Effects of Cerebellar Damage

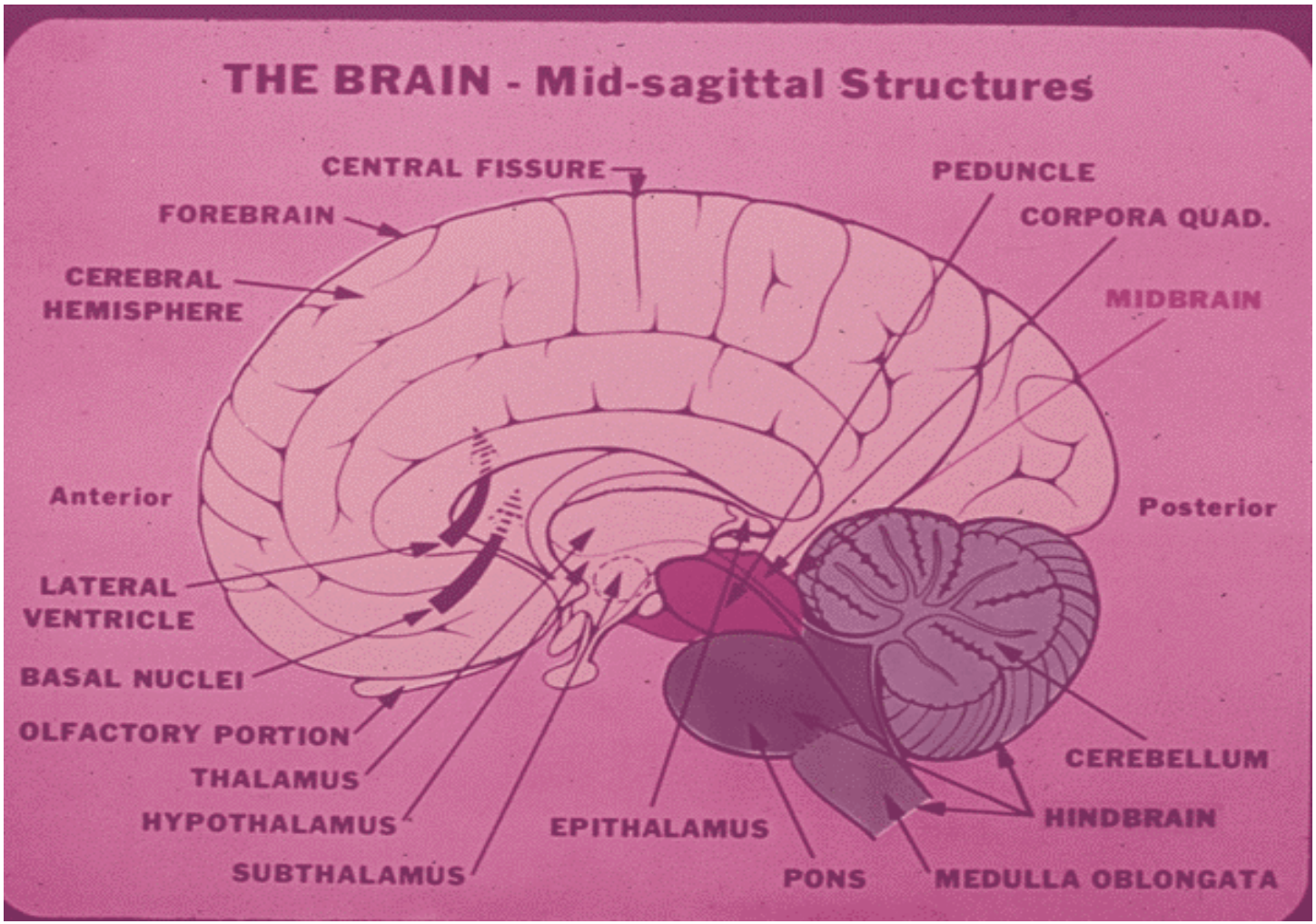
- Impaired rapid alternation movements
- Directed movements overshoot their mark (past-pointing on finger-to-nose).

Diencephalon

- COMPOSED OF THREE THALAMIC STRUCTURES:

- Thalamus
- Epithalamus (pineal body)
- Hypothalamus

Diencephalon



Epithalamus

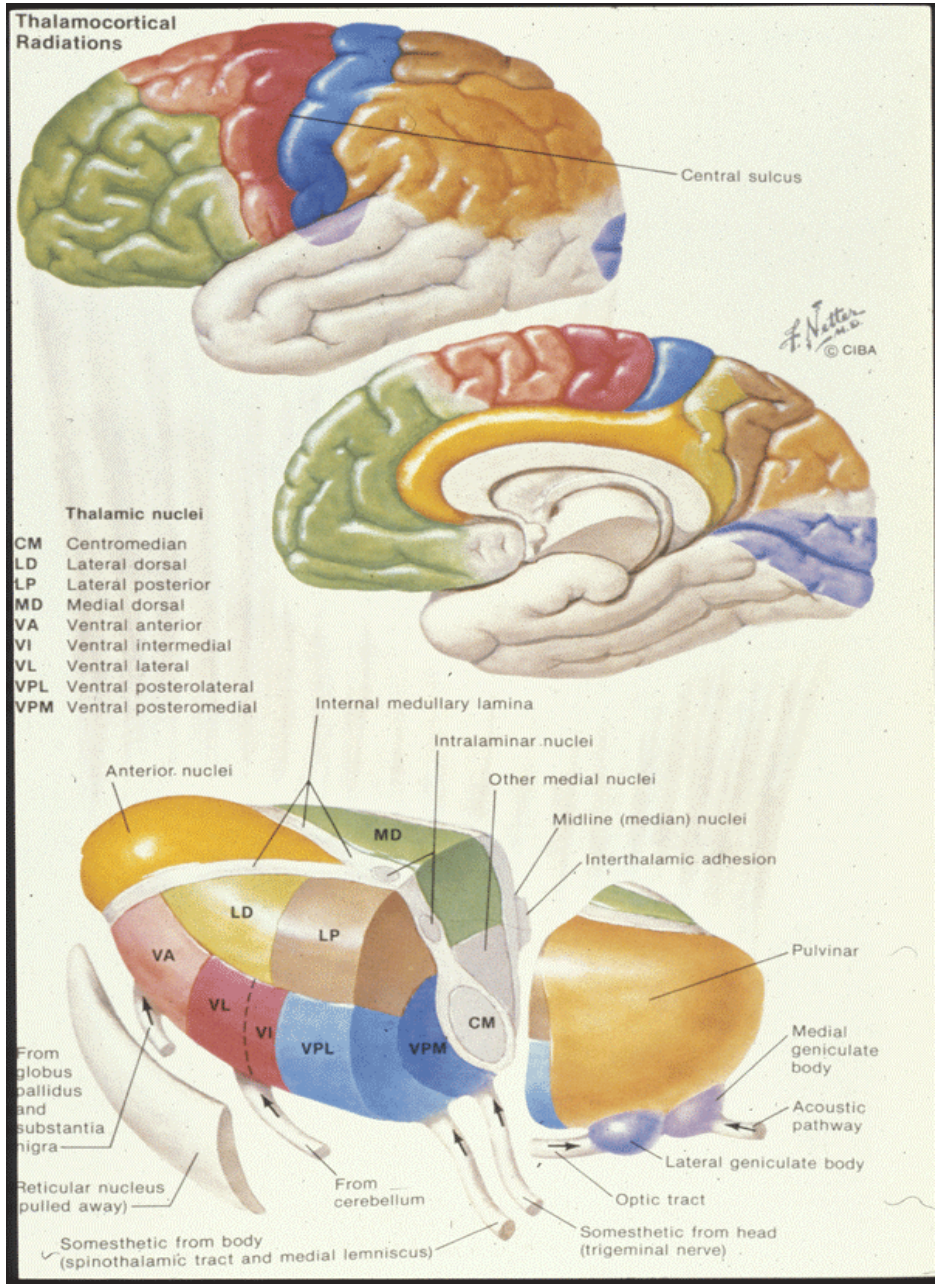
- Functions not well understood
- One of its structures – ***Pineal Body***

- Contains ***melanin***

- Regulates circadian rhythm
  (sleep-wake cycle)

Thalamus

- Contains many nuclei
- All sensory systems pass through (except olfaction)
- Vision, hearing, somatosensory systems have relays in thalamus on way to cortex
- Different parts of cortex also communicate via thalamic relay nuclei


Thalamocortical Radiations
Central sulcus
F. Netter M.D.
© CIBA
Thalamic nuclei
CM Centromedian
LD Lateral dorsal
LP Lateral posterior
MD Medial dorsal
VA Ventral anterior
VI Ventral intermedial
VL Ventral lateral
VPL Ventral posterolateral
VPM Ventral posteromedial
Internal medullary lamina
Intralaminar nuclei
Anterior nuclei
Other medial nuclei
Midline (median) nuclei
Interthalamic adhesion
MD
LD
LP
VA
VL
VI
VPL
VPM
CM
Pulvinar
Medial geniculate body
Acoustic pathway
Lateral geniculate body
Optic tract
From globus pallidus and substantia nigra
Reticular nucleus (pulled away)
From cerebellum
Somesthetic from body (spinothalamic tract and medial lemniscus)
Somesthetic from head (trigeminal nerve)

