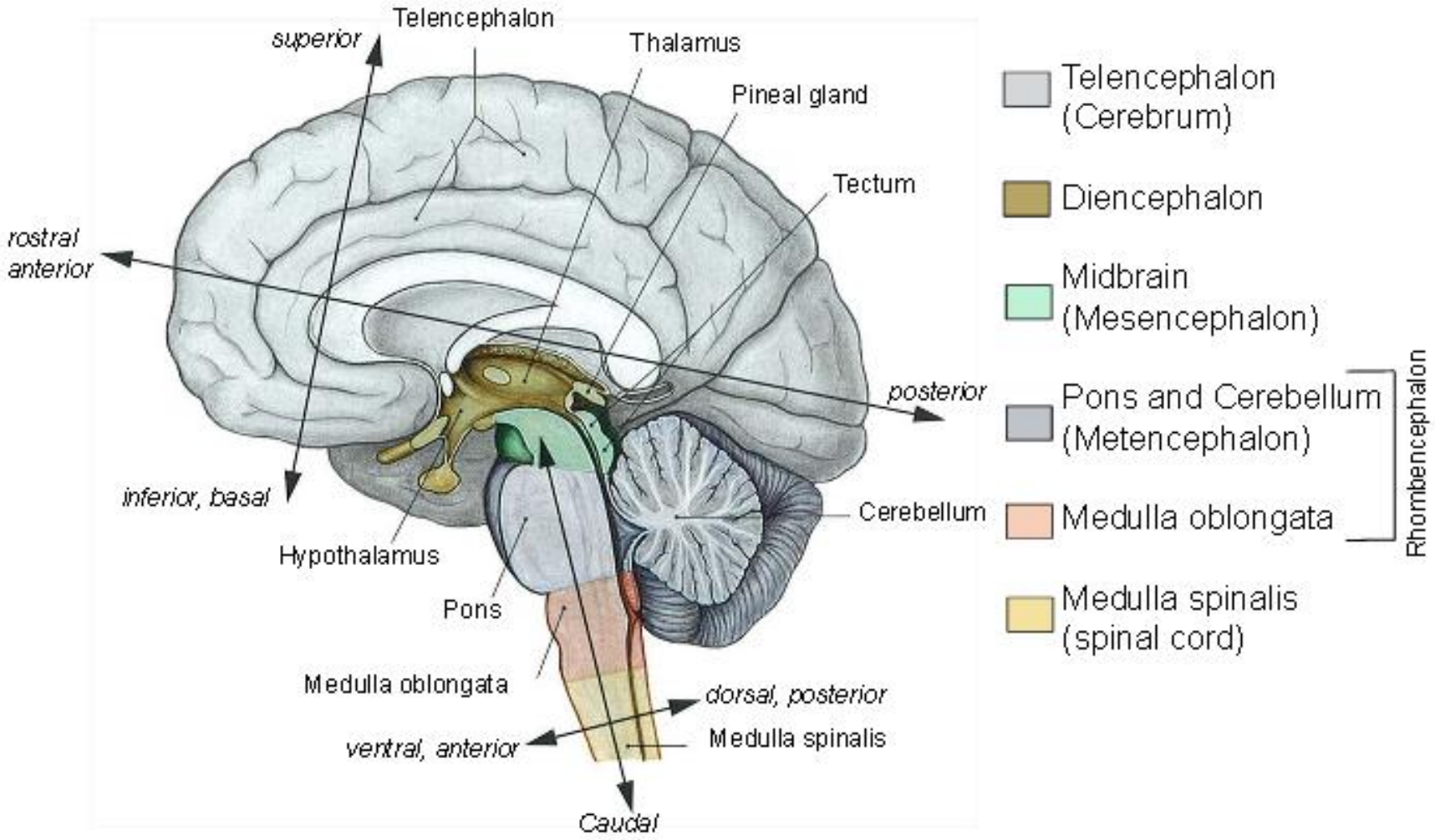

Corpus callosum
Thalamus
Corpus geniculatum laterale
Pulvinar thalami
Gl. pinealis
Tractus opticus
N. opticus
Infundibulum
Colliculus superior
Colliculus inferior
Lamina tecti
Corpus mammillare
Crus cerebri
Brachium colliculi inferioris
Cerebellum
Voll


Corpus callosum
Ventriculus lateralis
Septum pellucidum
Fornix
Lamina affixa
Taenia choroidea
Habenula
Pulvinar thalami
Nucleus caudatus
V. thalamo-striata
Adhesio interthalamica
Ventriculus tertius
Thalamus
(Corpus pineale)
Colliculus superior
Colliculus inferior

Diencephalon

- Hypothalamus
- Epithalamus
- Thalamus
- Metathalamus
- Subthalamus

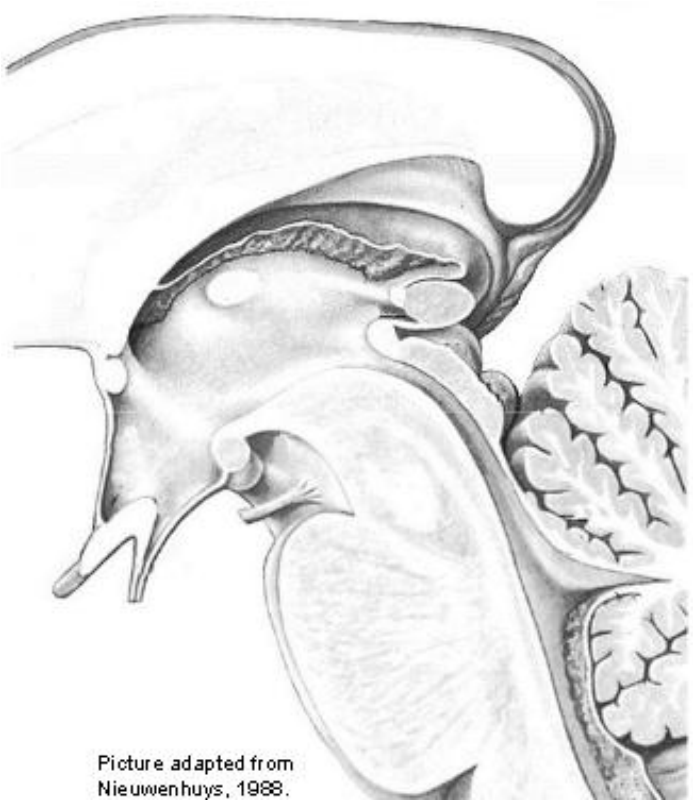




Schematics agittal section. Adapted from Sobotta 23 Ed.

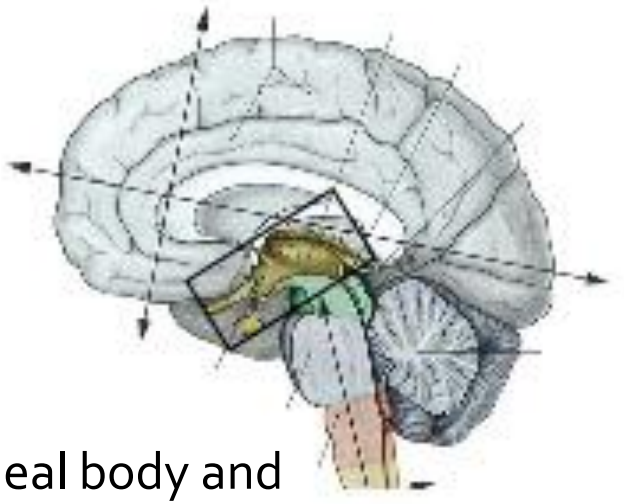
Diencephalon

- Literally "between-brain„
- Diencephalon is the area of the brain between the telencephalon and brainstem.
- It consists of the thalamus, subthalamus, hypothalamus, metathalamus, and epithalamus.



Picture adapted from Nieuwenhuys, 1988.

Diencephalon



Epithalamus

- Epithelial roof of the third ventricle, habenula, pineal body and afferent/efferent connections, including striae medullares.

(dorsal) Thalamus

- Large mass of relay nuclei for reciprocal information flow between subcortical areas and telencephalon.

Subthalamus

- Continuation of the tegmentum, with several nuclei including the pars reticulata of the substantia nigra. Functionally part of the basal ganglia.

Hypothalamus

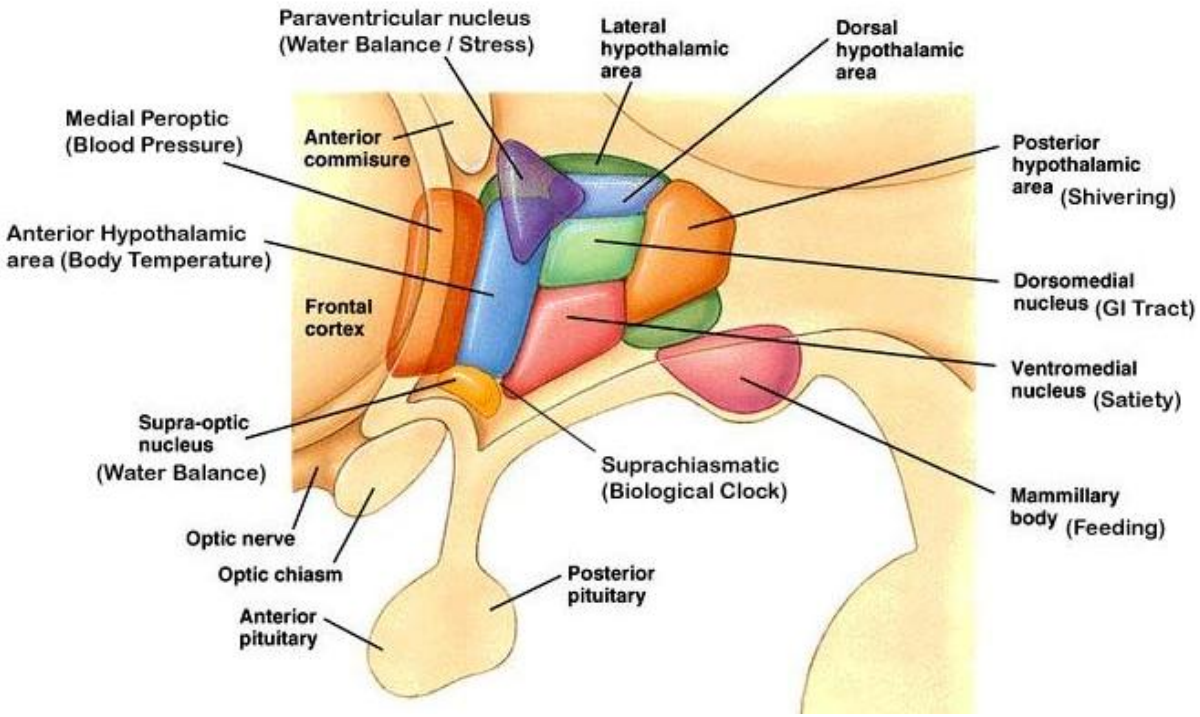
- Extends from the optic chiasm to the mammillary bodies. Contains a multitude of nuclei (e.g. suprachiasmatic nucleus, mammilary bodies)

