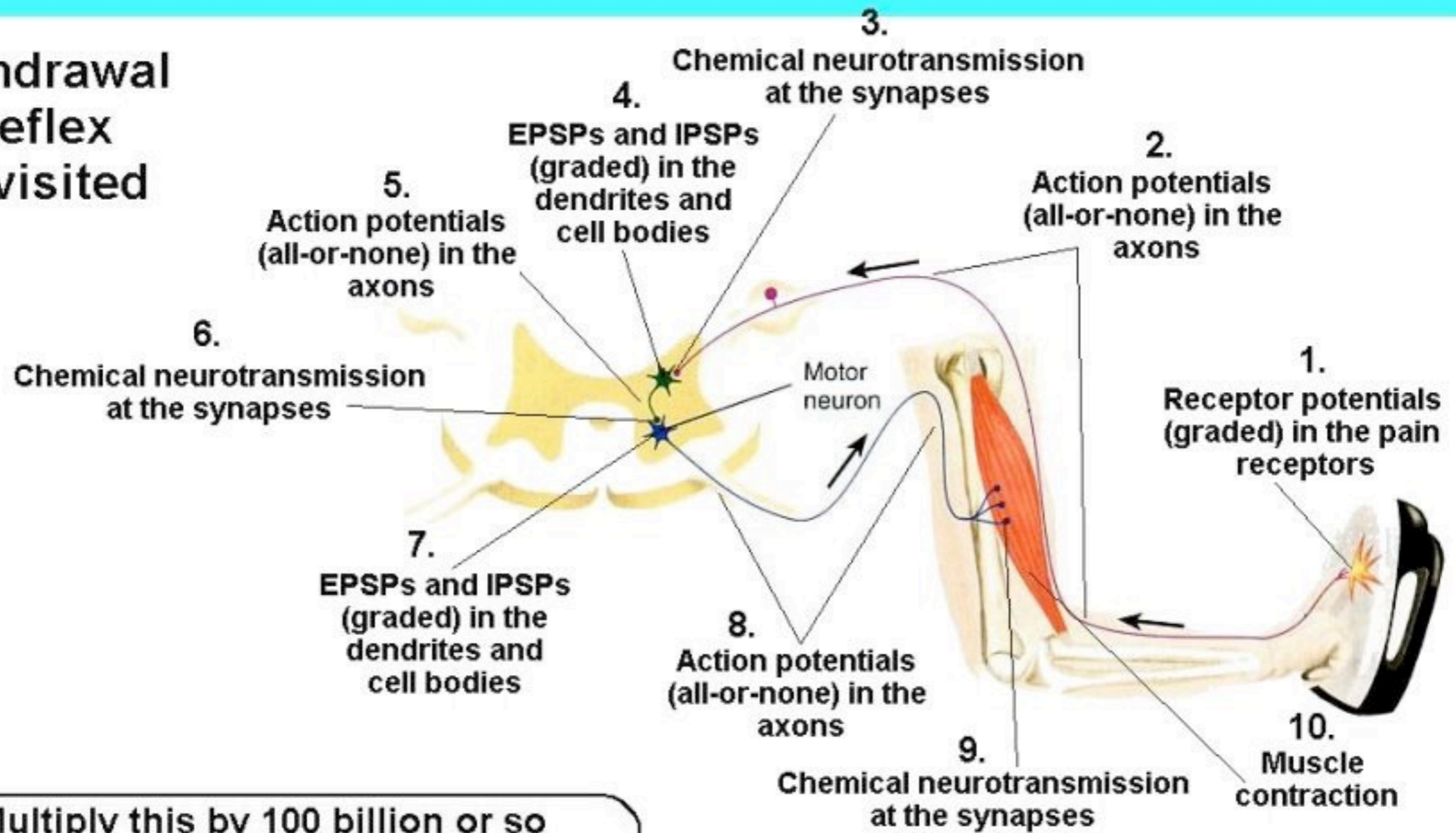


Neuroanatomy

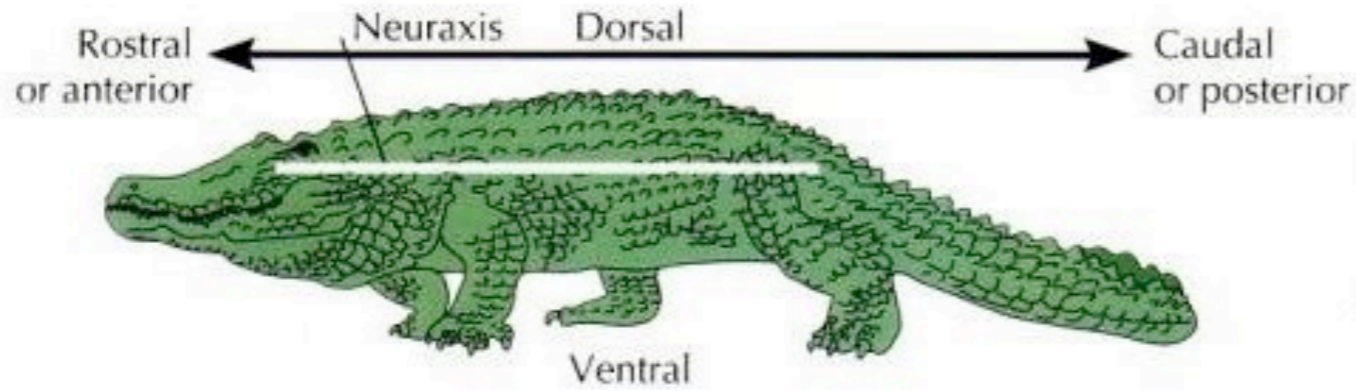


Neurons Wired Together into a Functional Network

Withdrawal Reflex Revisited



Multiply this by 100 billion or so and you have the human nervous system.

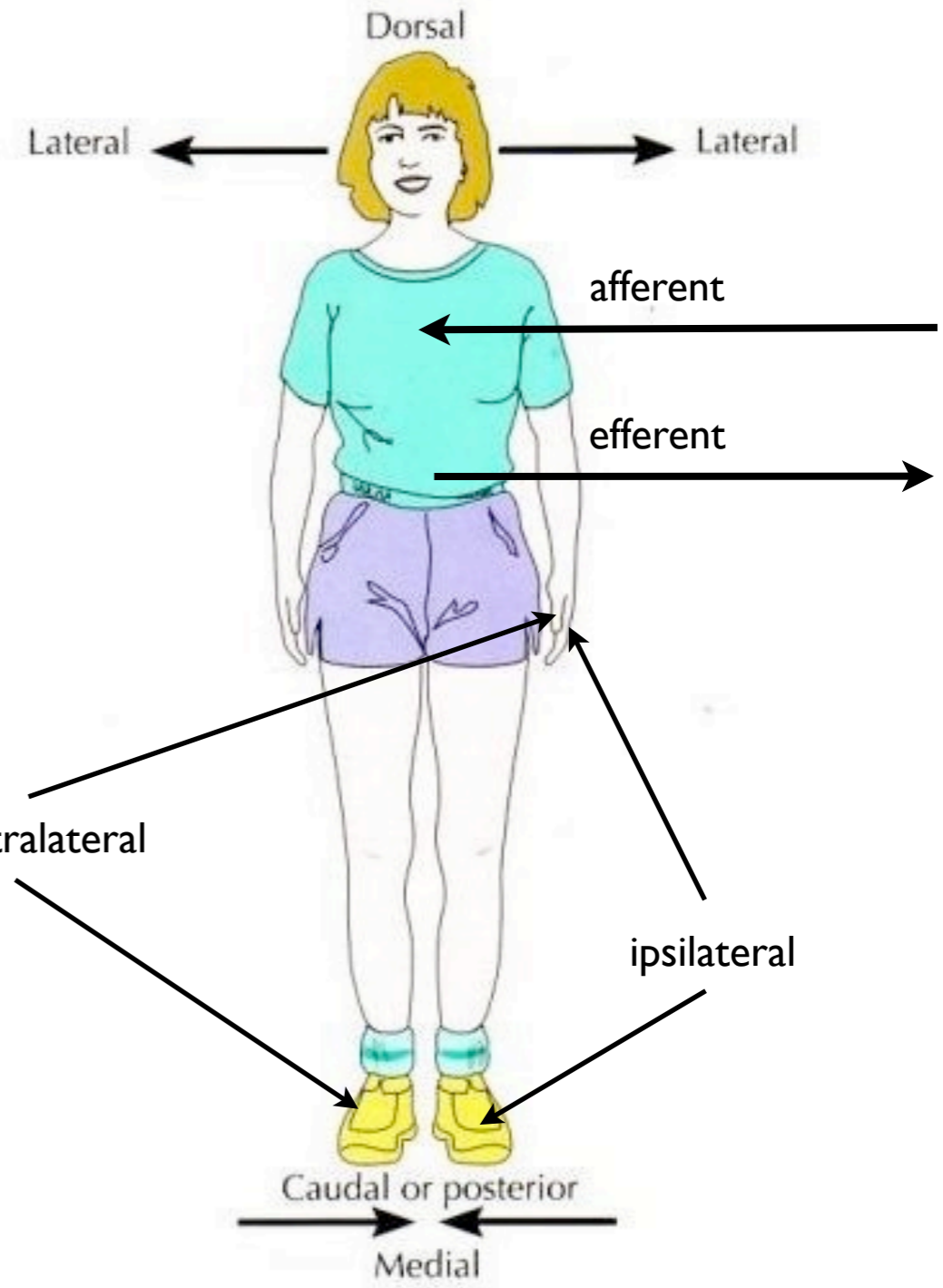
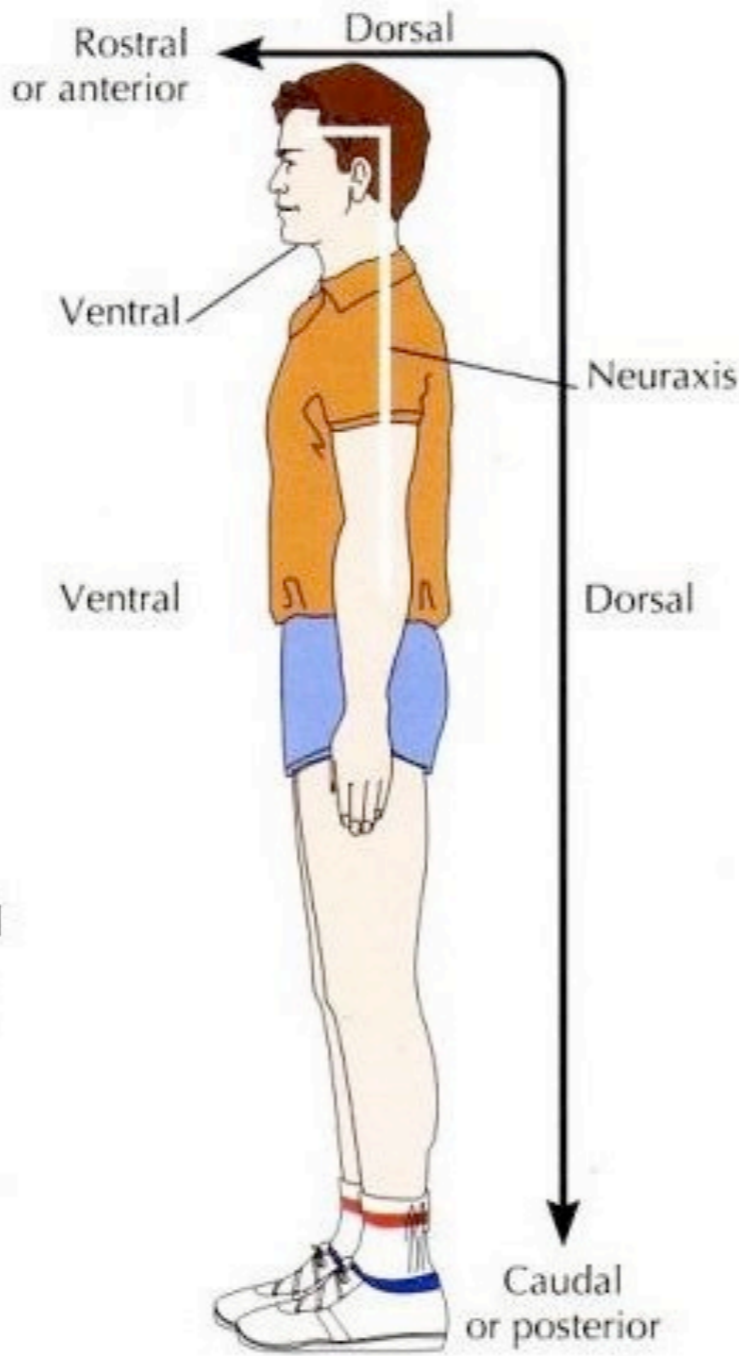


superior ↑
inferior ↓



PAIRS OF TERMS

- dorsal - ventral
- anterior - posterior
- rostral - caudal
- lateral - medial
- superior - inferior
- ipsilateral - contralateral
- afferent - efferent
- proximal - distal



Direction Finding

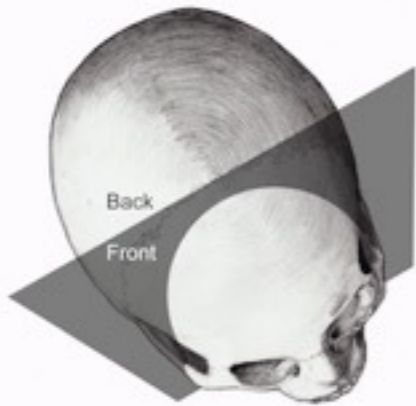


Planes of Section

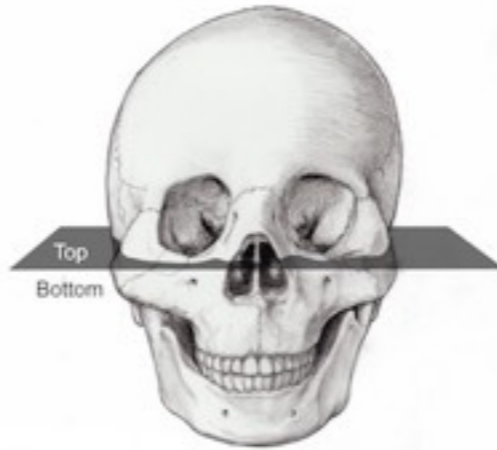
special case:
midsagittal



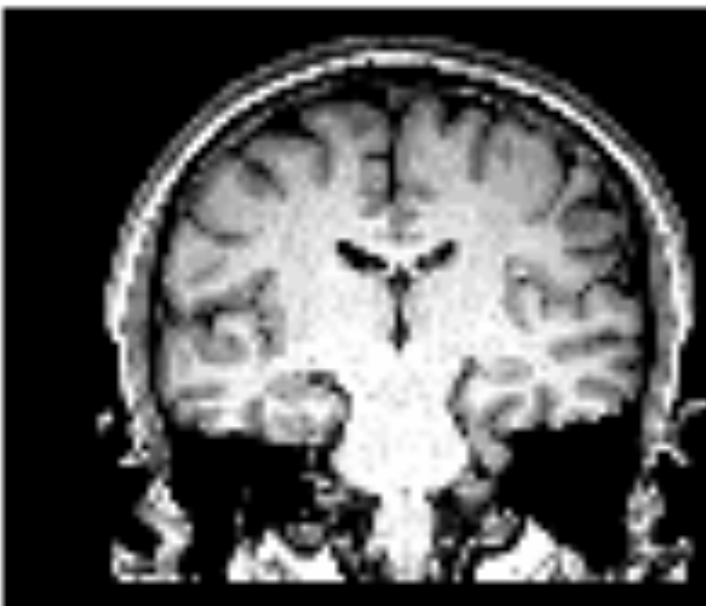
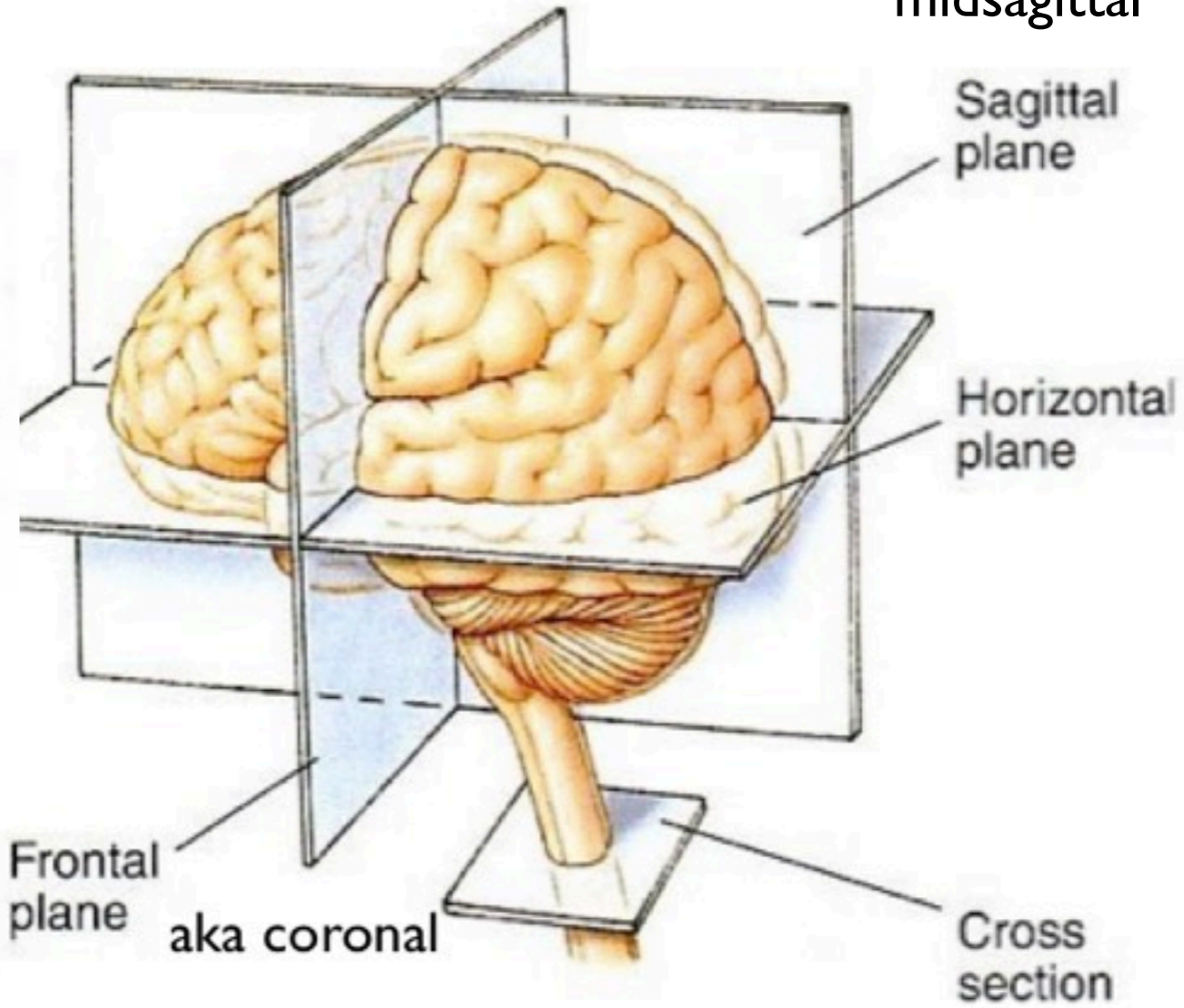
(mid)sagittal



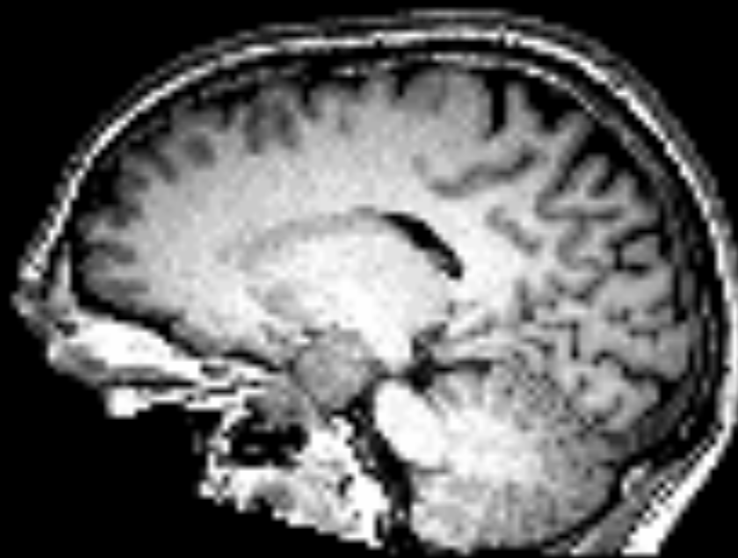
frontal or
coronal



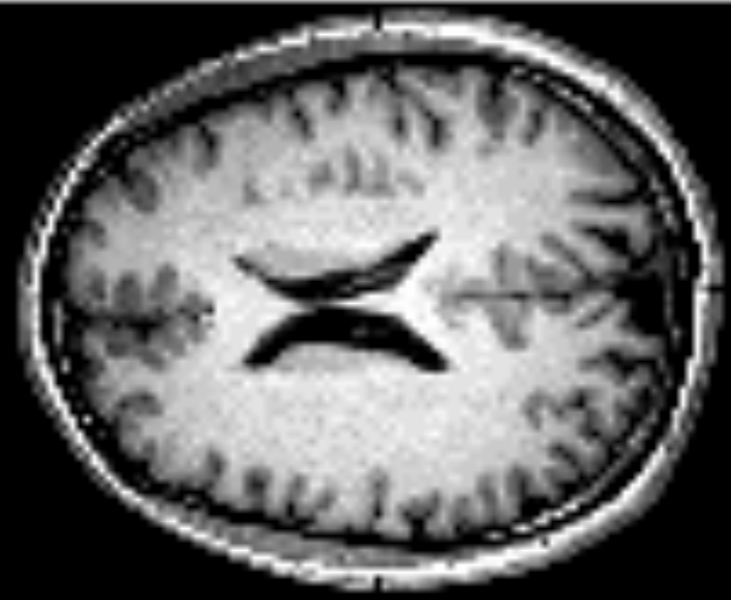
horizontal or
transverse



frontal or coronal

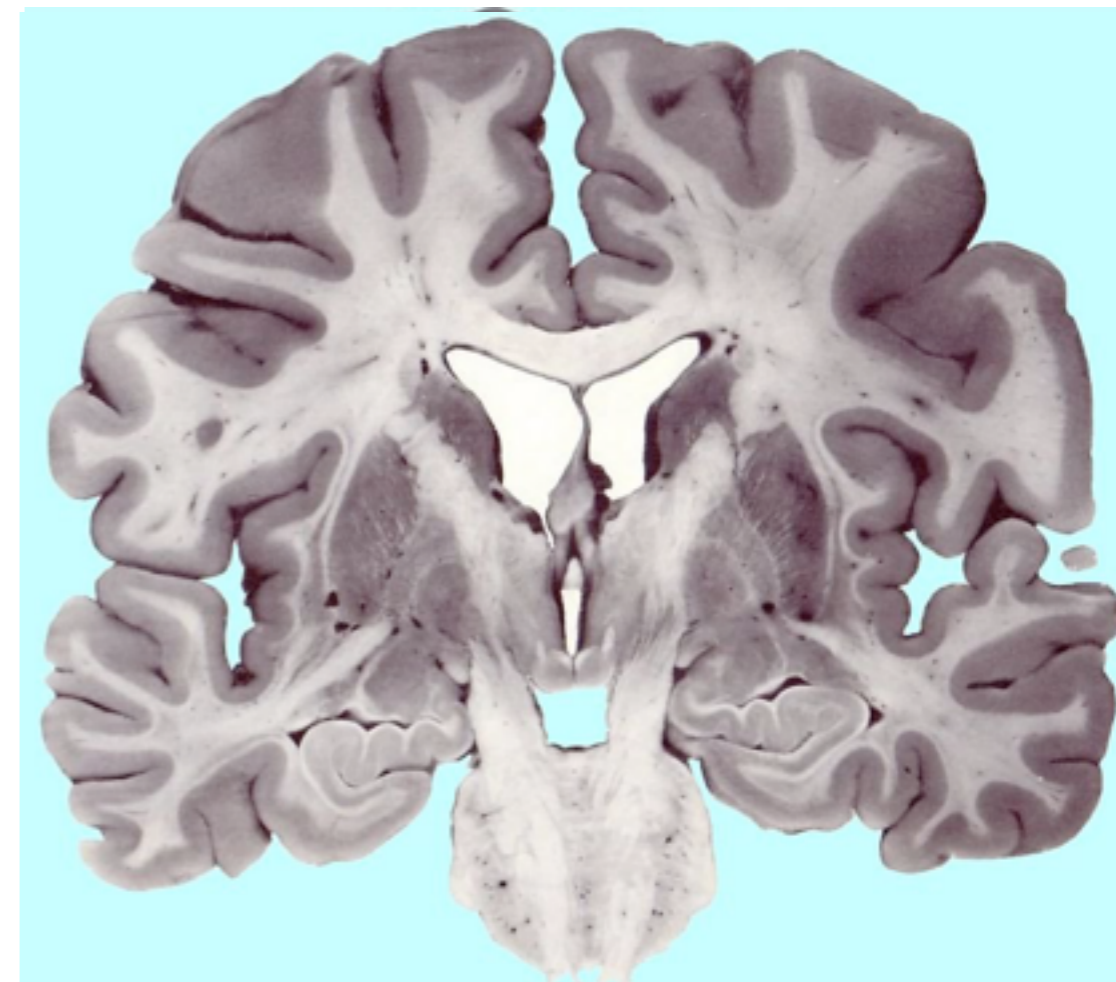
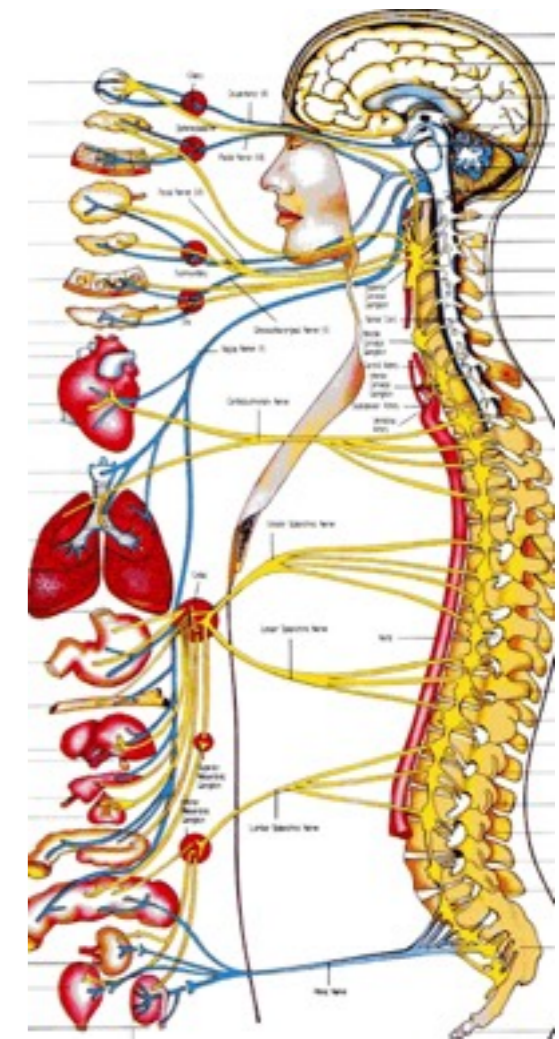


sagittal



horizontal

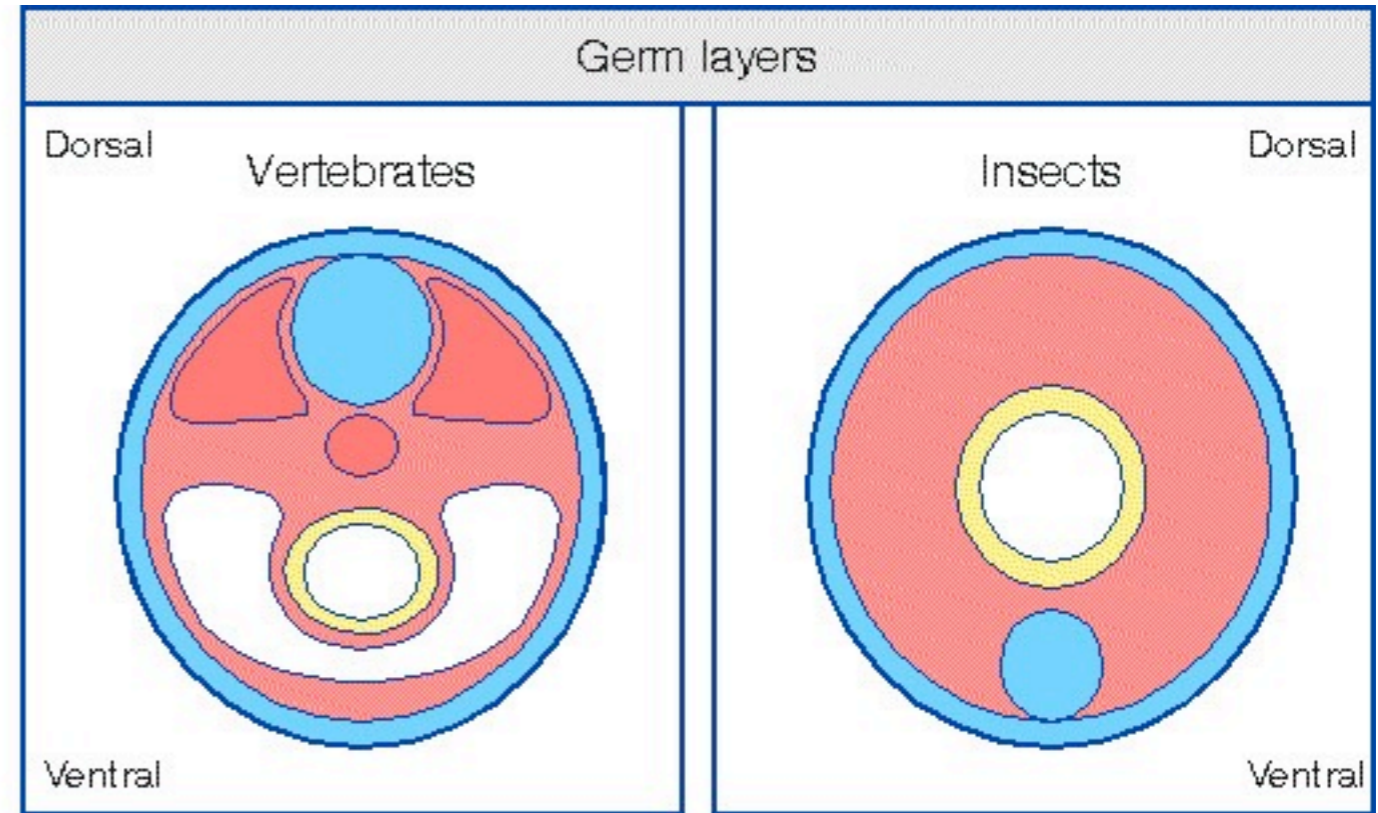
- Some basic terms in neuroanatomy
 - central nervous system (CNS) = brain + spinal cord
 - peripheral nervous system (PNS) = cranial nerves + spinal nerves + peripheral ganglia
 - nucleus - a local collection of cell bodies in the CNS
 - ganglion - a local collection of cell bodies in the PNS (exception: basal ganglia)
 - tract - a bundle of axons in the CNS
 - nerve - a bundle of axons in the PNS
 - gray matter - areas where there are lots of cell bodies in the CNS appear grayish in color
 - white matter - areas where there are lots of myelinated axons in the CNS appear white in color