Hypothalamus

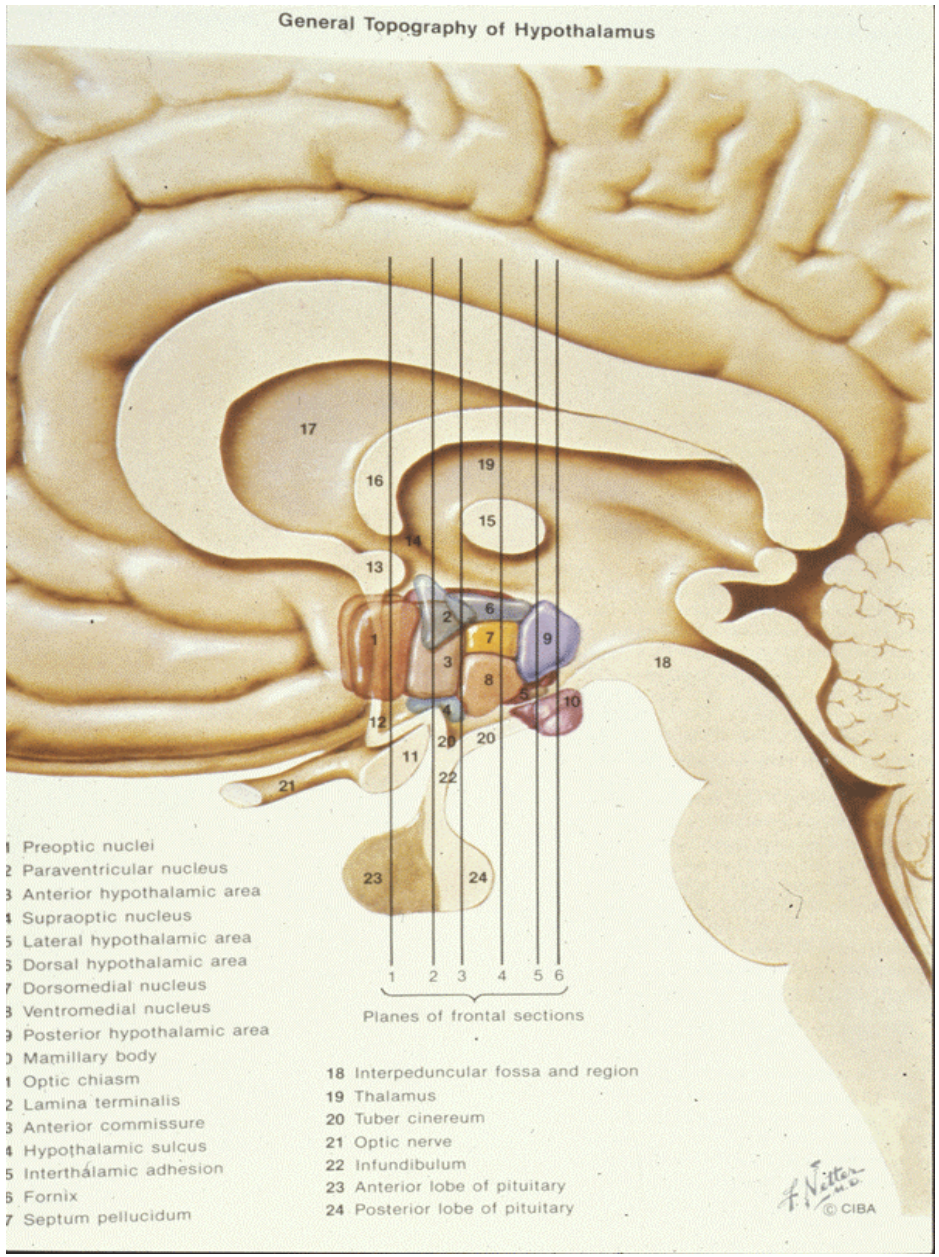
- Composed of ~22 small nuclei
- Ascending fiber systems pass through it
- Projects to pituitary gland and
- Brainstem nuclei

Hypothalamus

- Chief brain nucleus controlling autonomic nervous system

- Regulates feeding, sexual behavior, sleep, temperature, emotional behavior, endocrine function

General Topography of Hypothalamus



1 Preoptic nuclei
2 Paraventricular nucleus
3 Anterior hypothalamic area
4 Supraoptic nucleus
5 Lateral hypothalamic area
6 Dorsal hypothalamic area
7 Dorsomedial nucleus
8 Ventromedial nucleus
9 Posterior hypothalamic area
0 Mamillary body
1 Optic chiasm
2 Lamina terminalis
3 Anterior commissure
4 Hypothalamic sulcus
5 Interthalamic adhesion
6 Fornix
7 Septum pellucidum

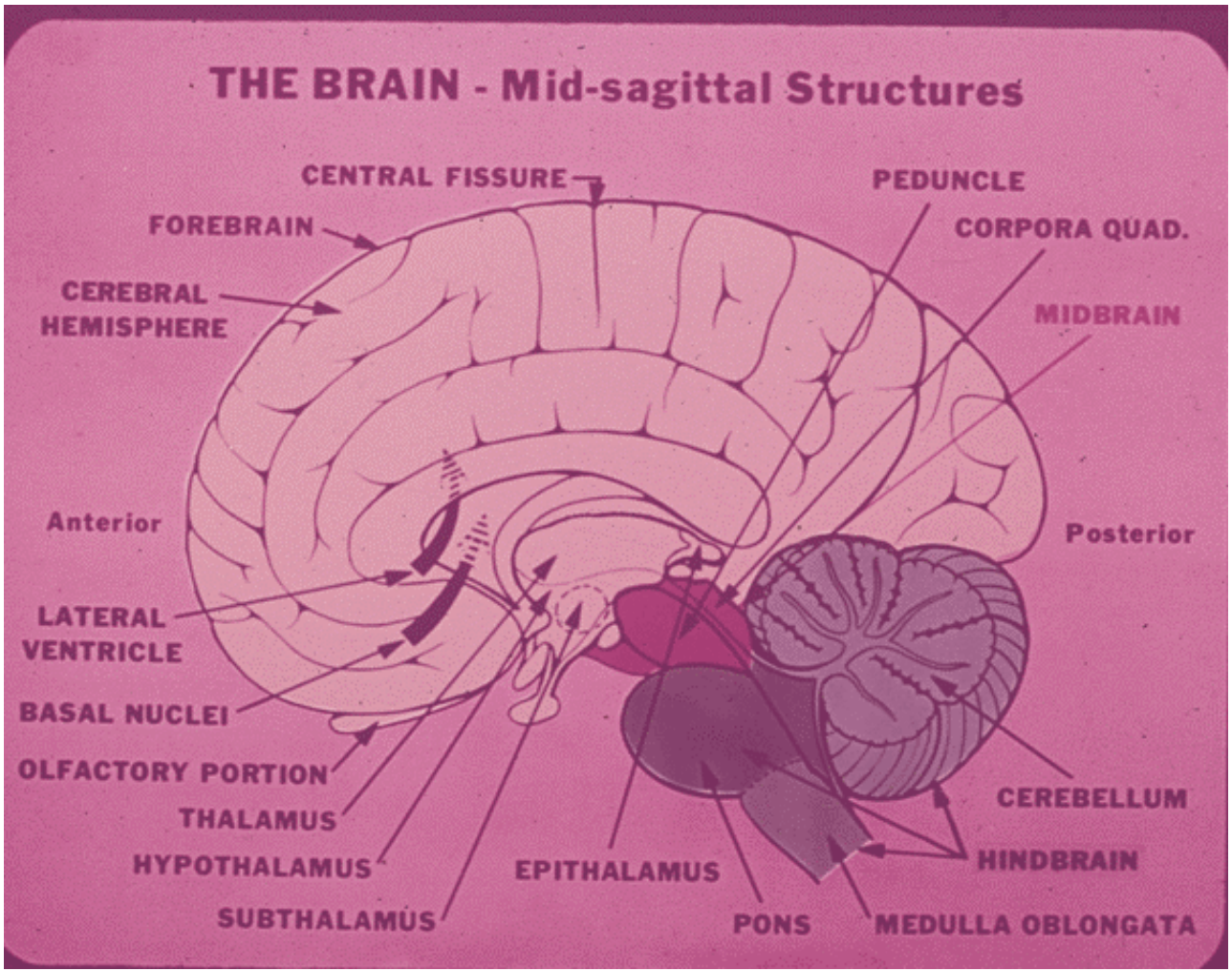
18 Interpeduncular fossa and region
19 Thalamus
20 Tuber cinereum
21 Optic nerve
22 Infundibulum
23 Anterior lobe of pituitary
24 Posterior lobe of pituitary

Forebrain

- Consists of:

- Cortex
- Limbic structures
- Thalamus
- Olfactory bulbs and tract

Forebrain


THE BRAIN - Mid-sagittal Structures
CENTRAL FISSURE
FOREBRAIN
CEREBRAL HEMISPHERE
PEDUNCLE
CORPORA QUAD.
MIDBRAIN
Anterior
Posterior
LATERAL VENTRICLE
BASAL NUCLEI
OLFACTORY PORTION
THALAMUS
HYPOTHALAMUS
SUBTHALAMUS
EPITHALAMUS
PONS
CEREBELLUM
HINDBRAIN
MEDULLA OBLONGATA

Cortex

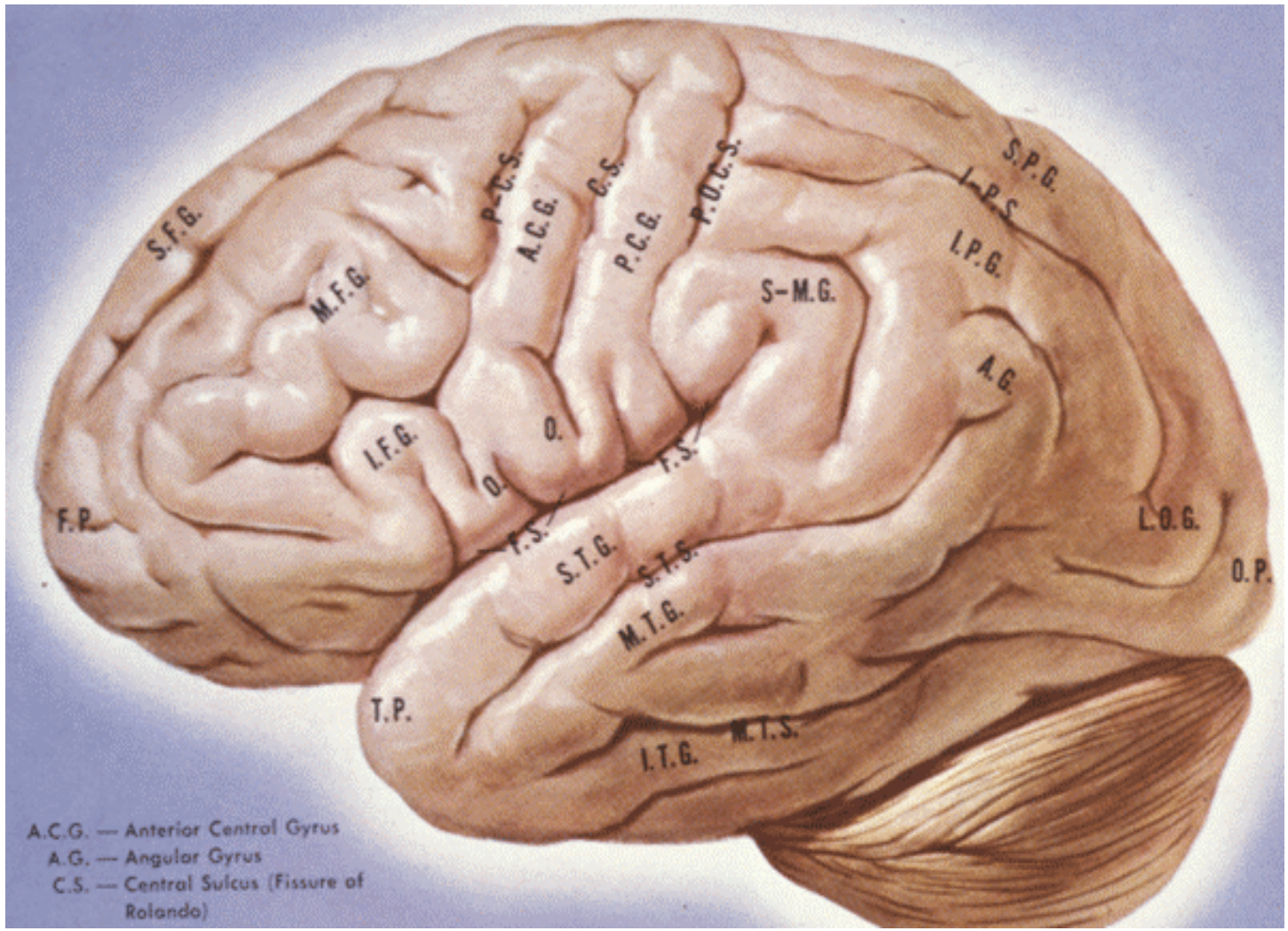
- Or neocortex - most of forebrain by volume
- 80% of human brain (by volume)
- 4 to 6 layers of cells (gray matter)
- Area up Thickness from 1.5mm to 3.0mm
- Wrinkled - nature's solution to confining huge cortical surface inside skull

Cortex

- Consists of clefts and ridges
- Cleft extends deep into brain = ***fissure***
- A more shallow cleft = ***sulcus*** (sulci)
- A ridge is called = ***gyrus*** (gyri)

- Hemispheric & individual variation in location and size of gyri and sulci.