Hypothalamus

- Regulatory functions of visceral, endocrine, autonomic and emotional processes:
  - Temperature regulation
  - Sympathetic and parasympathetic events
  - Endocrine function of pituitary
  - Emotional and sexual behaviour
  - Feeding and drinking behaviour
  - Affective processes
  - Sleep and wake cycle

Anterior-posterior levels of hypothalamus

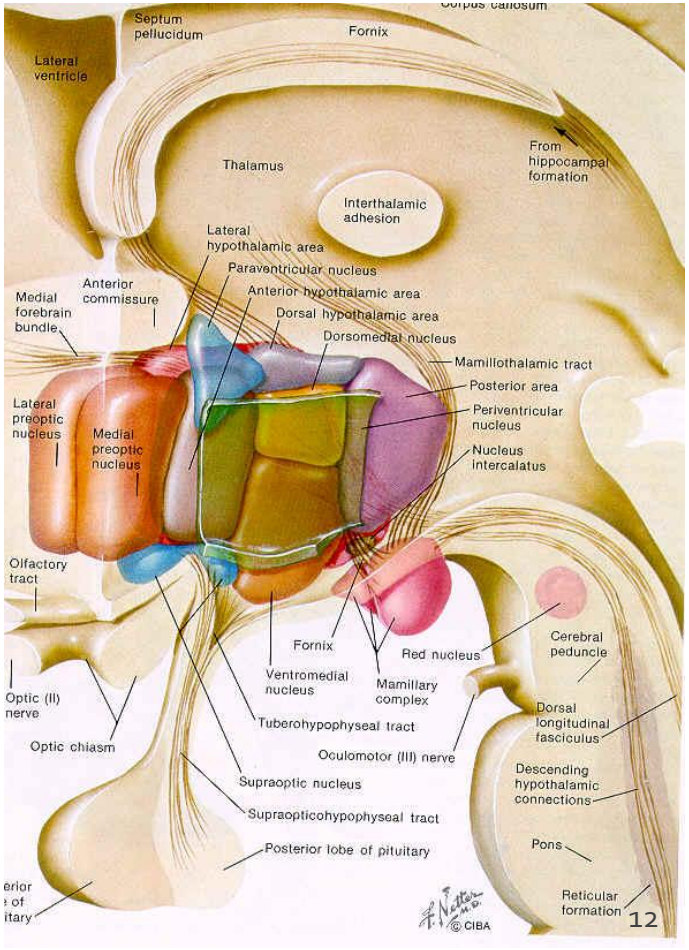
- Anterior (supraoptic) + preoptic area
- Mid-level (tuberoinfundibulary) area
- Posterior (mammillary) area



Hypothalamus: Anterior + preoptic area

- ***Suprachiasmatic*** (retinal inputs for diurnal rhythms and hormone release)
- ***Preoptic nuclei*** (lat. and med. – endocrine and temperature regulations)
- ***Supraoptic***
- ***Paraventricular***

} Vazopressin
Oxytocin

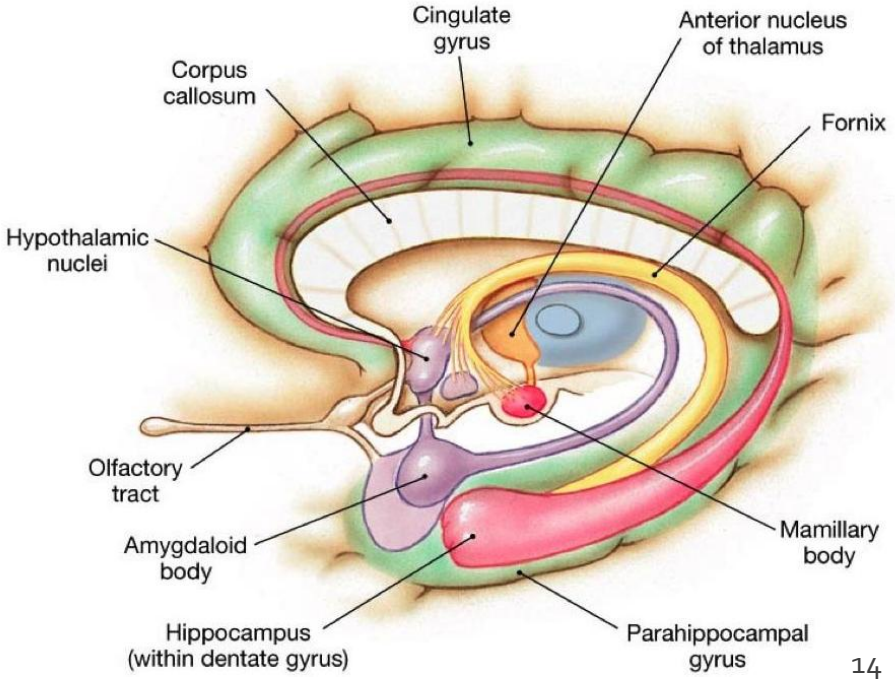


Hypothalamus: Mid-level area

- ***Nucl. infundibularis (arcuatus)*** – DA (prolactine release-inhibiting hormone)
- ***Nucl. ventromedialis*** (rage behaviour, inhibition of feeding, endocrine control)
- ***Nucl. dorsomedialis***
- ***Tuberal nuclei*** (regulatory hormones for pituitary)

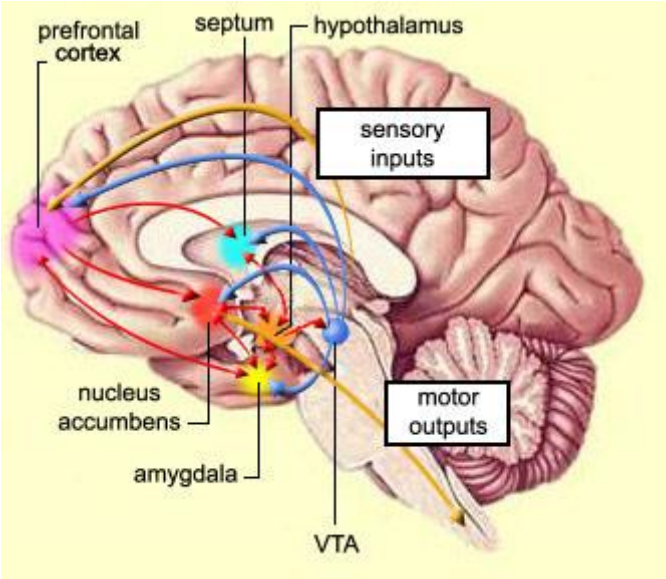
Hypothalamus: Posterior area

- Mammillary bodies
  - Inputs from fornix
  - Mammillothalamic tract (to anterior thalamic nucleus)
  - Papez circuit

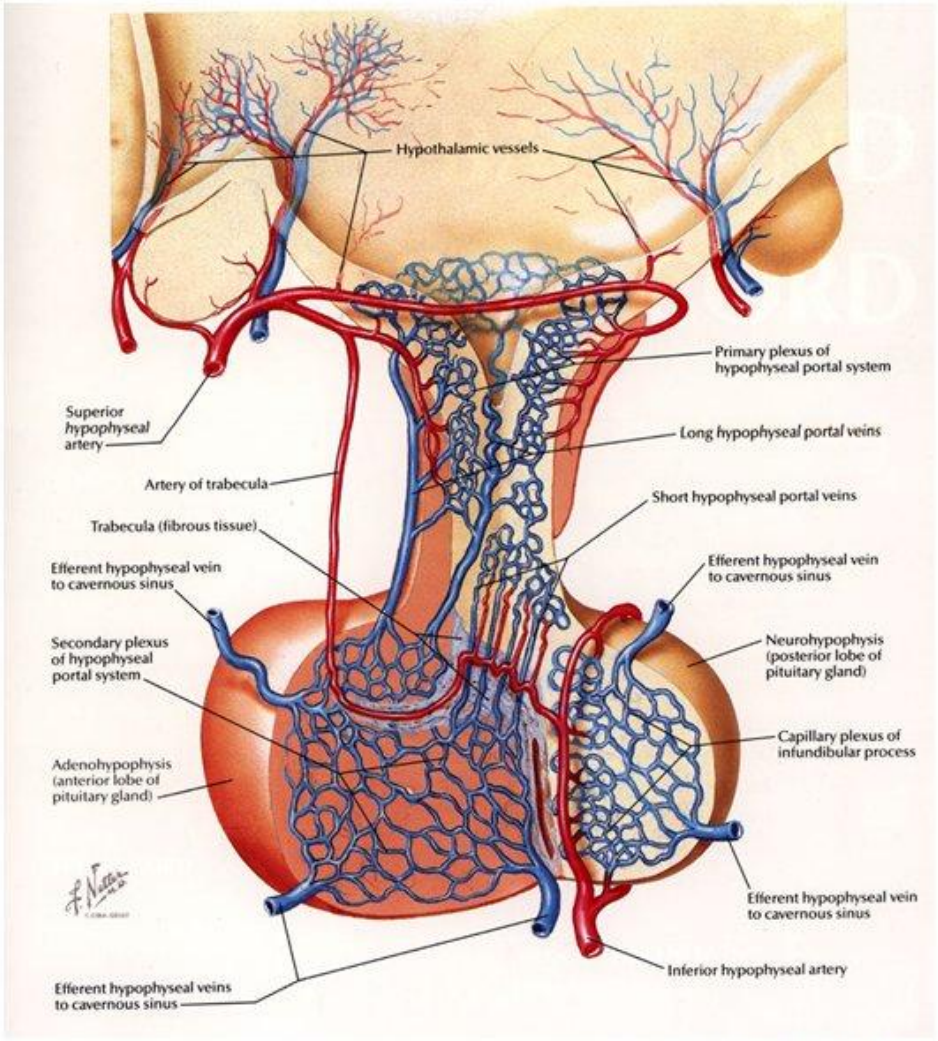


Functional hypothalamic regions

- **Medial (periventricular)** – releasing hormones for pituitary, modulation of feeding, generation of affective processes, control of autonomic functions
- **Lateral** – ***fasciculus medialis telecephali*** *(medial forebrain bundle,* ***MFB****), behavioral processes (drinking, predation)*