- Naming conventions for tracts
 - begins with the location of the cell bodies and ends with the location of the terminal buttons (e.g. spinothalamic, corticospinal, spinocerebellar)
 - prominent tracts may retain their old names: e.g., fornix, pyramidal tract
- other names for tracts: fasciculus, capsule, commissure, lemniscus, peduncle (used in special cases)

Development

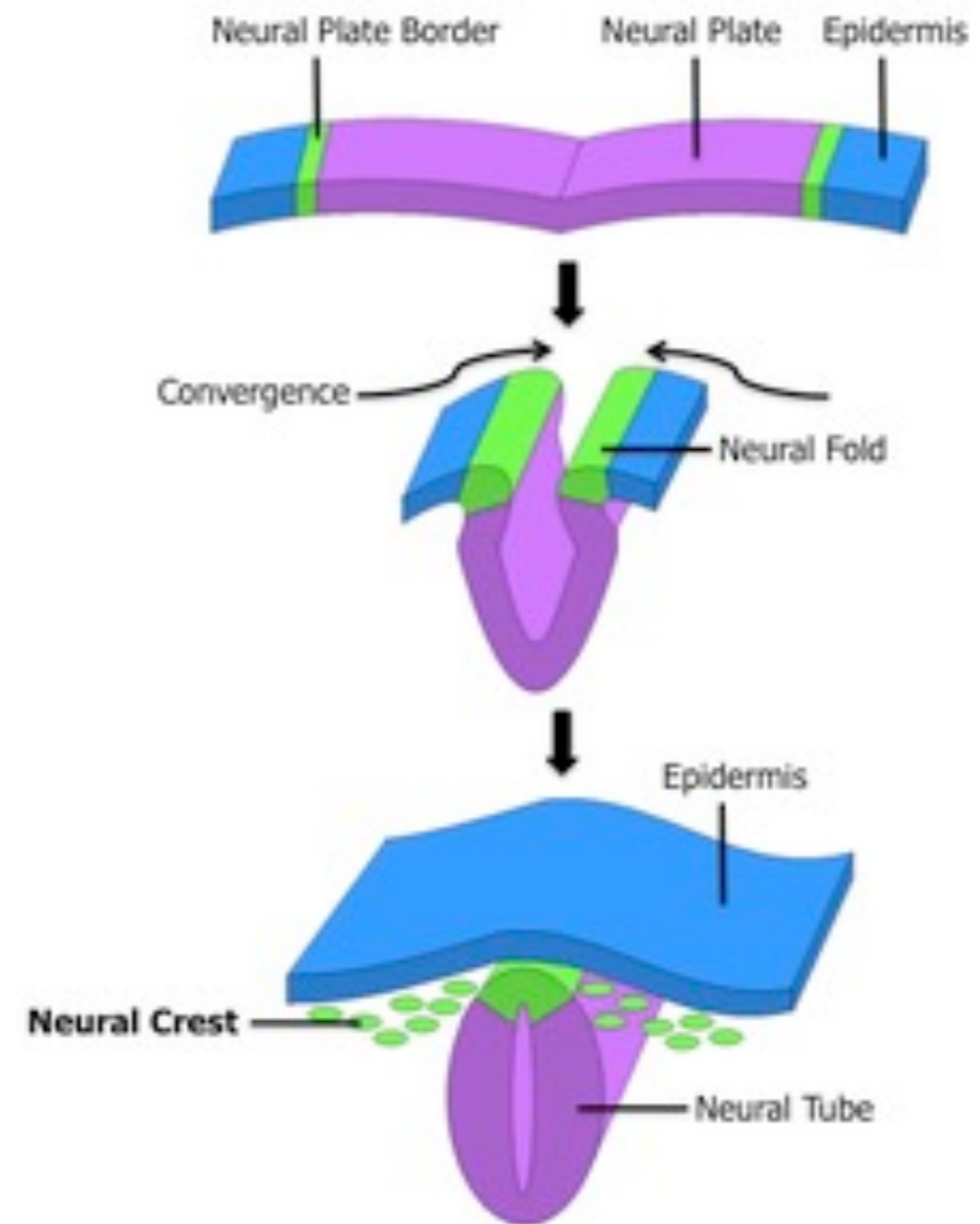
- three cell layers of the embryo: ectoderm, mesoderm, endoderm
- the nervous system (and skin) forms from the ectoderm



Germ layers	Organs	
Endoderm	gut, liver, lungs	gut
Mesoderm	skeleton, muscle, kidney, heart, blood	muscle, heart, blood
Ectoderm	skin, nervous system	cuticle, nervous system

Development

- a neural plate forms and gradually folds into a neural tube
- lots of things can go wrong



Warning: the next slide is a little rough!

Development

- anencephaly - missing cerebral hemispheres when the cephalic (head) end of the neural tube fails to close
- micro(en)cephaly - zika (a mosquito borne virus)

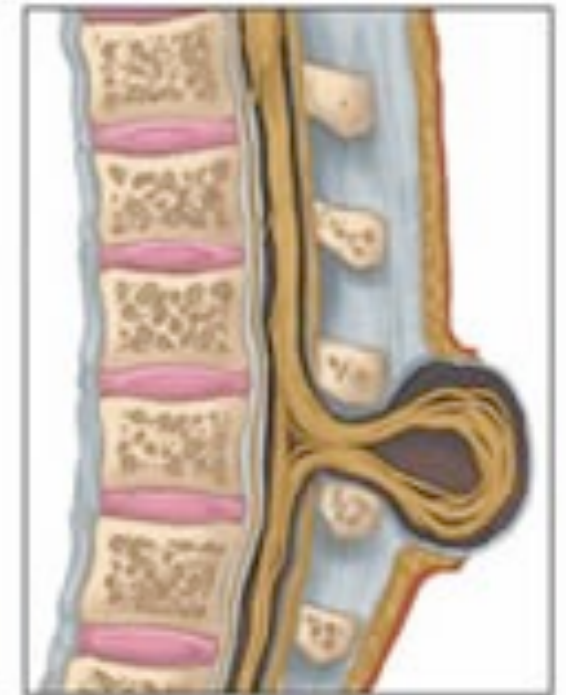


Range of Microcephaly Severity



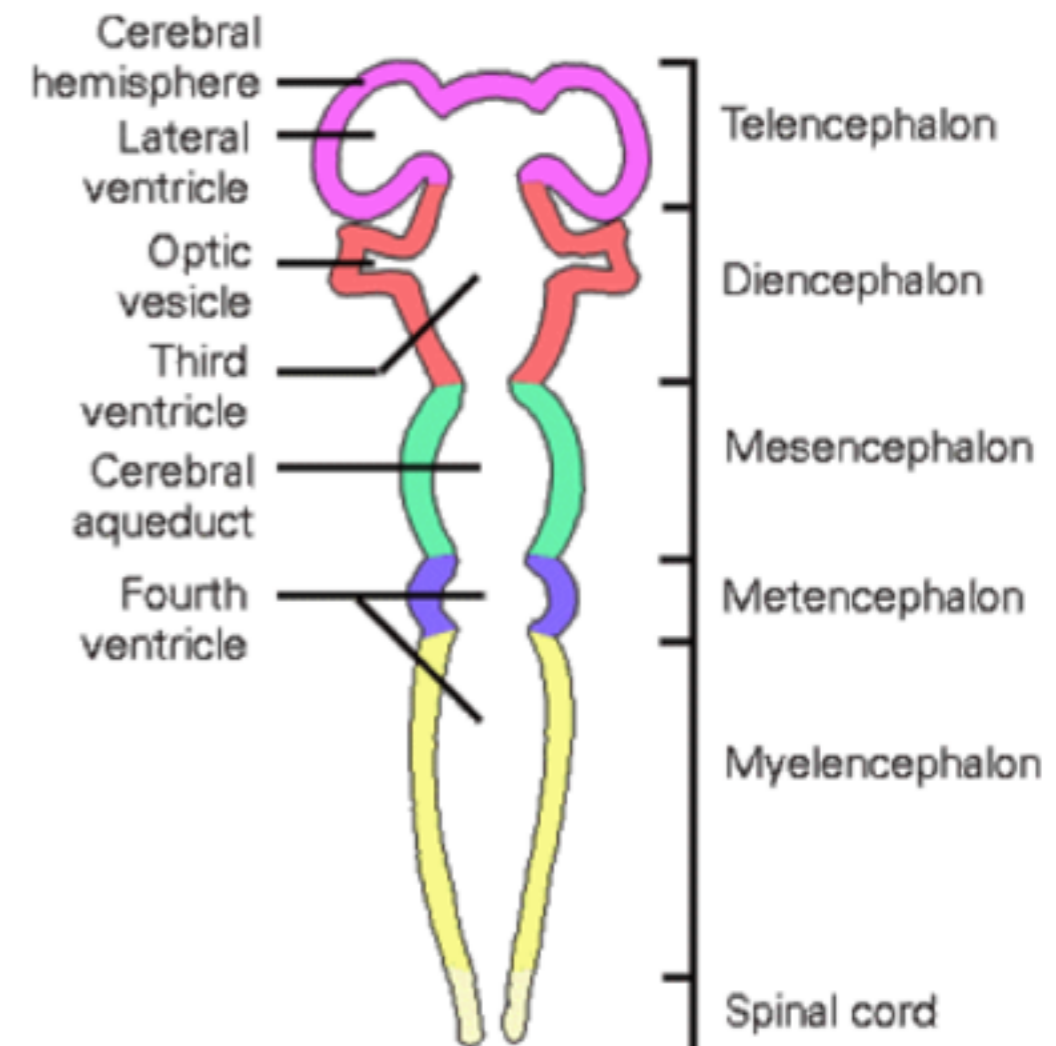
Development

- myeloschisis - abnormal formation of the spinal cord
- spina bifida being one of the milder forms (lower spine and spinal cord, generally)

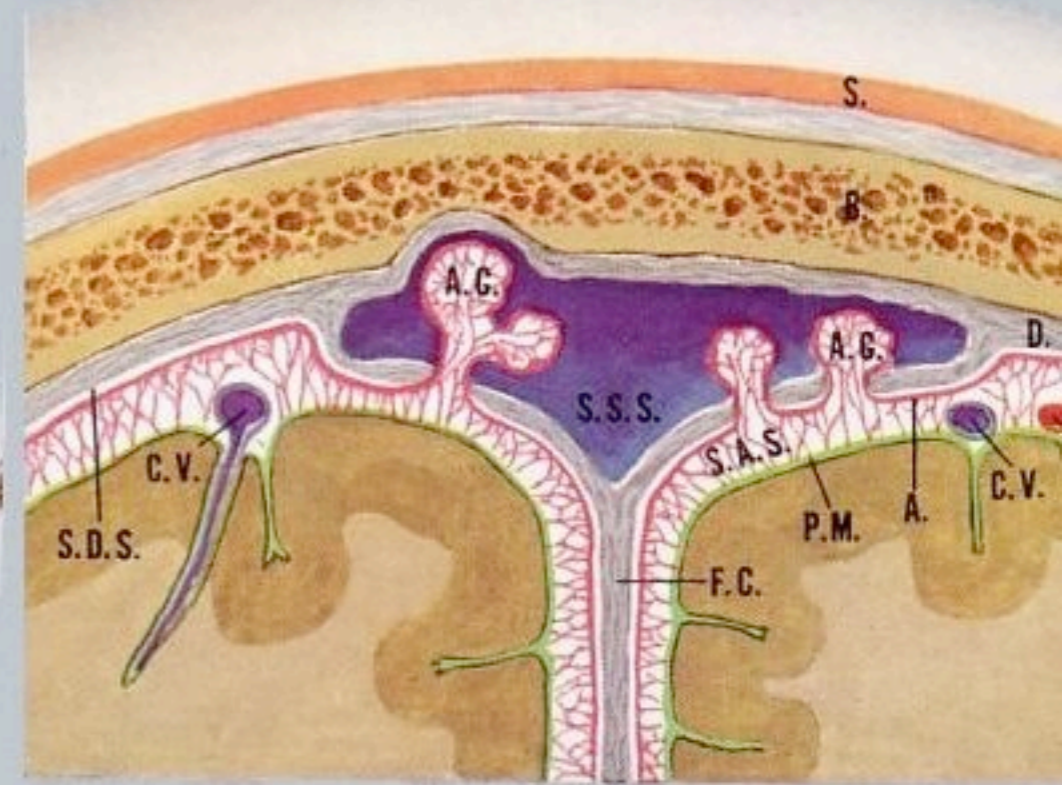


Development

- eventually, the developing nervous system becomes roughly segmented into six regions
 - telencephalon - cerebral hemispheres
 - diencephalon - thalamus and hypothalamus
 - mesencephalon - midbrain
 - metencephalon - pons and cerebellum
 - myelencephalon - medulla
 - spinal cord



Meninges



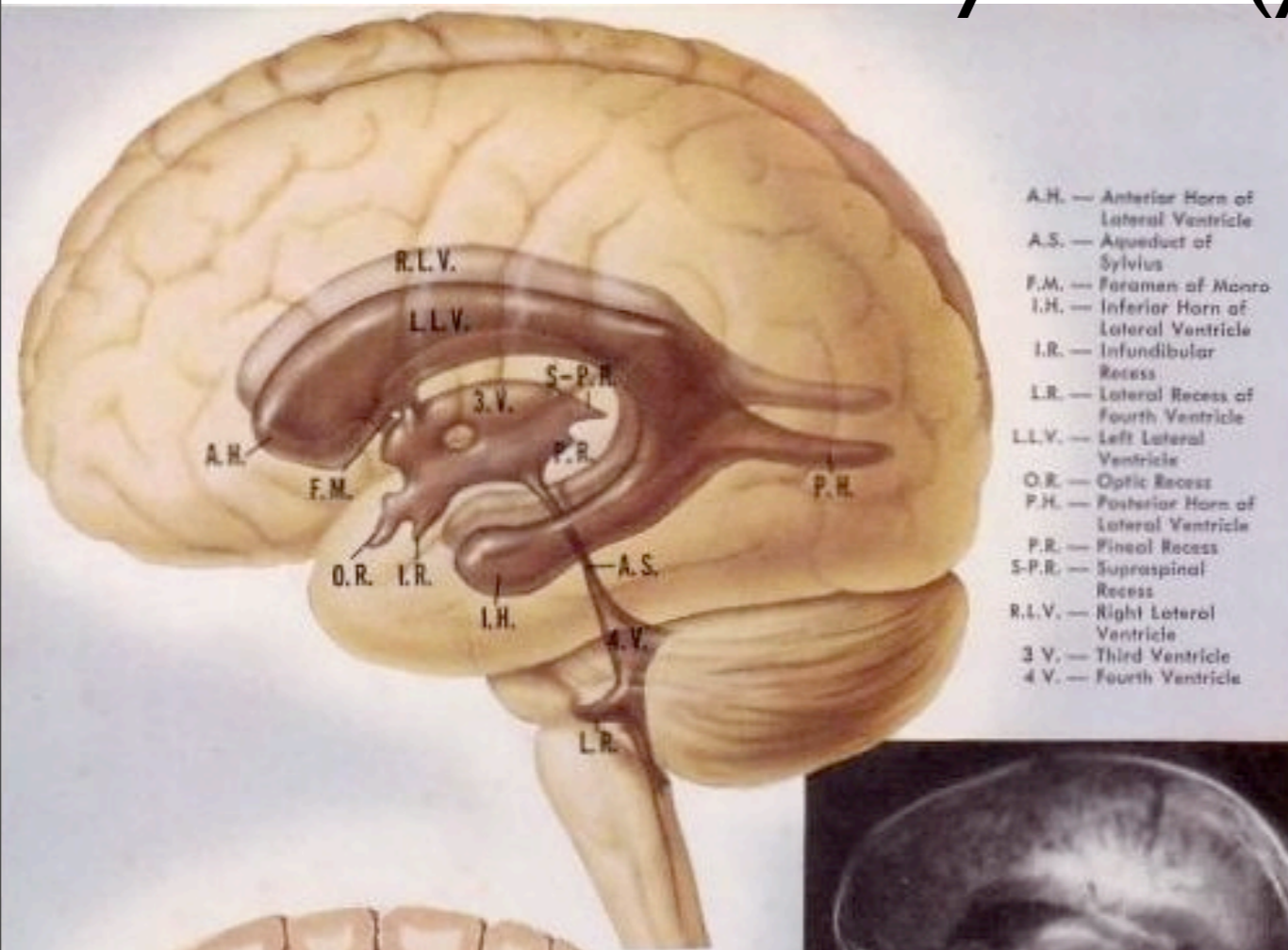
- A. — Arachnoid
- A.G. — Arachnoid Granulation
- B. — Bone
- C.A. — Cerebral Artery
- C.V. — Cerebral Vein
- D. — Dura Mater
- F.C. — Falx Cerebri
- P.M. — Pia Mater
- S. — Skin
- S.A.S. — Sub-Arachnoid Space
- S.D.S. — Sub-Dural Space
- S.S.S. — Superior Sagittal Sinus

Meninges (Ciba)

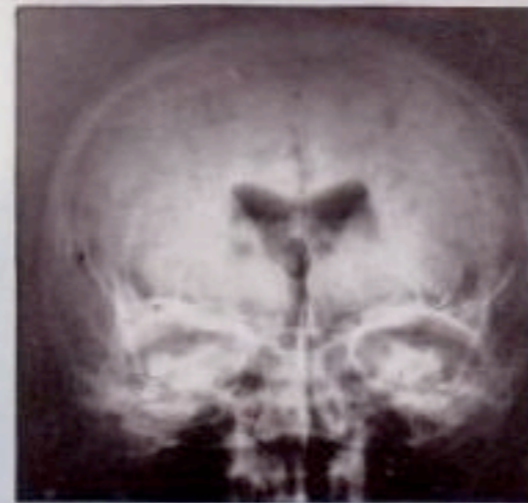
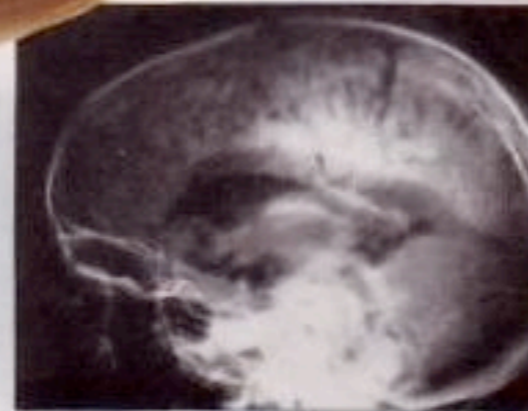
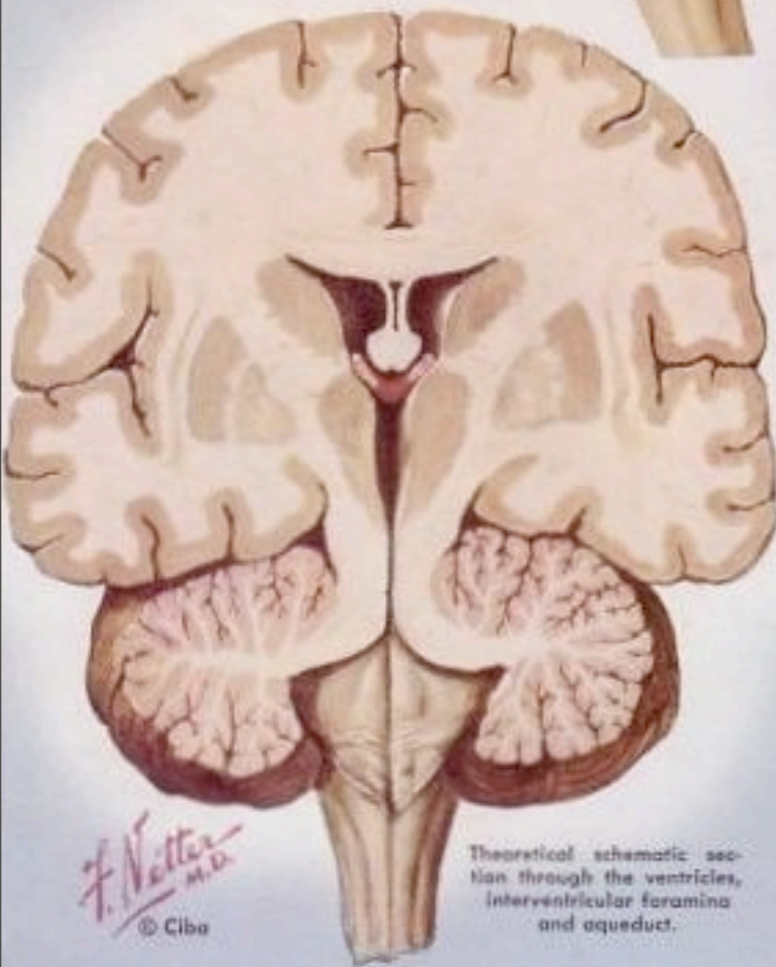
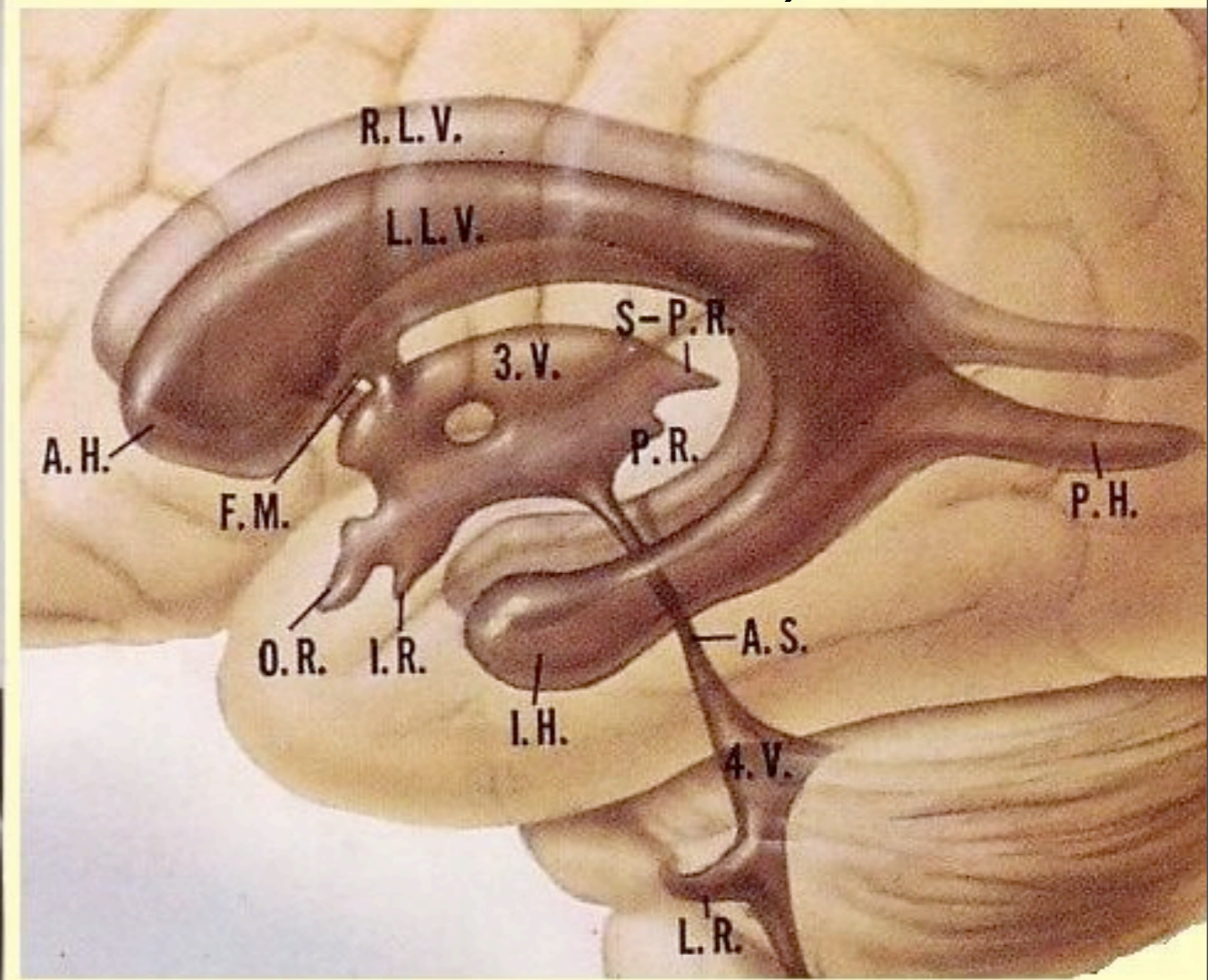
- 1) dura mater
- 2) arachnoid mater
- 3) pia mater

F. Netter
M.D.
© Ciba

Ventricular System (your brain is hollow)



A.H. — Anterior Horn of Lateral Ventricle
 A.S. — Aqueduct of Sylvius
 F.M. — Foramen of Monro
 I.H. — Inferior Horn of Lateral Ventricle
 I.R. — Infundibular Recess
 L.R. — Lateral Recess of Fourth Ventricle
 L.L.V. — Left Lateral Ventricle
 O.R. — Optic Recess
 P.H. — Posterior Horn of Lateral Ventricle
 P.R. — Pineal Recess
 S-P.R. — Supraspinal Recess
 R.L.V. — Right Lateral Ventricle
 3.V. — Third Ventricle
 4.V. — Fourth Ventricle



The Ventricular System (Ciba)

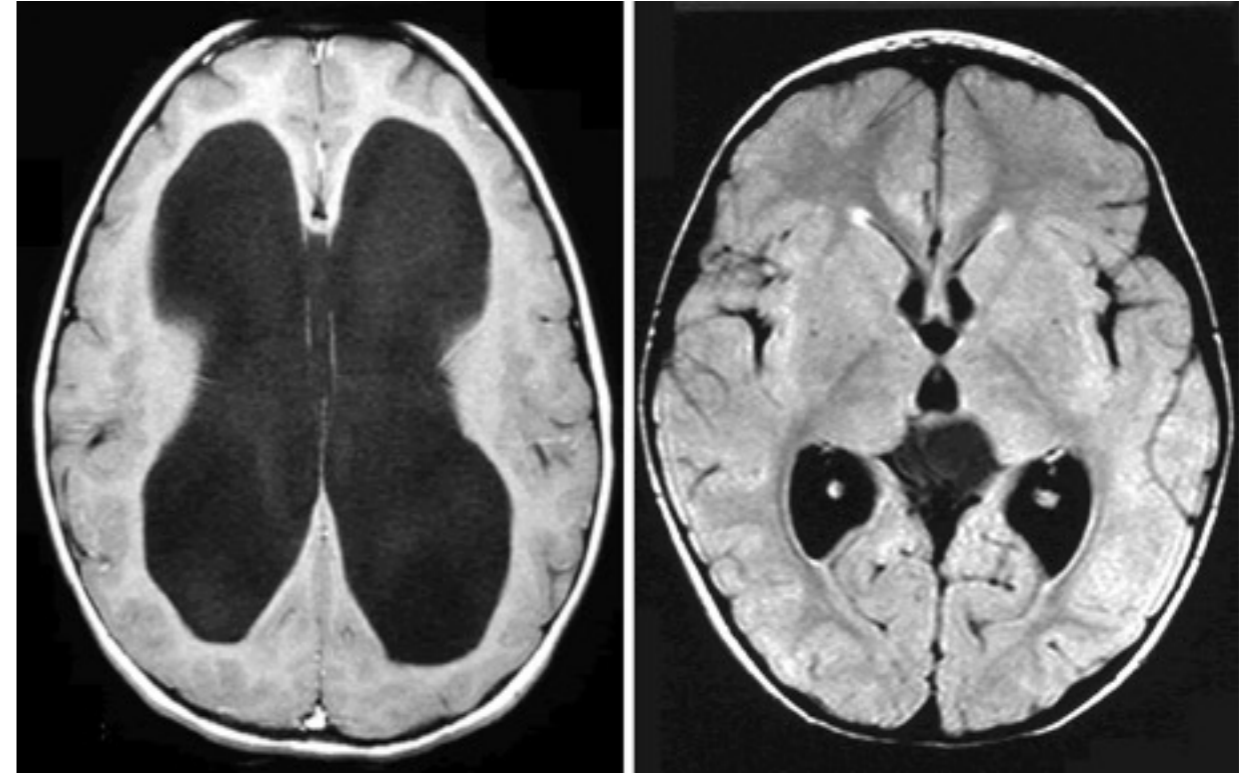
- 1) lateral ventricles
- 2) third ventricle
- 3) cerebral aqueduct
- 4) fourth ventricle
- 5) subarachnoid space

Cerebrospinal Fluid (CSF)

- fills the ventricles and subarachnoid space
- produced in the choroid plexus in lateral and 3rd ventricles
- about 125 milliliters (or 1/2 cup)
- circulation - lateral ventricle to the third ventricle, through the cerebral aqueduct to the fourth ventricle, then through three small foramens into the subarachnoid space
- functions: cushioning and buoyancy, waste disposal

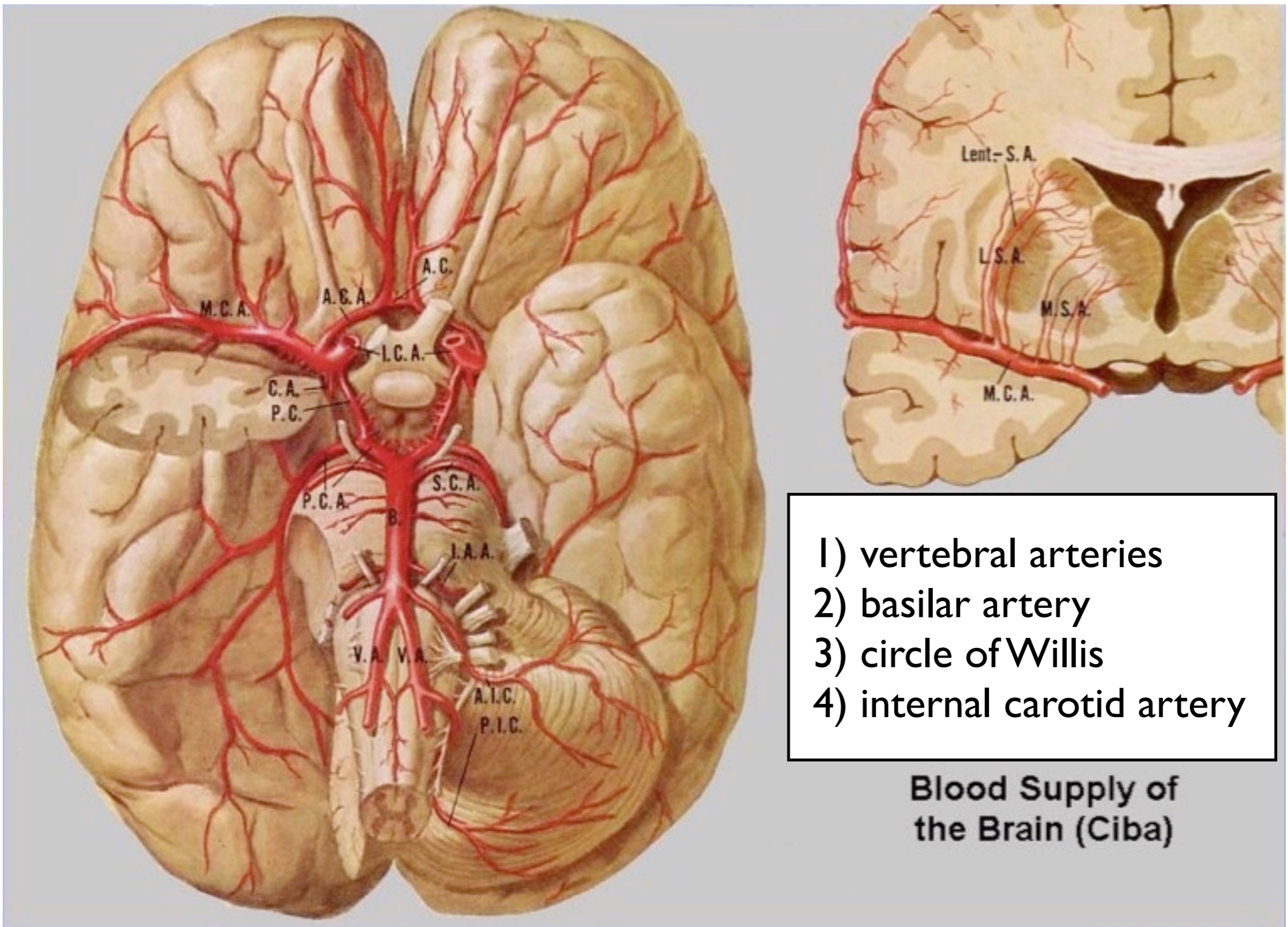
Hydrocephalus

- “water on the brain”
- blockage of one of the smaller foramens or aqueducts can result in build-up of CSF behind the block
- the blockage is usually in the cerebral aqueduct
- corrected surgically
- this can happen in adults, too!