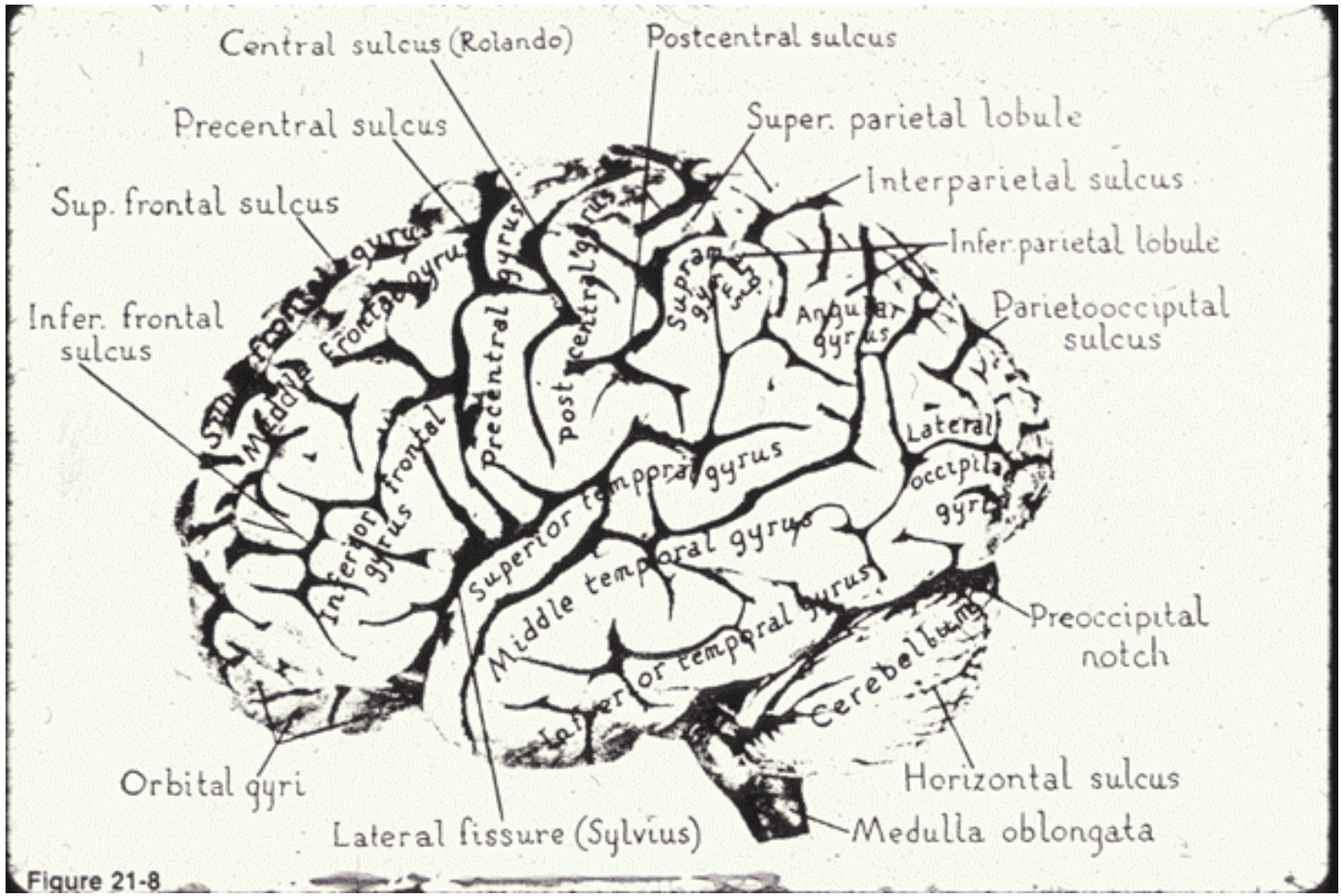
Cortical Gyri & Sulci



Cortical Landmarks

- Easy to locate:
- ***Lateral (Sylvian) fissure***
- ***Central sulcus a.k.a., Fissure of Rolando***
- ***Medial Longitudinal Fissure a.k.a., interhemispheric fissure***

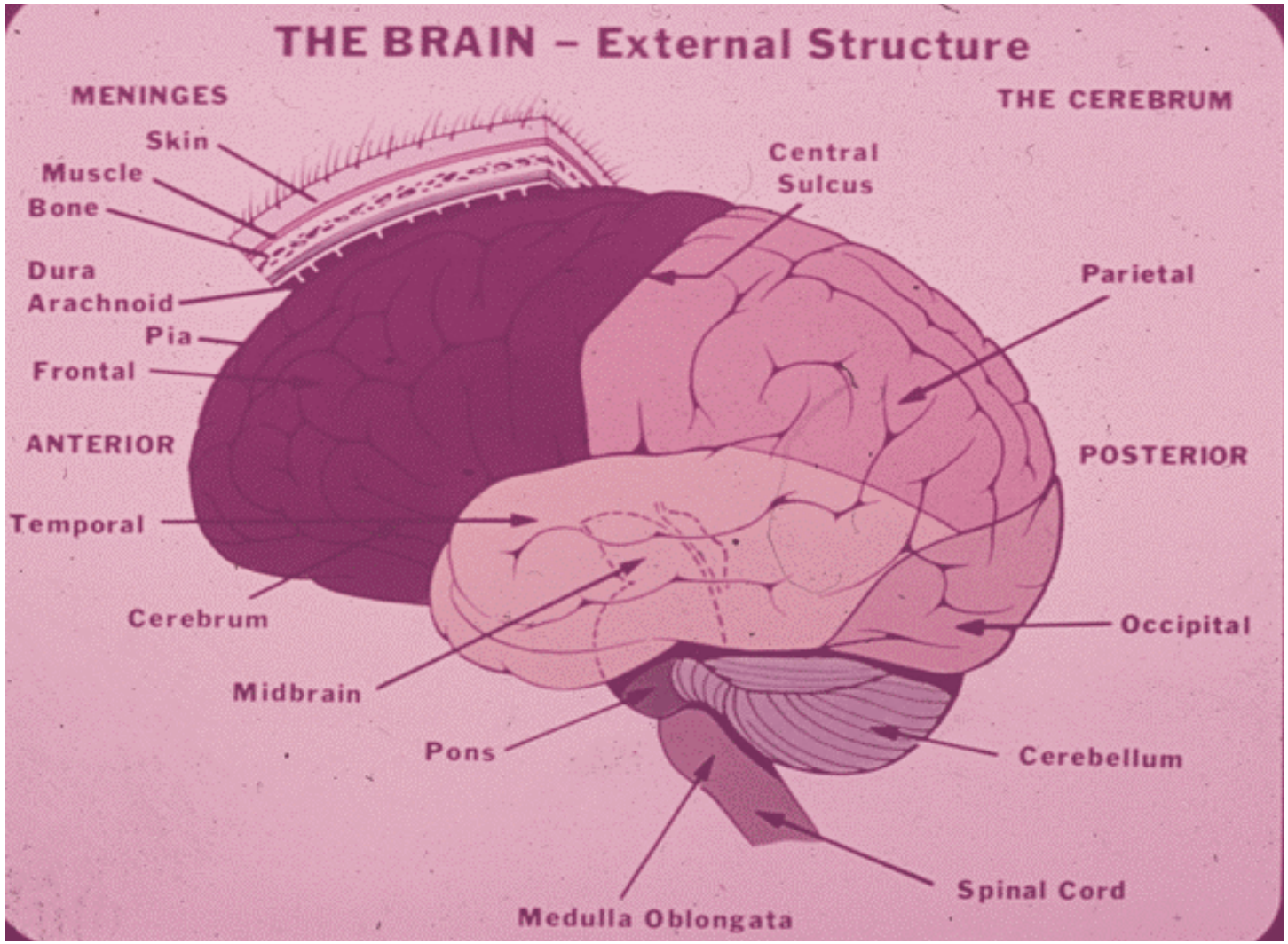
Cortical Landmarks



Hemispheres & Lobes

- Brain divided into 2 nearly symmetrical hemispheres
- Each hemisphere divided into 4 lobes:
- Frontal
- Parietal
- Temporal
- Occipital