Hypophyseal Vessels



From F. Netter Atlas of Human anatomy. Ciba Geigy 1989

Afferent hypothalamic connections

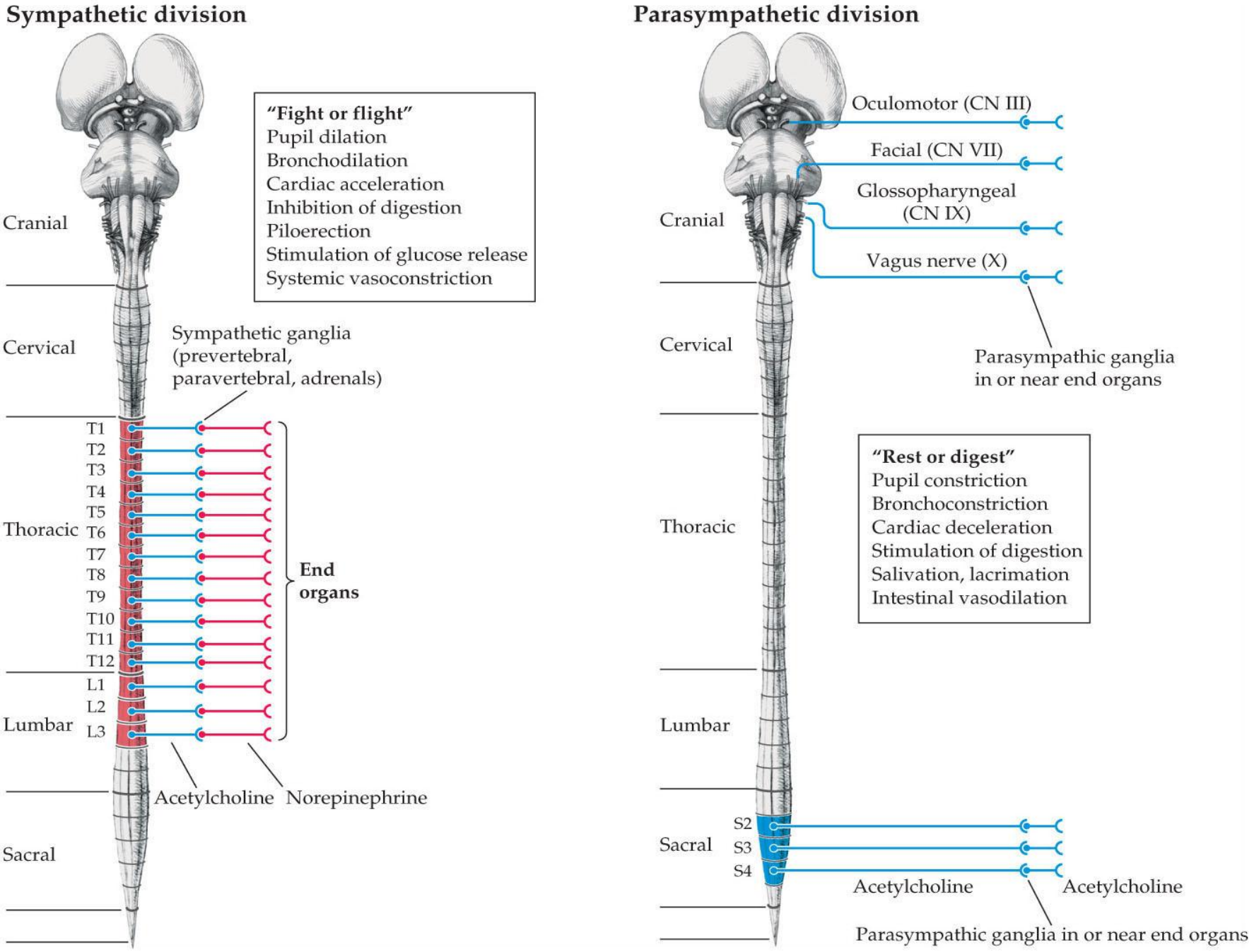
- Brainstem tegmentum (nuclei raphe, LC, RF, mesencephalic PAG) → MFB (fasciculus telecephalicus medialis)
- Limbic structures
- Retina (regulation of the circadian rhythm)
- Frontal and orbitofrontal cortex

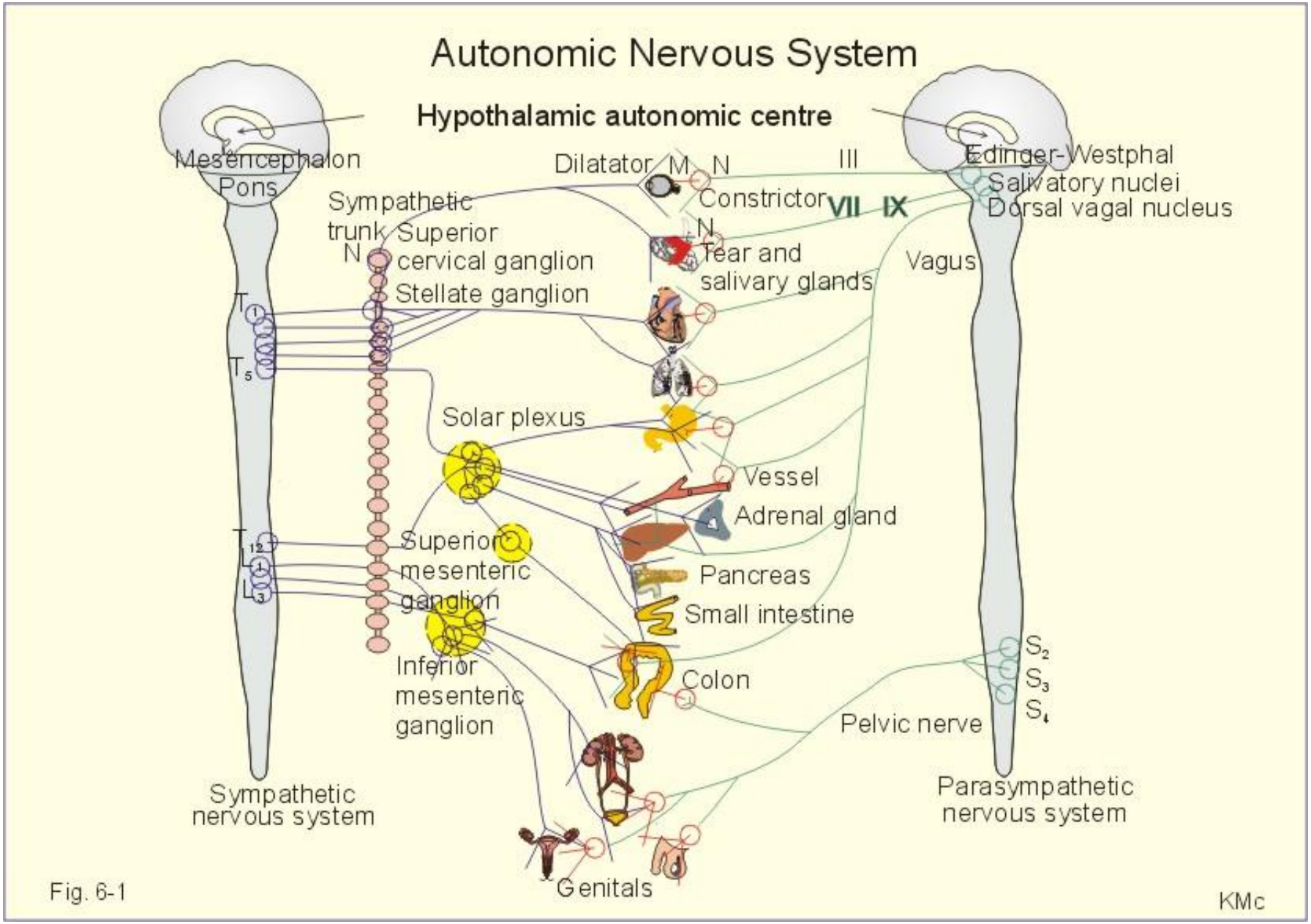
Efferent hypothalamic conections

- Axons of the neuroendocrine cells:
  1. Hypothalamic infundibulary system – anterior pituitary (portal vascular system)
  2. Neurohypophyseal system – posterior pituitary (ADH and oxytocin)
- Hypothalamo-cortical fibers
- MFB
- Hypothalamo-thalamic fibers

TABLE 9-2 Functions of the Hypothalamus

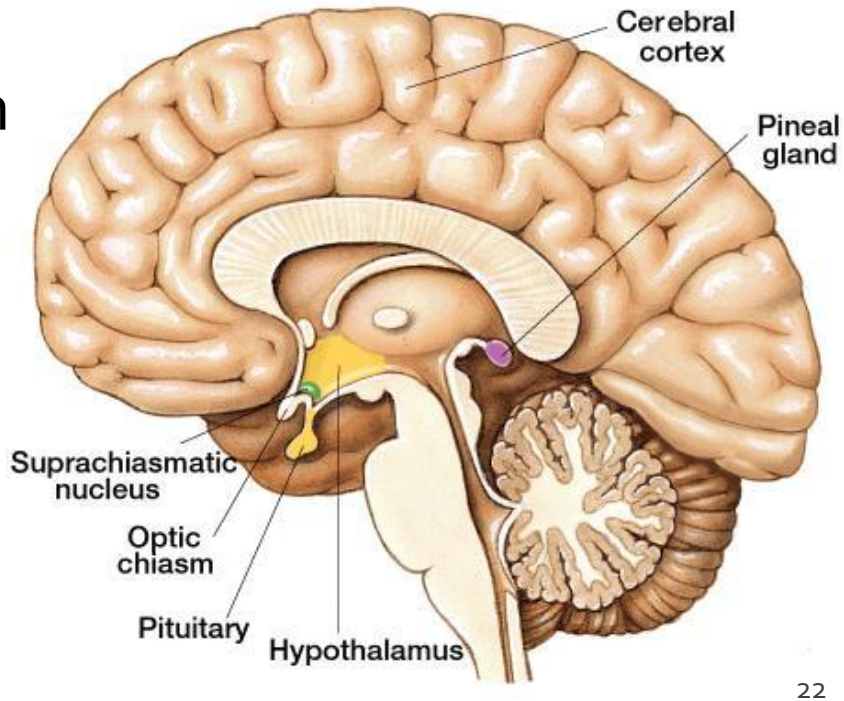
1. Activates sympathetic nervous system
   - Controls catecholamine release from adrenal medulla (as in fight-or-flight reaction)
   - Helps maintain blood glucose concentrations through effects on endocrine pancreas
2. Maintains body temperature
   - Stimulates shivering and sweating
3. Controls body osmolarity
   - Motivates thirst and drinking behavior
   - Stimulates secretion of vasopressin [p.226]
4. Controls reproductive functions
   - Directs secretion of oxytocin (for uterine contractions and milk release)
   - Directs trophic hormone control of anterior pituitary hormones FSH and LH [p.227]
5. Controls food intake
   - Stimulates satiety center
   - Stimulates feeding center
6. Interacts with limbic system to influence behavior and emotions
7. Influences cardiovascular control center in medulla oblongata
8. Secretes trophic hormones that control release of hormones from anterior pituitary gland