Normal Ventricles





(blood is drained away via sinuses embedded in the dura, and eventually via the jugular vein)

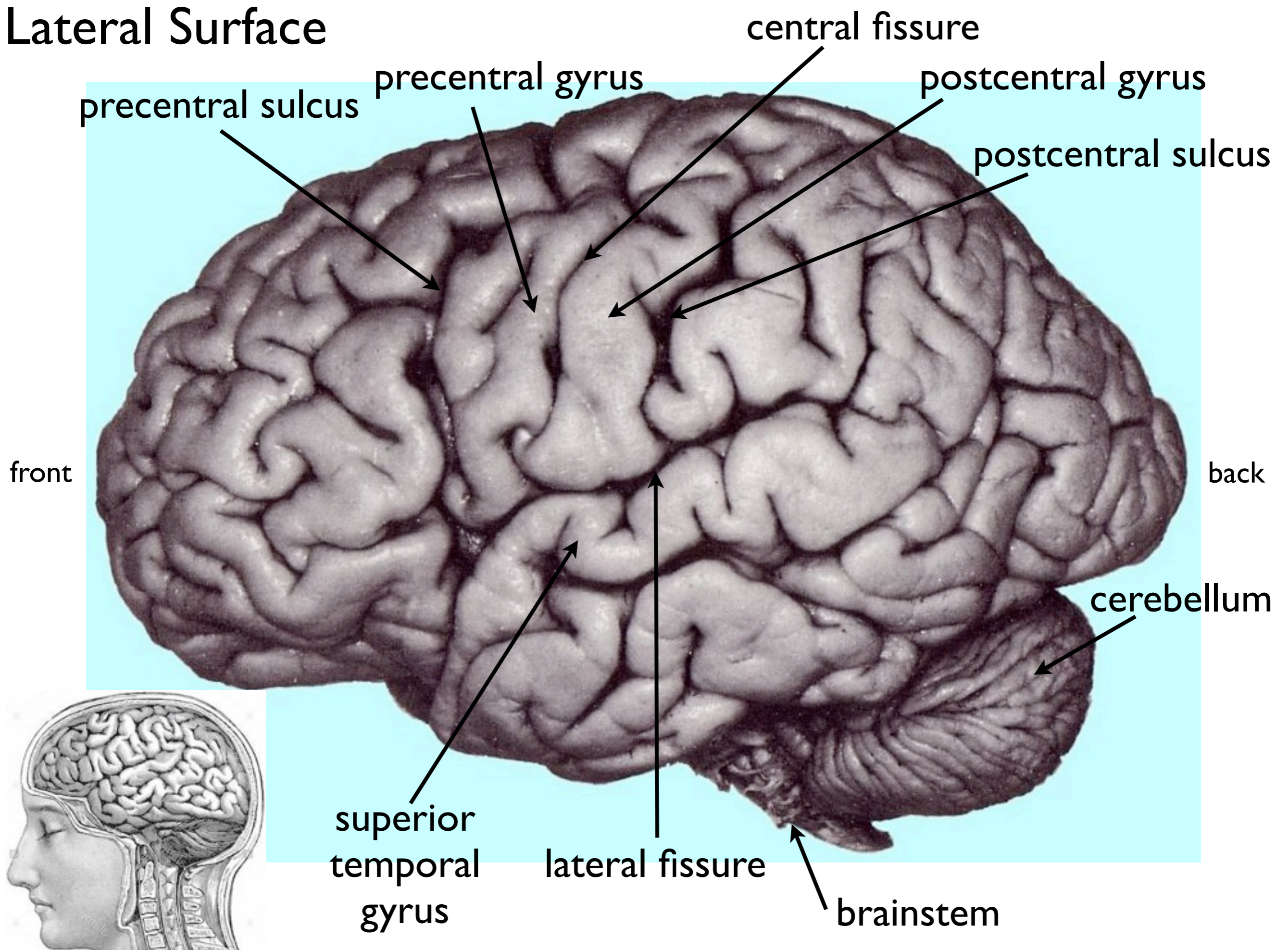
Energy Needs of the Brain

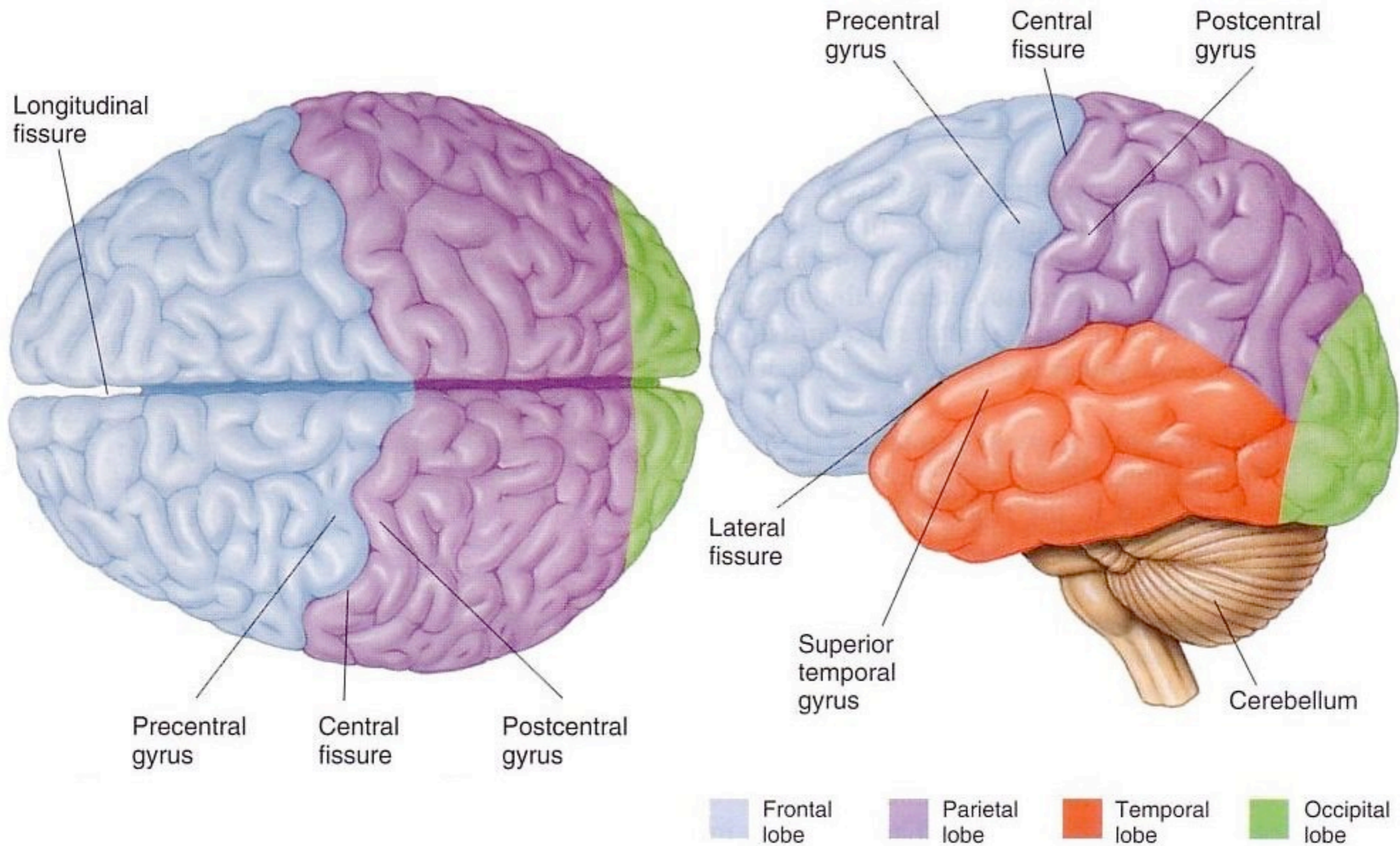
(your brain runs on sugar)

- consumes about 20% of oxygen carried in the blood (even though it is only about 2% of adult body weight, about 3 pounds)
- requires about 400 Calories per day (all in carbohydrates) - burns 15 watts (about 1/4 Cal/min) more or less continuously
- when the body is at rest, it is the most expensive tissue in the body to maintain
- when the body is active, muscles burn more energy than the brain

Telencephalon

Lateral Surface





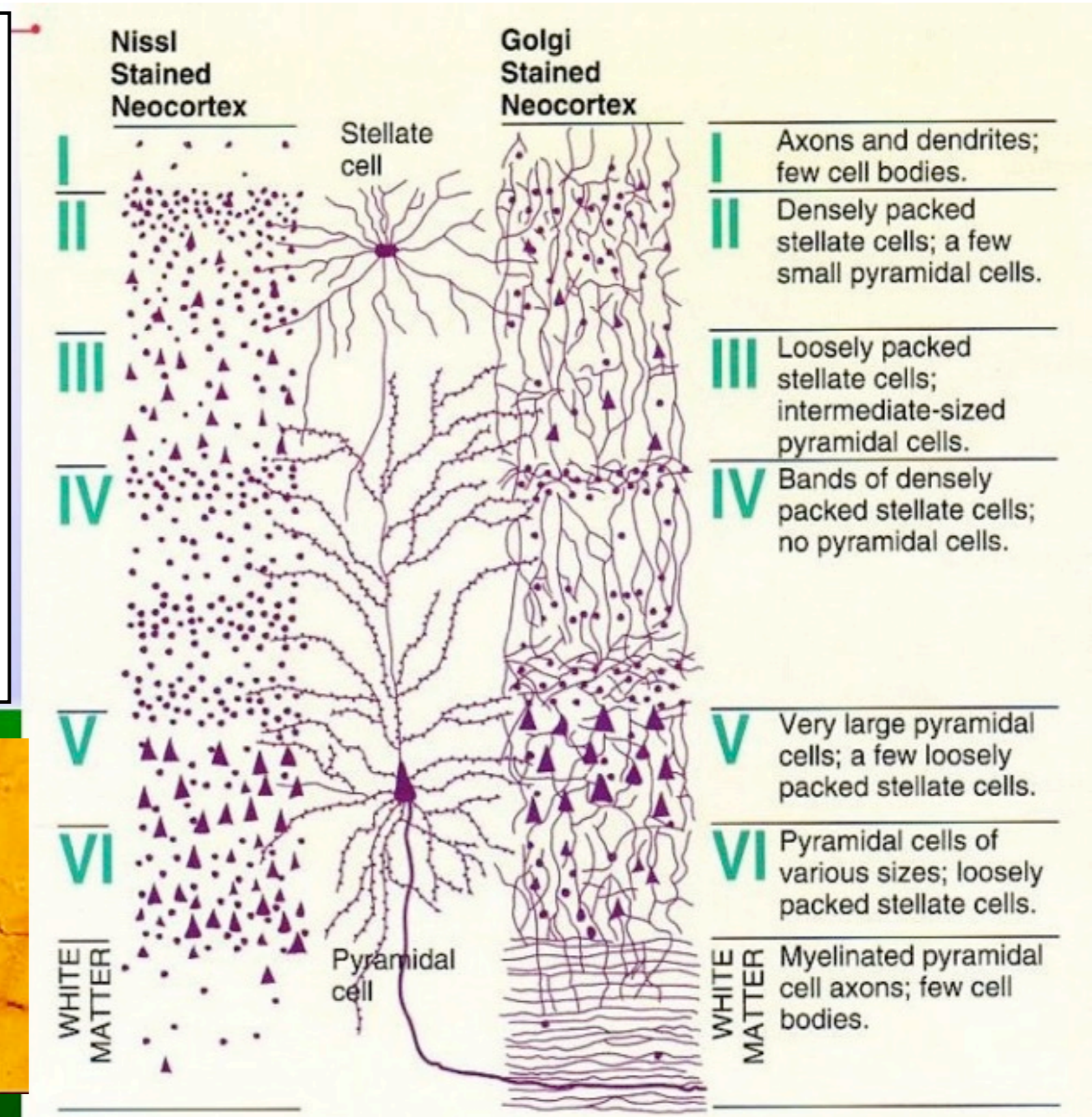
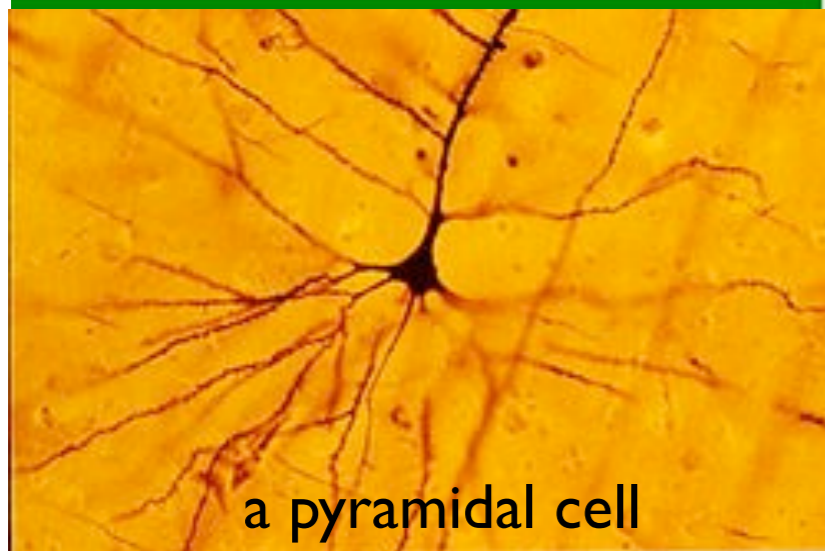
Lobes of the Cerebral Hemispheres

Kinds of Cortex (cx): primary sensory, sensory association, primary motor, secondary motor or premotor, prefrontal



Structure of Cortex

neocortex
 six-layered
 cortex
 input layers
 output layers
 etc.

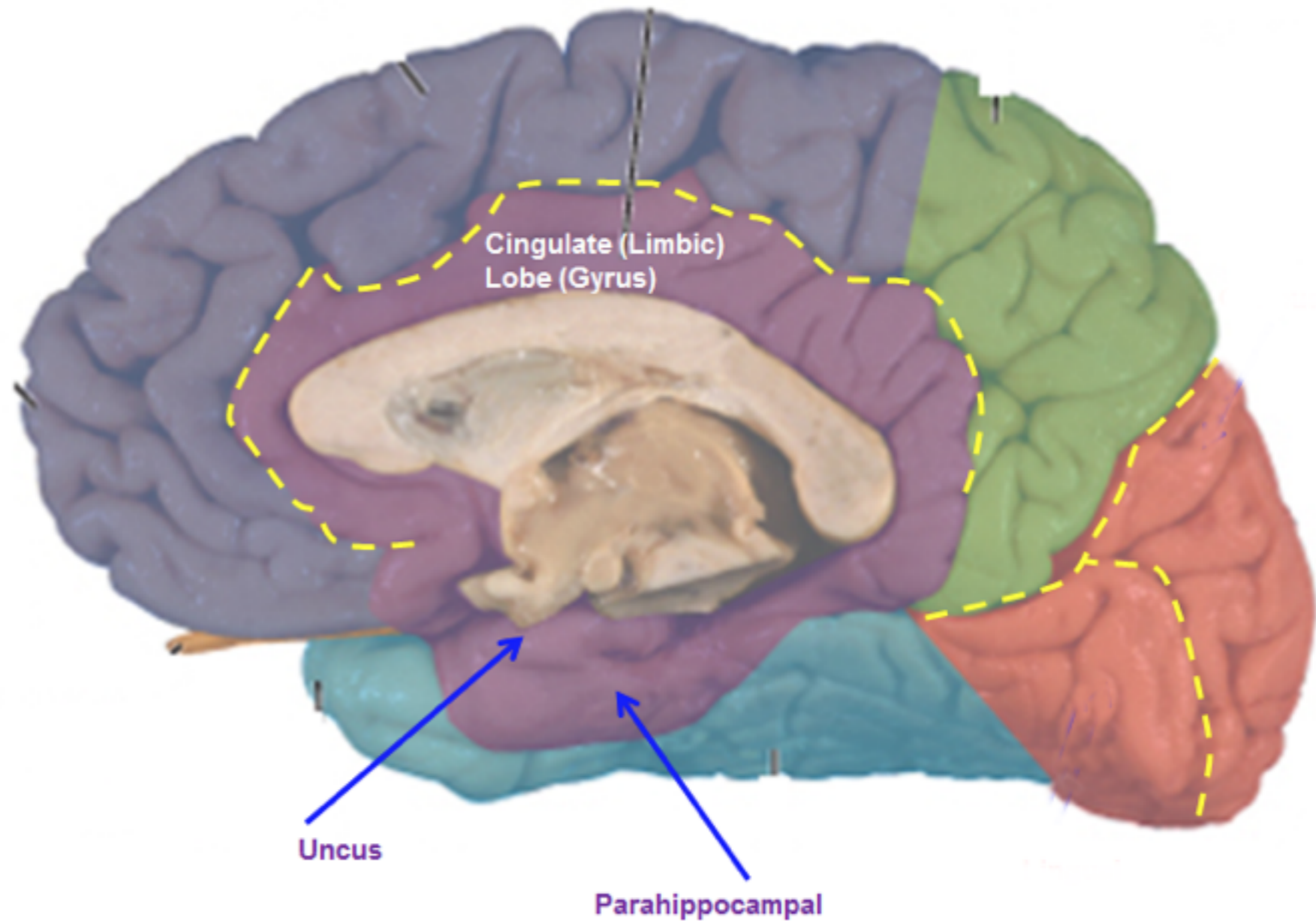


Structure of Cortex

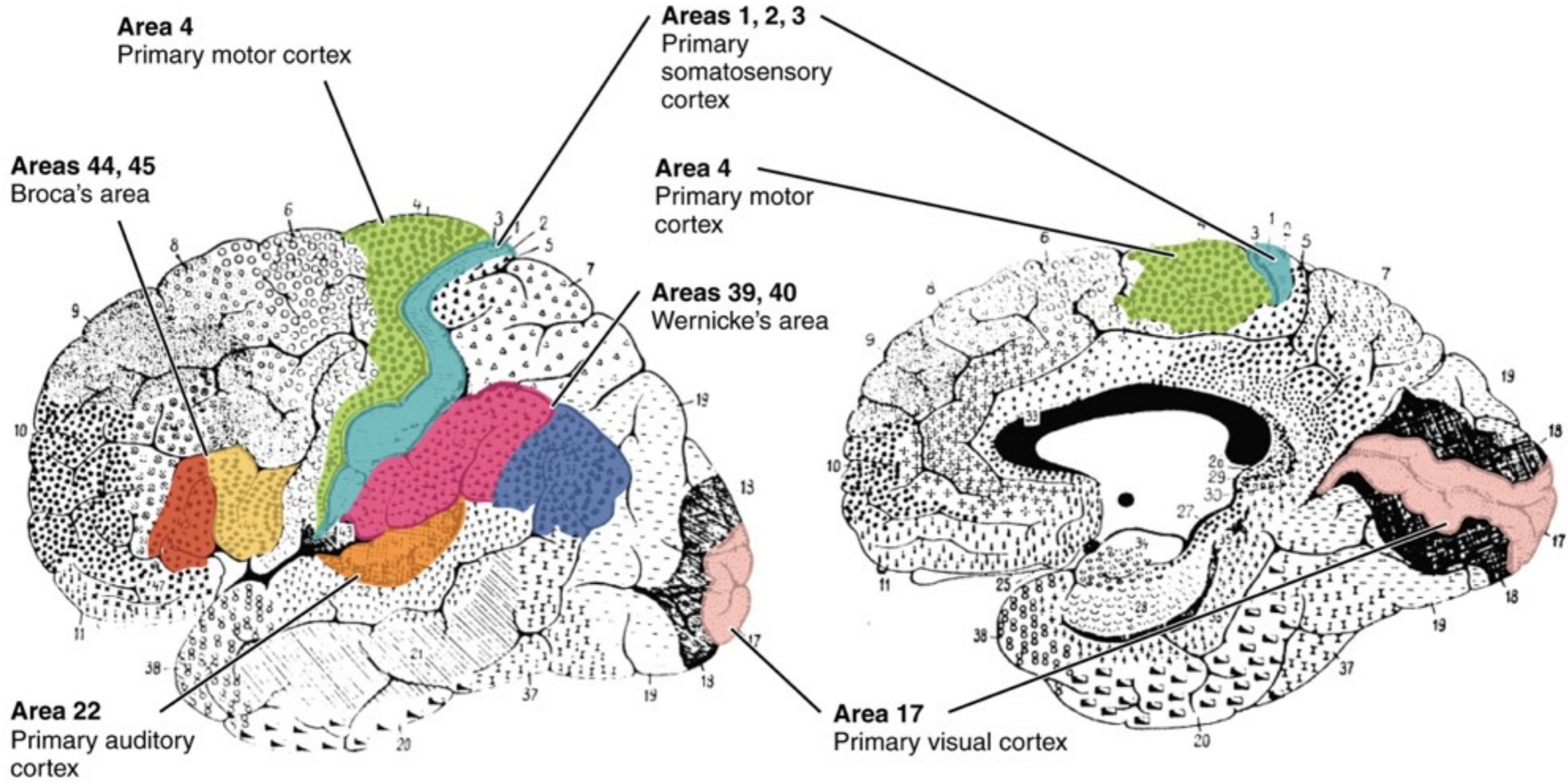
as opposed to
the limbic cortex
(light purple)

an evolutionarily
more primitive cx

3 to 5-layered
cortex



Brodmann Areas



Brodmann's cytoarchitectonic map (1909):
Lateral surface

Brodmann's cytoarchitectonic map (1909):
Medial surface

Midsagittal Section

(anterior)
cingulate gyrus
(limbic cortex)