Four Lobes of Brain

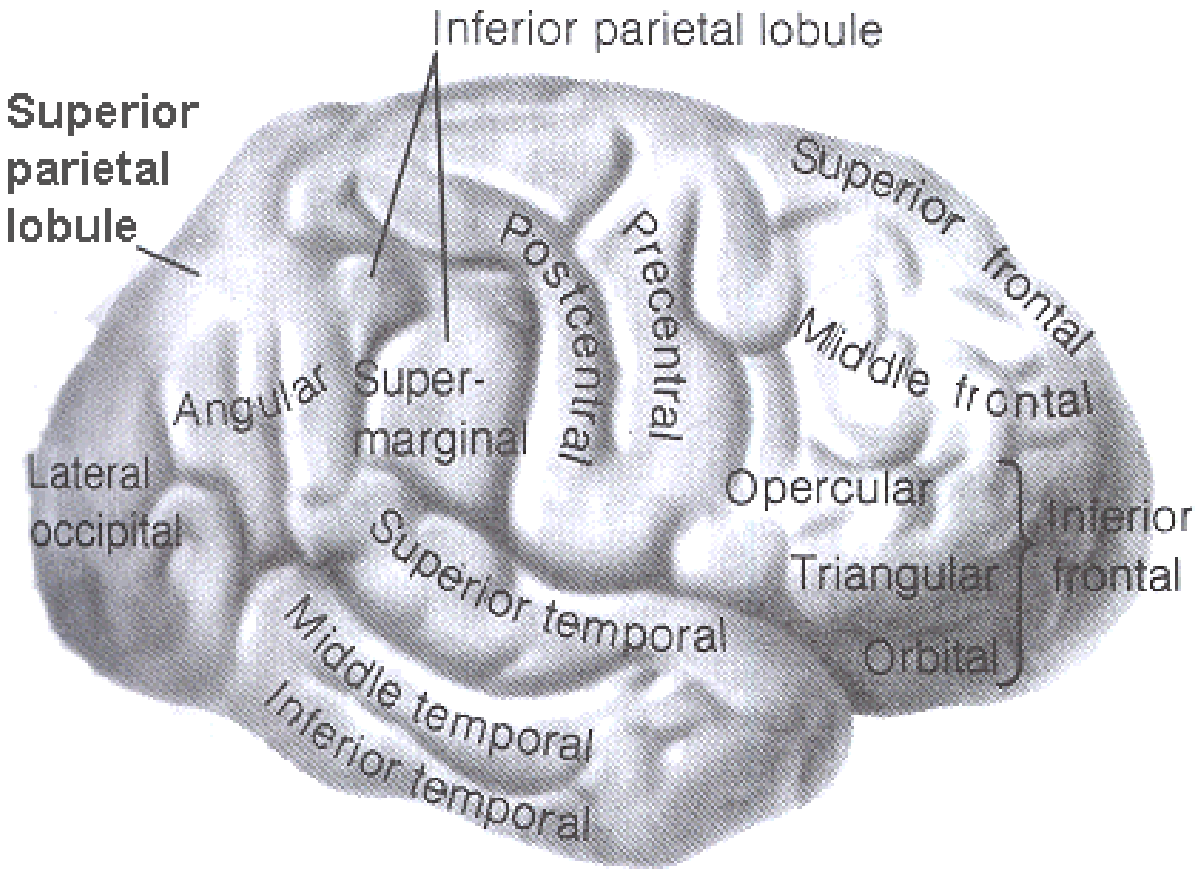


Frontal Lobe Gyri - Lateral

- PREFRONTAL LOBE:
- Superior frontal gyrus
- Middle frontal gyrus
- Inferior frontal gyrus

- FRONTAL LOBE:
- Precentral gyrus

Frontal Lobe Gyri - Lateral

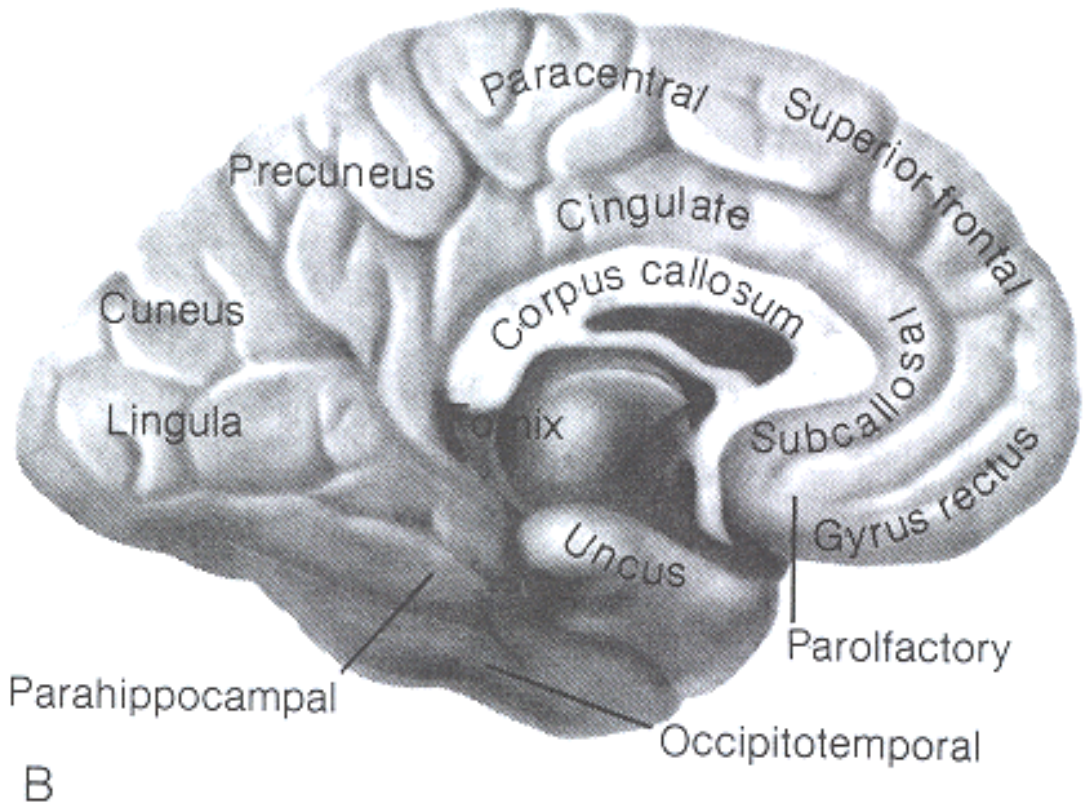


Frontal Lobe Gyri - Medial

- Superior frontal gyrus (includes SMA)
- Gyrus rectus
- Subcallosal gyrus
- Cingulate gyrus (anterior portion)

- Paracentral gyrus

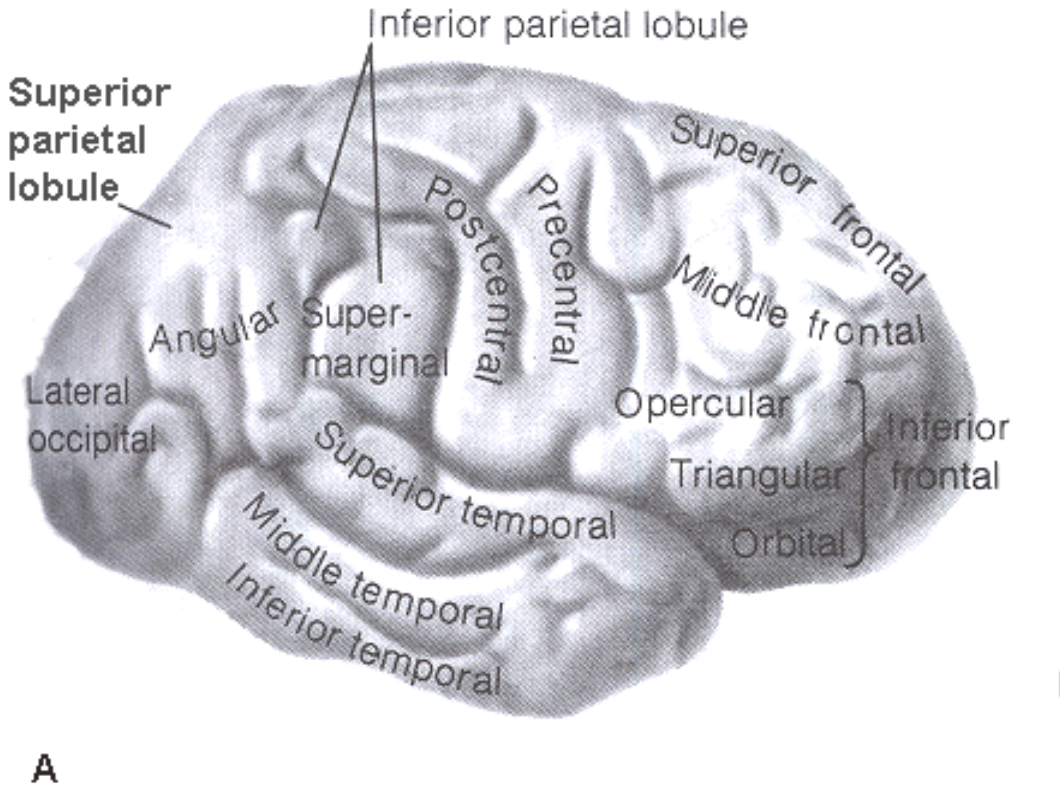
Frontal Lobe Gyri - Medial



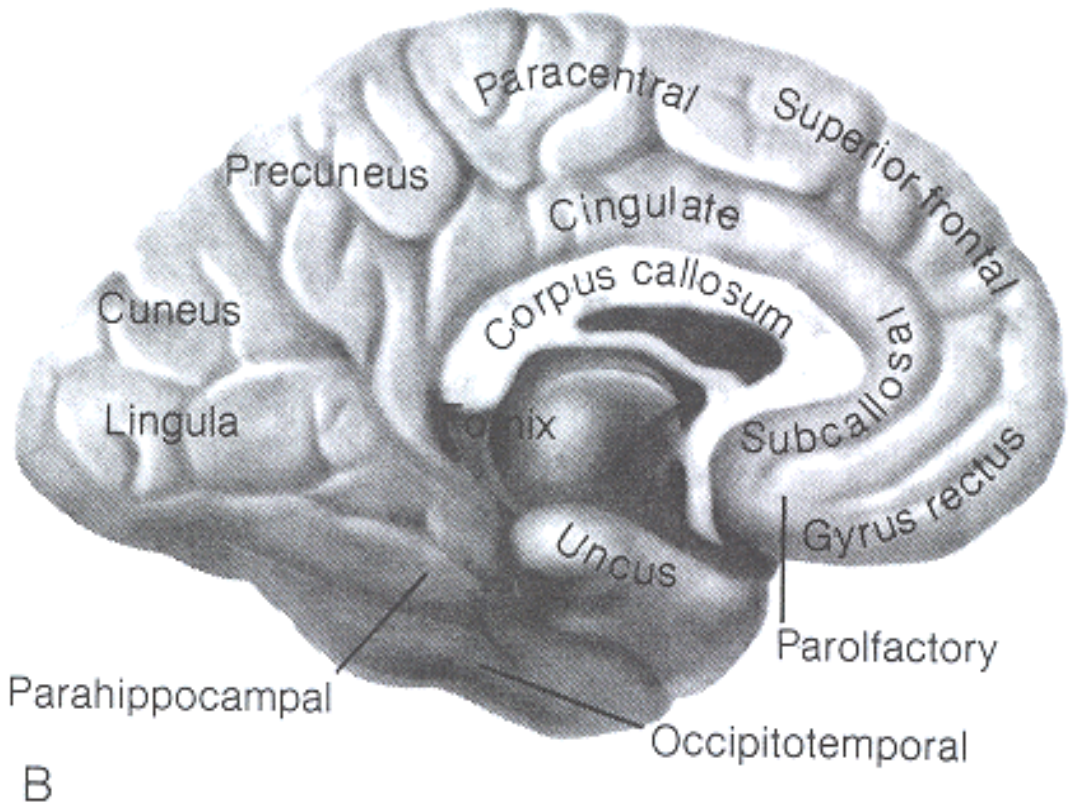
Parietal Lobe Gyri

- LATERAL GYRI:
- Superior parietal lobule
- Supermarginal gyrus
- Angular gyrus
- MESIAL GYRI:
- Precuneous