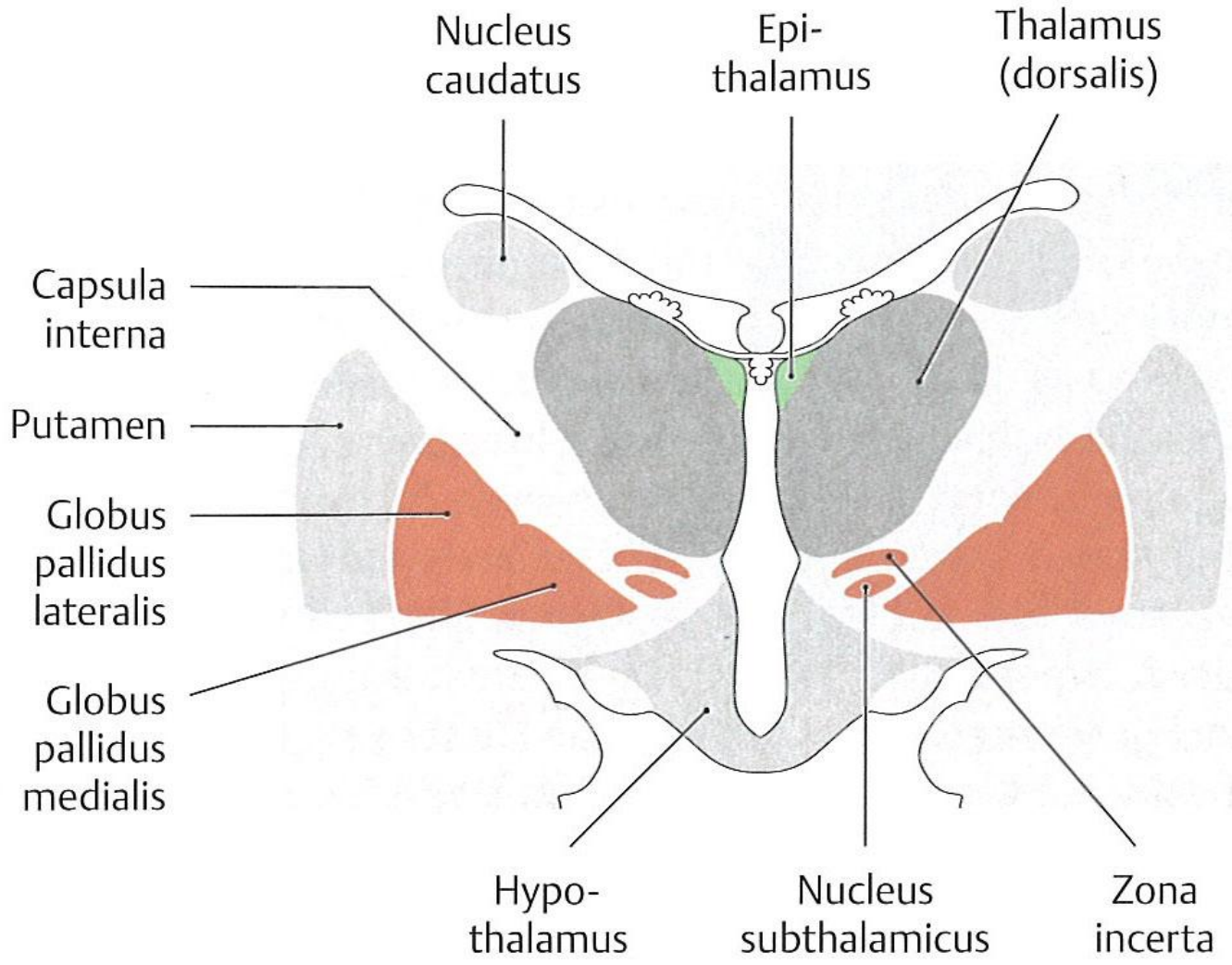

Sympathetic division
"Fight or flight"
Pupil dilation
Bronchodilation
Cardiac acceleration
Inhibition of digestion
Piloerection
Stimulation of glucose release
Systemic vasoconstriction
Cranial
Cervical
Sympathetic ganglia (prevertebral, paravertebral, adrenals)
T1
T2
T3
T4
T5
Thoracic
T6
T7
T8
T9
T10
T11
T12
End organs
L1
L2
Lumbar
L3
Acetylcholine
Norepinephrine
Sacral
Parasympathetic division
Oculomotor (CN III)
Facial (CN VII)
Glossopharyngeal (CN IX)
Vagus nerve (X)
Cranial
Cervical
Parasympathic ganglia in or near end organs
"Rest or digest"
Pupil constriction
Bronchoconstriction
Cardiac deceleration
Stimulation of digestion
Salivation, lacrimation
Intestinal vasodilation
Thoracic
Lumbar
S2
Sacral
S3
S4
Acetylcholine
Acetylcholine
Parasympathic ganglia in or near end organs


Autonomic Nervous System
Hypothalamic autonomic centre
Mesencephalon
Pons
Dilatator M N
Constrictor
N
Tear and
salivary glands
III
VII IX
Edinger-Westphal
Salivatory nuclei
Dorsal vagal nucleus
Vagus
Sympathetic
trunk Superior
N cervical ganglion
Stellate ganglion
T1
T5
Solar plexus
Vessel
Adrenal gland
T12
L1
L3
Superior
mesenteric
ganglion
Pancreas
Small intestine
Inferior
mesenteric
ganglion
Colon
S2
S3
S4
Pelvic nerve
Sympathetic
nervous system
Parasympathetic
nervous system
Genitals
Fig. 6-1
KMc

Epithalamus

- Smallest part of the diencephalon
  - Corpus pineale (epiphysis cerebri) – pineal gland
  - Habenular complex:
    - Commissura habenularum
    - Habenulae
  - Stria medullaris




Nucleus caudatus
Epi-thalamus
Thalamus (dorsalis)
Capsula interna
Putamen
Globus pallidus lateralis
Globus pallidus medialis
Hypo-thalamus
Nucleus subthalamicus
Zona incerta

Habenular complex

- Habenulopeduncular tract (fasciculus retroflexus)- unknown function
- Stria medullaris – afferent and efferent habenular fibers

Possible relay by which limbic system and hypothalamus influence midbrain structures

Pineal gland

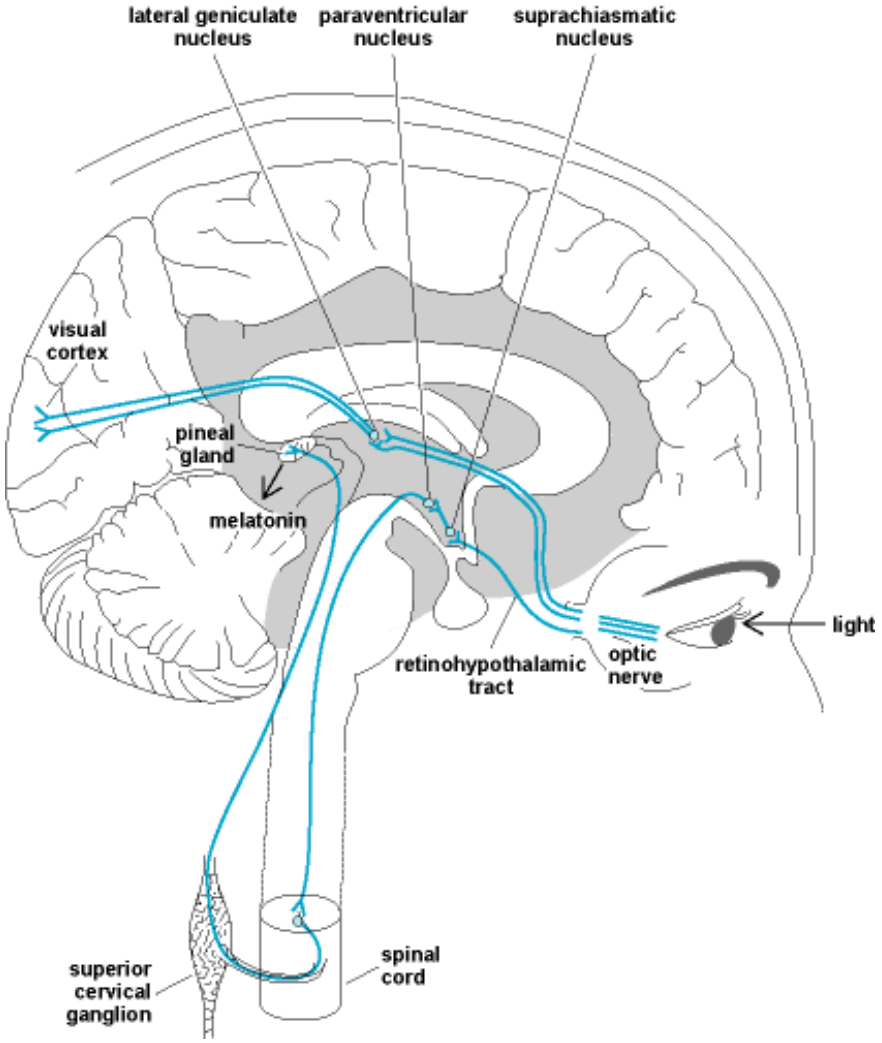
- No direct connections with CNS
- Inputs from sympathetic NS via superior cervical ganglia
  - Pinealocytes – melatonin, serotonin, norepinephrine, hypothalamic-releasing hormones (during childhood)

Pineal gland

- Circadian rhythm

(retina - suprachiasmatic nucl - thoracic cord - sup.cervical ganglia)