corpus callosum

cingulate sulcus

pineal gland

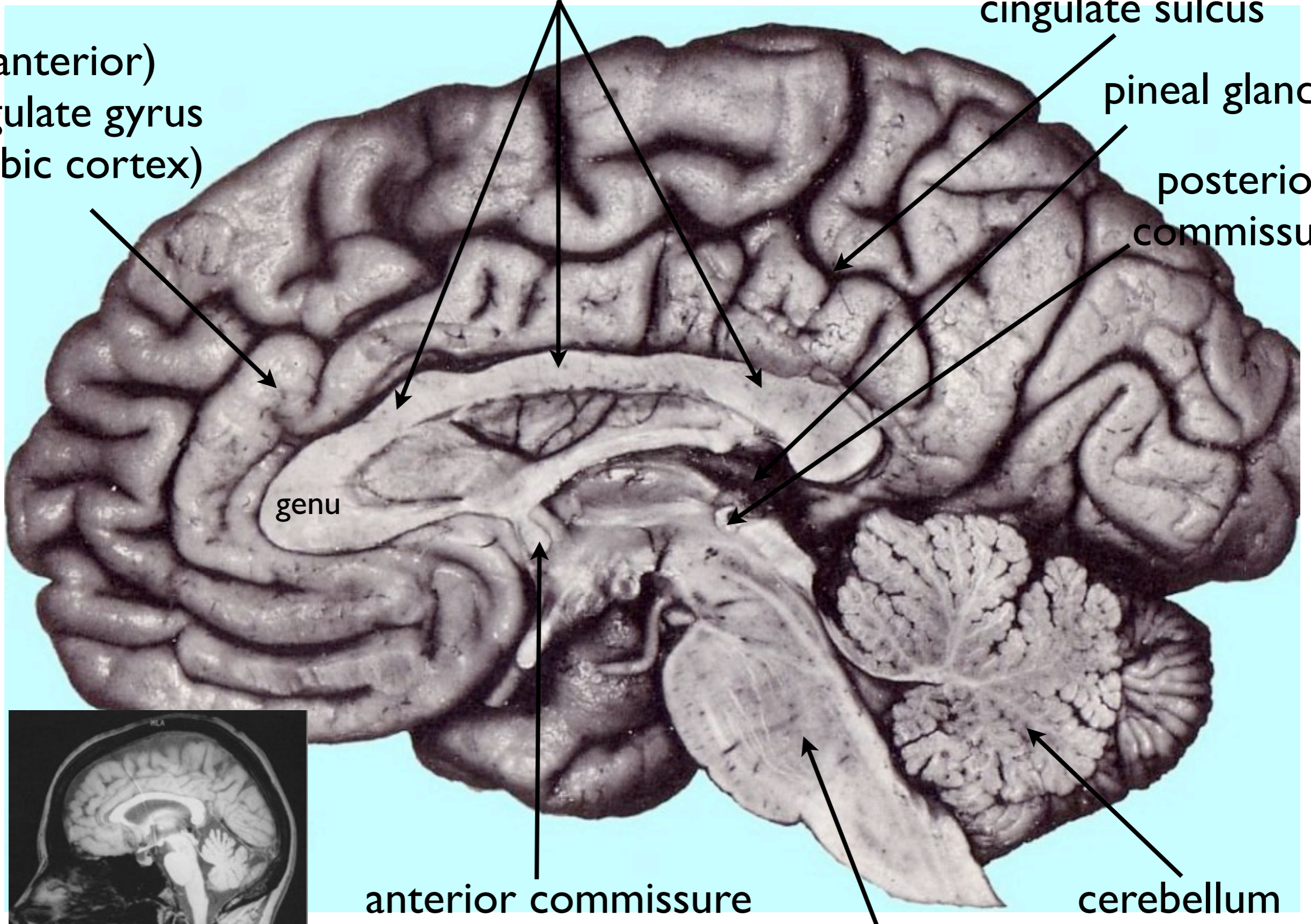
posterior
commissure

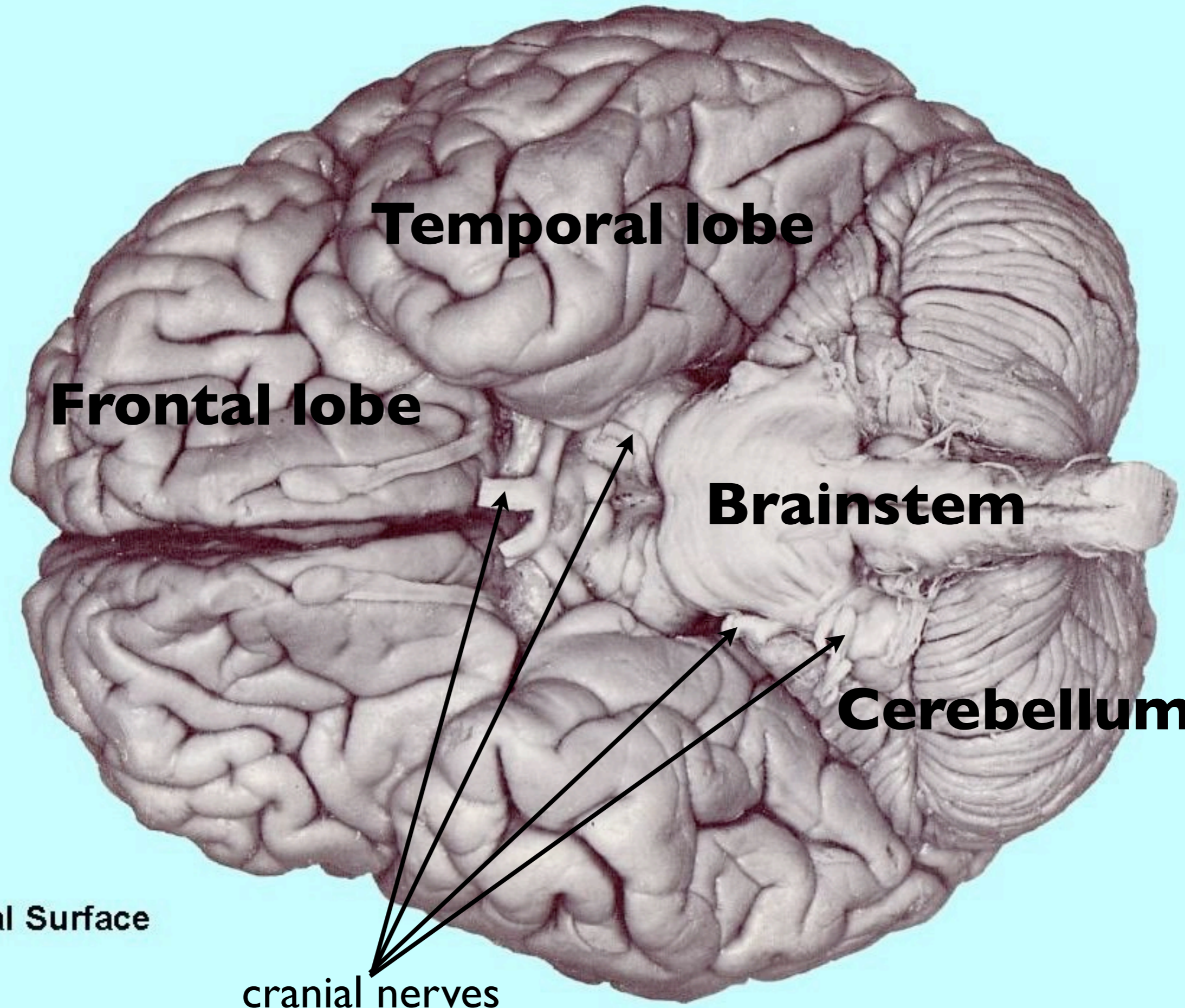
genu

anterior commissure

brainstem

cerebellum





Frontal lobe

Temporal lobe

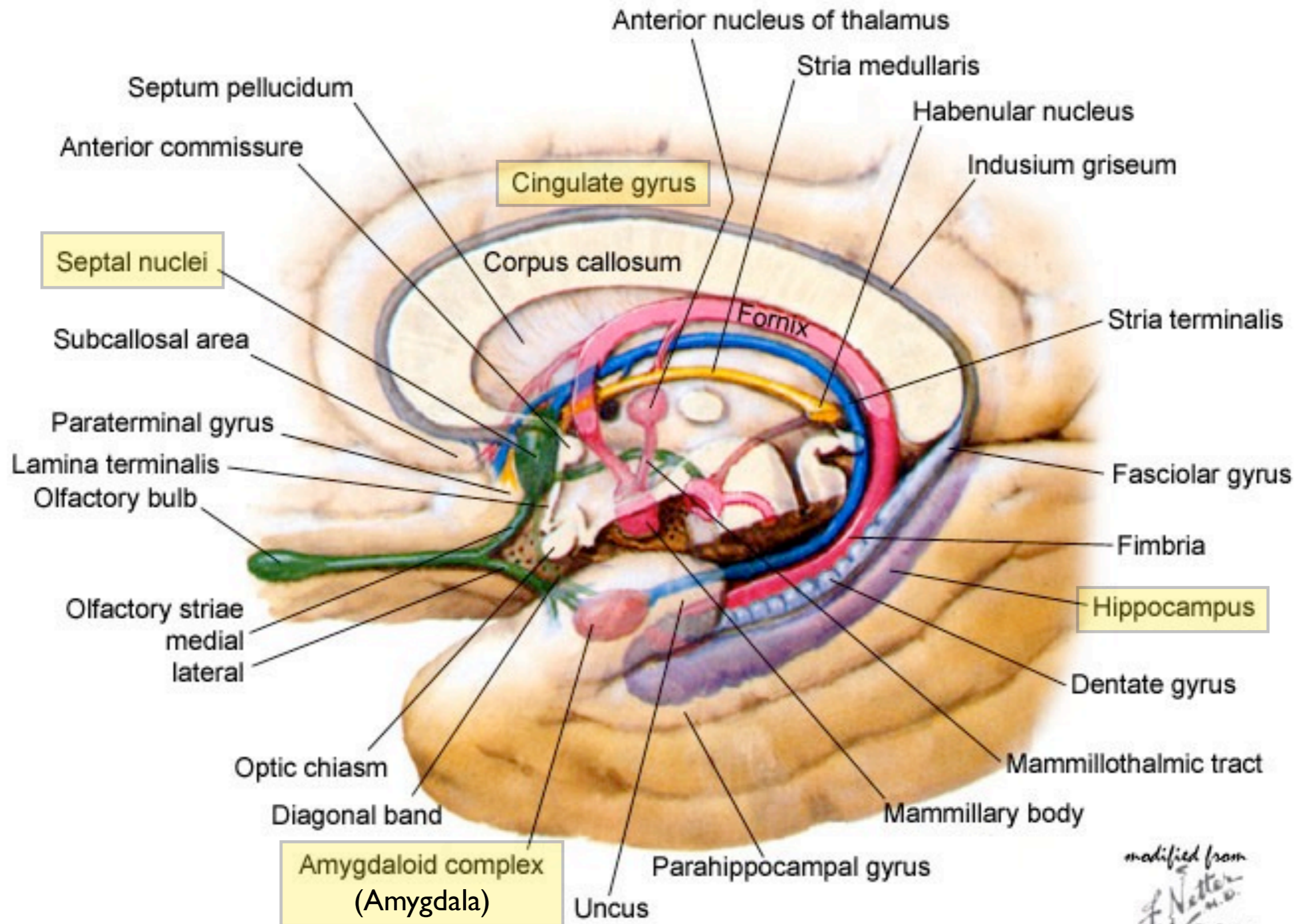
Brainstem

Cerebellum

cranial nerves

Ventral Surface

Limbic System



modified from
F. Netter
M.D.
© CIBA

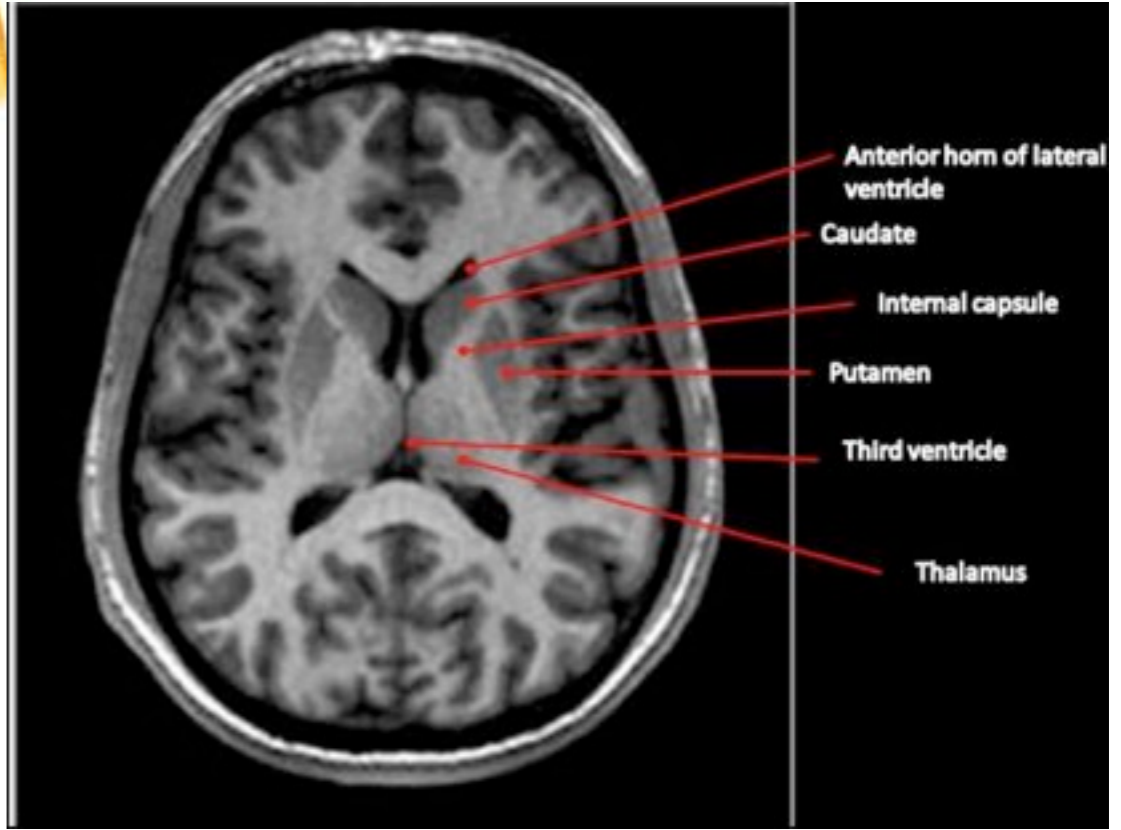
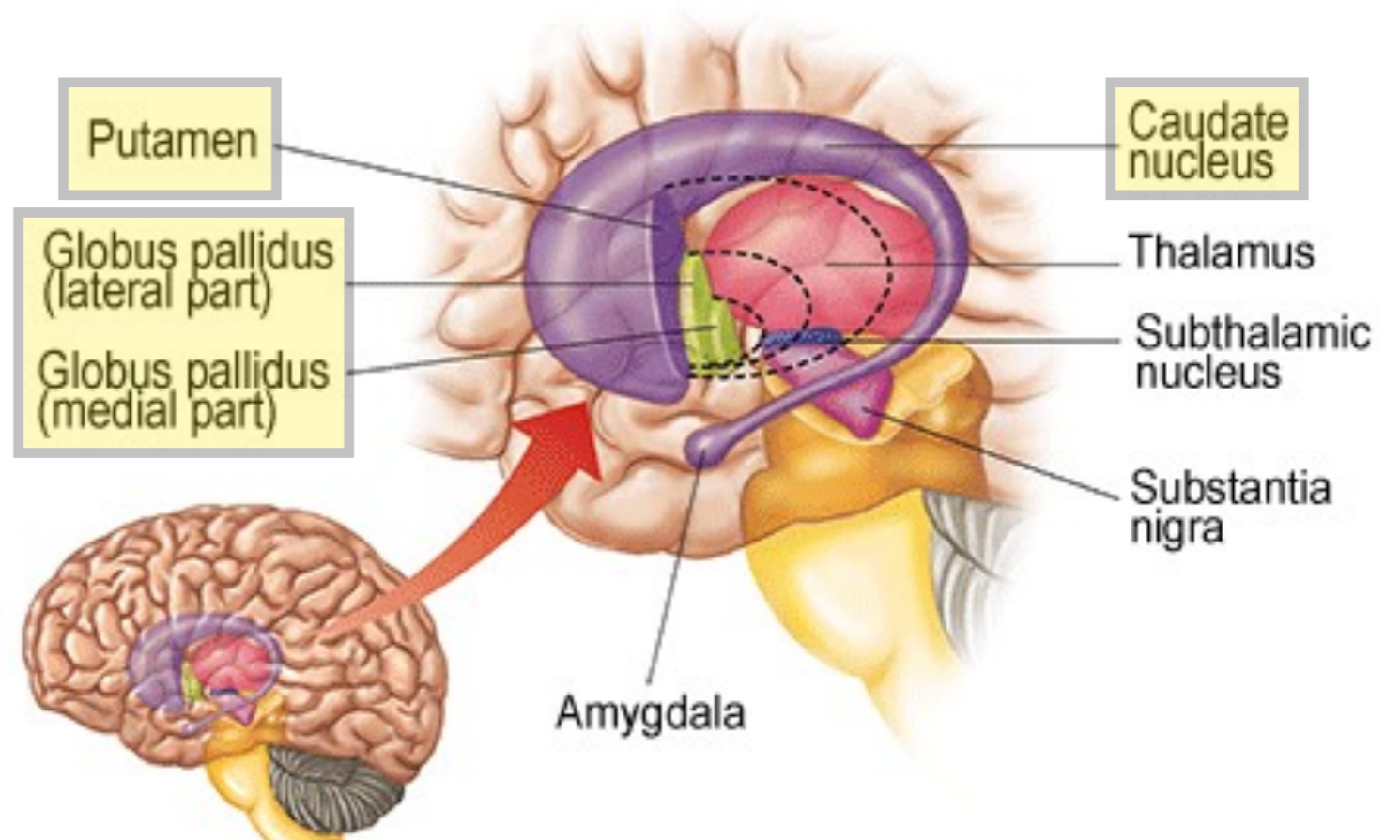
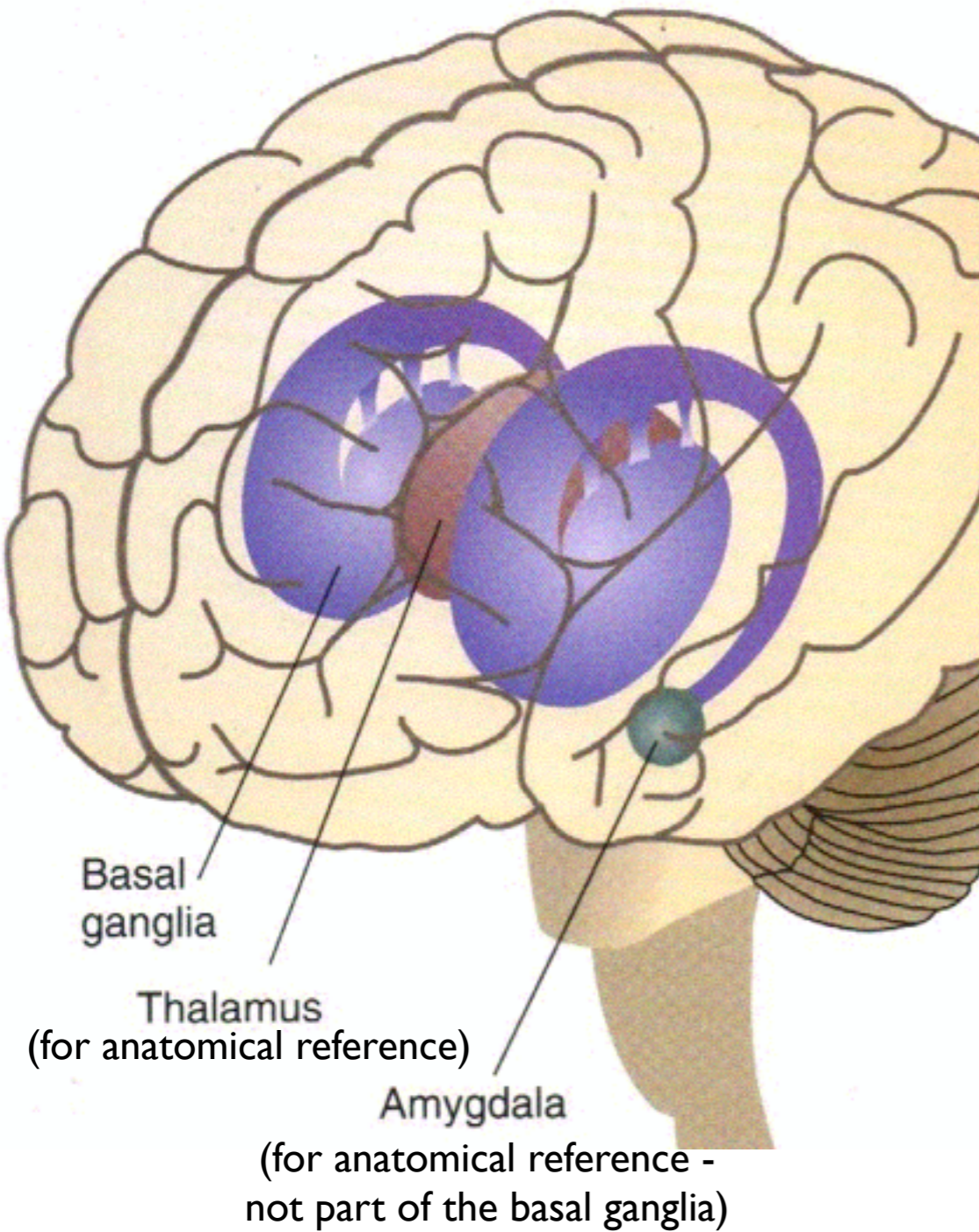
Limbic System Functions

- amygdala
 - emotion, emotional learning, fear
 - attaching emotional consequences to environmental events
 - people (and animals) with damage in the amygdala tend to have an impaired sense of fear
- cingulate cortex
 - motivation and attaching motivational significance to recent behaviors
 - e.g., pain of social rejection

Limbic System Functions

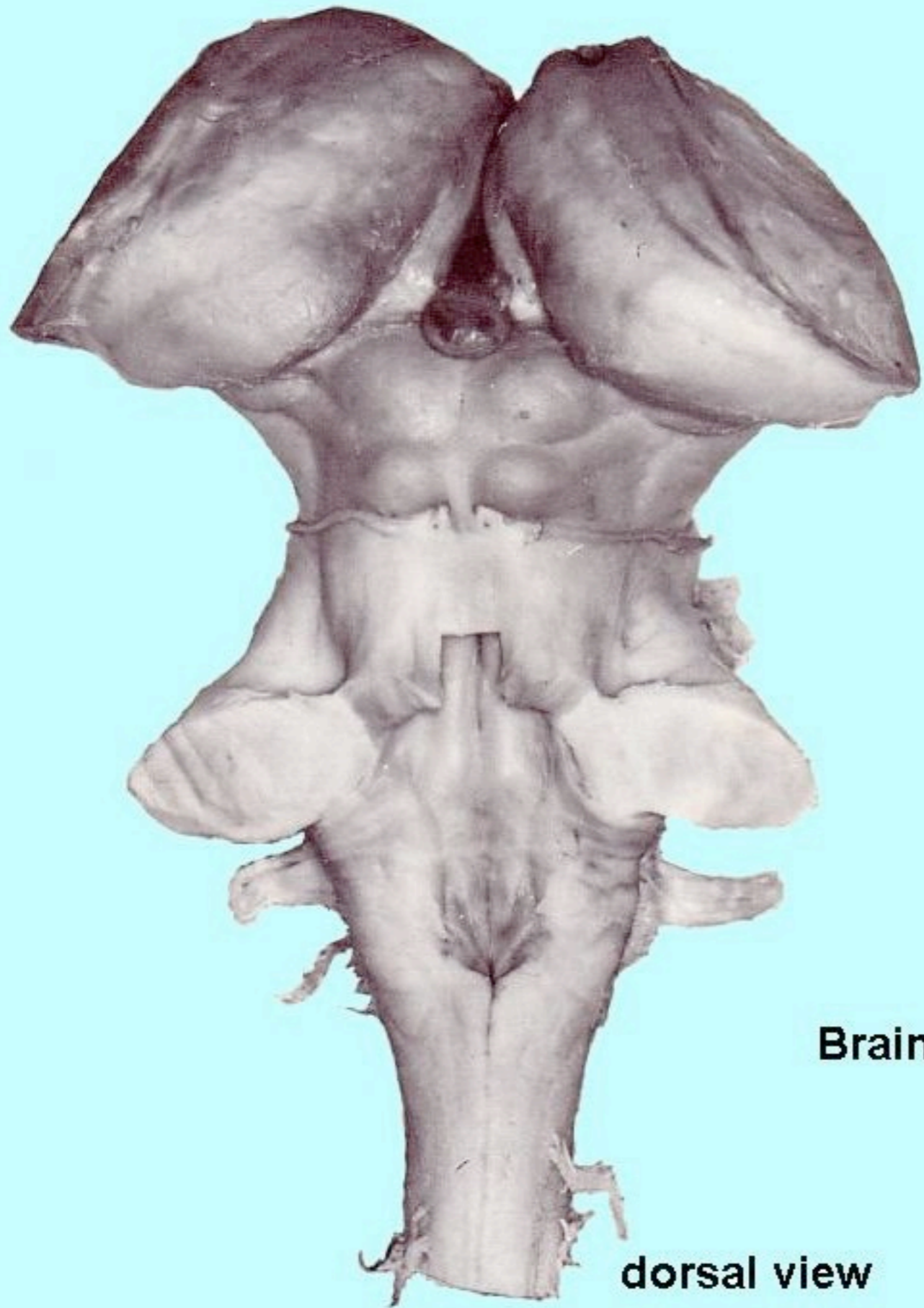
- septal nuclei
 - pleasure, reinforcement, social behavior
 - drives a theta rhythm in the hippocampus associated with learning and memory
 - lesions in animals cause “septal rage”
- hippocampus
 - memory consolidation - damage often results in STM failing to be consolidated to LTM
 - spatial learning and cognitive maps

Basal Ganglia



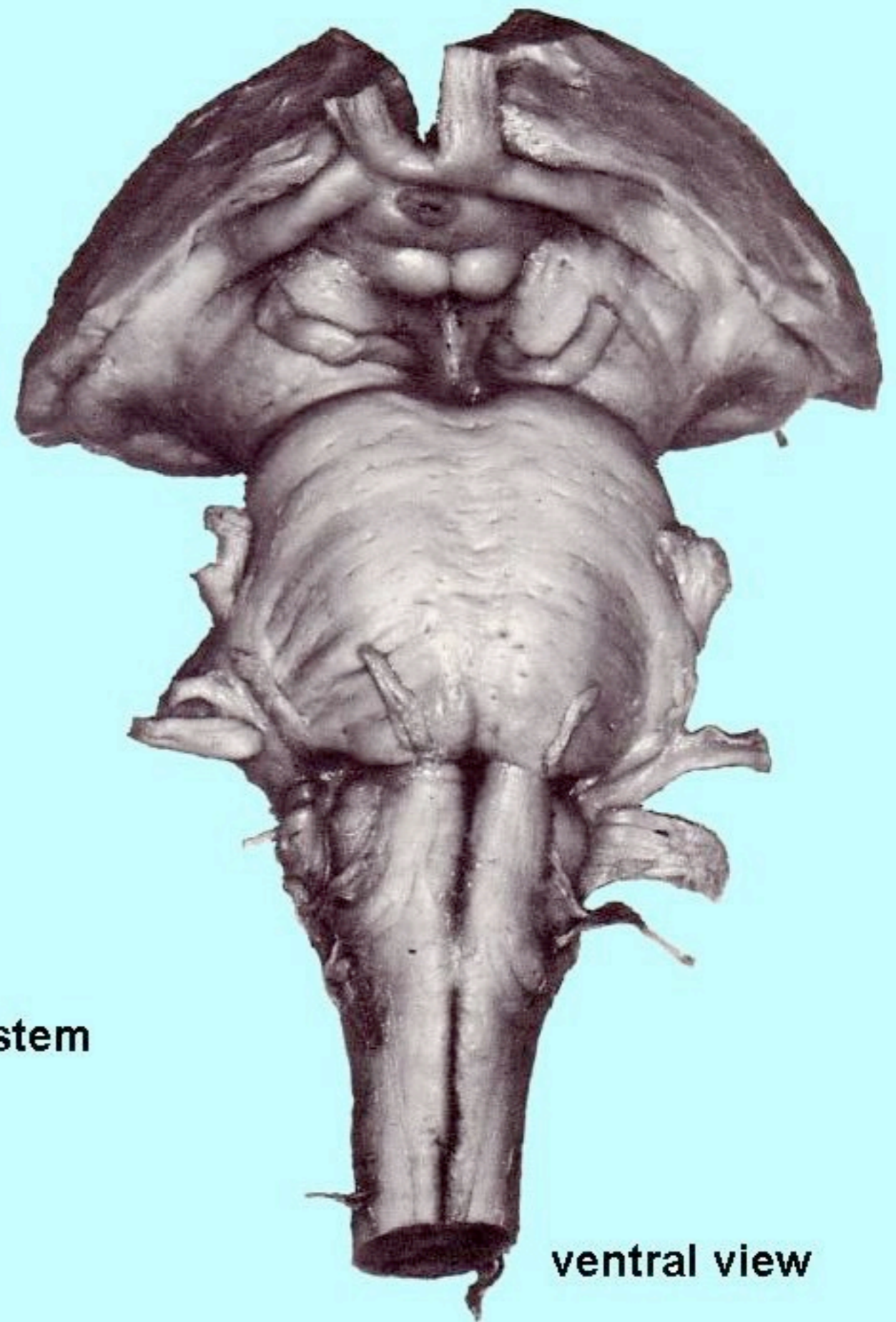
functions: movement, behavior selection, damage results in movement disorders

Diencephalon



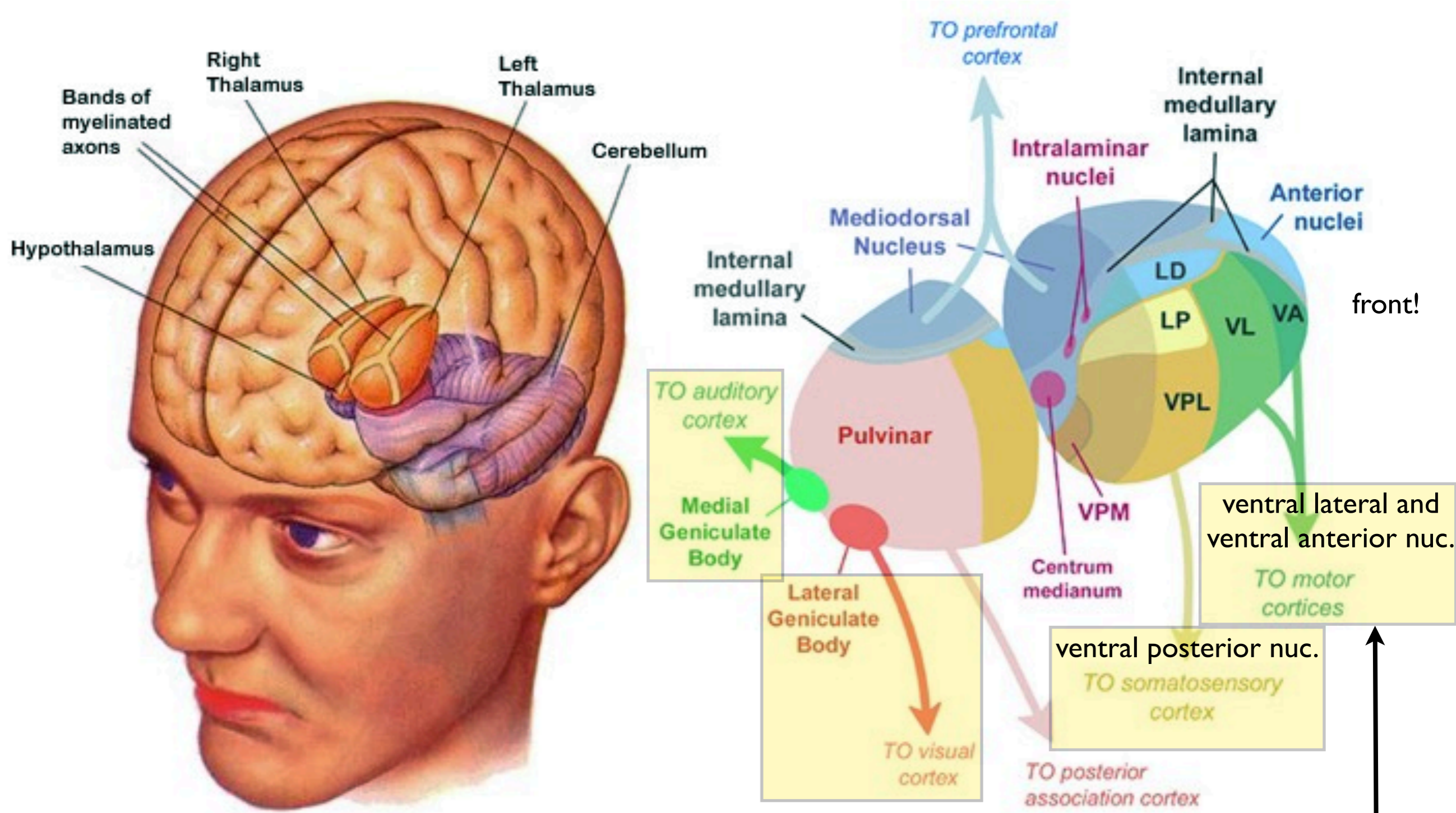
dorsal view

Brainstem



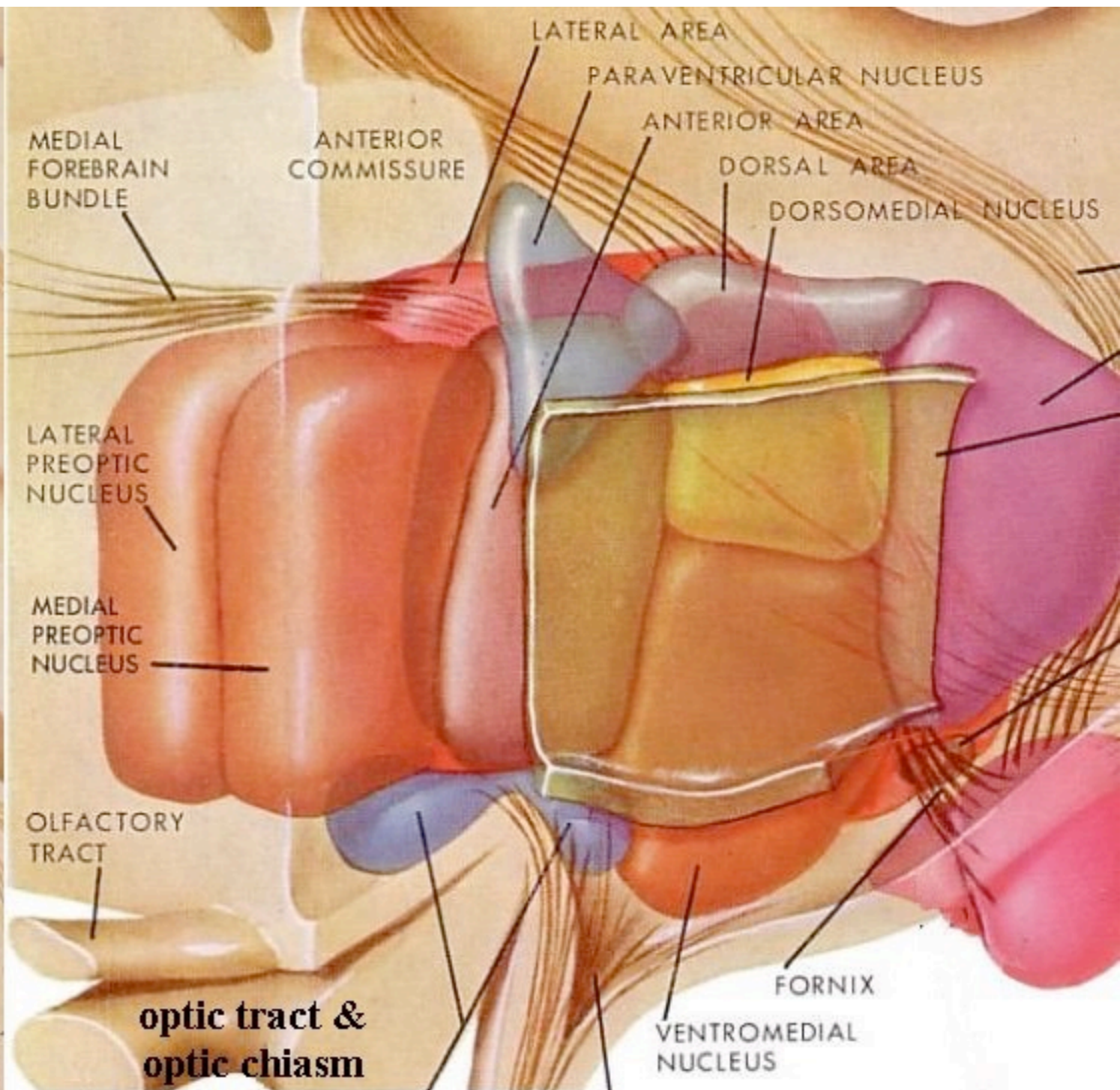
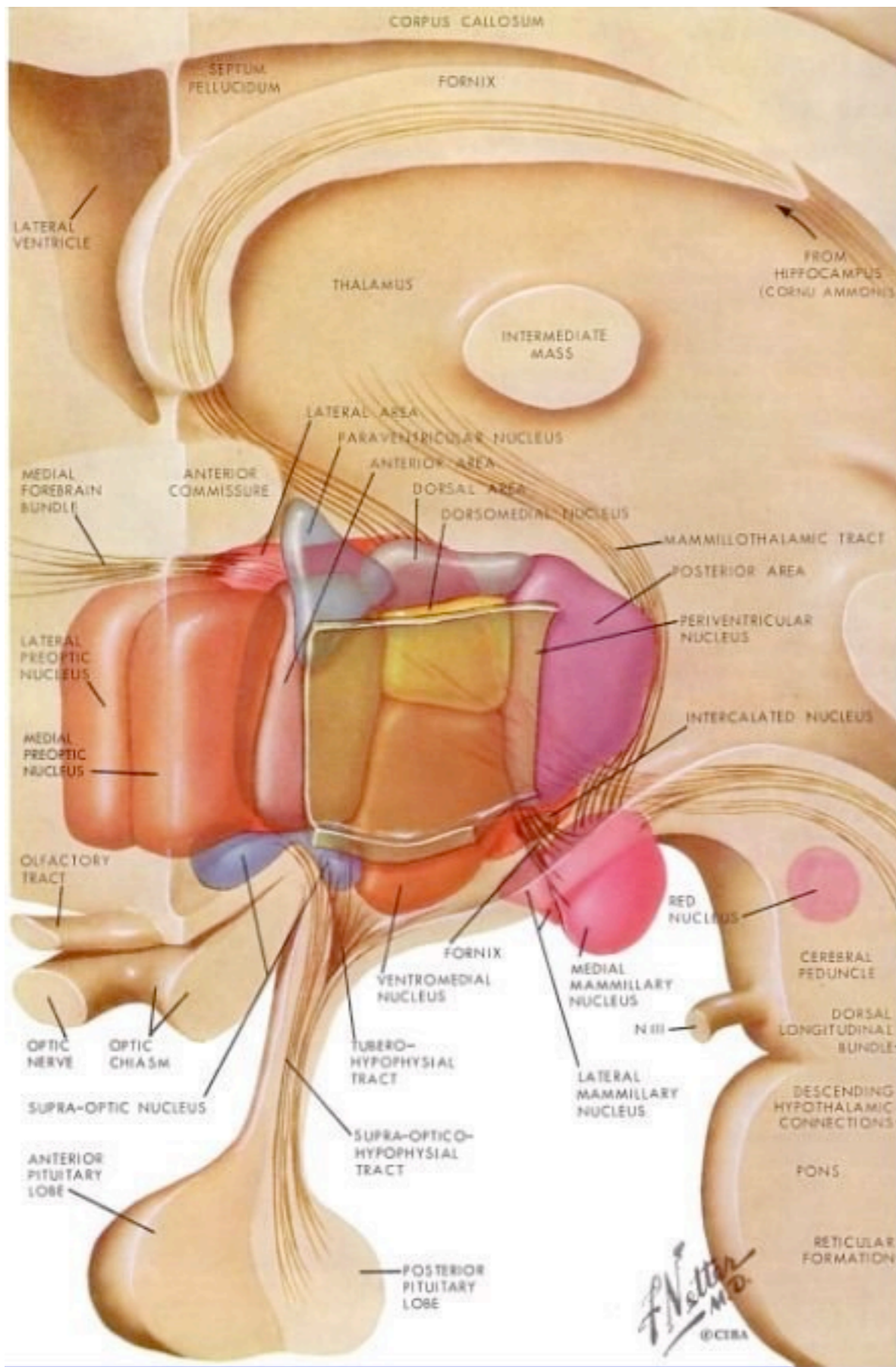
ventral view