Parietal Lobe Gyri - Lateral



Parietal Lobe Gyri - Mesial

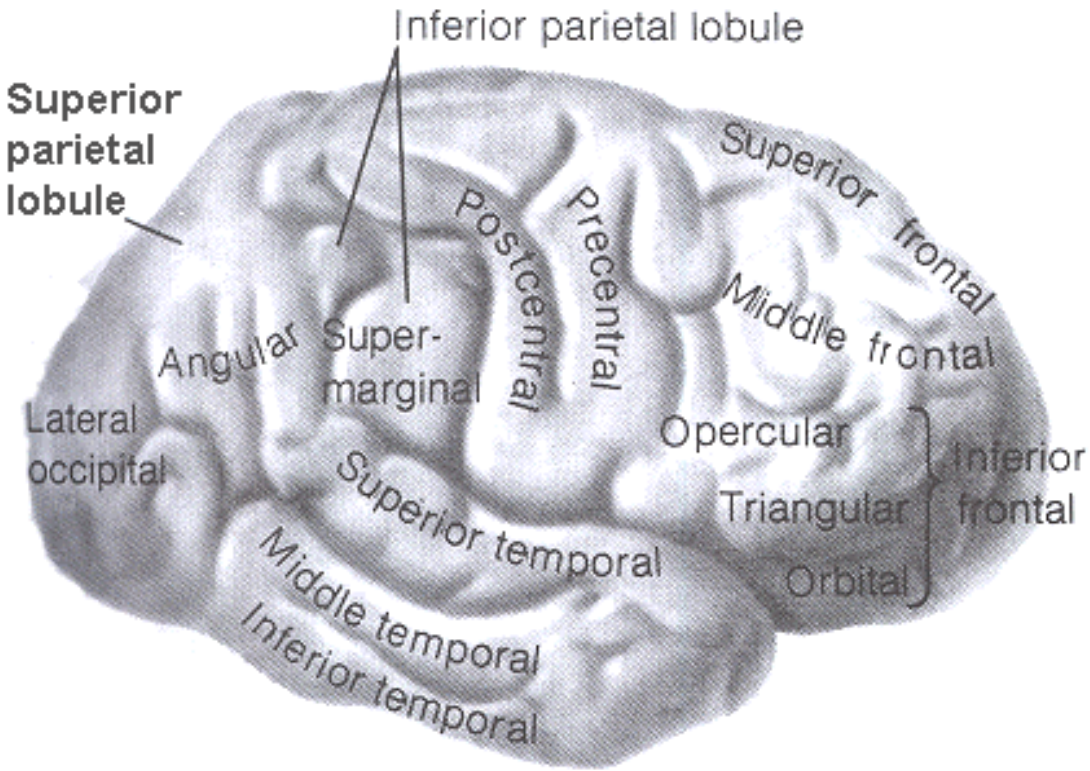


Temporal Lobe Gyri

- LATERAL:

- Superior temporal gyrus
- Middle temporal gyrus
- Inferior temporal gyrus

Temporal Lobe Gyri - Lateral

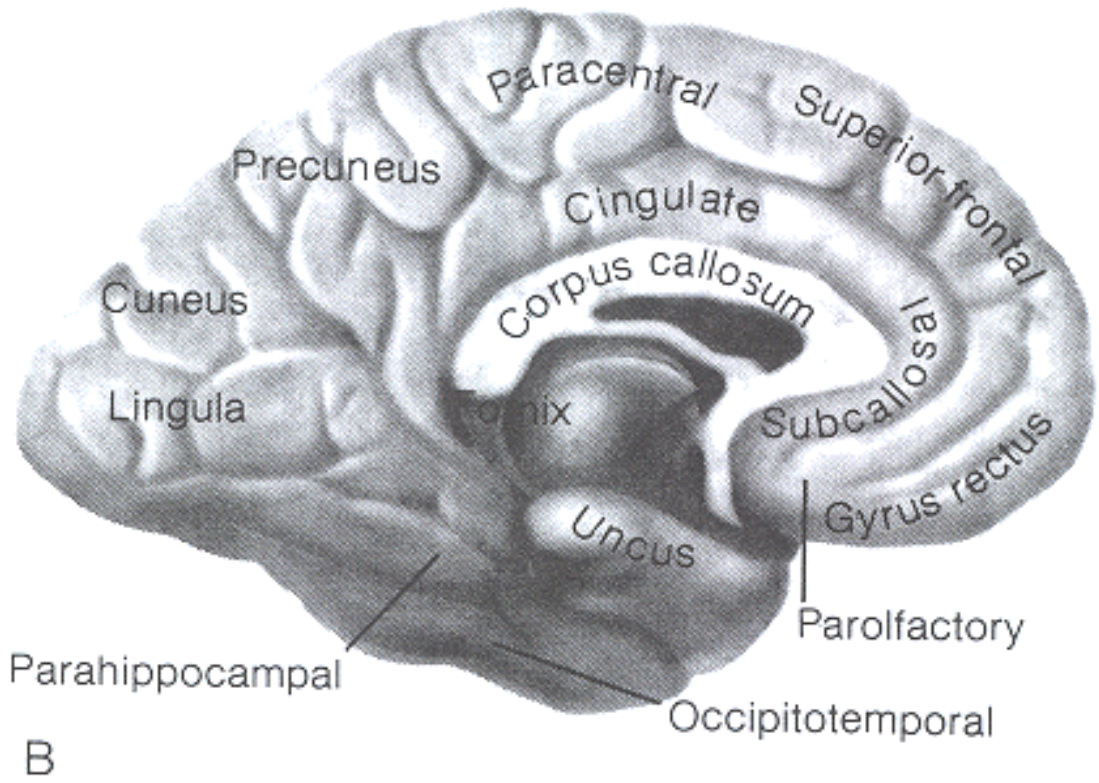


Temporal Lobe Gyri - Other

- MESIAL:
- Uncus

- INFERIOR SURFACE:
- Parahippocampal gyrus
- Occipitotemporal gyrus (a.k.a., fusiform)