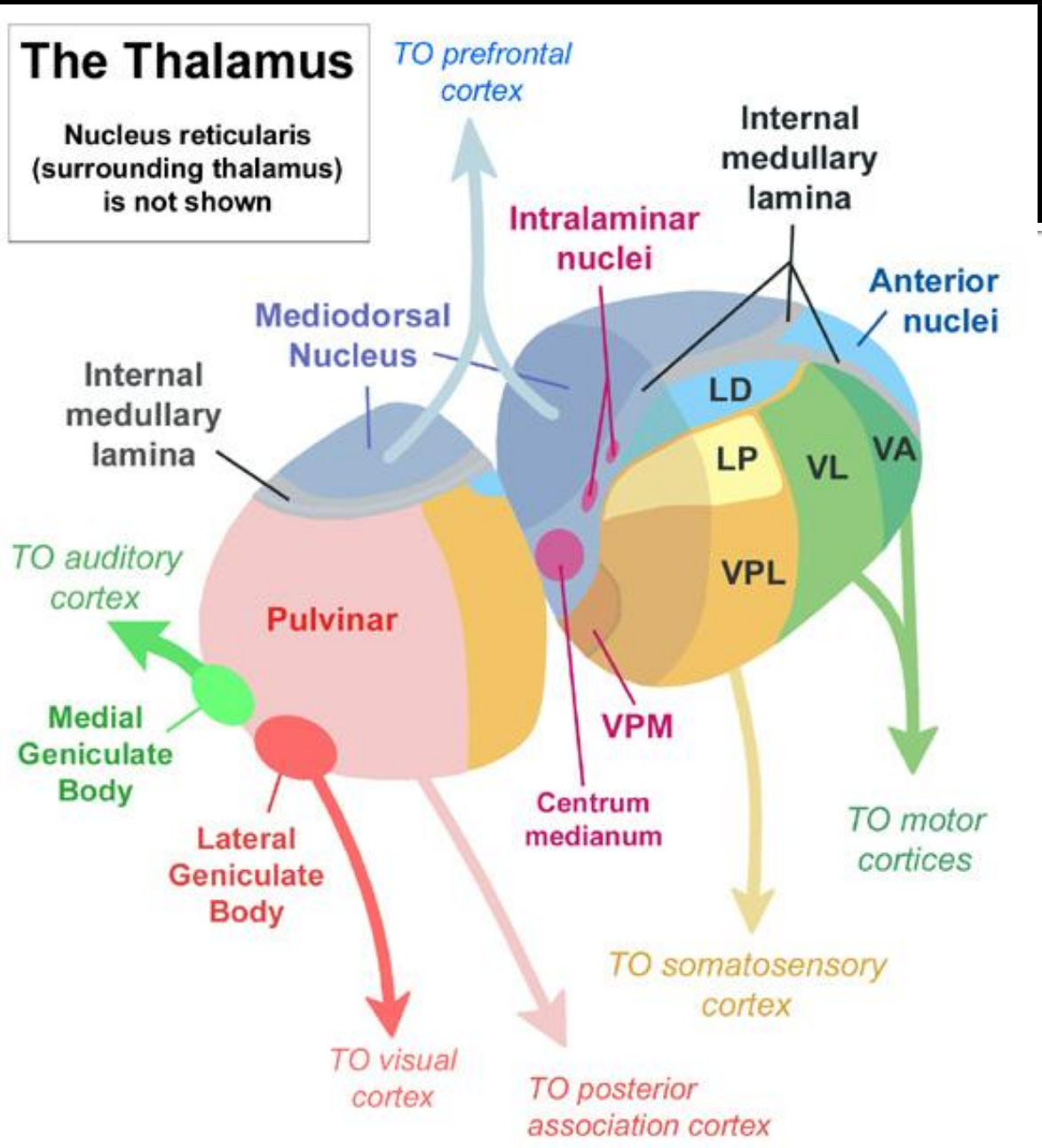
- Melatonin secretion



Thalamus

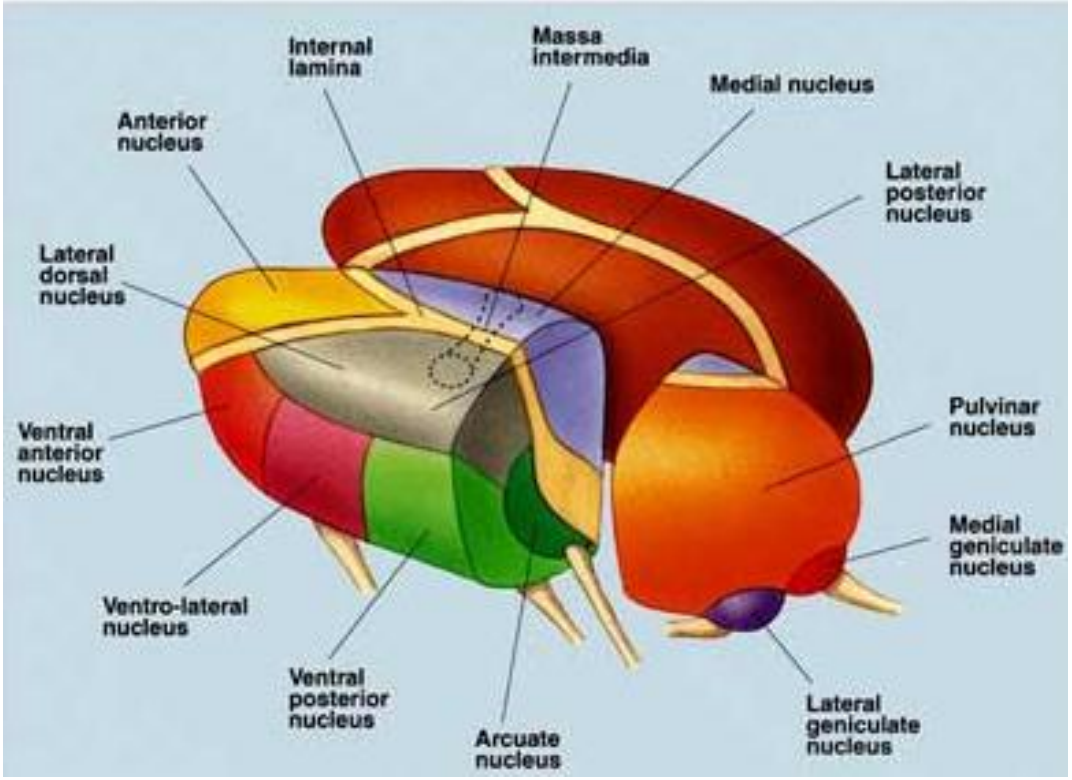
- Oval shaped
- Largest component of the diencephalon
- Relay

(CNS to cortex)



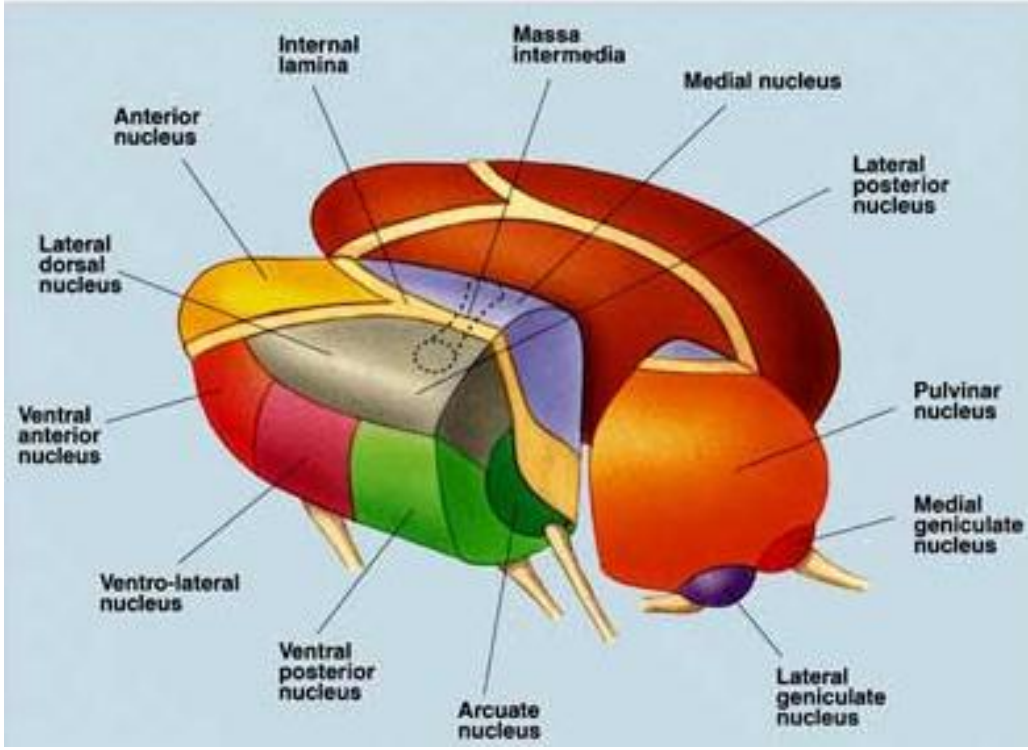
Thalamus

- Lateral
- Rostral
- Dorsomedial region



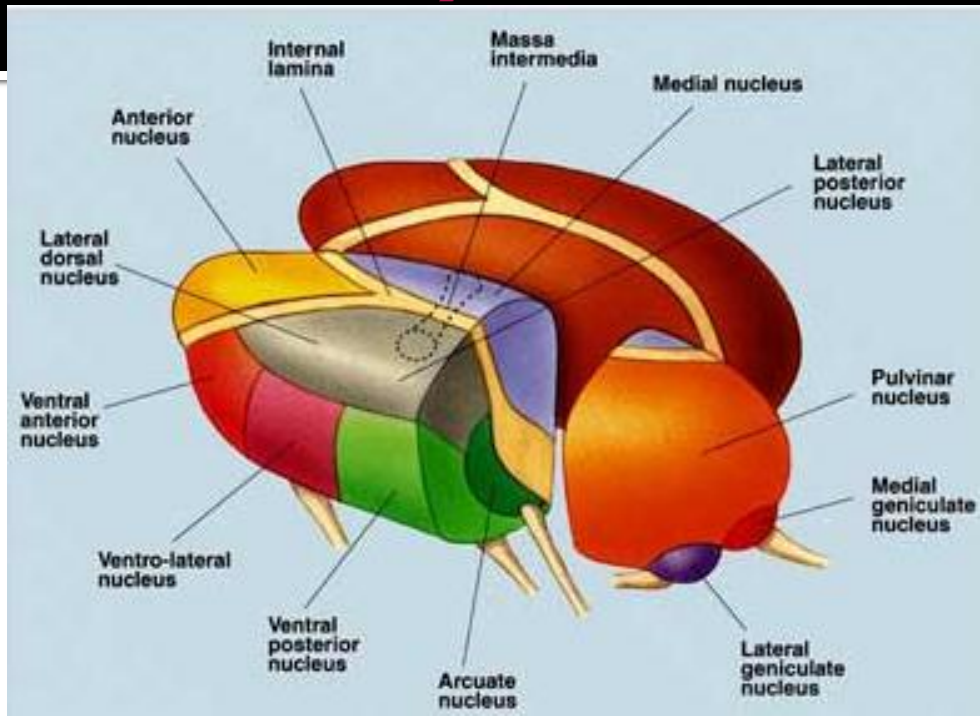
Thalamic territories

- Ventral
- Lateropost. + pulvinar
- Rostral
- Dorsomedial
- Reticular
- Intralaminar



Ventral thalamic territory

- Motor and somatosensory relays

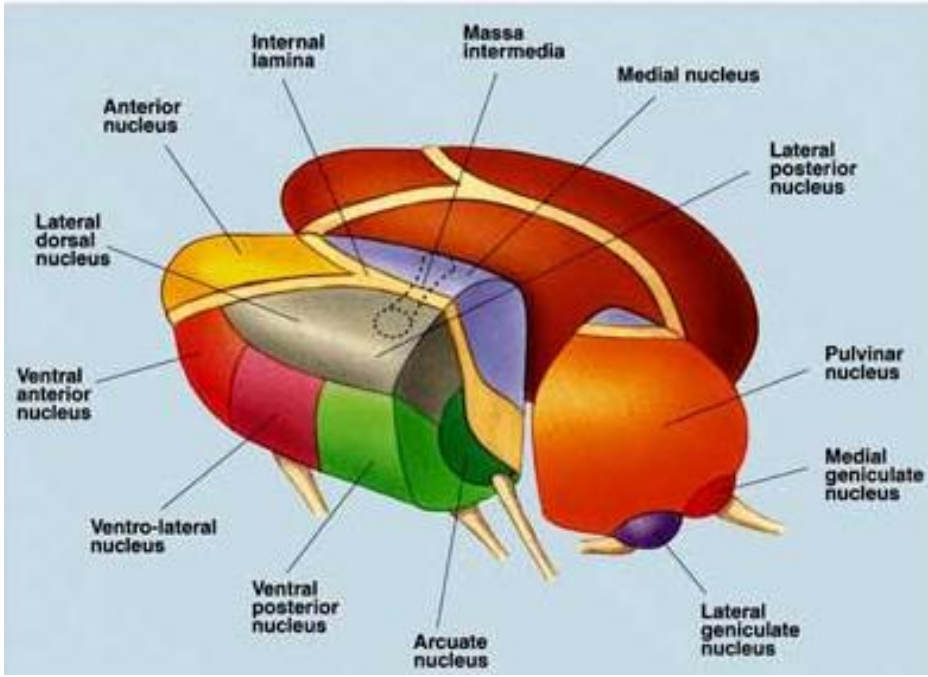


- 2 motor nuclei (ventral anterior and ventral lateral nucl.)
- 2 somatosensory nuclei (ventral posterior lateral (VPL) and ventral posterior medial (VPM) nuclei) – ventral basal complex

Lateroposterior territory and pulvinar

- Lateral dorsal nucl. – unknown function
- Pulvinar nucleus – cognitive functions (auditory and visual stimuli)

- Connections with parietal cortex
- NO afferent subcortical projections!