Thalamus - a relay into the neocortex



Nuclei of the Thalamus

from basal ganglia and cerebellum



Nuclei of the Hypothalamus (Ciba)

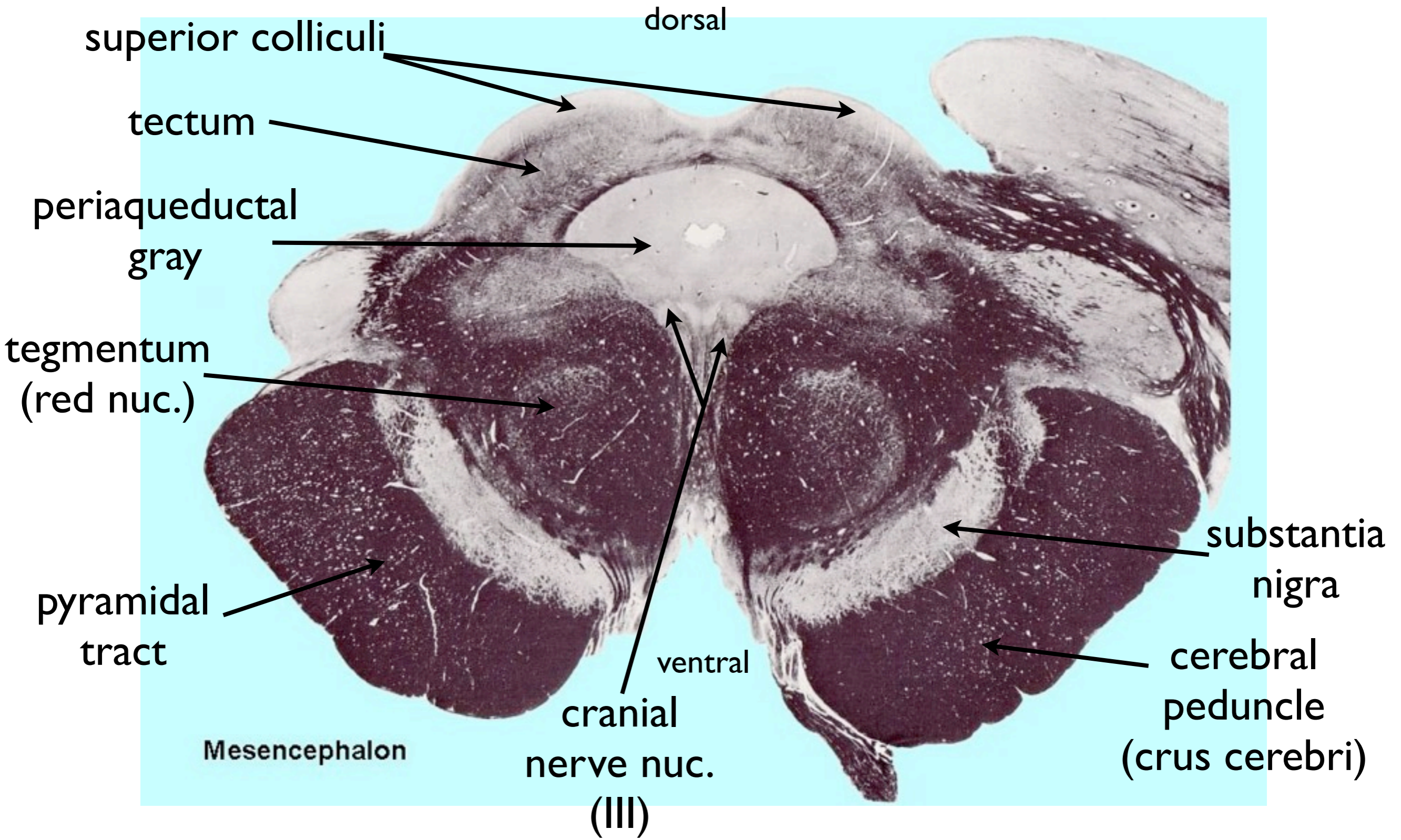
Functions of the Hypothalamus

- emotion and motivation via interconnections with the limbic system (some consider it part of the limbic system)
- homeostatic (self-regulating) drives such as hunger and thirst
- regulation of the pituitary gland
- regulation of the autonomic nervous system

The Lower Brainstem

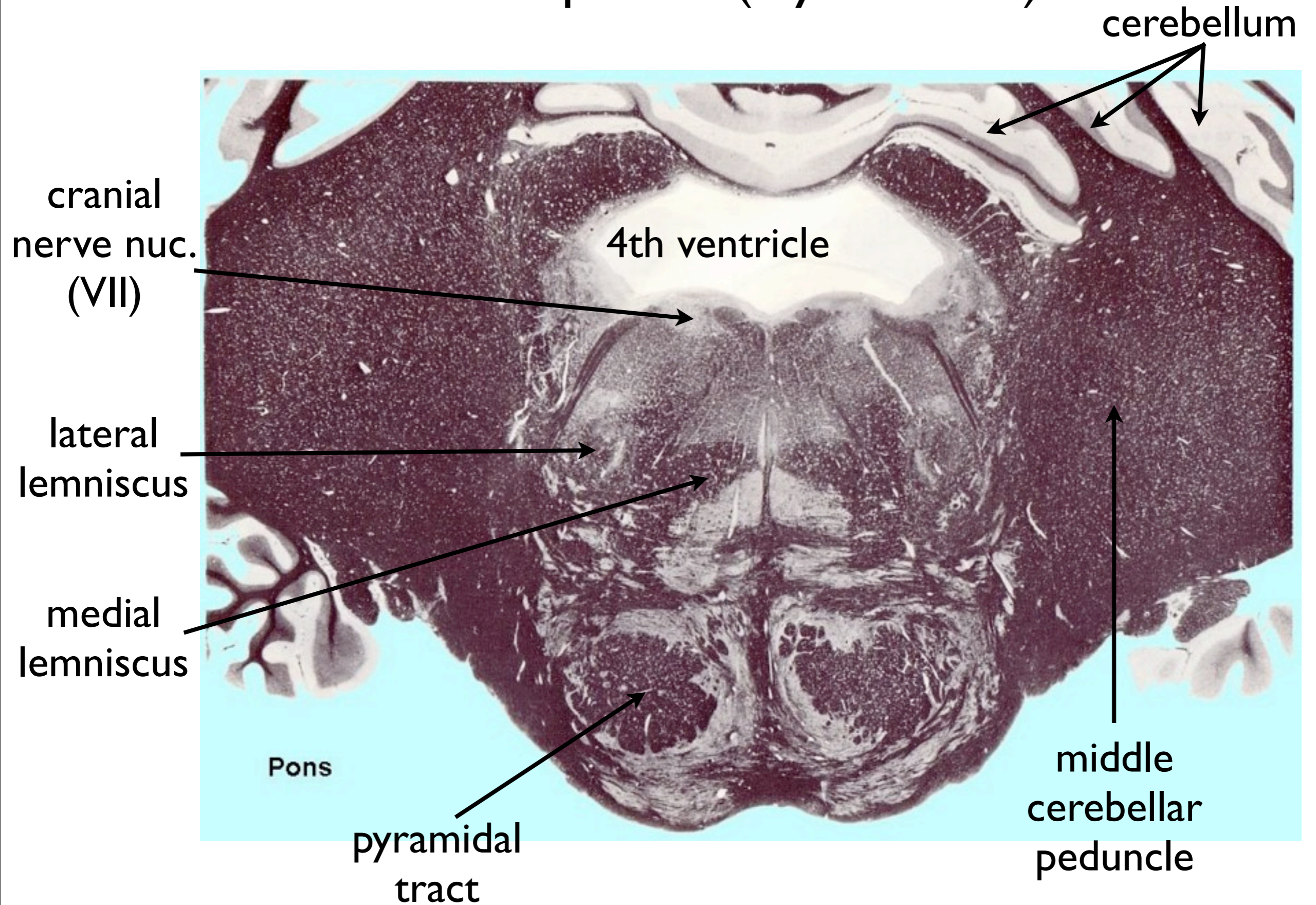
mesencephalon
metencephalon
myelencephalon

mesencephalon (myelin stain)



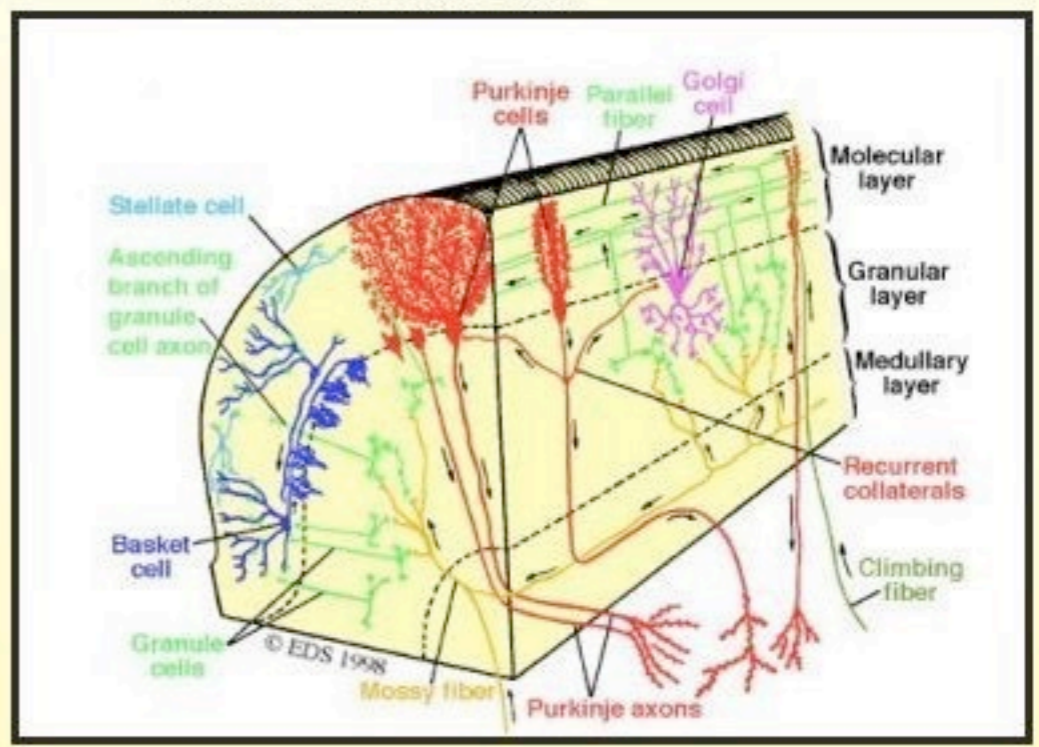
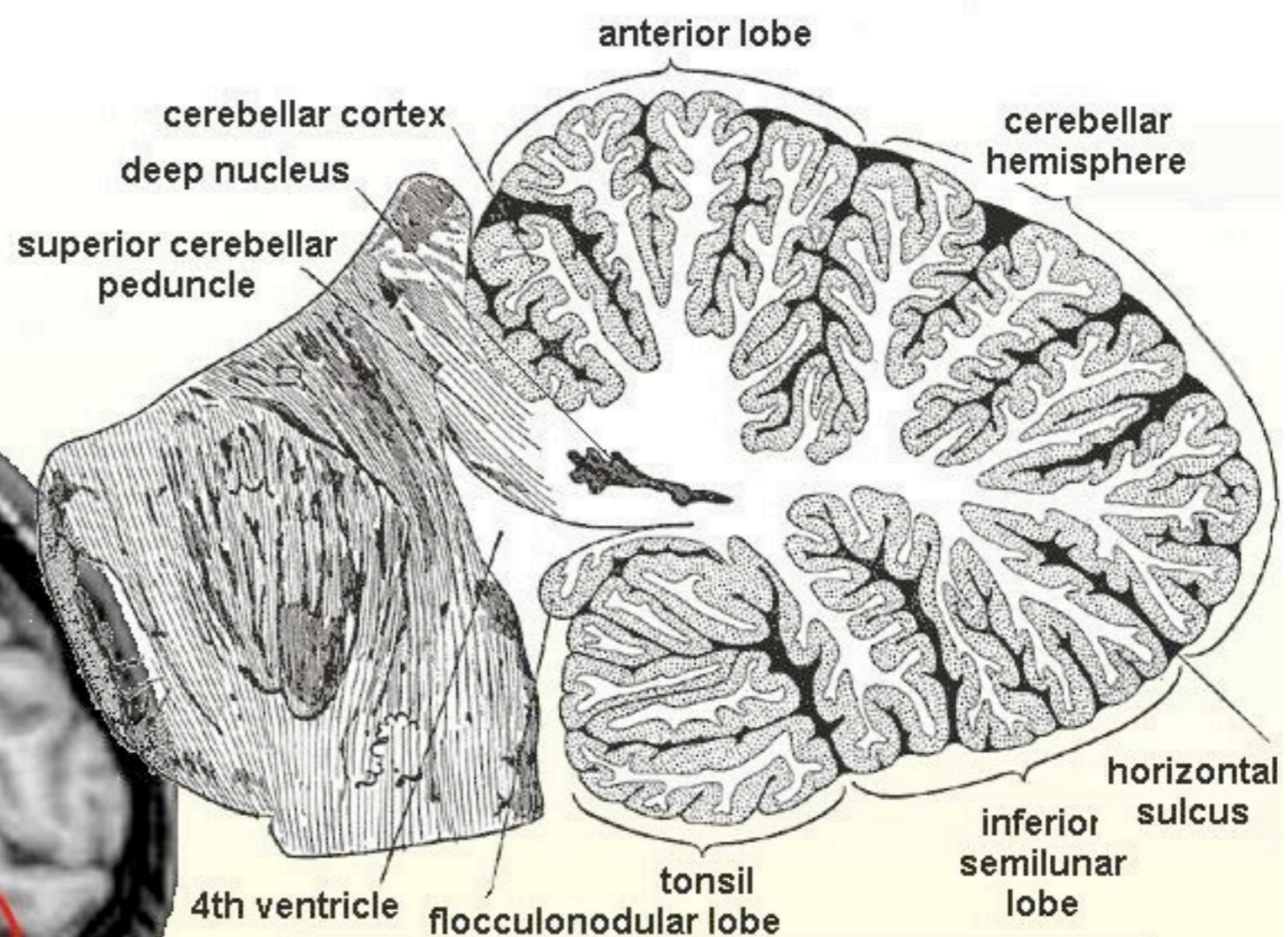
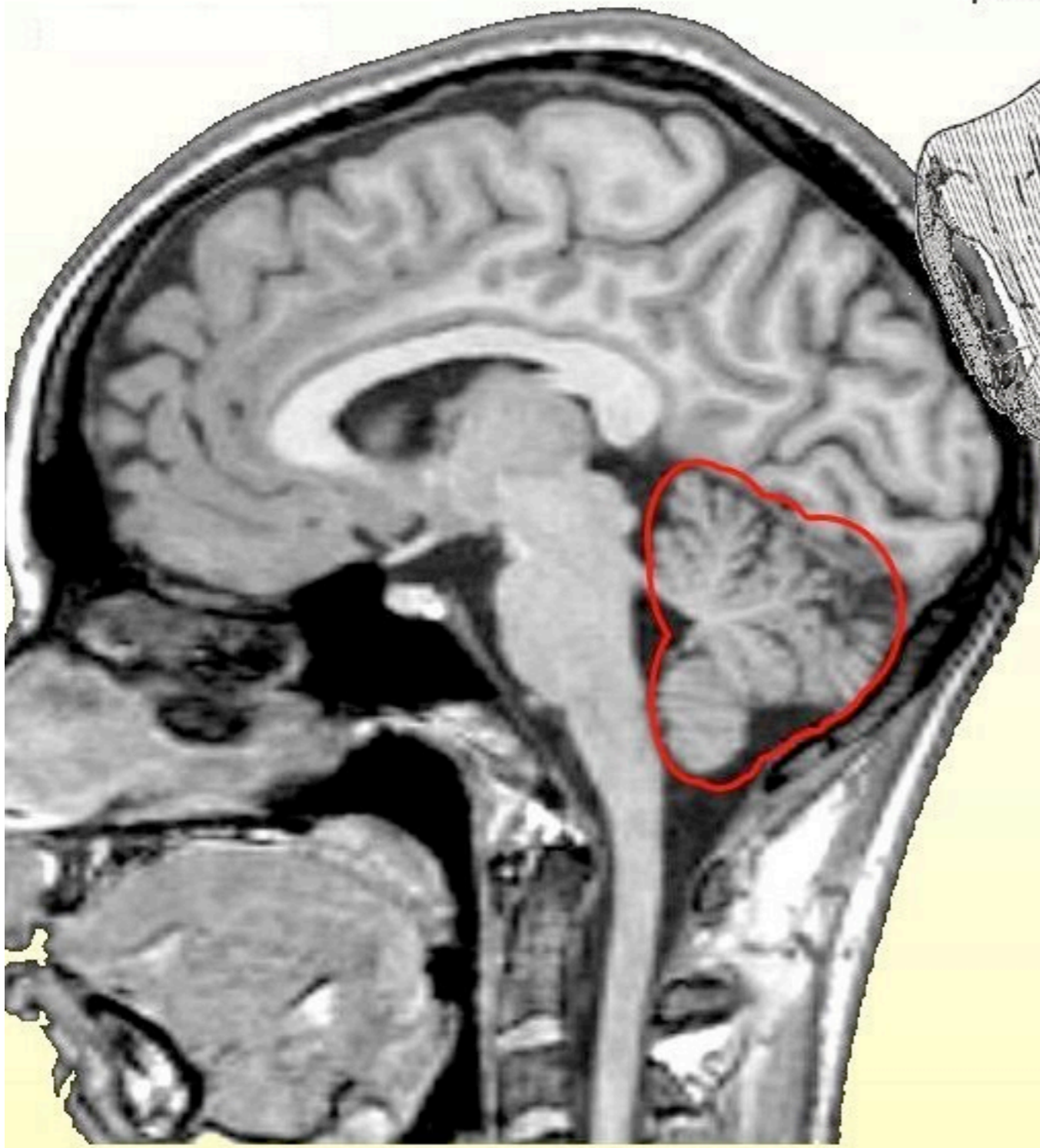
General rule of thumb in the brainstem and spinal cord: the more dorsal something is, the more likely it is to be sensory, and the more ventral the more likely it is to be motor.

metencephalon (myelin stain)

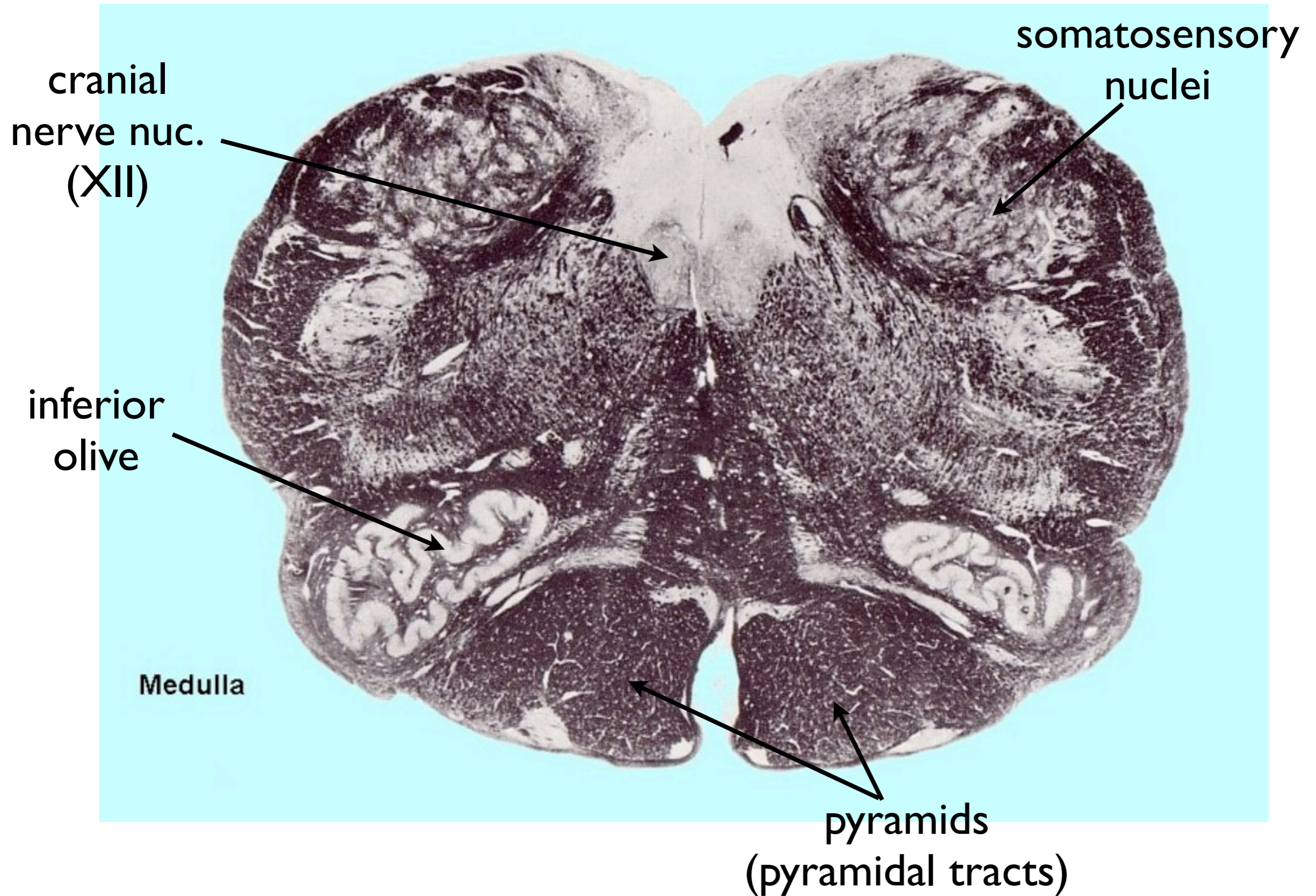


Cerebellum

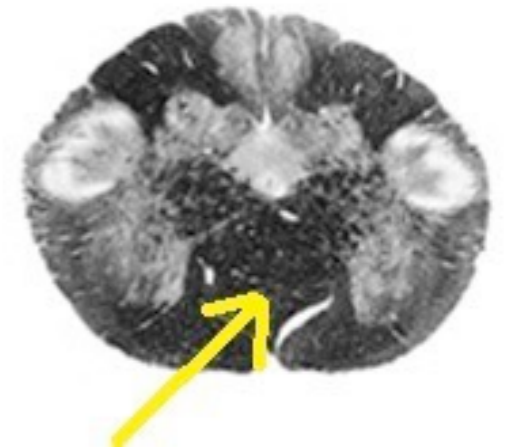
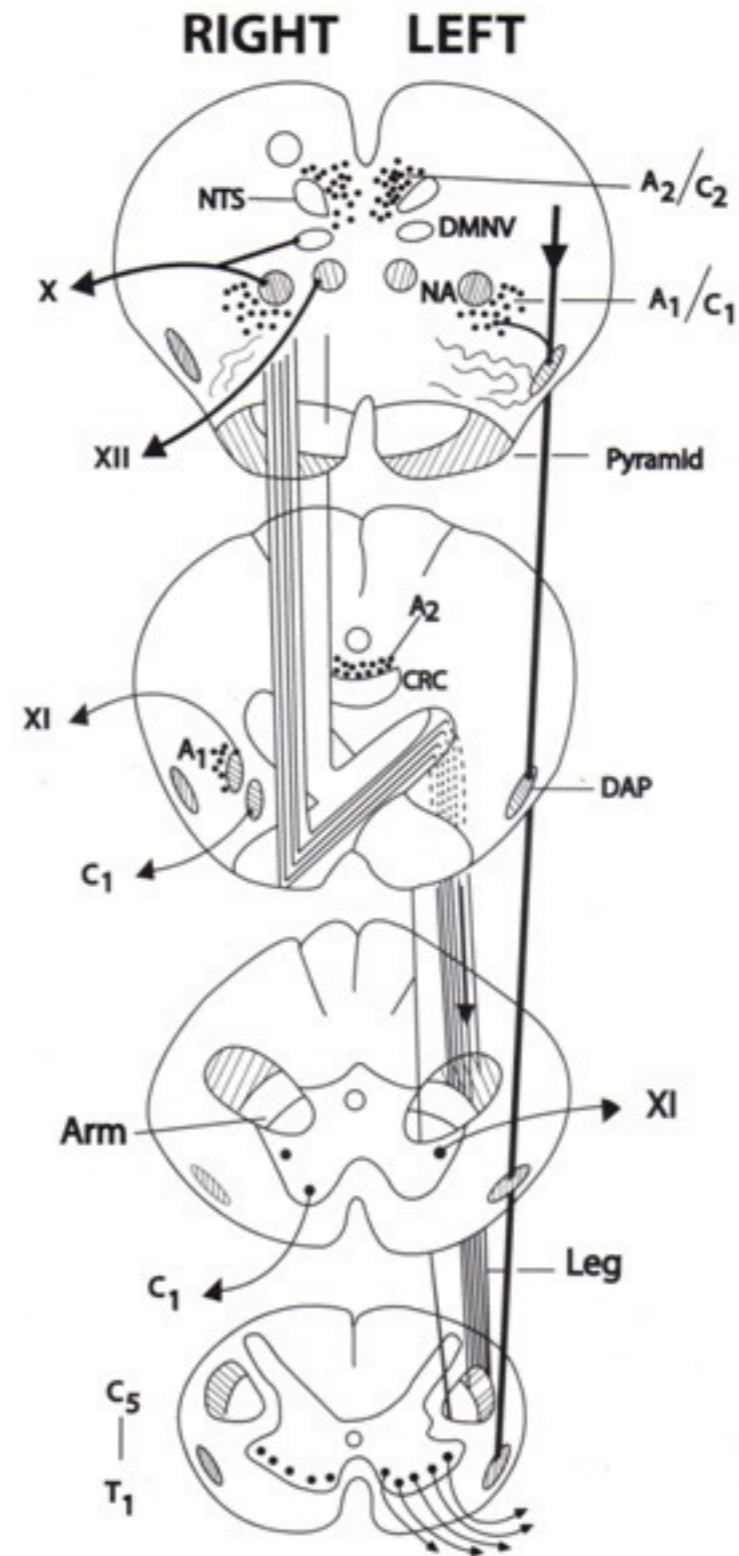
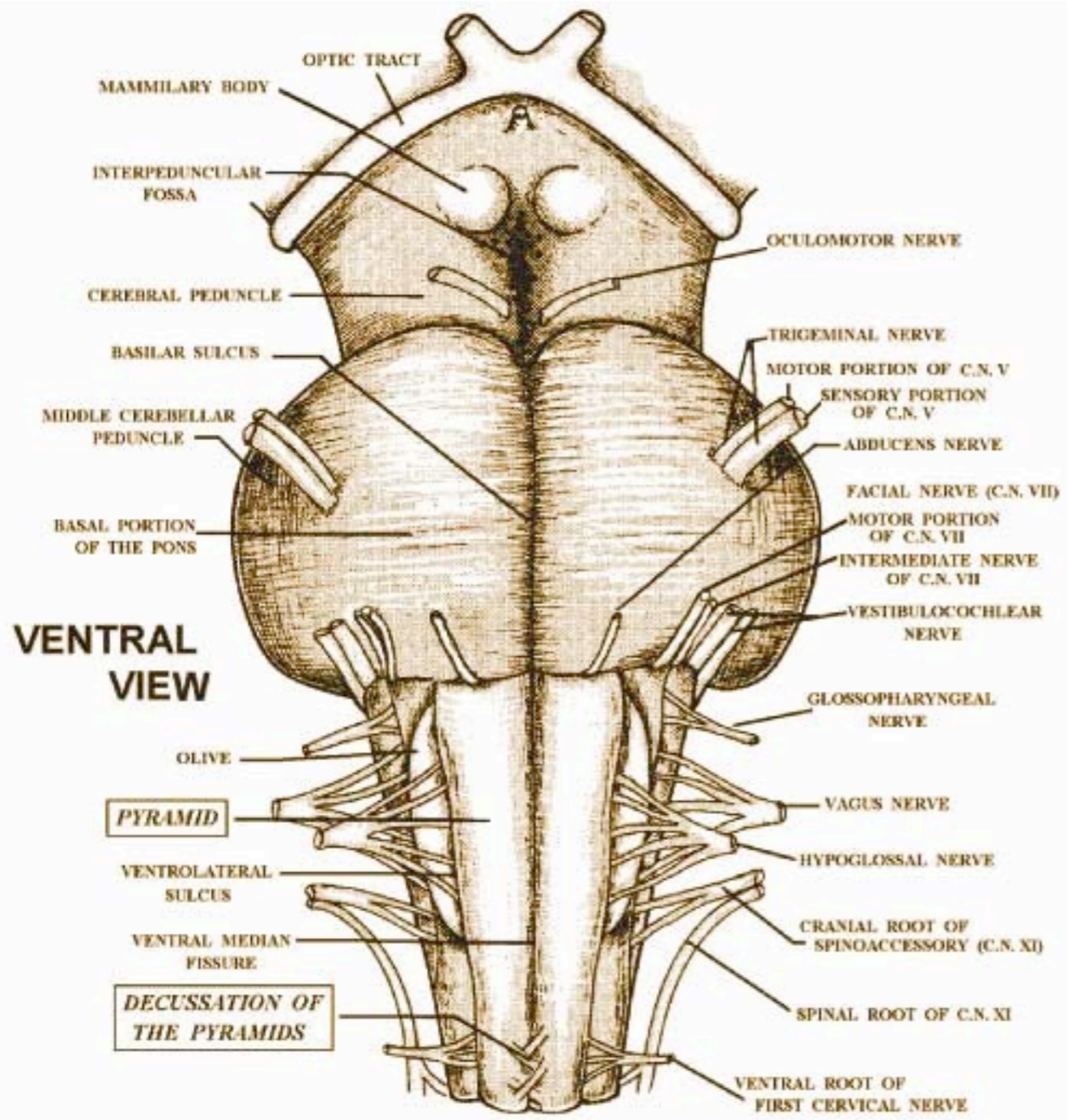
(as shown in an MRI sagittal section of the entire head)



myelencephalon (myelin stain)