Temporal Lobe Gyri - Medial

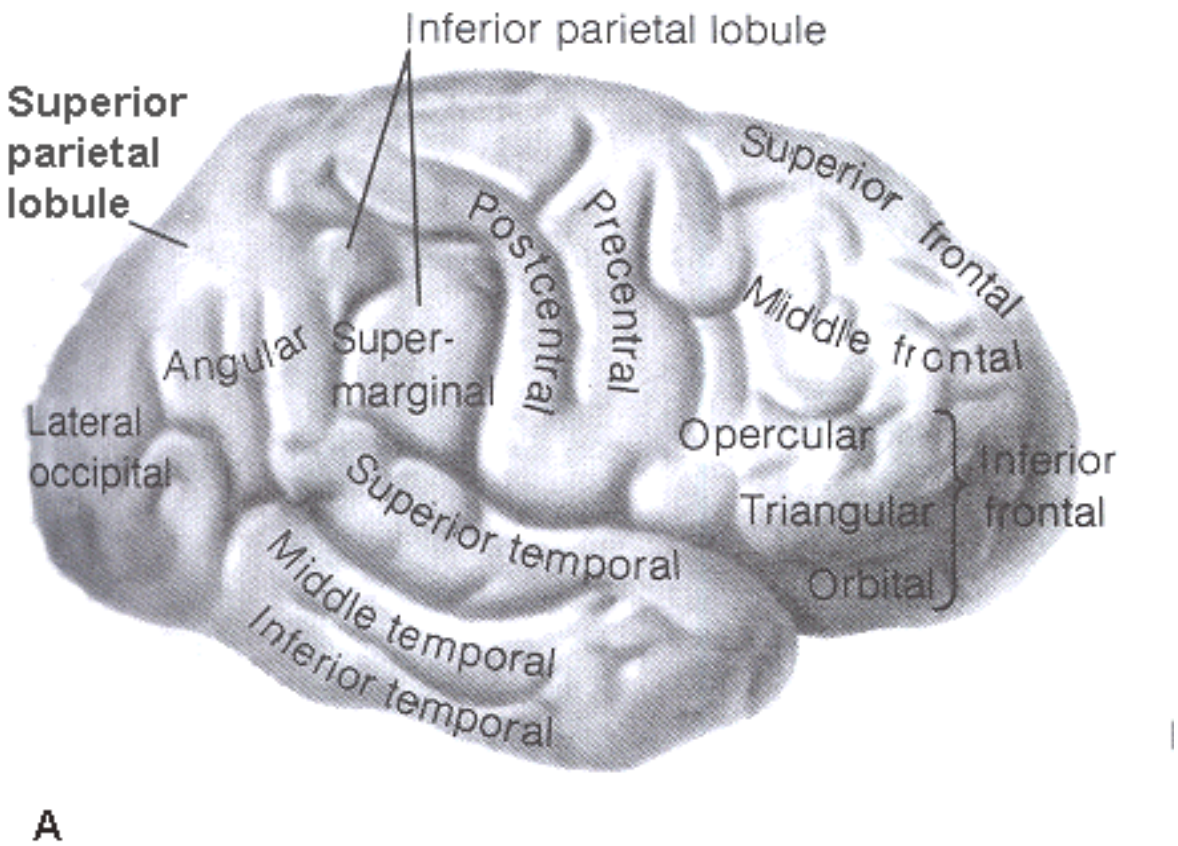


Occipital Lobe Gyri

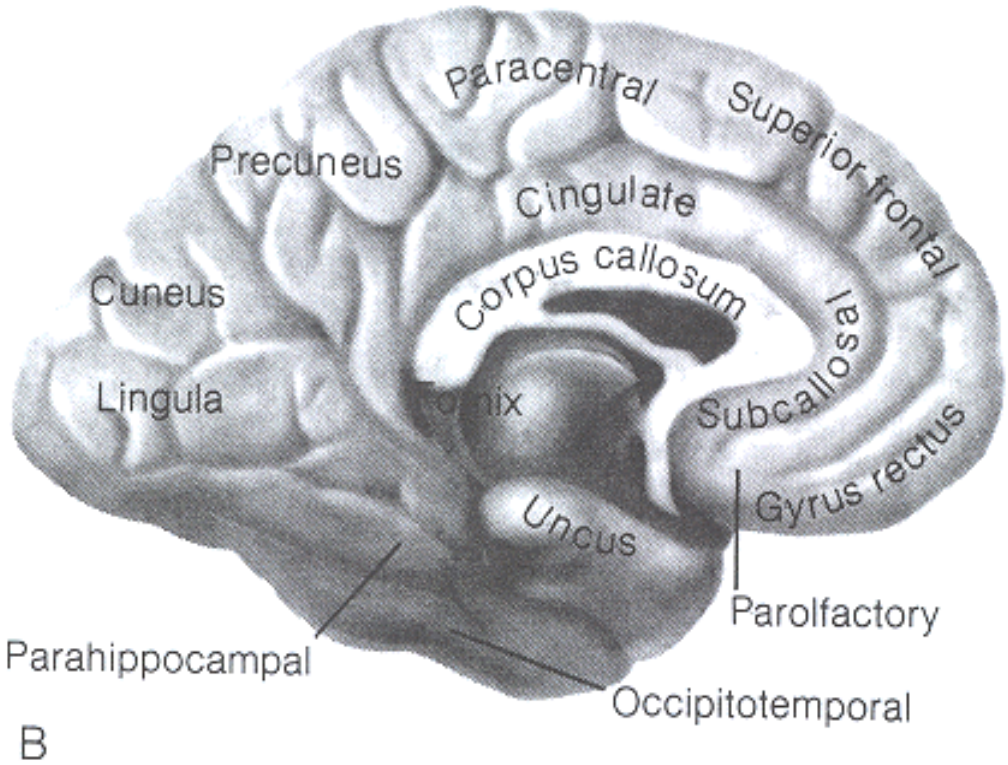
- LATERAL:
- Lateral occipital gyrus

- MEDIAL:
- Cuneus
- Lingual gyrus

Occipital Lobe Gyri - Lateral

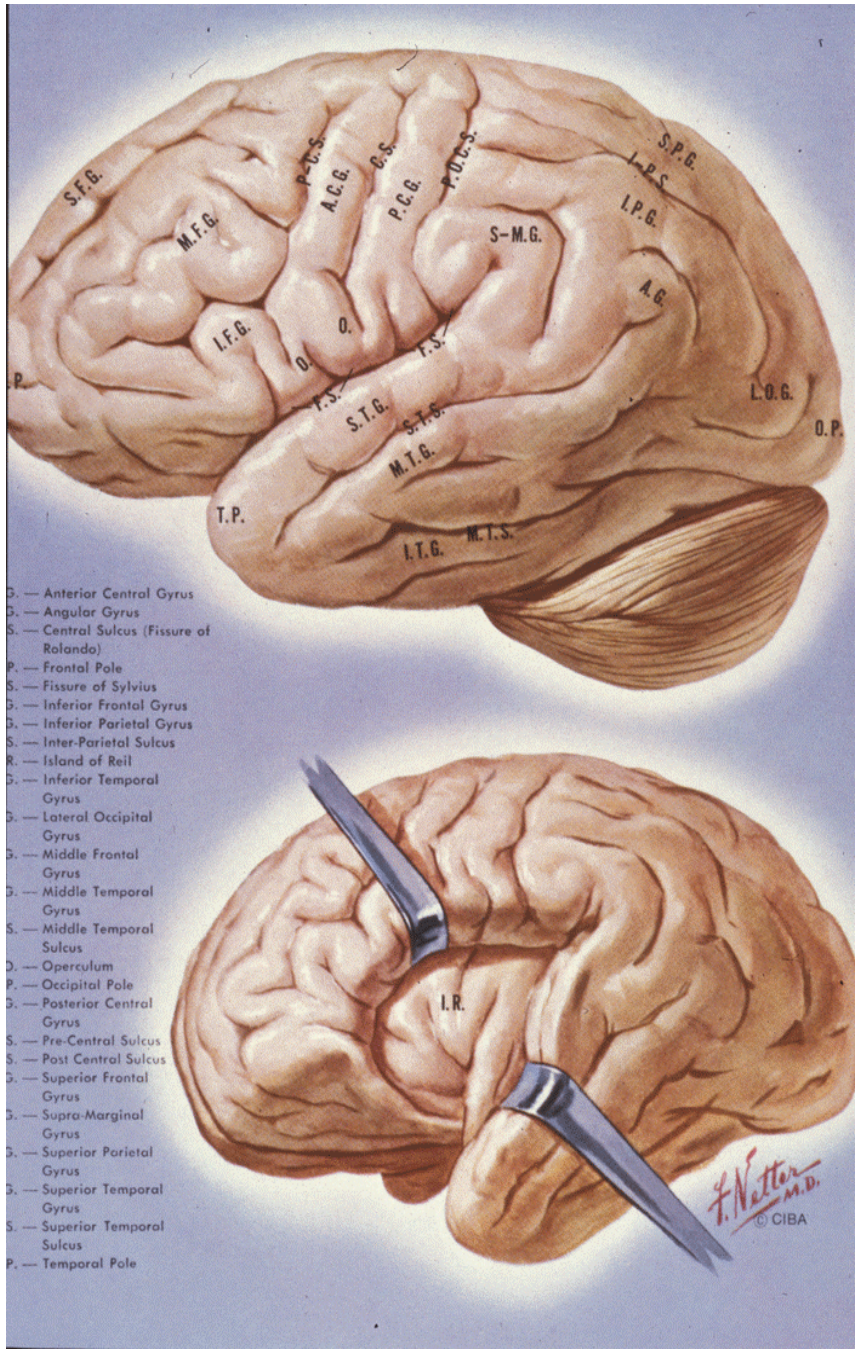


Occipital Lobe Gyri - Medial



Insula

- Cortex that lies underneath posterior-inferior frontal lobe
- (***Frontal Opercular*** region)
- and
- Anterior-superior temporal lobe
- (***Temporal Opercular*** region)



G. — Anterior Central Gyrus
G. — Angular Gyrus
S. — Central Sulcus (Fissure of Rolando)
P. — Frontal Pole
S. — Fissure of Sylvius
G. — Inferior Frontal Gyrus
G. — Inferior Parietal Gyrus
S. — Inter-Parietal Sulcus
R. — Island of Reil
G. — Inferior Temporal Gyrus
G. — Lateral Occipital Gyrus
G. — Middle Frontal Gyrus
G. — Middle Temporal Gyrus
S. — Middle Temporal Sulcus
O. — Operculum
P. — Occipital Pole
G. — Posterior Central Gyrus
S. — Pre-Central Sulcus
S. — Post Central Sulcus
G. — Superior Frontal Gyrus
G. — Supra-Marginal Gyrus
G. — Superior Parietal Gyrus
G. — Superior Temporal Gyrus
S. — Superior Temporal Sulcus
P. — Temporal Pole

Topography of Neocortex

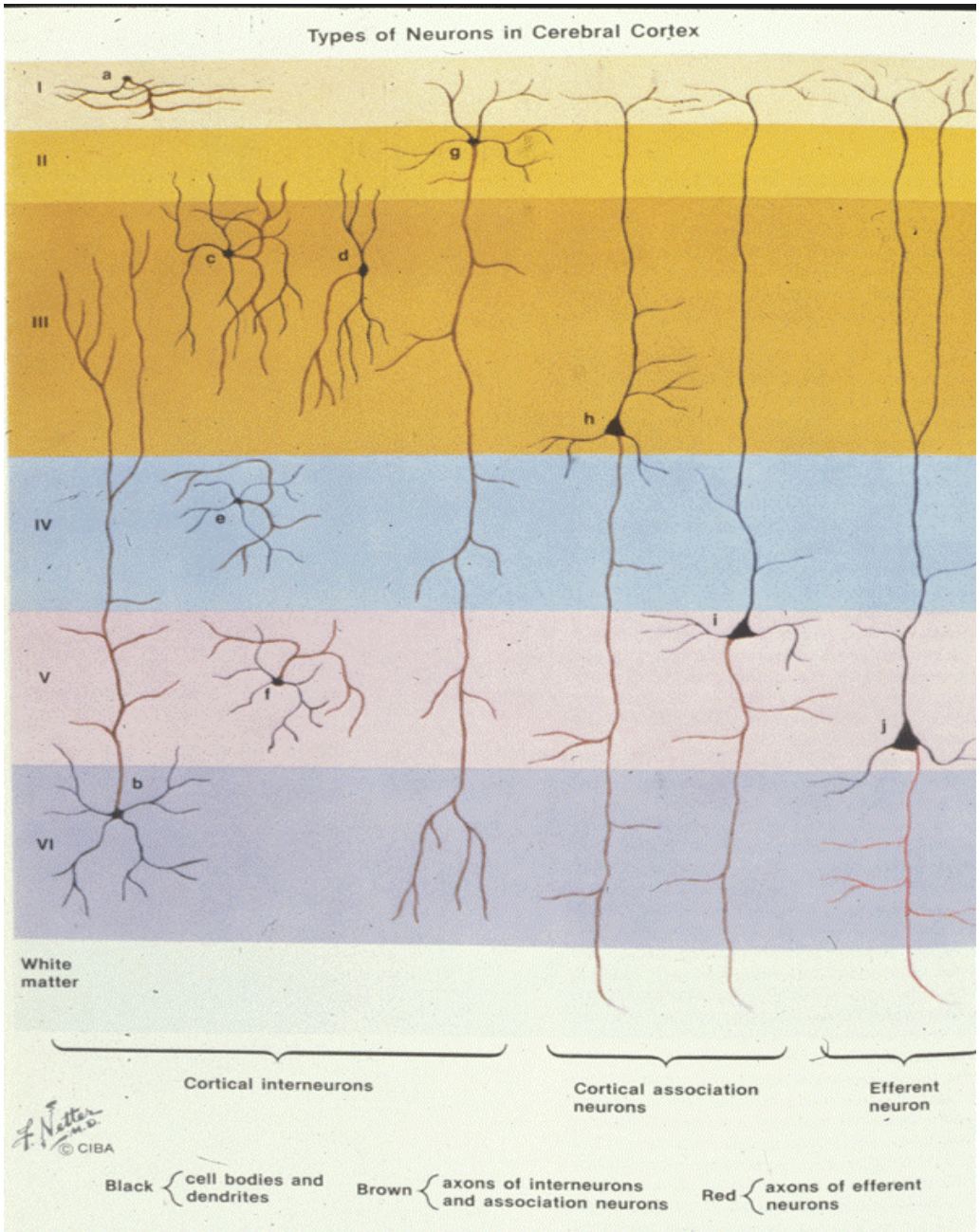
- Projection maps – tracing axons from sensory systems to cortex & from cortex to motor systems.
- Cytoarchitectonic maps – study of different types of cells across neocortex.
- Functional maps – lesions, electrical stimulation of cortex, recording cortex in response to sensory stimulation, functional neuroimaging.