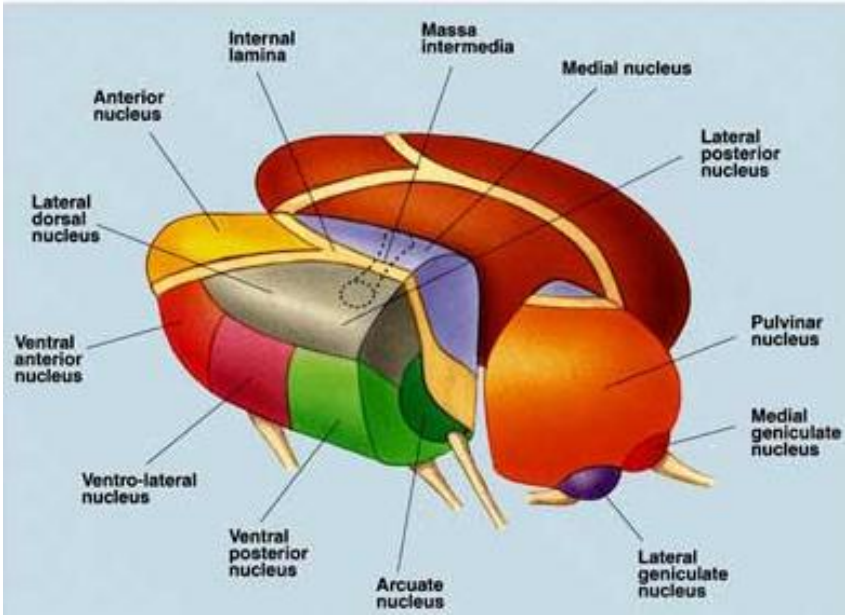


Rostral territory

- Anterior nucleus of the thalamus
- Connections with hippocampal formation, cingulate gyrus, mammillary bodies (mammillothalamic bundle)
- Memory function

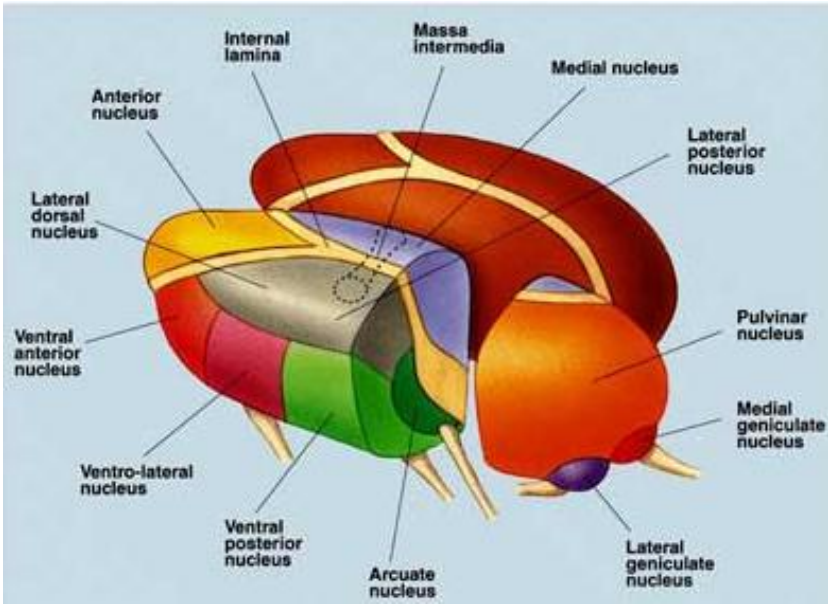
Injury:

- *Disorders of autonomic functions*
- *Korsakoff's syndrome*



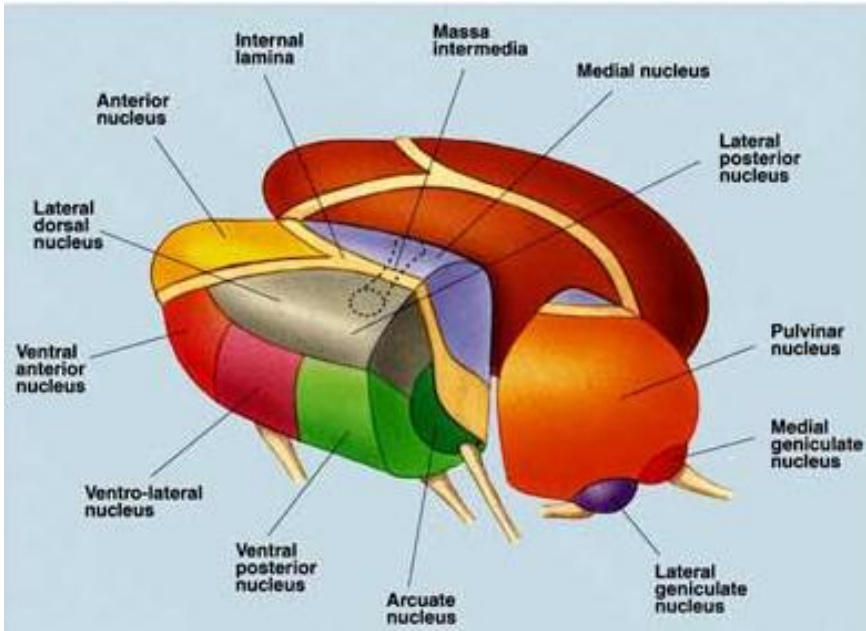
Dorsomedial territory

- Connections with limbic, frontal and prefrontal cortex
- Aferent inputs from sup. colliculus, SN, mesencephalic tegmentum, vestibul. nuclei
- Mediation of affective processes and emotional behavior
- Massive in humans



Reticular territory

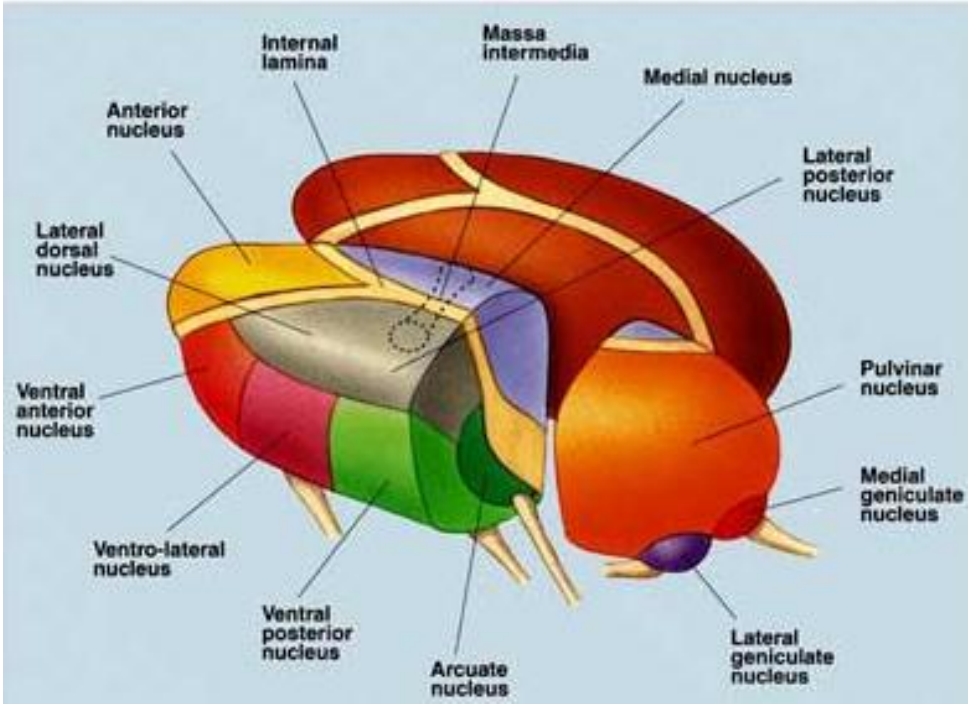
- Nonspecific thalamic nuclei
- Subcortical connections
- Rostral extension of RF and zona incerta
- **GABA**; inhibitory system of negative feedback for other thalamic nuclei
- Sleep and wake cycles

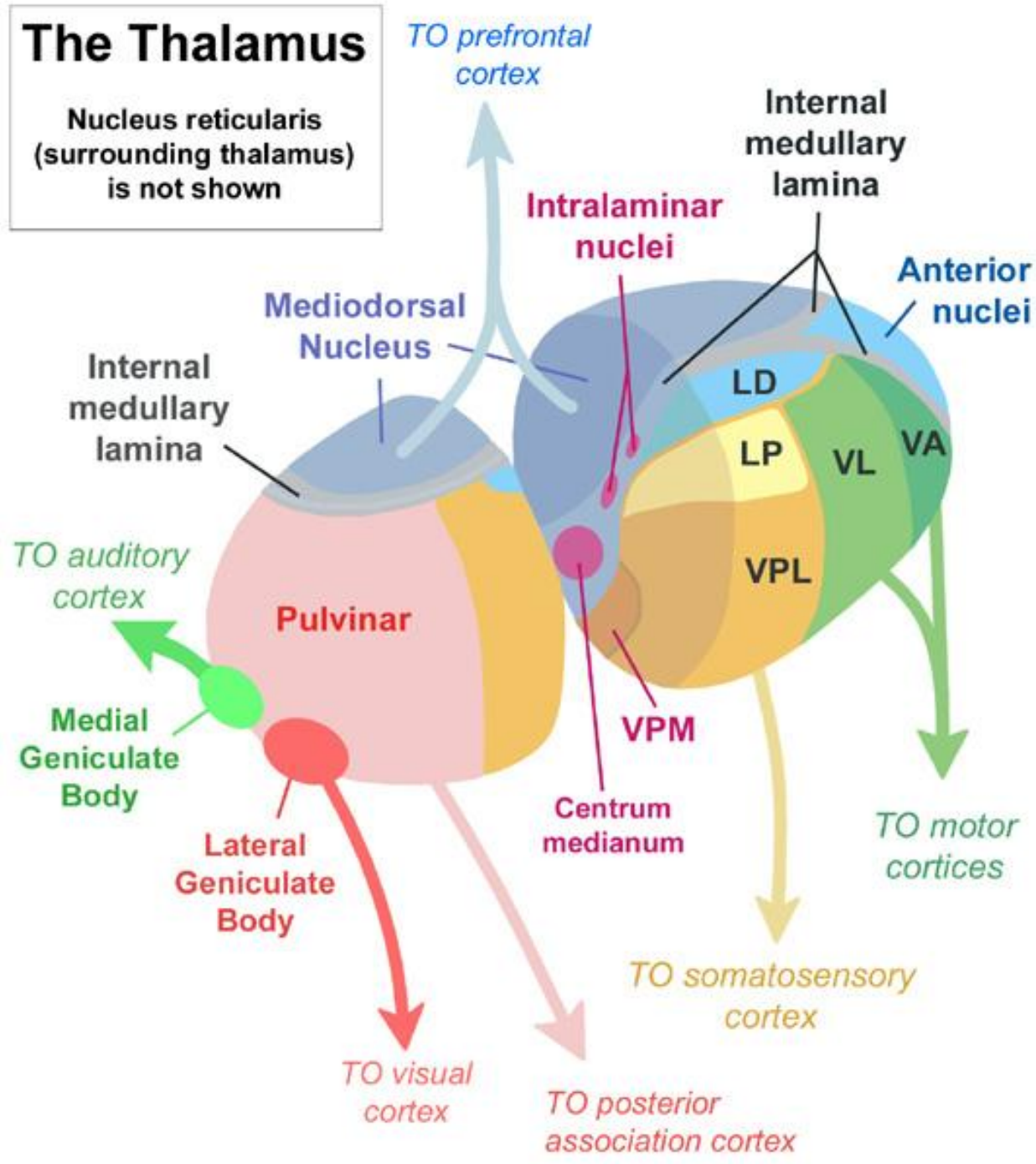


Intralaminar territory

- Subcortical connections
- Nonspecific cortical activation (connecting RF and other thalamic nuclei)