Decussation of the pyramidal (corticospinal) tract



**(1.)
UPPER MOTOR NEURON
LESION**

Contralateral Hemiparesis

**Postural Flexion of Arm,
Extension of Leg**

Muscles Hypertonic

Tendon Reflexes Hyperactive

Atrophy Not Prominent

No Muscle Fasciculations

Pathological Reflexes Present



Flexed elbow



Bent wrist



Pronated forearm



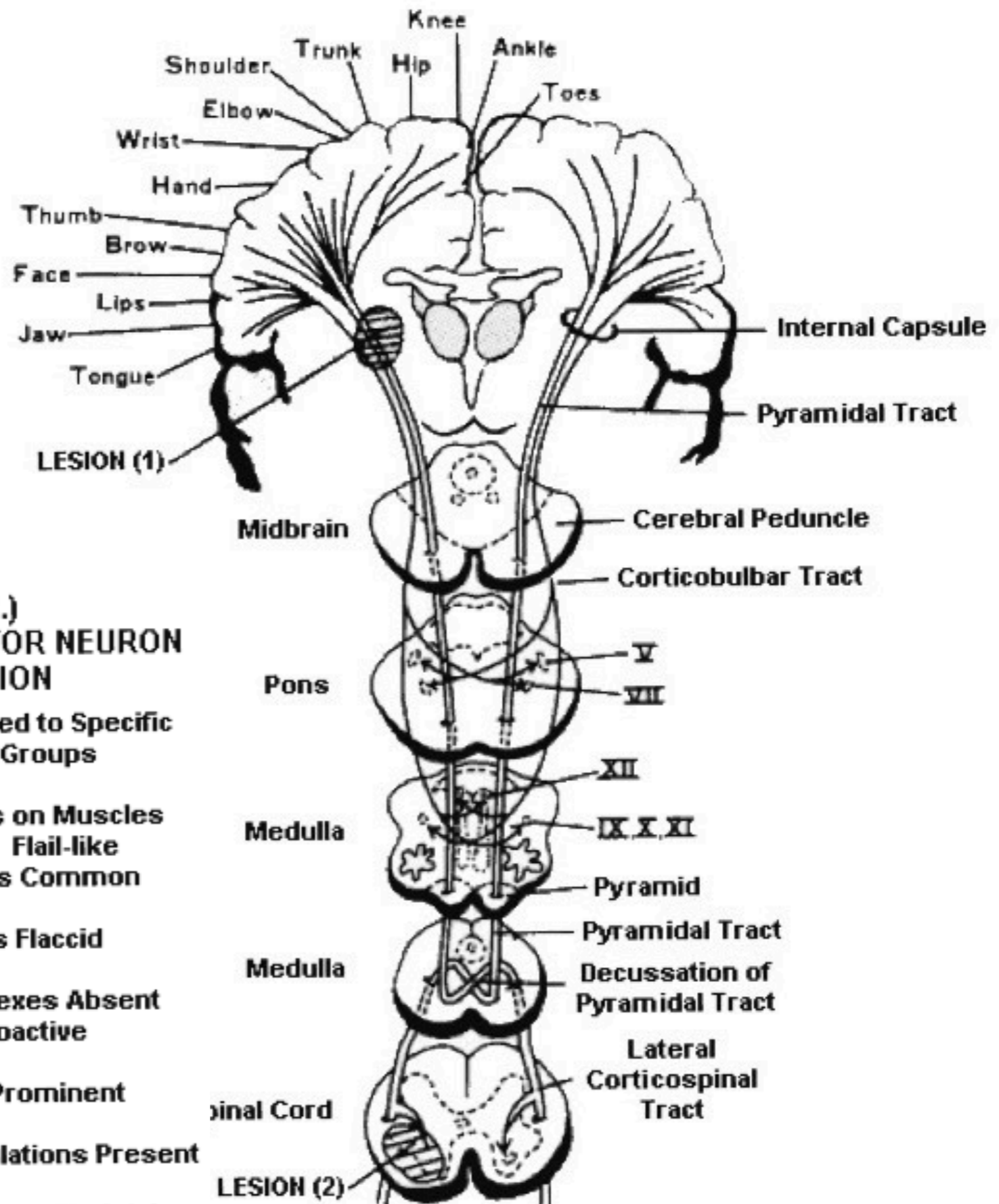
Clenched fist



Thumb in palm

spastic
paralysis

THE PYRAMIDAL MOTOR SYSTEM



**(2.)
LOWER MOTOR NEURON
LESION**

**Paresis Limited to Specific
Muscle Groups**

**Gait Depends on Muscles
Affected. Flail-like
Movements Common**

Muscles Flaccid

**Tendon Reflexes Absent
or Hypoactive**

Atrophy Prominent

Muscle Fasciculations Present

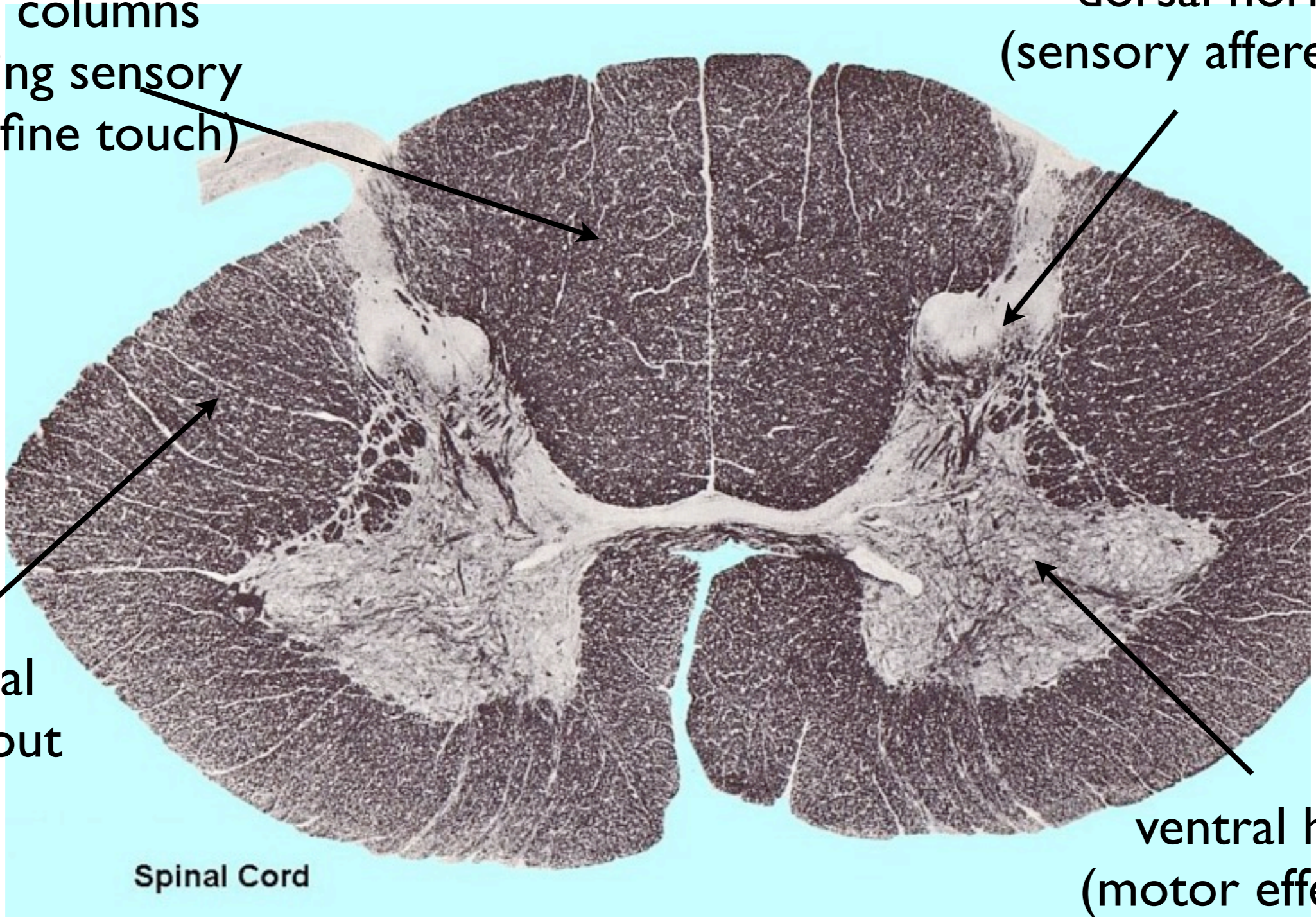
**Contractures & Skeletal
Deformities May Develop**

Spinal Cord

spinal cord (myelin stain)

dorsal columns
(ascending sensory
tracts - fine touch)

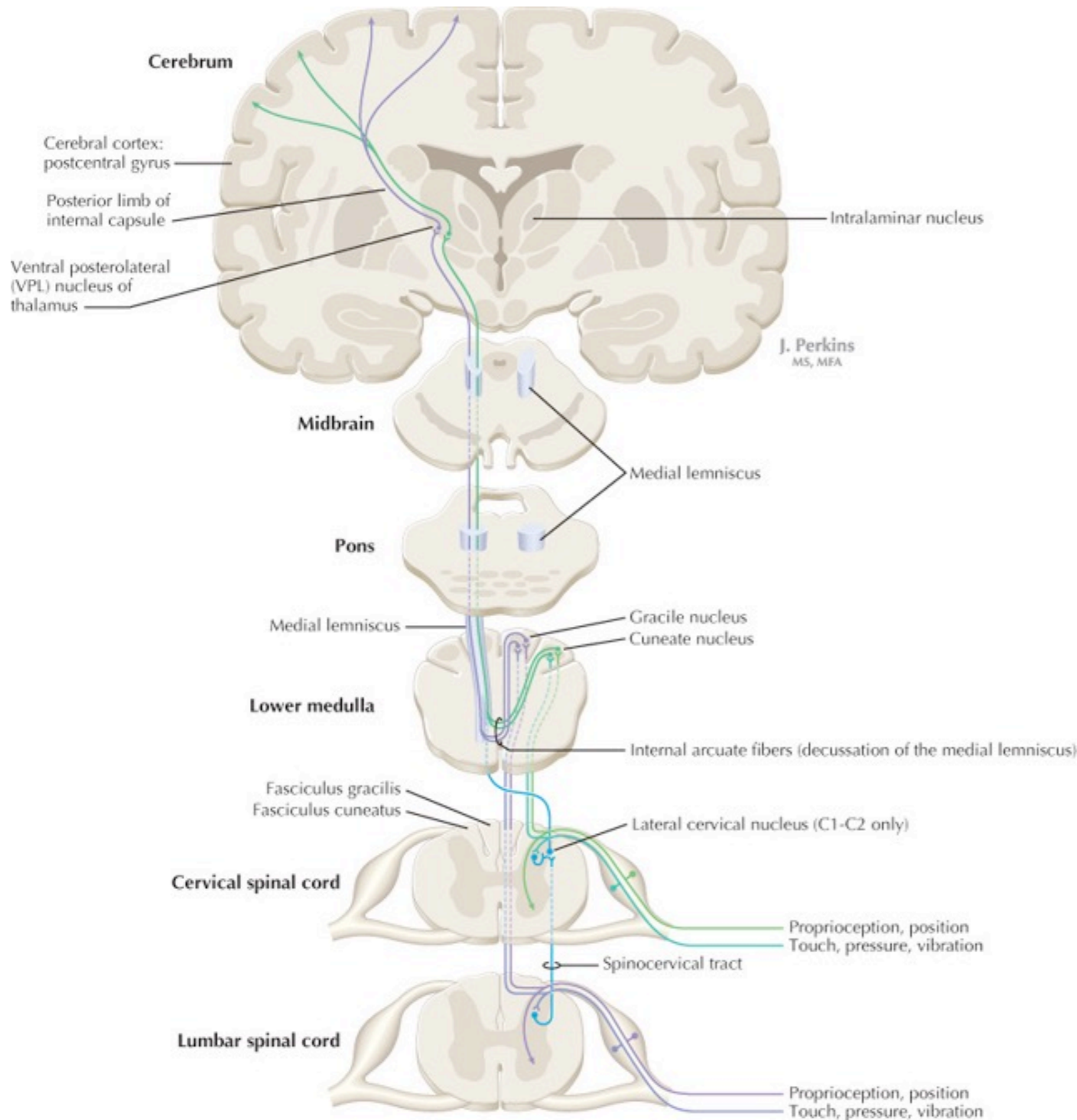
dorsal horn
(sensory afferents)



pyramidal
tract (about
here)

ventral horn
(motor efferents)

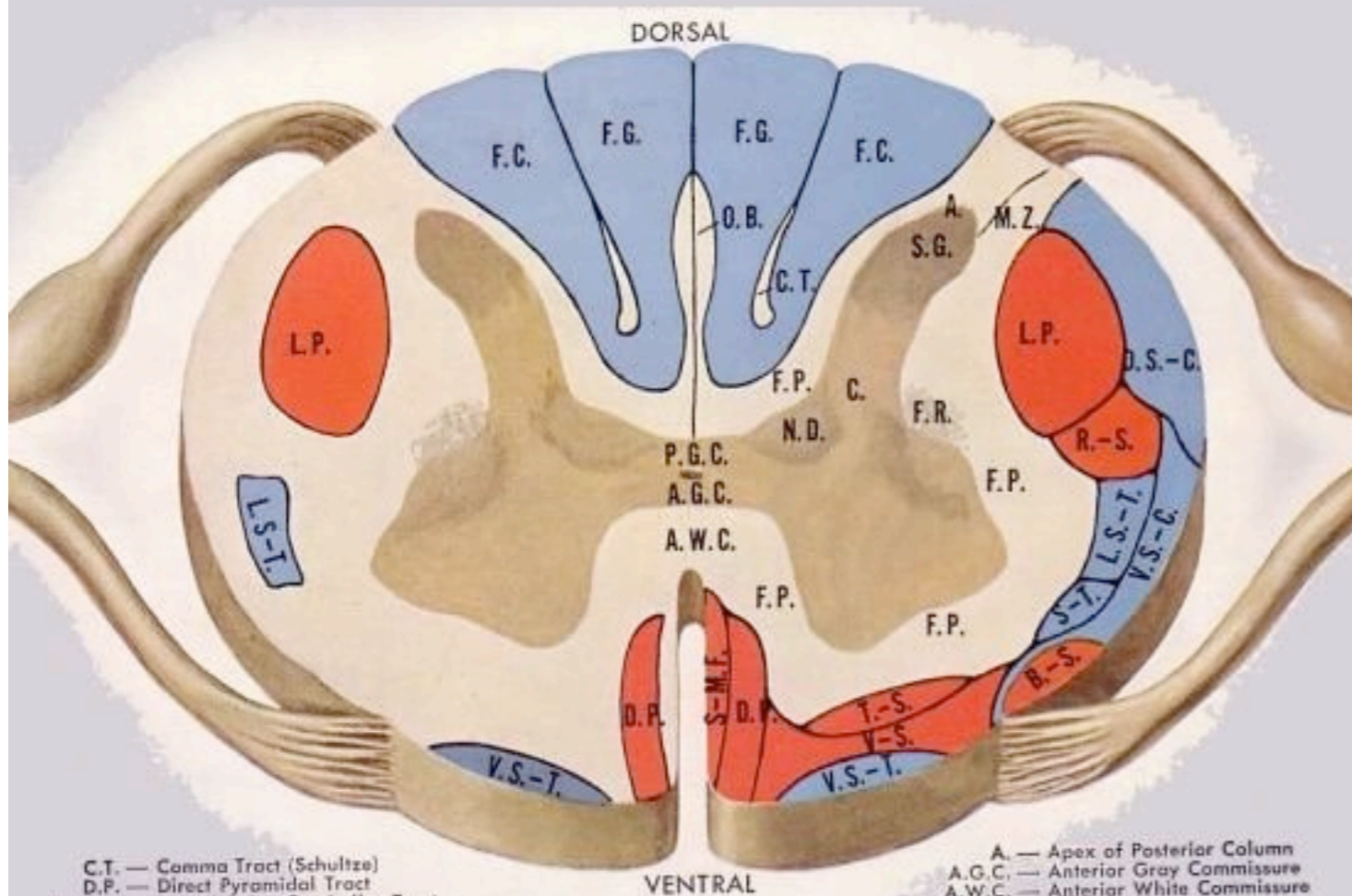
Spinal Cord



Somatosensory System (fine touch)

Felten & Shetty: Netter's Atlas of Neuroscience, 2nd Edition.
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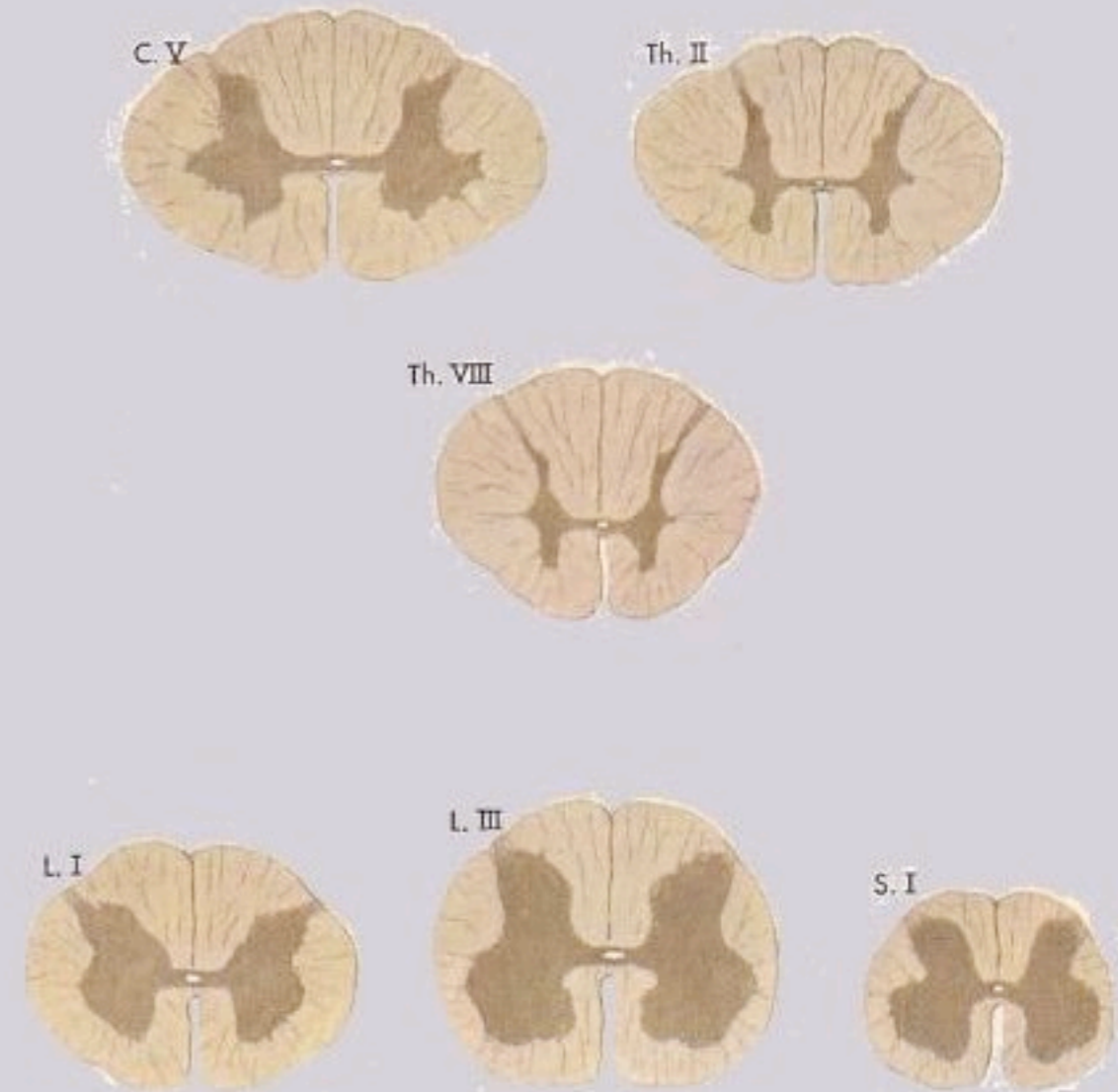
Schematic section of spinal cord (Ciba)



- C.T. — Gamma Tract (Schultze)
- D.P. — Direct Pyramidal Tract
- D.S.-C. — Dorsal Spino-Cerebellar Tract
- F.C. — Funiculus Cuneatus (Burdach)
- F.G. — Funiculus Gracilis (Goll)
- L.P. — Lateral Pyramidal Tract
- L.S.-T. — Lateral Spino-Thalamic Tract
- O.B. — Oval Bundle
- R.S. — Rubro-Spinal Tract
- S.T. — Spino-Tectal Tract
- T.S. — Tecto-Spinal Tract
- V.S.-C. — Ventral Spino-Cerebellar Tract (Gower)
- V.S.-T. — Ventral Spino-Thalamic Tract

Schematic section through spinal cord, showing on left the tracts of greatest clinical importance and, on right, other tracts and landmarks as well.
(RED indicates tracts from brain to cord; BLUE, from cord to brain.)

- A. — Apex of Posterior Column
- A.G.C. — Anterior Gray Commissure
- A.W.C. — Anterior White Commissure
- B.S. — Bulbo-Spinal Tract (Helwig's Bundle)
- C. — Cervix of Posterior Column
- F.P. — Fasciculus Proprius
- F.R. — Formatio Reticularis
- M.Z. — Marginal Zone
- N.D. — Nucleus Dorsalis
- P.G.C. — Posterior Gray Commissure
- S.G. — Substantia Gelatinosa
- S-M.F. — Sulca-Marginal Fasciculus
- V.S. — Vestibulo-Spinal Tract

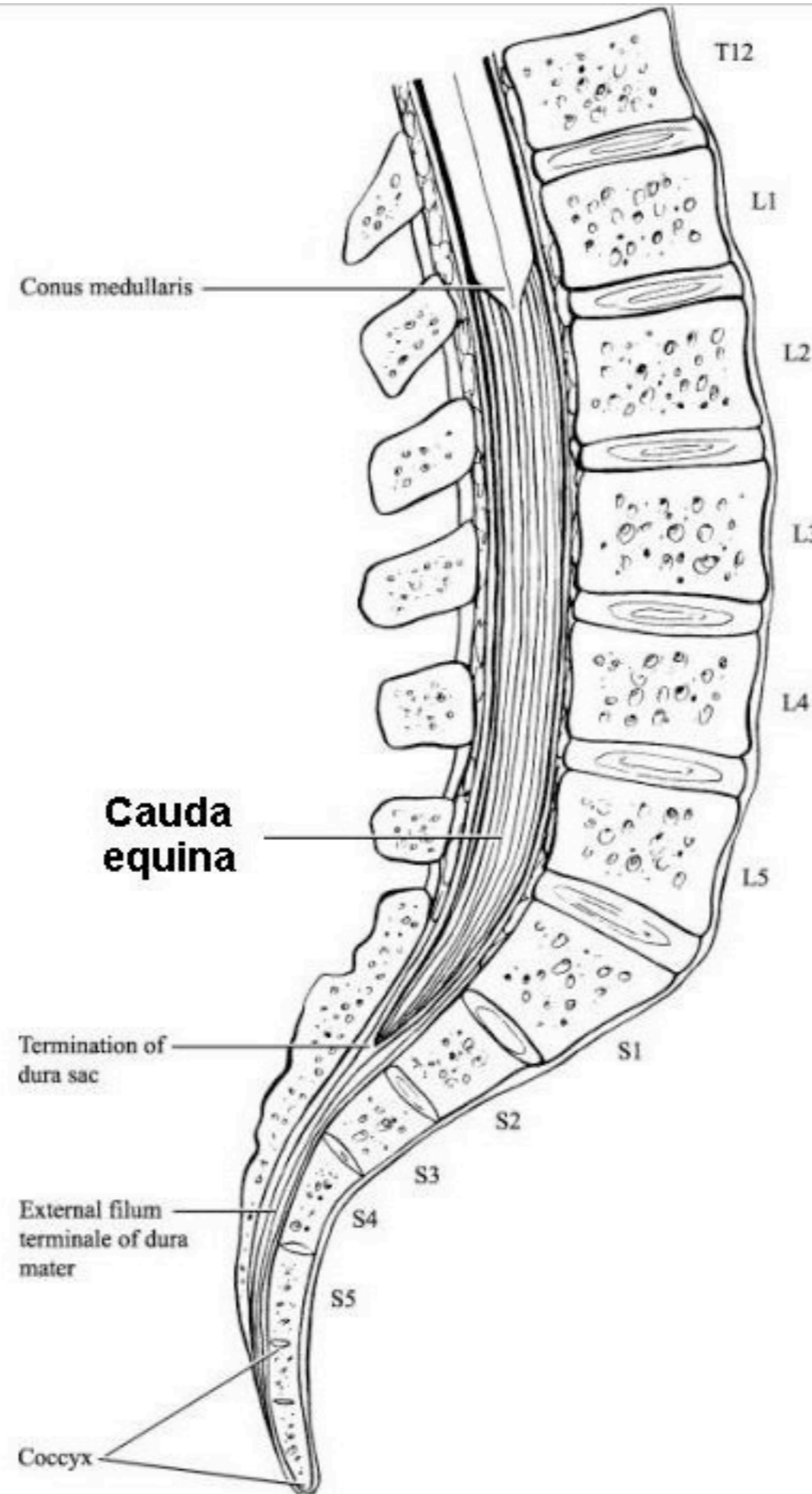


Representative sections through cord at various levels.



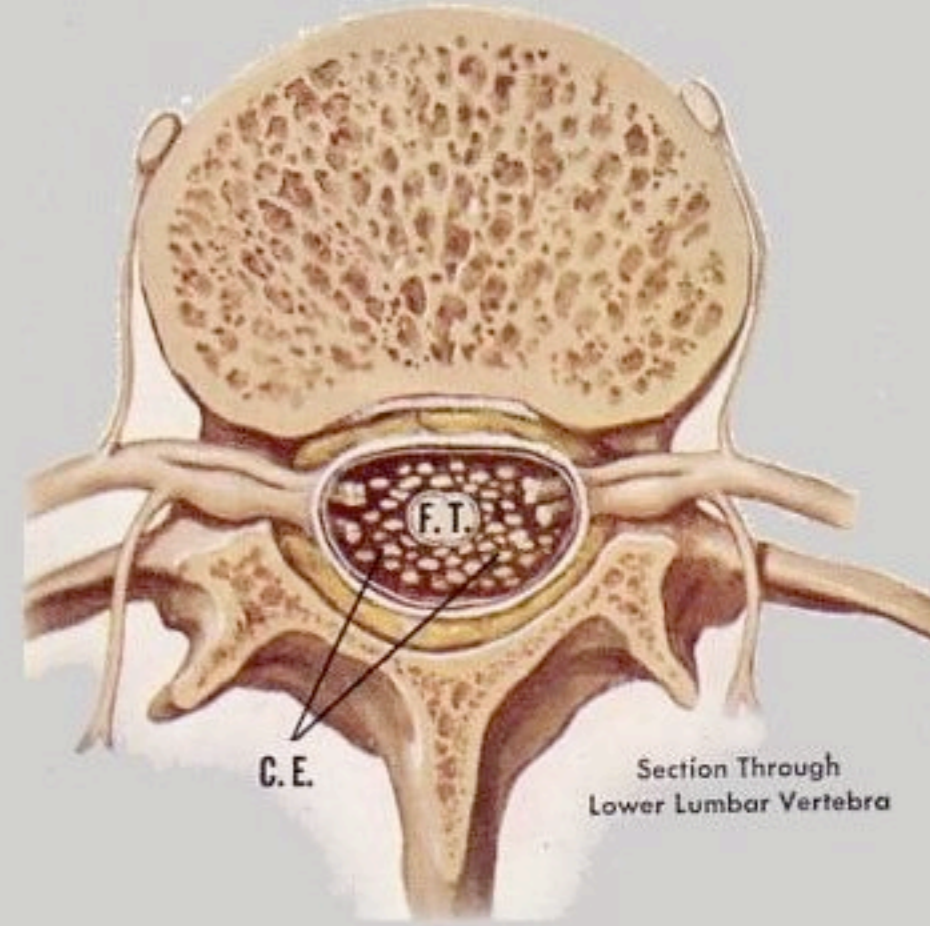
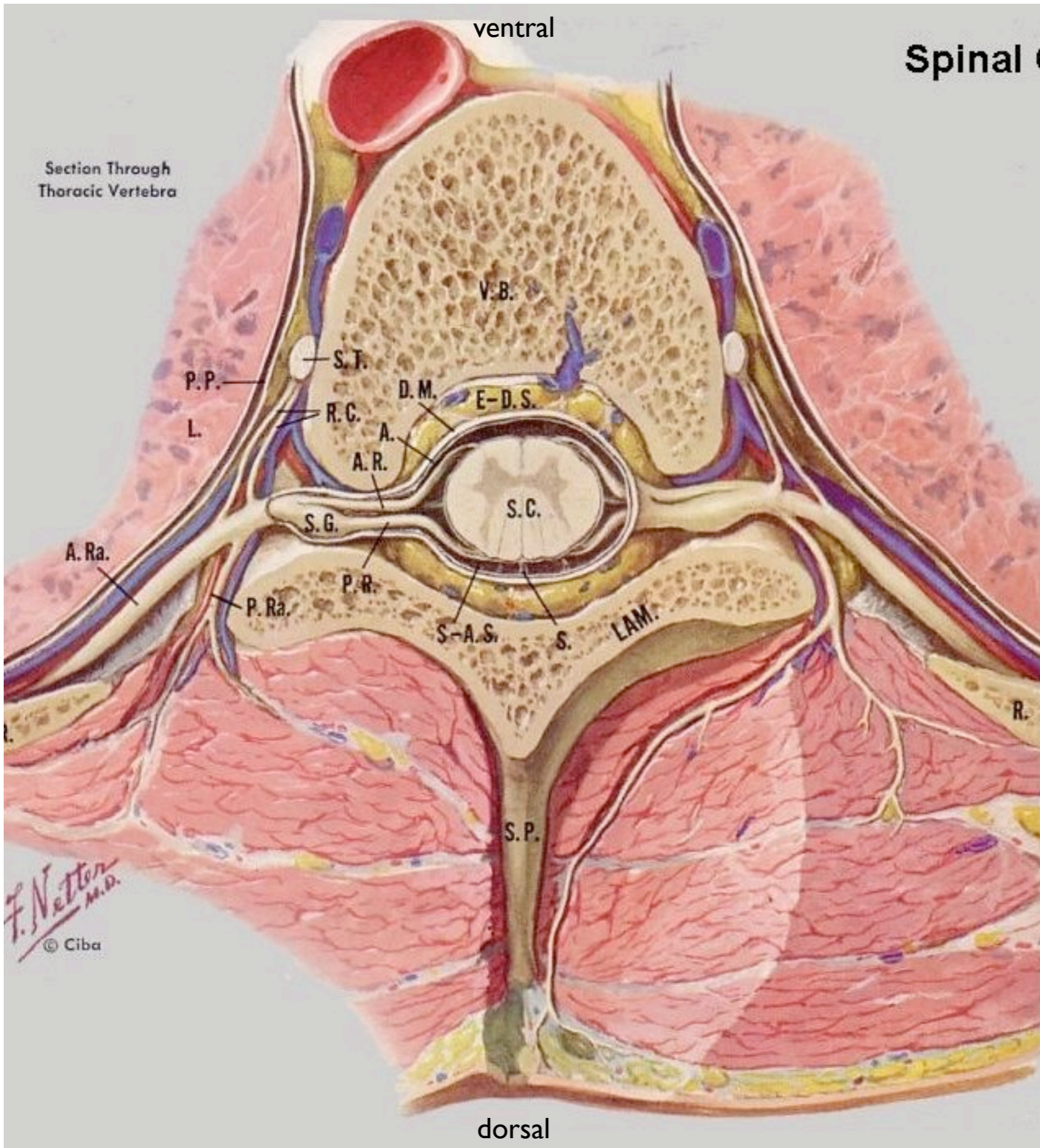
Sensory pathways are shown in blue;
motor pathways are shown in red.