Projection Maps

- Each sensory system projects to a particular brain region.
- Vision = occipital lobe
- Hearing = temporal lobe
- Somatosensory system = parietal lobe
- Major motor outflow = frontal lobe
- ***Primary projection zones***

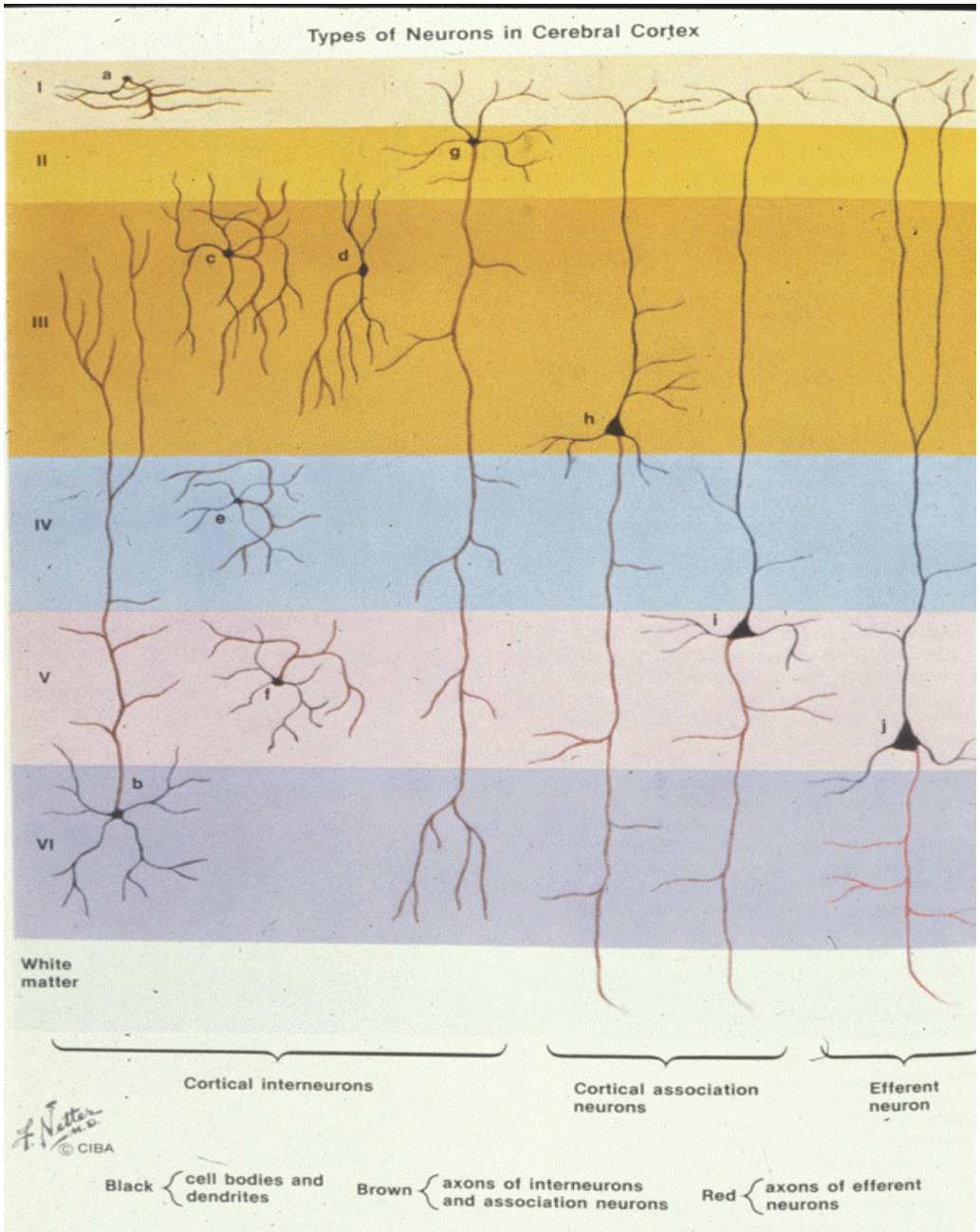
Projection Maps

- Primary projection area neurons send projections to adjacent areas
- Called ***Secondary projection zones***
- Elaborations on elemental sensory input (e.g., vision = color, stereopsis, texture)
- And higher-level associations and functions such as language, planning, memory.


Types of Neurons in Cerebral Cortex
I
II
III
IV
V
VI
a
b
c
d
e
f
g
h
i
j
White matter
Cortical interneurons
Cortical association neurons
Efferent neuron
F. Netter, M.D.
© CIBA
Black { cell bodies and dendrites
Brown { axons of interneurons and association neurons
Red { axons of efferent neurons

Cytoarchitecture of Cortex

- Cortical neurons arranged in 6 layers:
- Molecular layer I – most superficial layer
- External granular layer II – sensory
- External pyramidal layer III – motor
- Internal granular layer IV – sensory
- Internal pyramidal layer V – motor
- Polymorphic cell layer VI - innermost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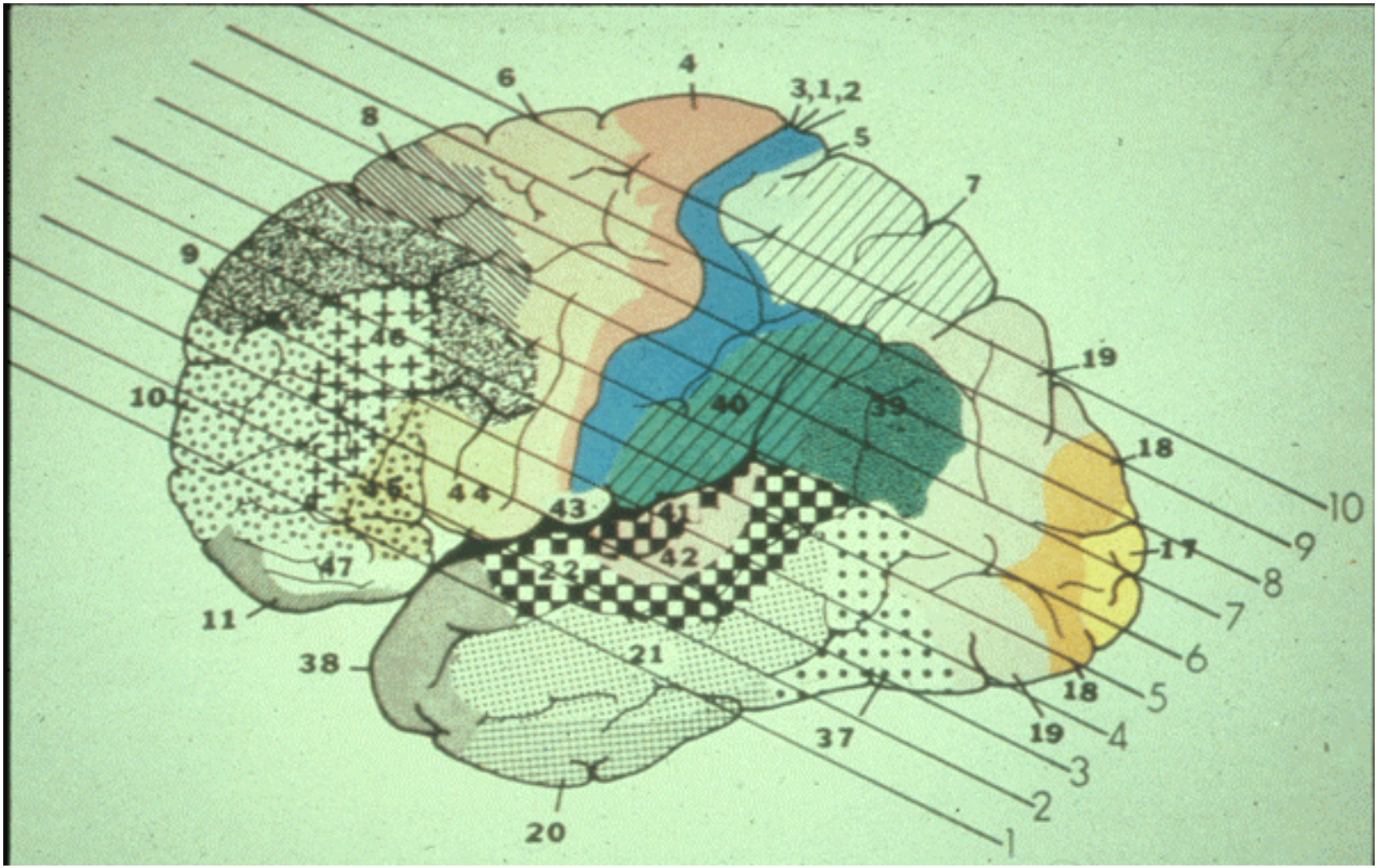
Cortical association neurons
Efferent neuron
F. Netter, M.D.
© CIBA
Black { cell bodies and dendrites
Brown { axons of interneurons and association neurons
Red { axons of efferent neurons