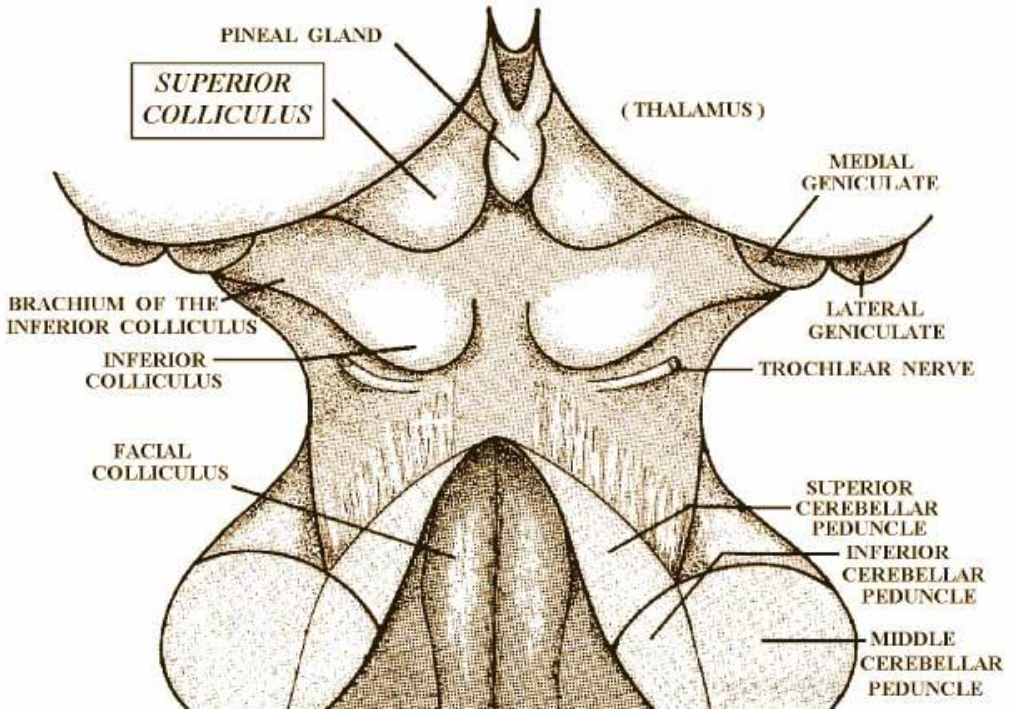
- Modulation of cortical activity during sleep, wake, focused attention, learning, pain perception…



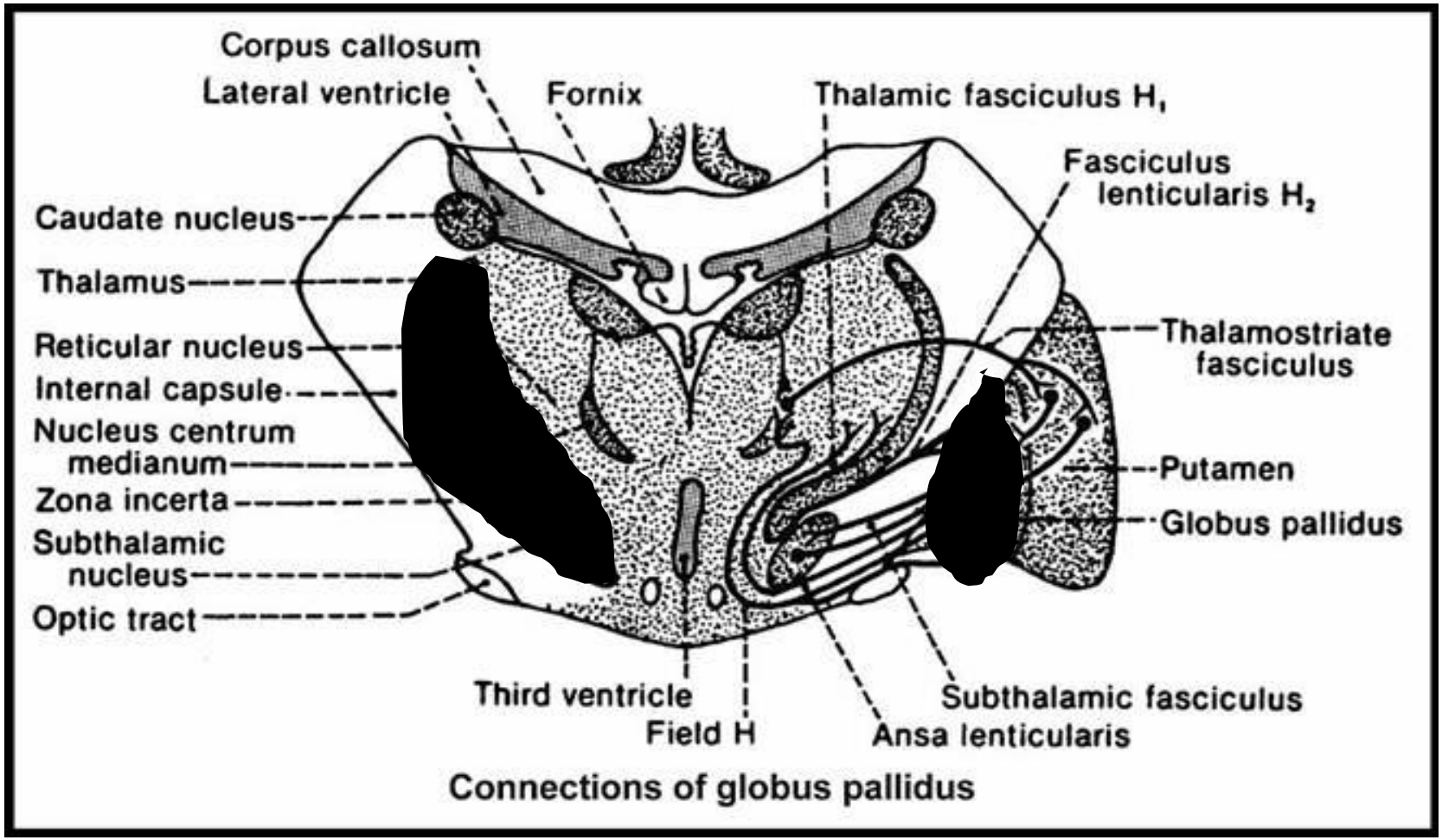

The Thalamus
Nucleus reticularis (surrounding thalamus) is not shown
TO prefrontal cortex
Internal medullary lamina
Intralaminar nuclei
Anterior nuclei
Mediodorsal Nucleus
Internal medullary lamina
LD
LP
VL
VA
VPL
TO auditory cortex
Pulvinar
Medial Geniculate Body
VPM
Centrum medianum
TO motor cortices
Lateral Geniculate Body
TO somatosensory cortex
TO visual cortex
TO posterior association cortex

Metathalamus

- ***Corpus geniculatum laterale*** – relay of visual impulses to the visual cortex from retina
- ***Corpus geniculatum mediale*** – relay for auditory system



Subthalamus

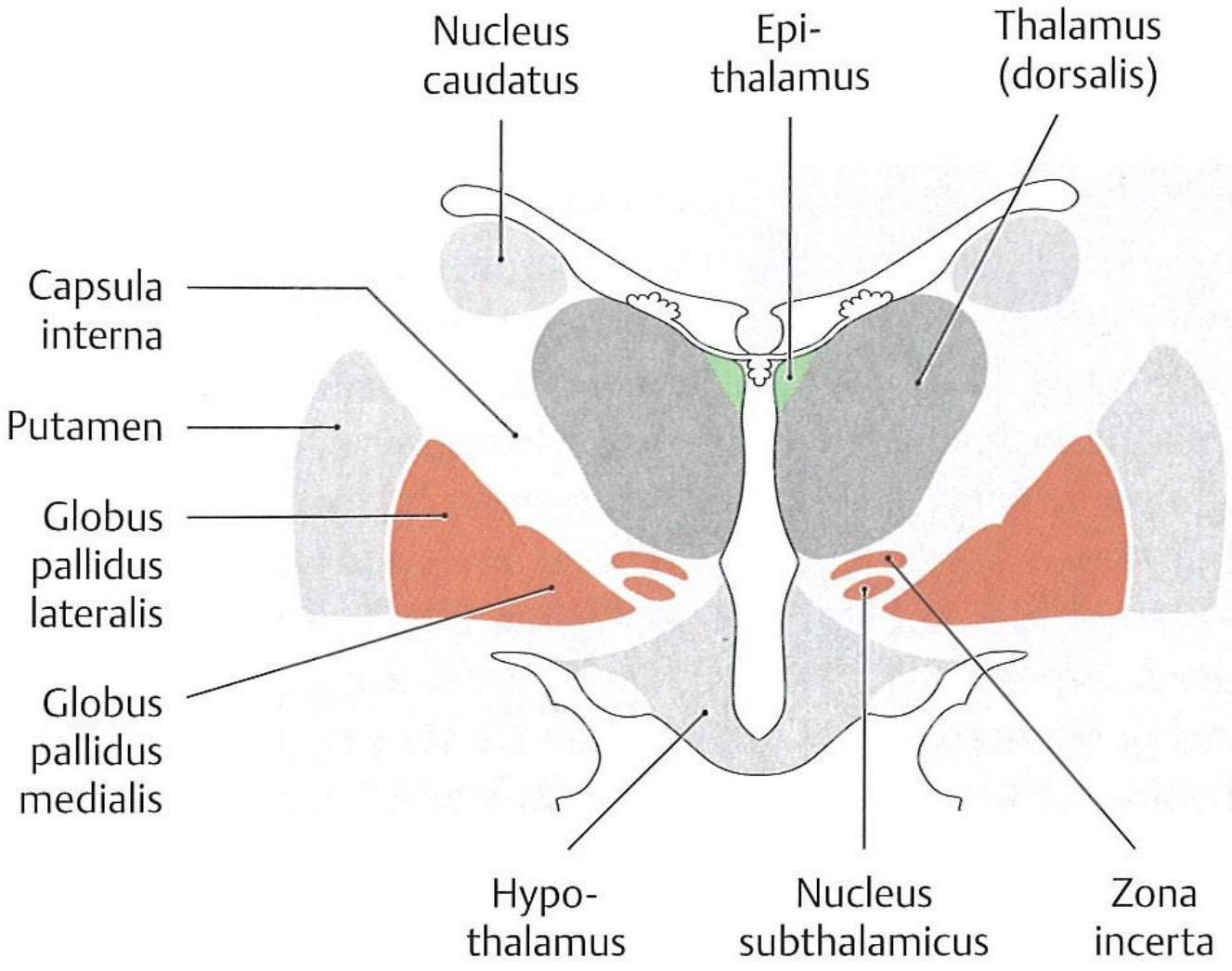


Connections of globus pallidus

Subthalamus

- Zona incerta (DA, tractus incerto-hypothalamicus)
- Nucl. subthalamicus (corpus subthalamicum Luysi) – reciprocal connections with the globus palidus – motor functions!