The spinal cord ends about 2/3 rds of the way down the spine.



Spinal Cord in situ (Ciba)

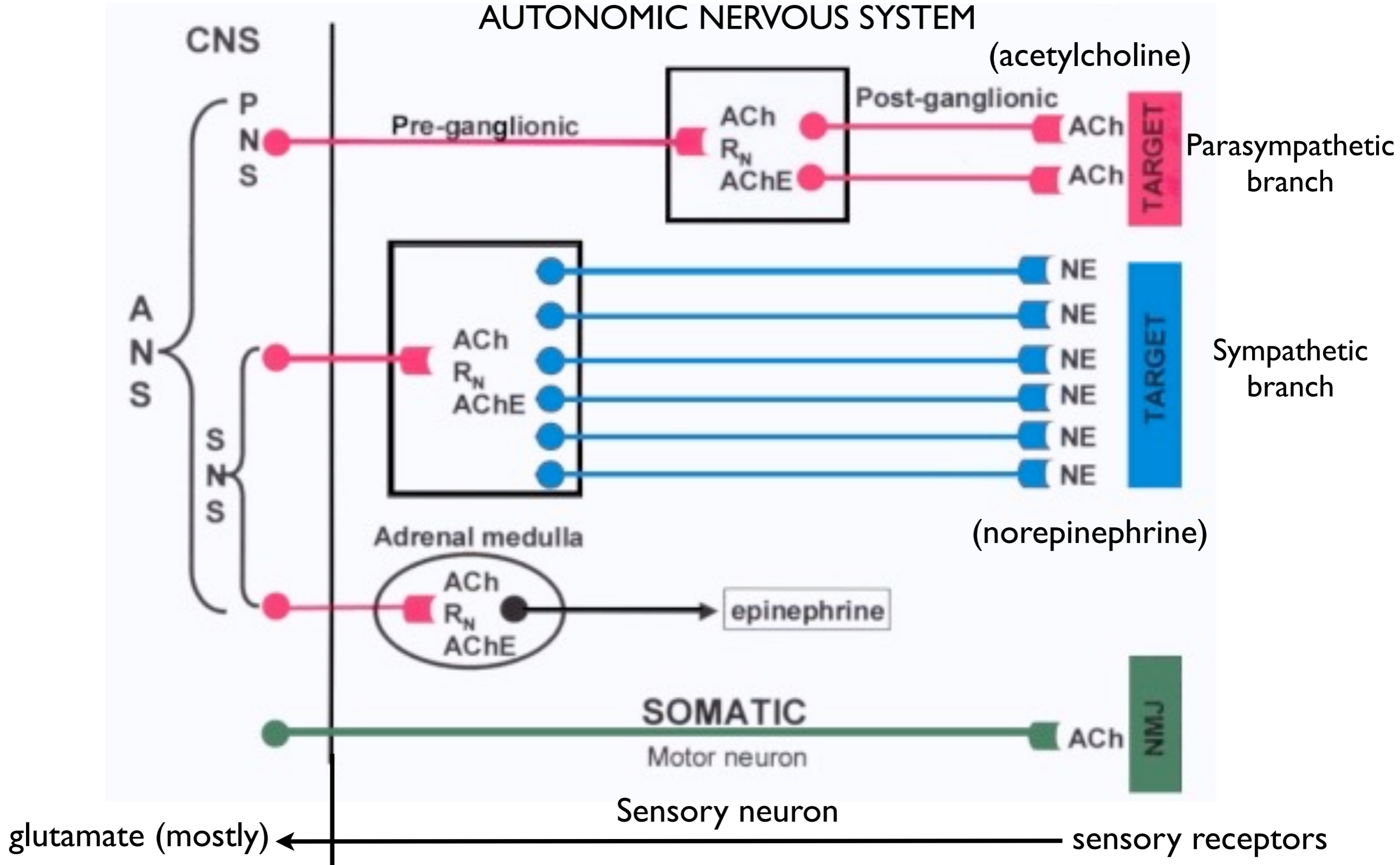
Section Through Thoracic Vertebra



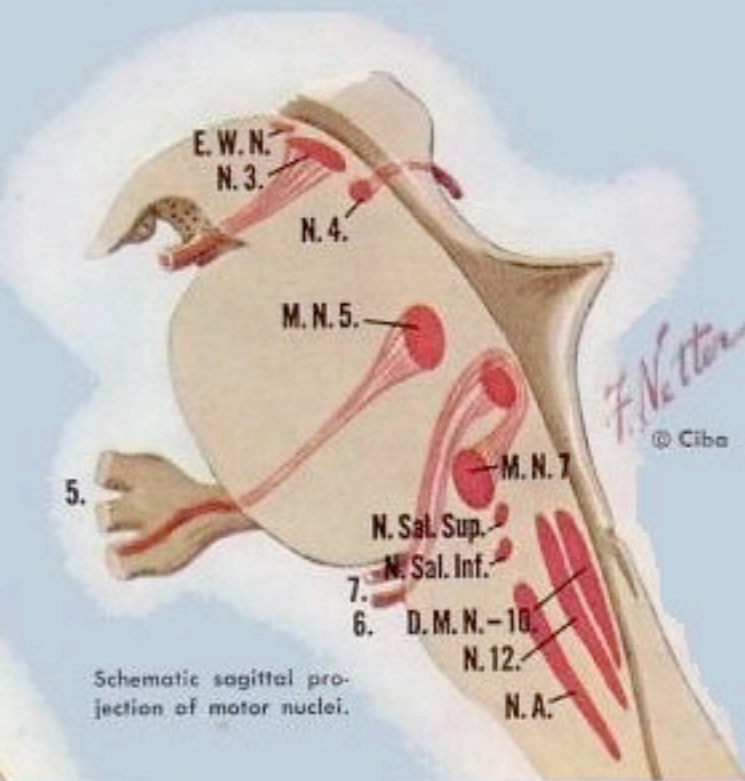
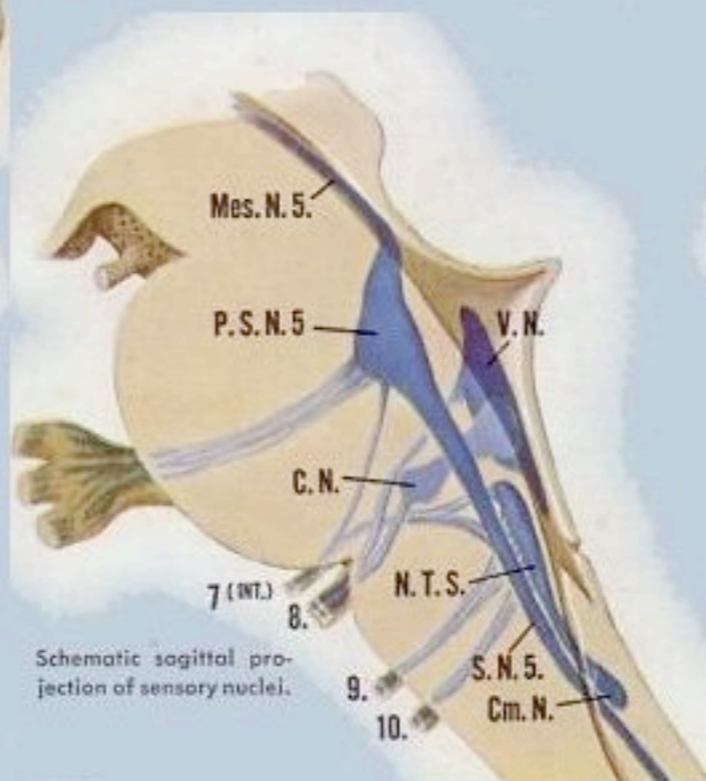
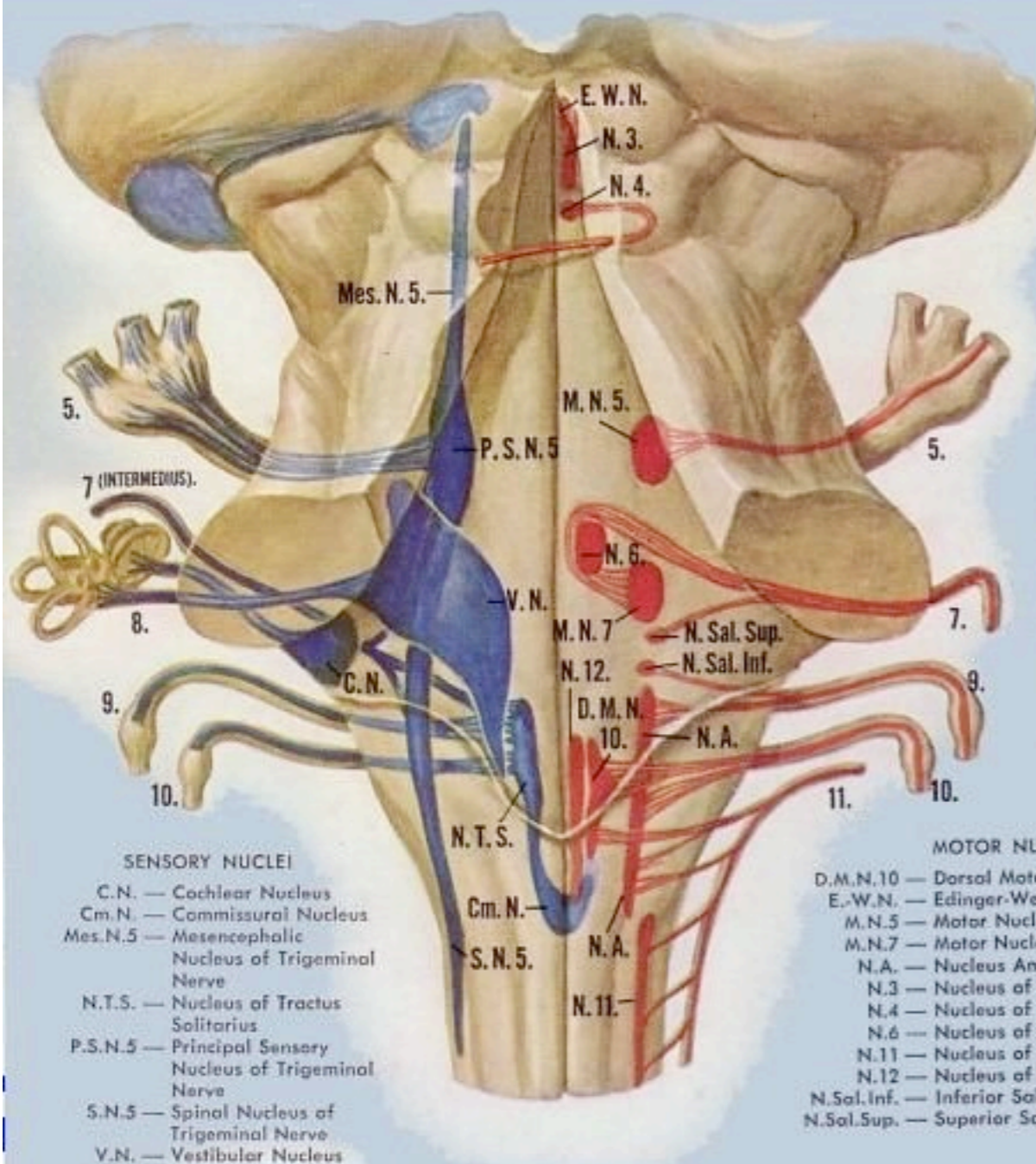
- A. — Arachnoid
- A.R. — Anterior Root of Spinal Nerve
- A.Ra. — Anterior Ramus of Thoracic Nerve (Intercostal Nerve)
- C.E. — Cauda Equina
- D.M. — Dura Mater
- E-D.S. — Epidural Space
- F.T. — Filum Terminale
- LAM. — Lamina
- L. — Lung
- P.P. — Parietal Pleura
- P.Ra. — Posterior Ramus of Thoracic Nerve
- P.R. — Posterior Root of Spinal Nerve
- R. — Rib
- R.C. — Rami Communicantes
- S. — Subarachnoid Septum
- S-A.S. — Subarachnoid Space
- S.C. — Spinal Cord
- S.G. — Spinal Ganglion
- S.P. — Spinous Process
- S.T. — Sympathetic Trunk
- V.B. — Vertebral Body

F. Netter M.D.
© Ciba

Spinal Nerves



cranial nerves



- MOTOR NUCLEI**
- D.M.N.10 — Dorsal Motor Nucleus of Vagus
 - E.-W.N. — Edinger-Westphal Nucleus
 - M.N.5. — Motor Nucleus of Trigeminal Nerve
 - M.N.7. — Motor Nucleus of Facial Nerve
 - N.A. — Nucleus Ambiguus
 - N.3. — Nucleus of Oculomotor
 - N.4. — Nucleus of Trochlear
 - N.6. — Nucleus of Abducens
 - N.11. — Nucleus of Spinal Accessory
 - N.12. — Nucleus of Hypoglossal
 - N.Sal.Inf. — Inferior Salivatory Nucleus
 - N.Sal.Sup. — Superior Salivatory Nucleus

Cranial Nerve Nuclei (Ciba)

— sensory fibres
— motor fibres

Optic (II)
sensory: eye



Trochlear (IV)
motor: superior oblique muscle



Abducent (VI)
motor: external rectus muscle



Oculomotor (III)
motor: all eye muscles except those supplied by IV and VI



Trigeminal (V)
sensory: face, sinuses, teeth, etc.
motor: muscles of mastication



Facial (VII)
motor: muscles of the face



Hypoglossal (XII)
motor: muscles of the tongue



Intermediate motor: submaxillary and sublingual gland

sensory: anterior part of tongue and soft palate



Glossopharyngeal (IX) motor: pharyngeal musculature

sensory: posterior part of tongue, tonsil, pharynx



Vestibulocochlear (VIII) sensory: inner ear



Vagus (X) motor: heart, lungs, bronchi, gastrointestinal tract

sensory: heart, lungs, bronchi, trachea, larynx, pharynx, gastrointestinal tract, external ear



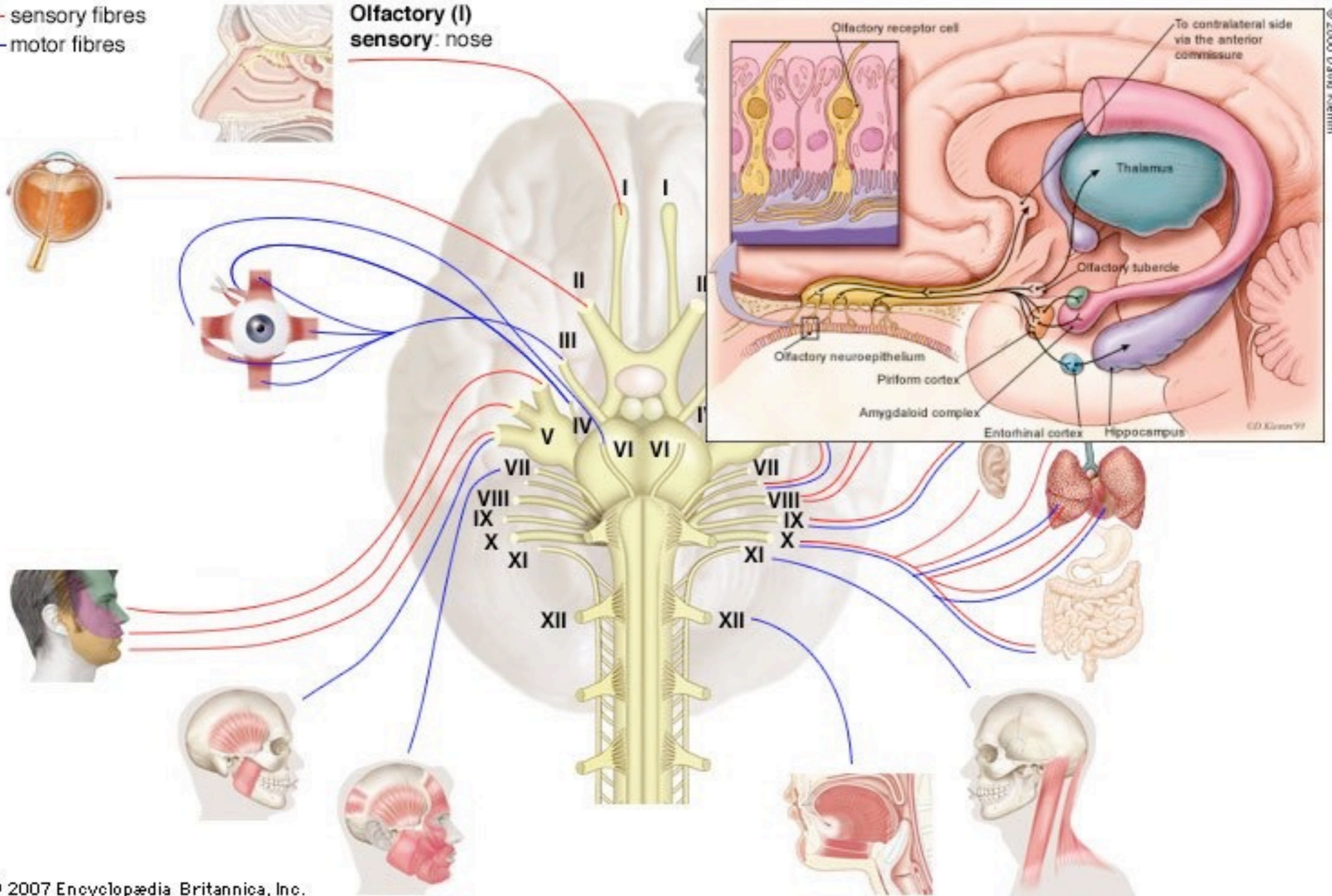
Accessory (XI) motor: sternocleidomastoid and trapezius muscles



cranial nerve I: olfactory nerve

— sensory fibres
— motor fibres

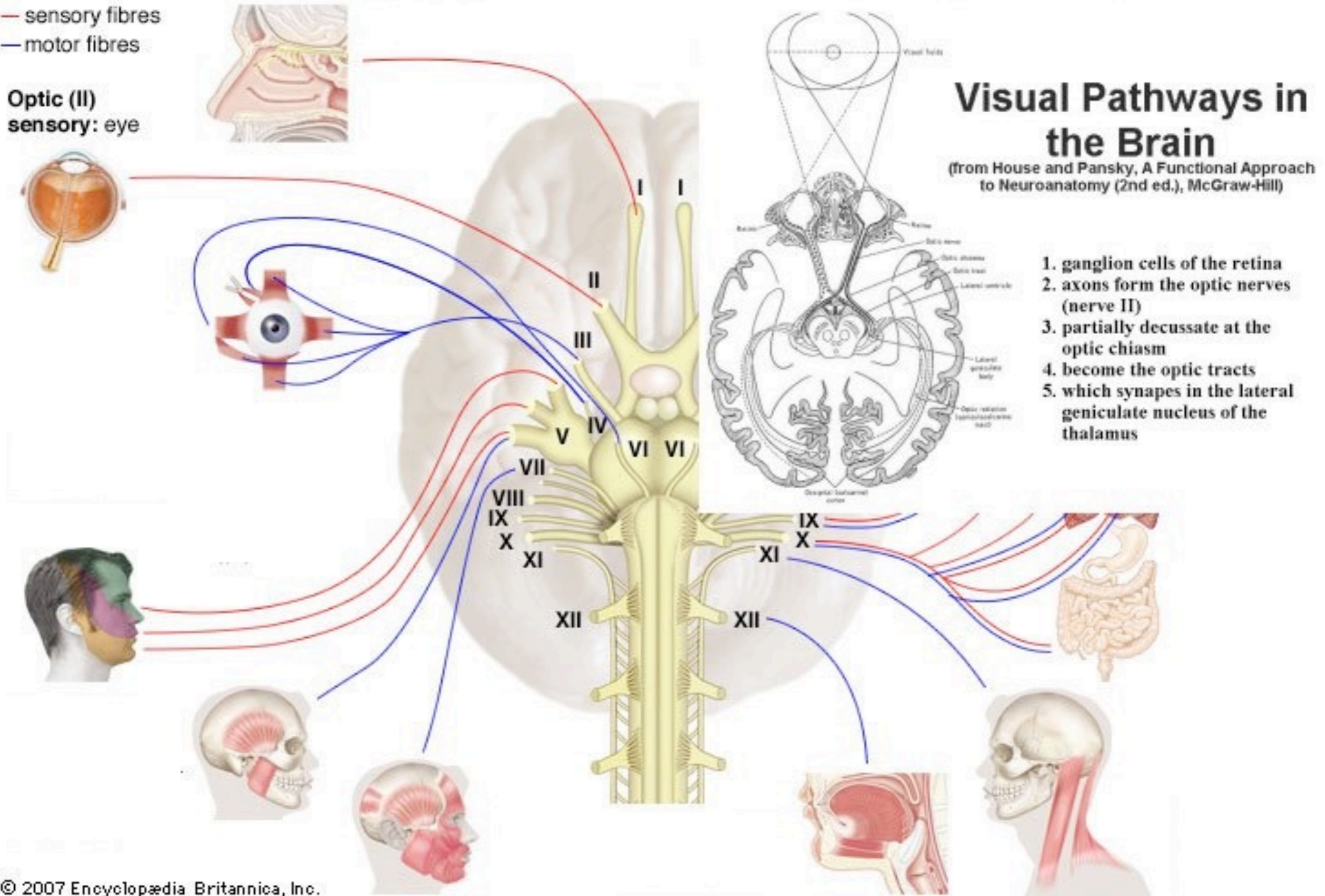
Olfactory (I)
sensory: nose



cranial nerve II: optic nerve

— sensory fibres
— motor fibres

Optic (II)
sensory: eye



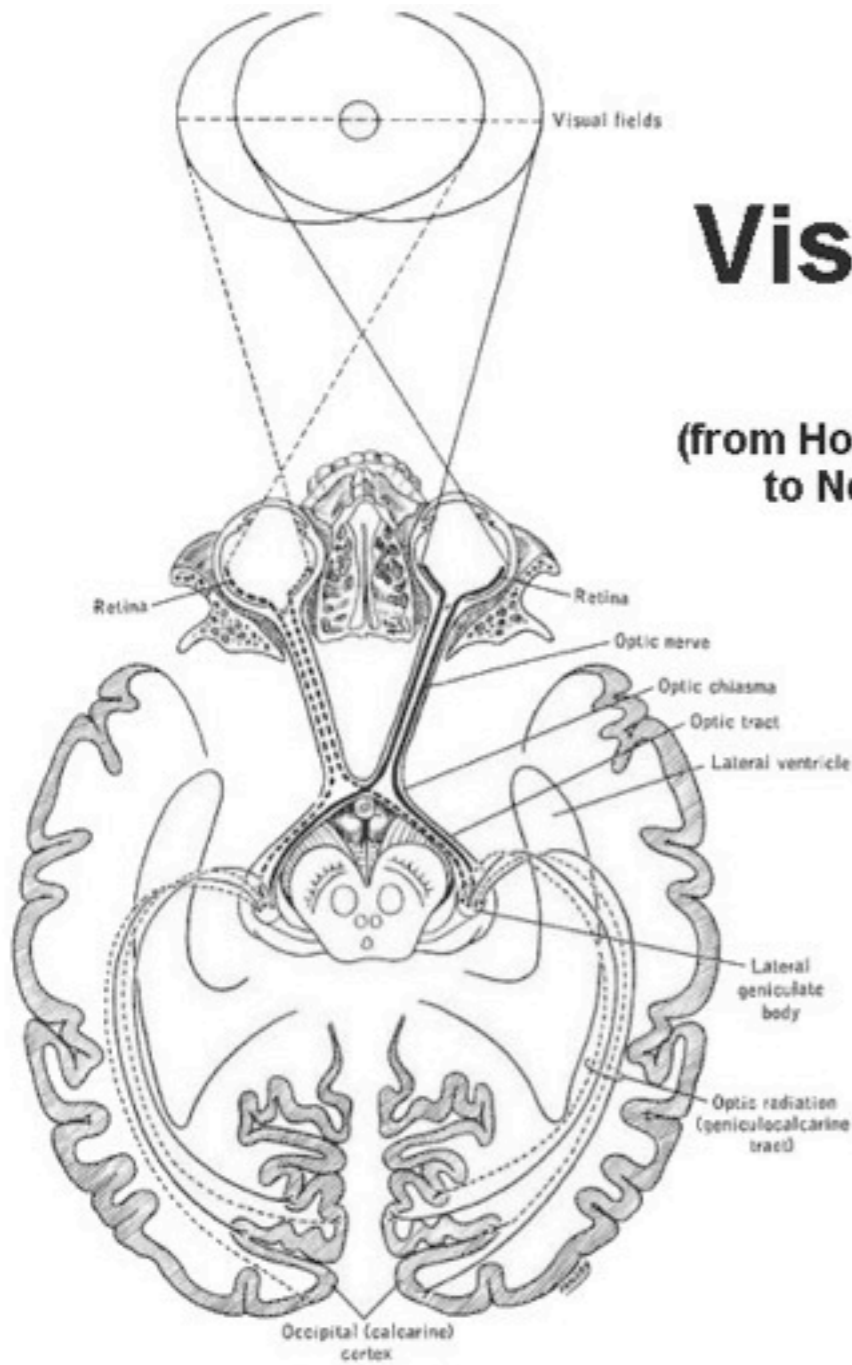
Visual Pathways in the Brain

(from House and Pansky, A Functional Approach to Neuroanatomy (2nd ed.), McGraw-Hill)

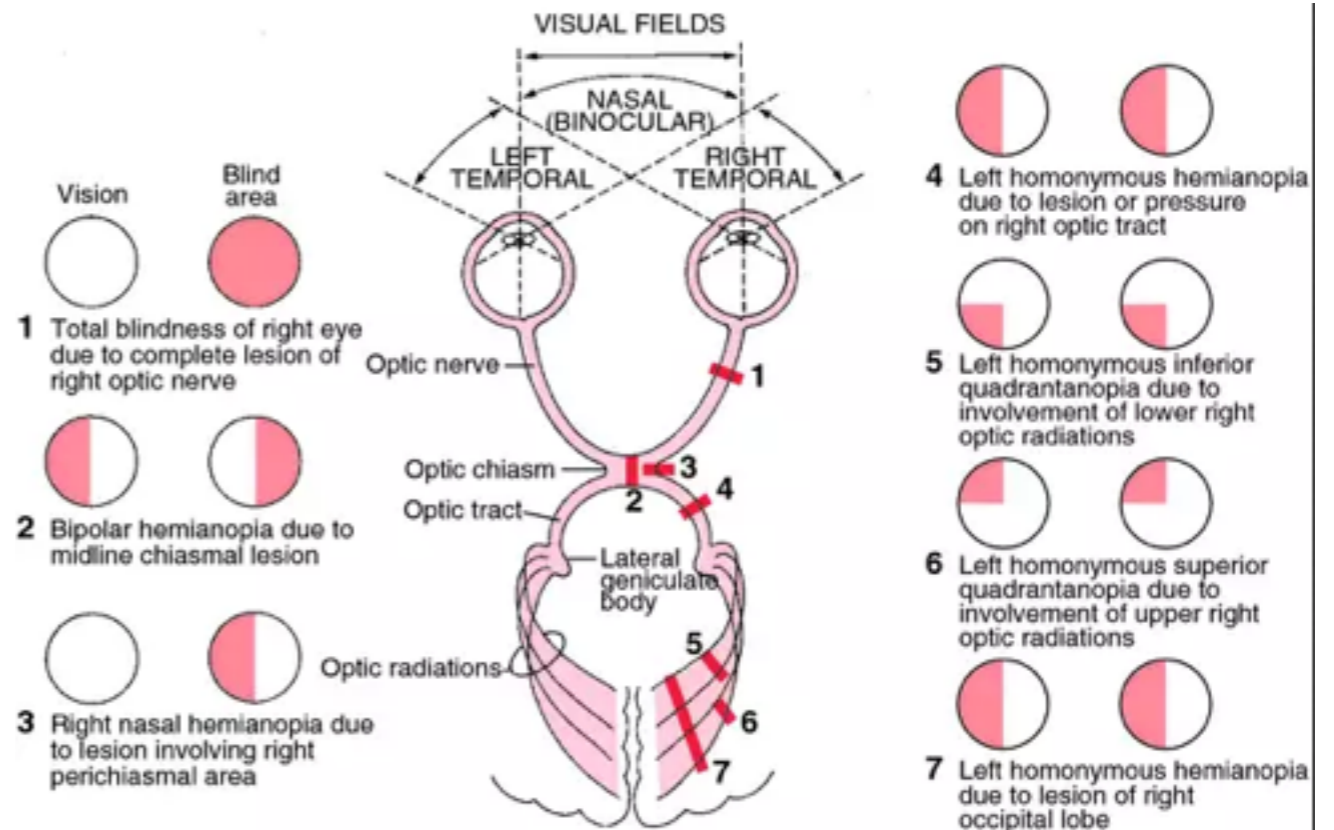
1. ganglion cells of the retina
2. axons form the optic nerves (nerve II)
3. partially decussate at the optic chiasm
4. become the optic tracts
5. which synapses in the lateral geniculate nucleus of the thalamus

Visual Pathways in the Brain

(from House and Pansky, A Functional Approach to Neuroanatomy (2nd ed.), McGraw-Hill)

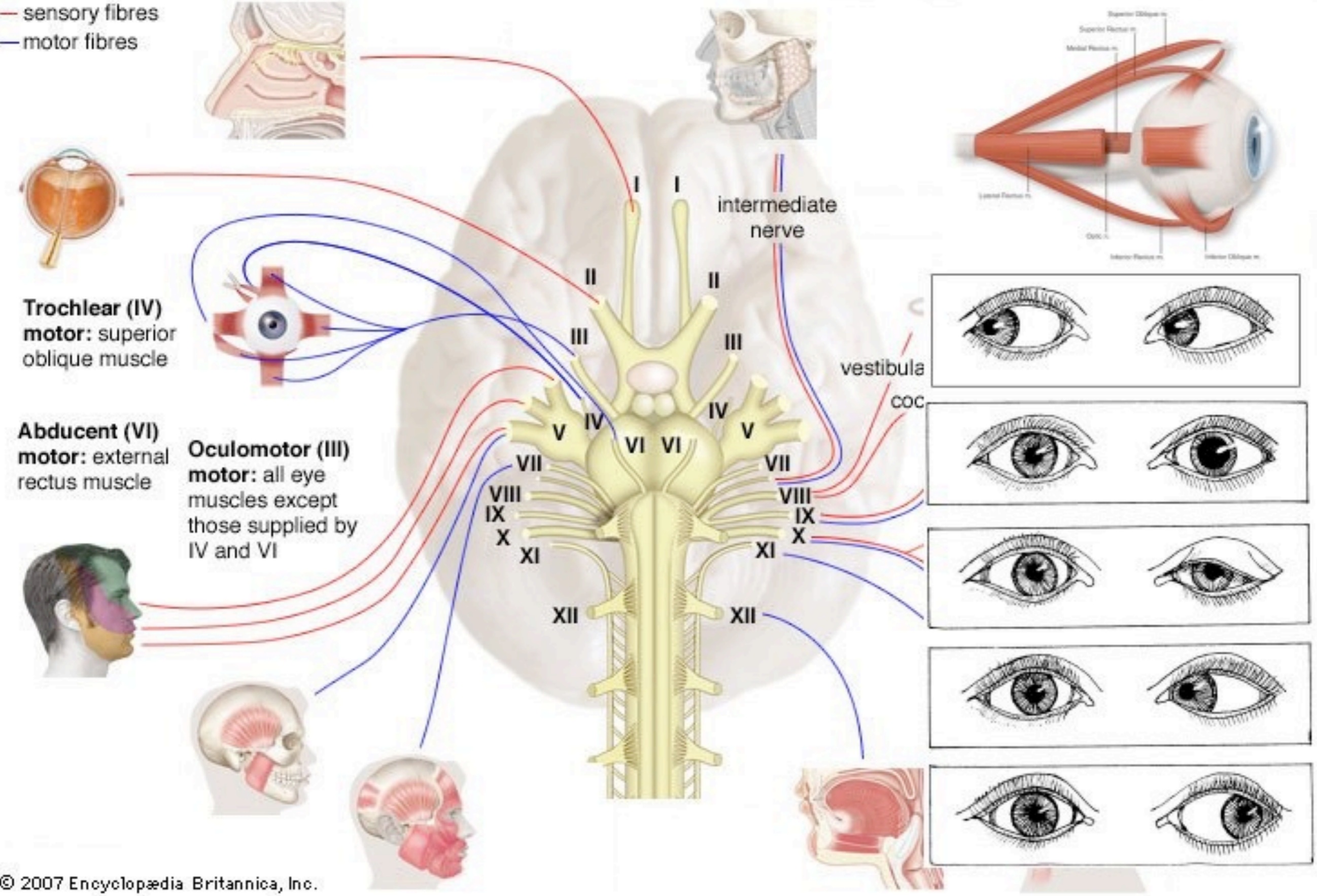


1. ganglion cells of the retina
2. axons form the optic nerves (nerve II)
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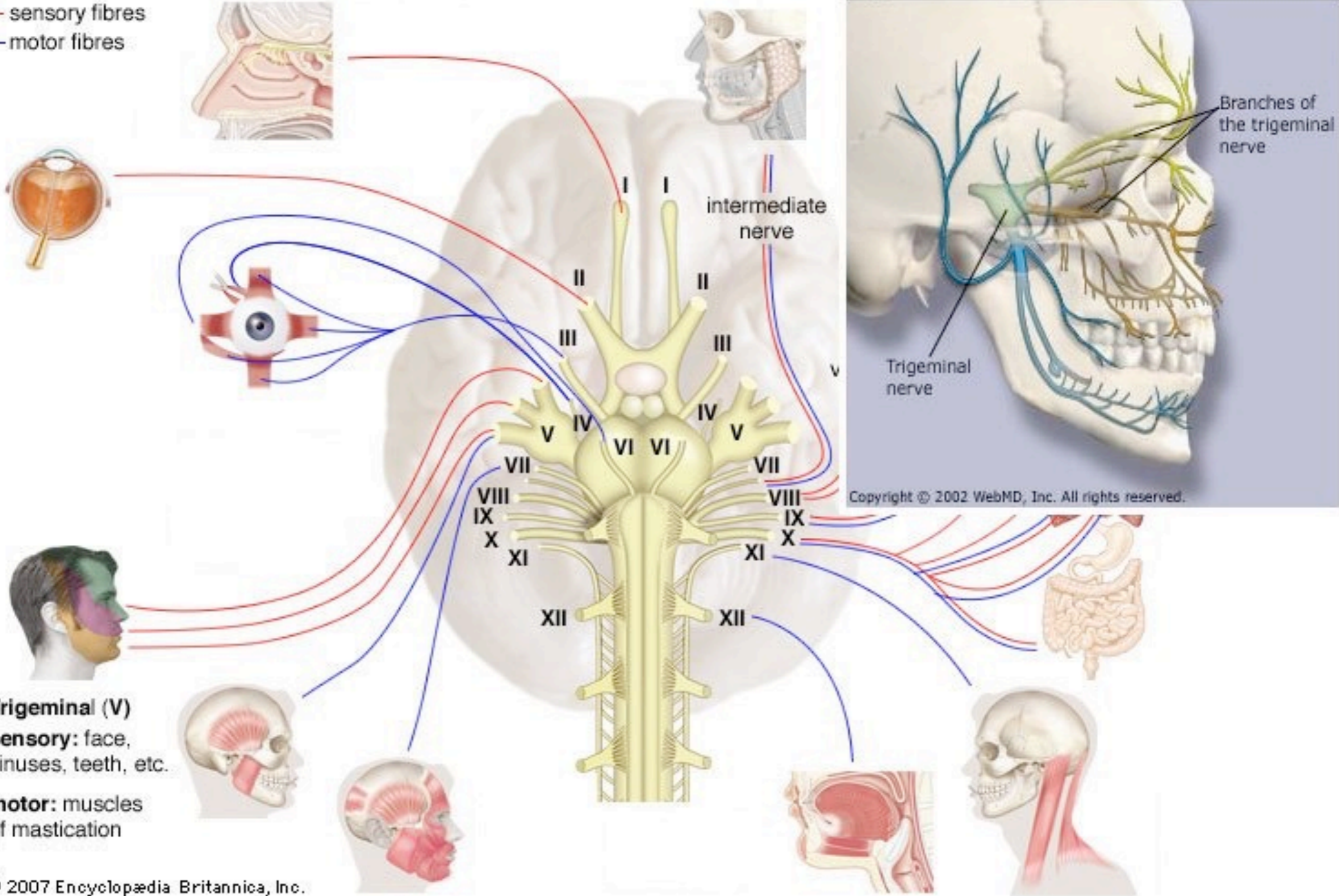
cranial nerves III, IV, and VI: eye movement

— sensory fibres
— motor fibres



cranial nerve V: trigeminal nerve

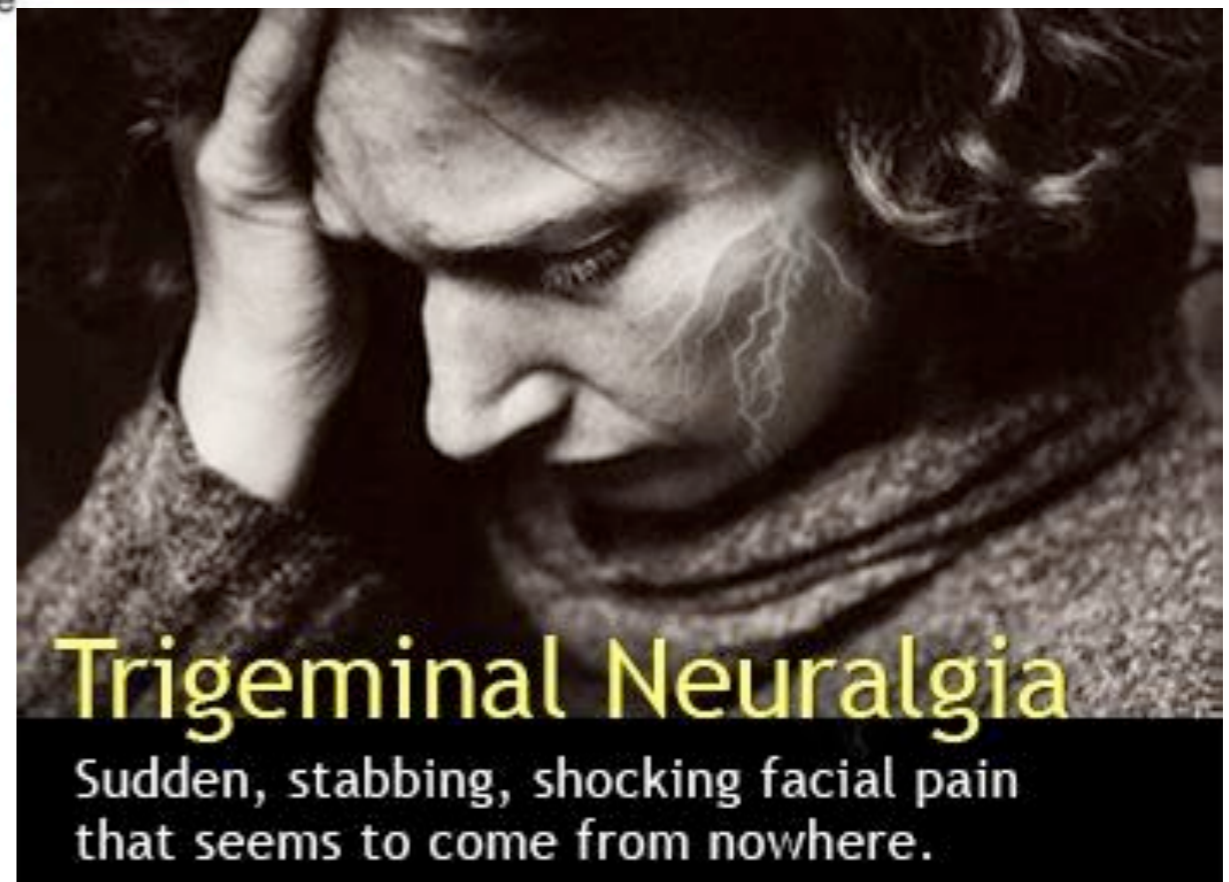
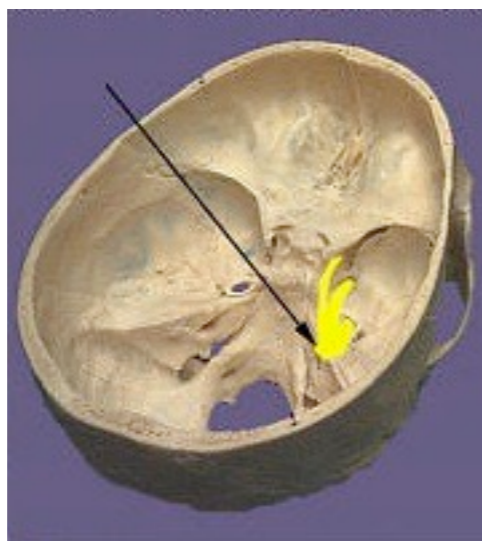
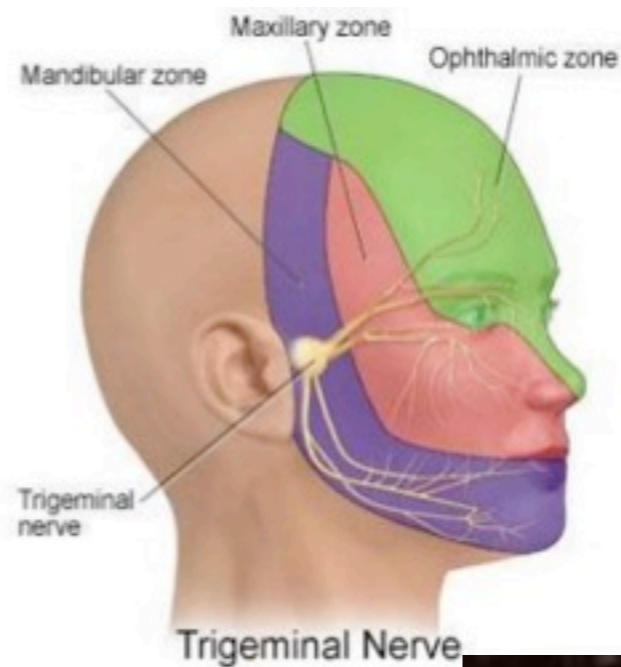
— sensory fibres
— motor fibres



Trigeminal (V)
sensory: face, sinuses, teeth, etc.
motor: muscles of mastication

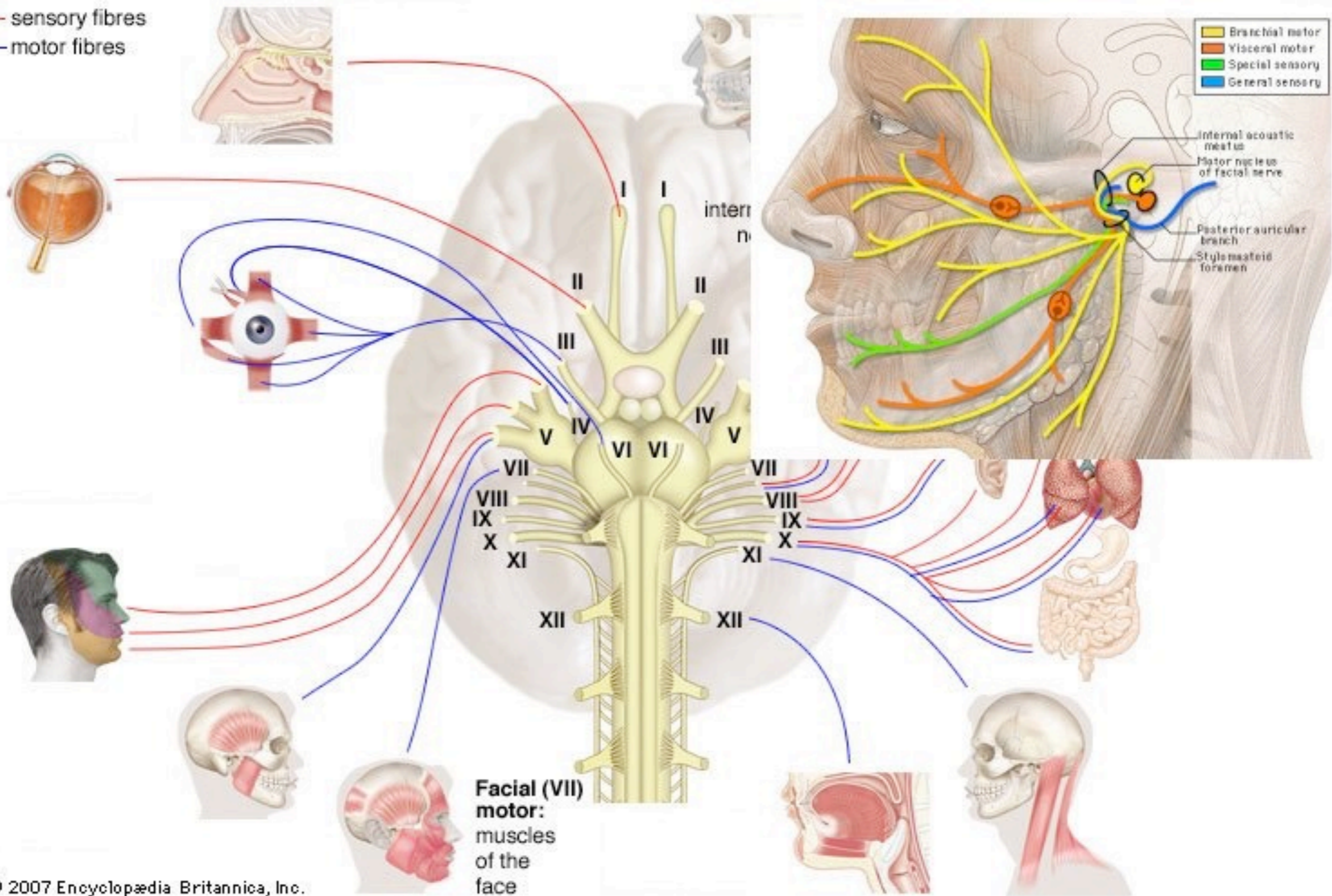
Trigeminal neuralgia or Tic douloureux

- ❖ Trigeminal nerve is fifth cranial nerve.
- ❖ Trigeminal nerve is responsible for sensation in the face and certain motor function such as biting, chewing.
- ❖ Three major branches ophthalmic nerve, maxillary nerve, mandibular nerve

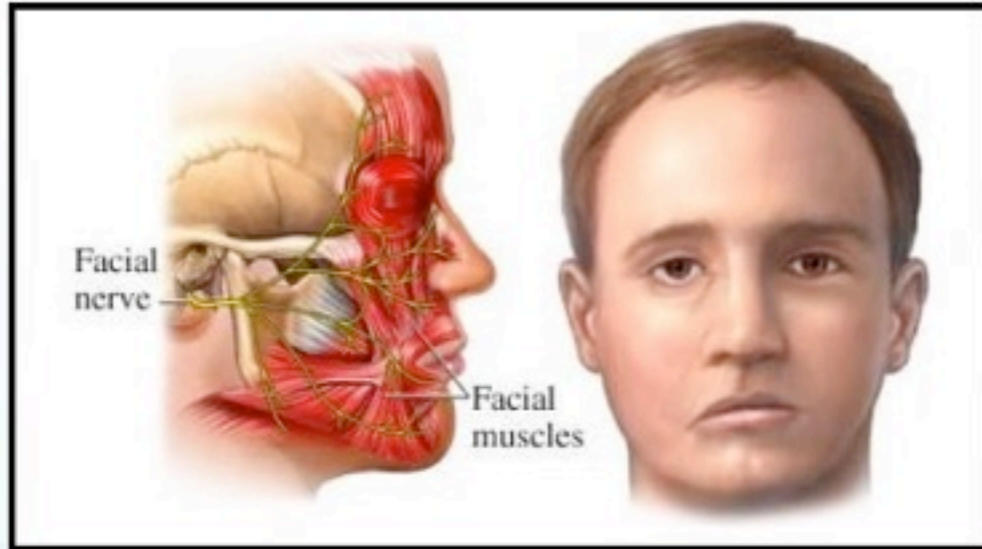


cranial nerve VII: facial nerve

— sensory fibres
— motor fibres



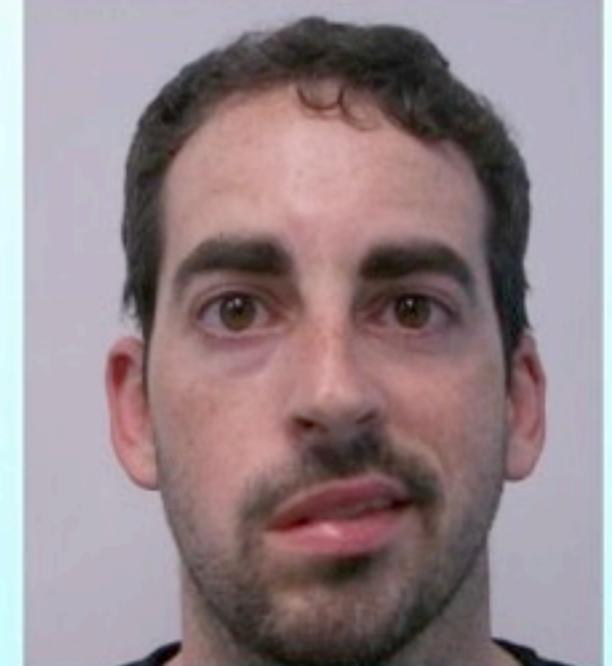
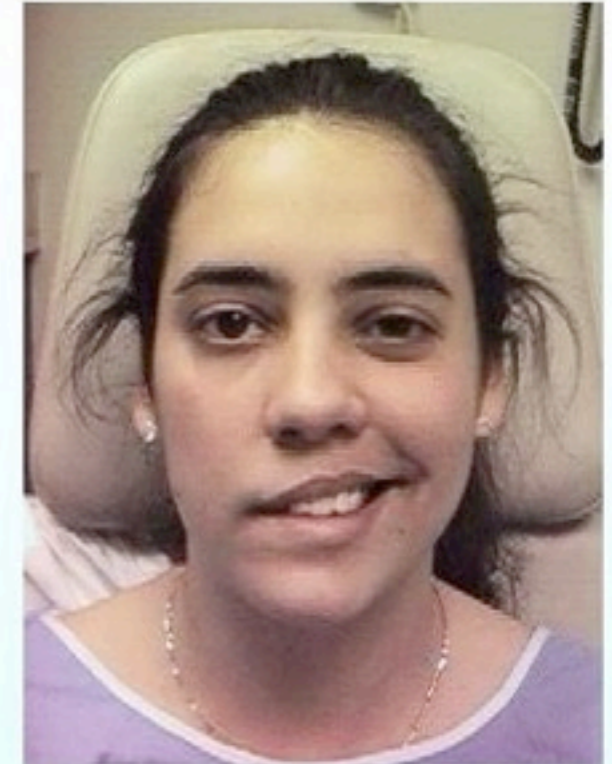
Facial Nerve Palsy (Bell's Palsy)



usually caused by:

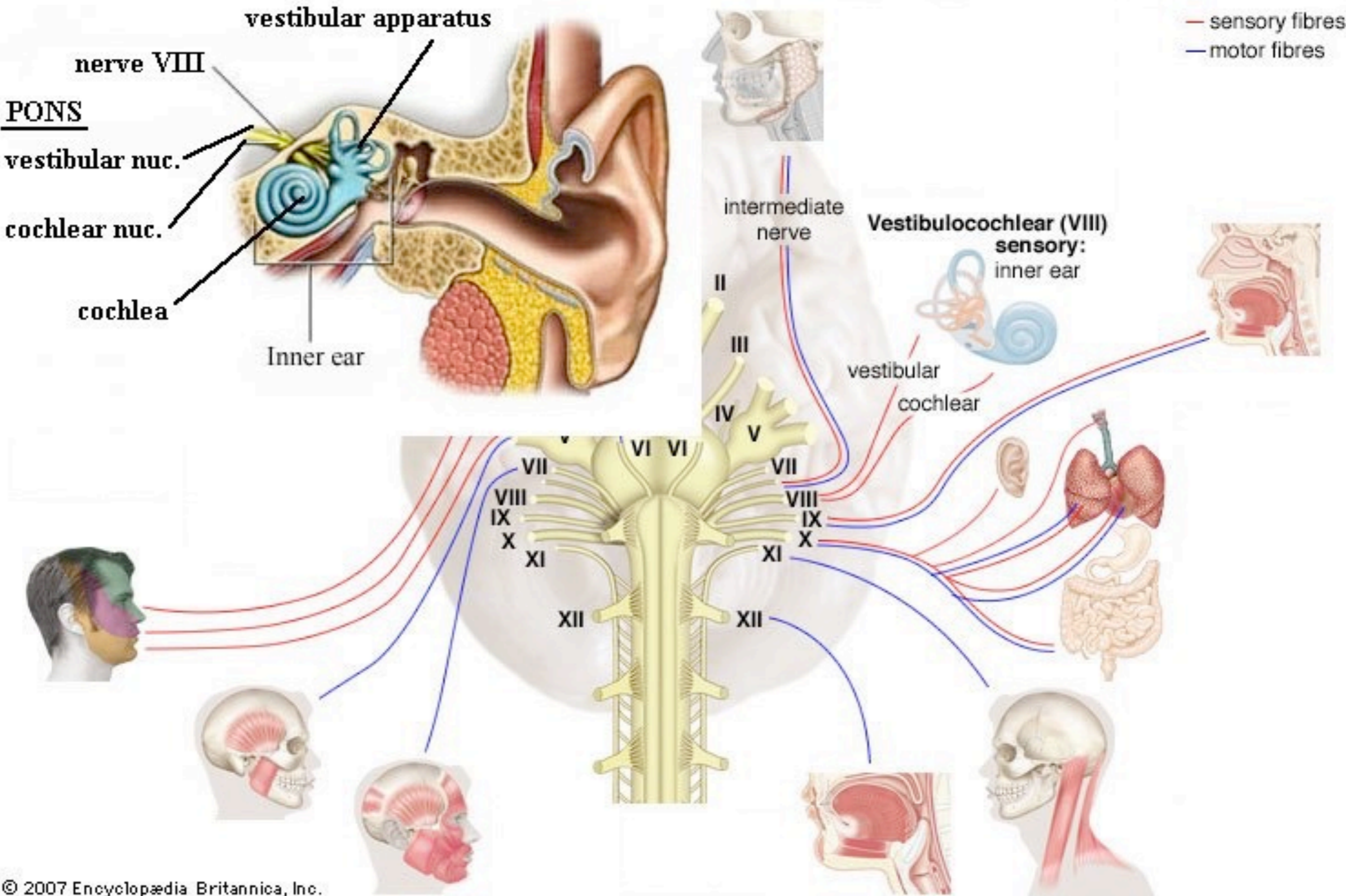
- 1) stroke
- 2) tumor
- 3) infection
 - a) Herpes zoster
 - b) Lyme disease
- 4) etc.

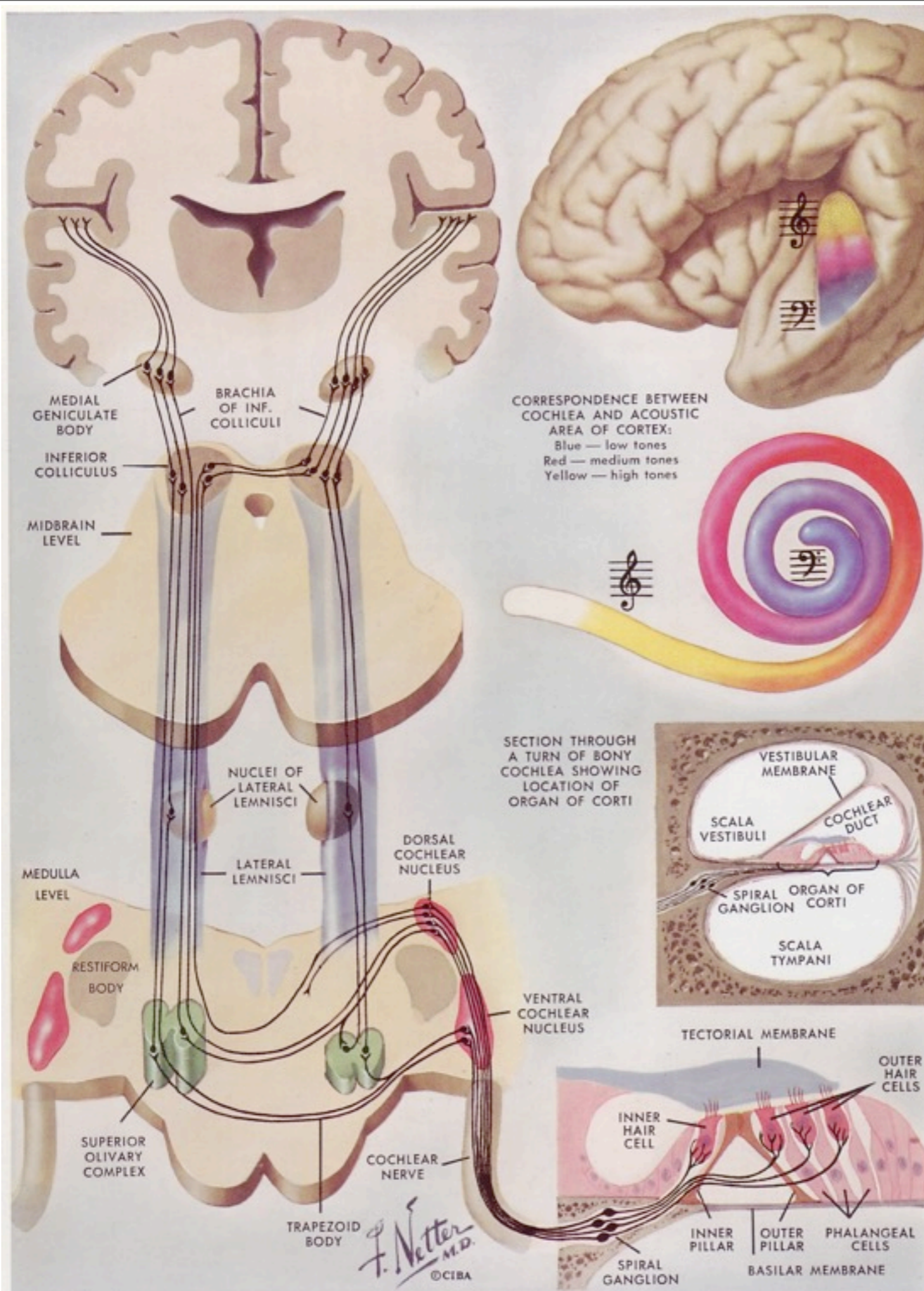
usually resolves on its own
within about two months



cranial nerve VIII: auditory nerve (and many other names!)

— sensory fibres
— motor fibres





auditory system

The End