- Motor functions associated with the basal ganglia


Nucleus caudatus
Epi-thalamus
Thalamus (dorsalis)
Capsula interna
Putamen
Globus pallidus lateralis
Globus pallidus medialis
Hypo-thalamus
Nucleus subthalamicus
Zona incerta

Subthalamic fibers

- Ansa lenticularis
- Fasciculus lenticularis
- Fasciculus thalamicus

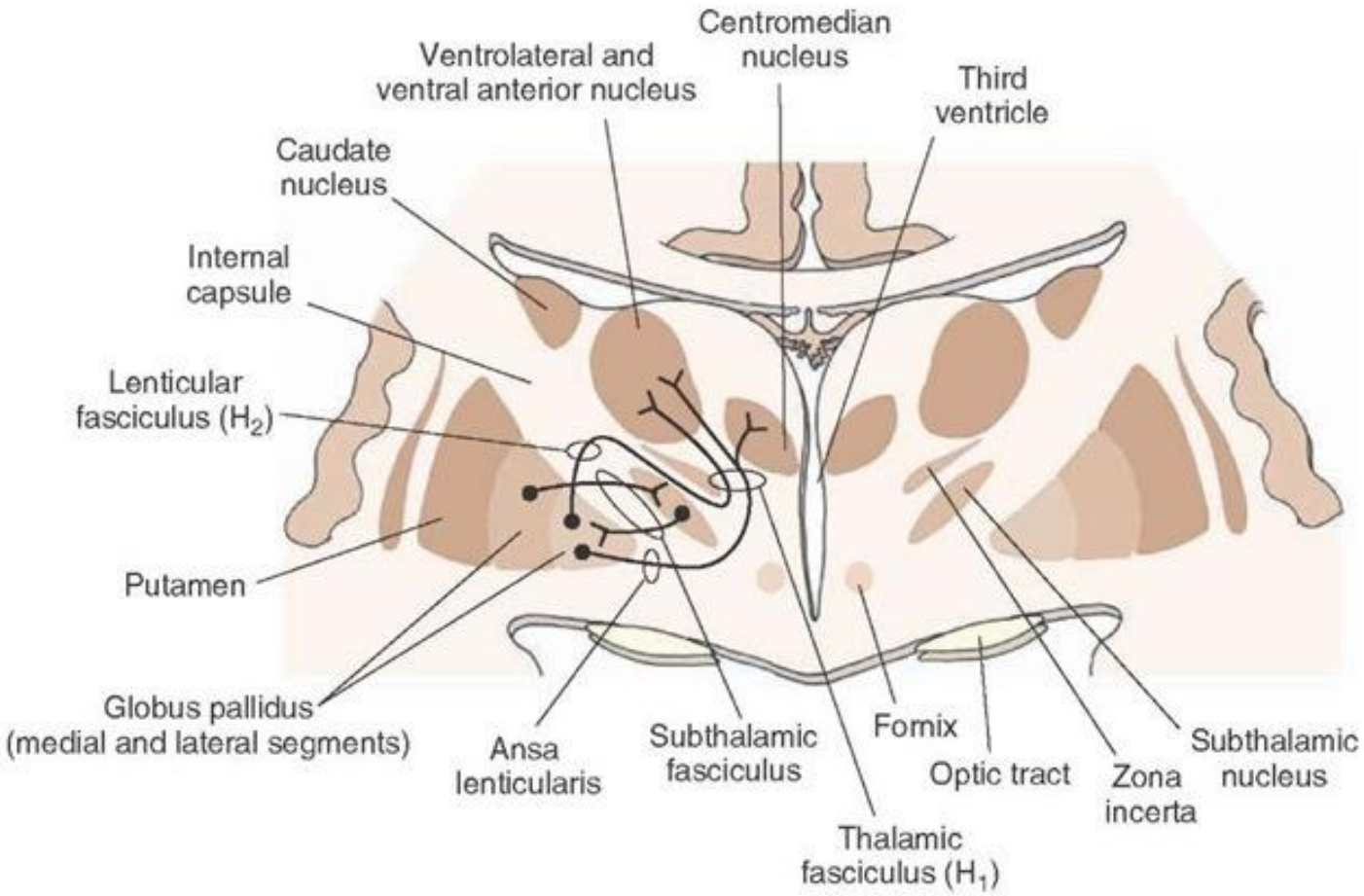
Basal ganglia outputs

- FLM
- Spinothalamic and trigeminothalamic fibers
  - ***"thalamic gatekeeper"***
- Nigrostriatal dopaminergic fibers
- Strionigral GABA-ergic fibers

Subthalamic fibers

- **Ansa lenticularis** – from medial segment of GP, ventromedial direction and caudally toward midbrain
- **Fasciculus lenticularis** – from pallidum, dorsomedial direction, around the dorsal surface of nucl. subth. and curve around the dorsal aspect of zona incerta, dorsolateral direction caudally toward midbrain

Subthalamic fibers - pathways of the basal ganglia



Subthalamic fibers - pathways of the basal ganglia

- Rostral to the red nucl. reverse course, rostral direction = **H field of Forel (pre-rubral field)**
- Joined by *dentatothalamic fibers* = **fasciculus thalamicus** (H1 field of Forel)
- Terminate in ventrolateral and ventral anterior thalamic nucl.
  - H2 field of Forel = fasciculus lenticularis

Diencephalon – quiz

List the 8 nuclei of the Medial Hypothalamic Zone (anterior to posterior)

- PreOptic
- Anterior
- SupraChiasmatic
- ParaVentricular
- DorsoMedial
- DorsoLater
- Infundibular
- Posterior

List the 6 nuclei of the Lateral Hypothalamic Zone

- PreOptic
- SupraChiasmatic
- SupraOptic
- Lateral
- TuberoMamillary
- Lateral Tuberal

- Visceral & Somatic afferents reach the hypothalamus through collateral branches from the ____ & from the ____

- LEMINSCI AFFERENT FIBERS
- RETICULAR FORMATION

- Olfaction travels to the hypothalamus through the ____
- MEDIAL FOREBRAIN BUNDLES

- Corticohypothalamic fibers arise from the ___ of the cerebral cortex and pass directly to the hypothalamus.

- FRONTAL LOBE

- Amygdalohypothalamic fibers pass through the amygdaloid complex to the hypothalamus through the ___ and by a route that passes inferior to the ___

- STRIA TERMINALIS
- LENTIFORM NUCLEUS

- Thalamohypothalmic fibers arise from the ___ and ___ nuclei

- DORSOMEDIAL
- MIDLINE THALAMIC

Where do tegmental fibers arise from?

- TEGMENTAL fibers to the hypothalamus arise from the midbrain

- Mammillothalmic tract arises in the mammilary body and efferent fibers terminate in the ___ of the thalamus. Here the pathway is relayed to the ___

- ANTERIOR NUCLEUS
- CINGULATE GYRUS

- The Mammilotegmental tract arises from the mamillary body and efferent fibers terminate in the cells of the ___ in the tegmentum of the ___

- RETICULAR FORMATION
- MIDBRAIN

Hypothalmophypophyseal Tract

- Which nuclei synthesize Vasopressin and Oxytocin?
- The hormones are carried along the axon together with a carrier protein ___ and release at the axon terminals, where it can be absorbed into the blood from Neurohypophysis

- SupraOptic nuclei synthesizes Vasopressin & ParaVentricular synthesizes Oxytocin
- NEUROPHYSINS

Which hypothalamic nucleus acts as an Osmoreceptor?

- Supraoptic nucleus is an osmoreceptor because it detects high osmotic pressure and increases output of Vasopressin which is an antidiuretic hormone that also causes vasoconstriction.

What is the role of the hypothalamus in autonomic system?

- Its the upper nervous center for the control of lower autonomic centers.

- In the hypothalamus, the ___ region is referred to as the hunger center.
- However stimulation of the __ region inhibits eating and is therefore called the satiety center.

- LATERAL
- MEDIAL

Which nuclei of the hypothalamus responds to cold temp?

- Posterior hypothalamic nuclei respond to cold temperature

Which nuclei of the hypothalamus causes thirst?

- Lateral hypothalamus increases water intake

Which nuclei of the hypothalamus inhibits appetite?

- Medial hypothalamus is the satiety center

Which nuclei of the hypothalamus controls circadian rhythms?

- Suprachiasmatic nucleus controls circadian rhythms.

Which nuclei of the hypothalamus controls the parasympathetic nervous system?

- Preoptic & Anterior nuclei control the parasympathetic system

Which nuclei of the hypothalamus controls the sympathetic nervous system?

- Preoptic & Lateral nuclei control the sympathetic nervous system

Which nuclei of the hypothalamus responds to hot temp?

- Anterior hypothalamus responds to heat

- The roof of the third ventricle, which is also the superior surface of the Diencephalon is the ___ . It is covered superiorly by a vascular fold of ___.

- TELA CHOROIDEA
- PIA MATTER

- The Lateral surface of the diencephalon is bounded by the ___ which is composed of white matter and consists of nerve fibers that connect the cerebral cortex with ___ and ___

- INTERNAL CAPSULE
- SPINAL CORD and BRAINSTEM

What does the stria medullaris thalami connect?

- The stria medullaris thalami are afferent fibers to the Habenular nucleus.

- All sensory systems except __ pass through the thalamus.
- Posteriorly the thalamus is expanded to for the ___. Inferiorly the thalamus is continuous with the ___ of the midbrain.

- OLFACTION
- PULVINAR
- TEGMENTUM

- The superior covering of the thalamus is a thin layer of white matter called the ___, and laterally a layer called the ___.
- The gray matter of the thalamus is divided by vertical sheets of white matter called the ___ .

- STRATUM ZONALE
- EXTERNAL MEDULLARY LAMINA
- INTERNAL MEDULLARY LAMINA

The Epithalamus contains

- Habenular nuclei and pineal gland.

The Habenular nucleus is a center for integration of:

- Olfactory
- Visceral
- Somatic Afferent Pathways

- The pineal gland is a small conical structure that is connected to the pineal stalk. Superiorly the base of the stalk is called the ___ and inferiorly ___.

- HABENULAR COMMISSURE
- POSTERIOR COMMISSURE

- The pineal gland contains two types of cells, the __ & __.
- Pineal gland contains NO nerve cells, but __ sympathetic fibers enter the gland and run along the blood vessels

- PINEALOCYTES & INTERSTITIAL CELLS
- ADRENERGIC

The Pineal gland affects the endocrine system by influencing the activity of:

- Pituitary
- Parathyroids
- Islets of Langerhans
- Adrenals
- Gonads

- Generally have an __ effect.
- INHIBITORY