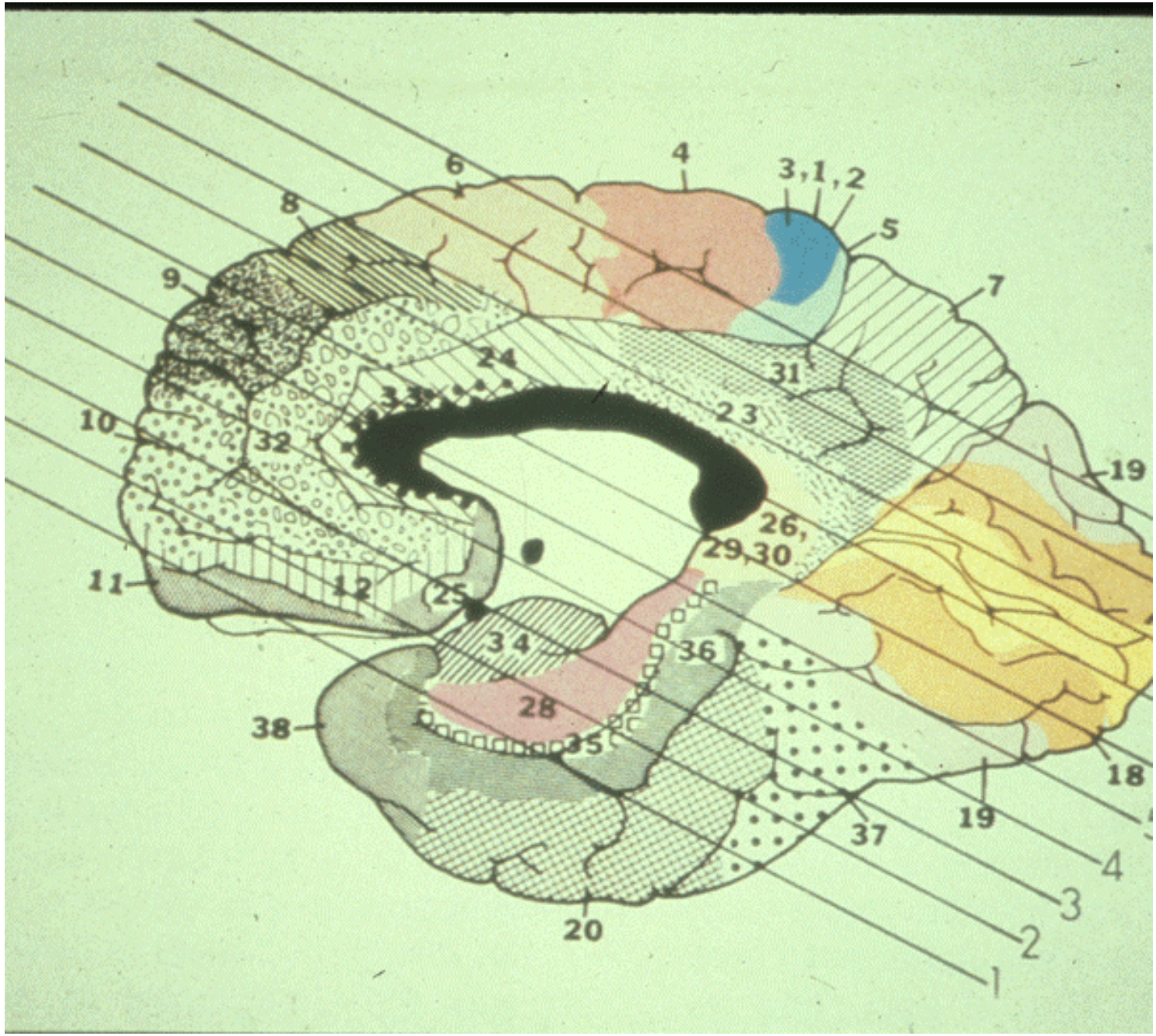
Cytoarchitecture of Cortex



Cytoarchitectural Maps

- Cortex microscopically examined to identify regions with unique organization.

- Brodmann's map one of most common.
- Number's on Brodmann's map have no special meaning – just the order in which he examined the areas.


6
4
3,1,2
8
5
9
7
24
31
33
23
10
32
19
26,
29,30
11
12
25
34
36
28
38
35
18
19
37
4
3
2
1
20

Brodmann's Map

- Learn major number/cortical function associations:
- Vision = area 17, 18, 19
- Audition = area 41, 42
- Touch (body senses) = areas 3,1,2
- Motor = area 4

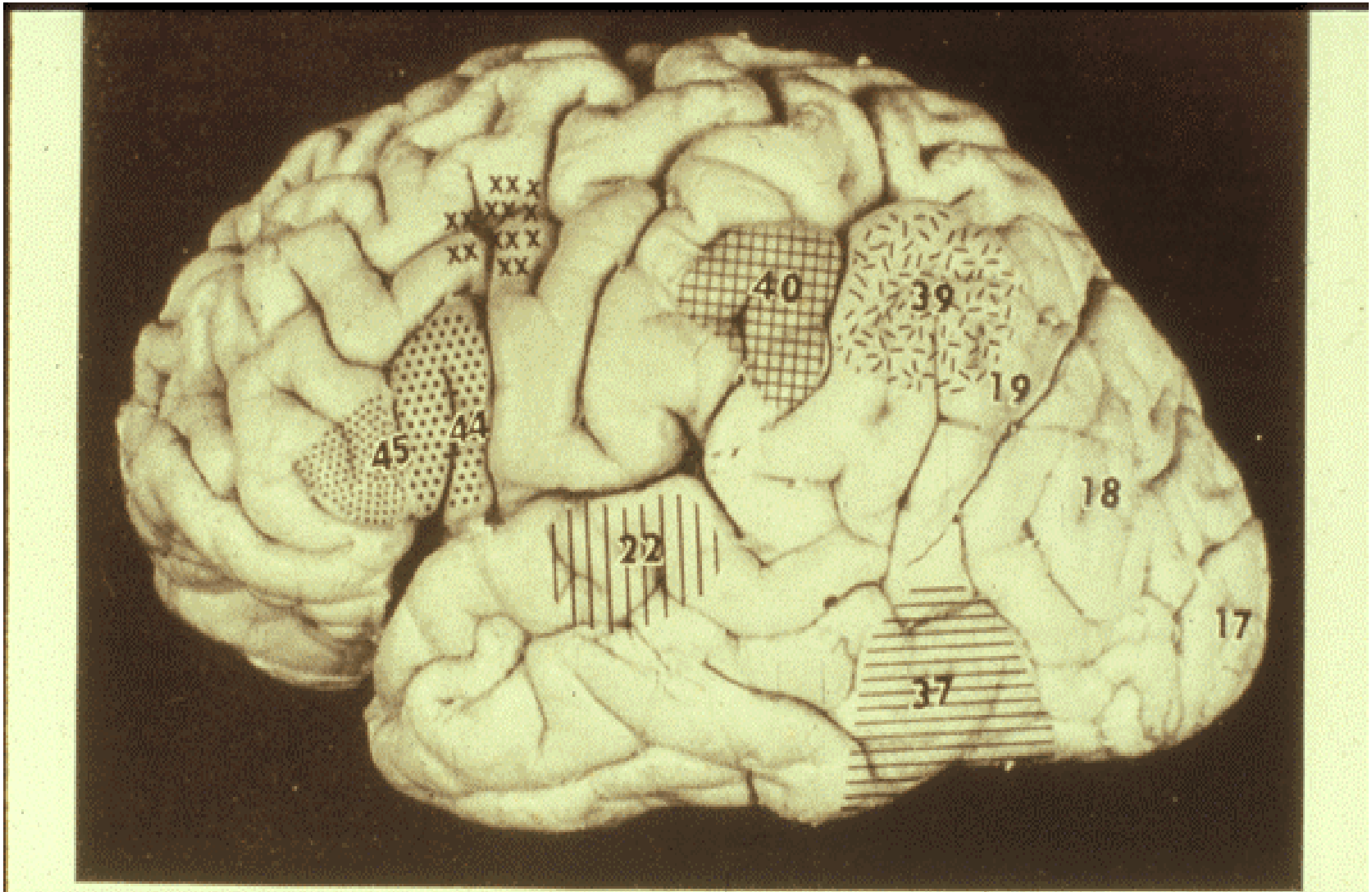


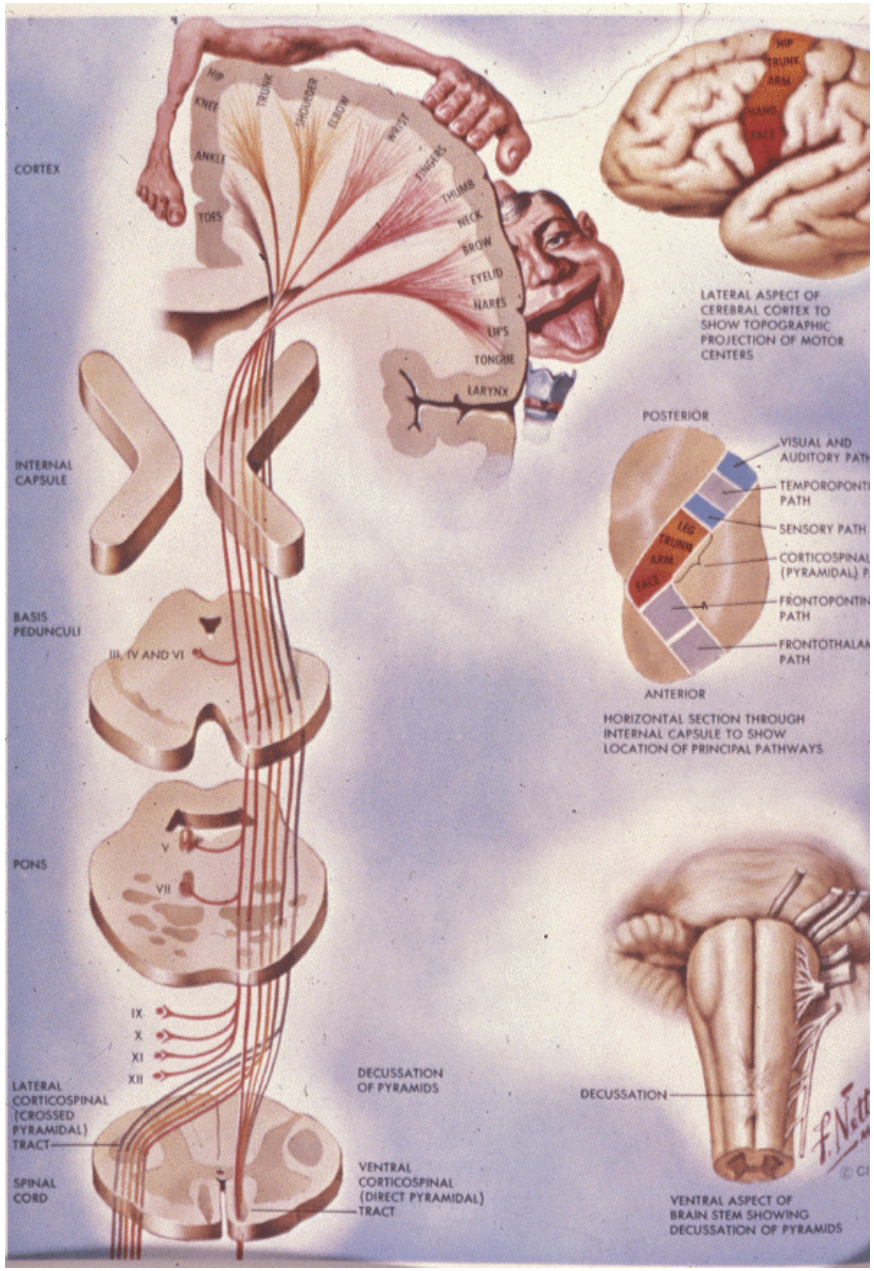
FIG. 335. Photograph of the lateral surface of the brain showing the location of some of the areas related to language. *Area 22*, auditory association cortex related to auditory aphasia or word deafness; *area 37*, visual-auditory association area; *area 39*, angular gyrus; *area 40*, supramarginal gyrus; *XXX*, area related to writing. Area 44 and the adjacent part of area 45 constitute approximately Broca's motor speech area.

Functional Maps

- Wilder Penfield – Montreal Neurologic Institute
- Stimulated awake pt's brains during brain surgery with electrodes
- Brief stimulation – observe movement or pt's reports sensation (body tickle or itch) – record response – move to next brain region.

Functional Maps

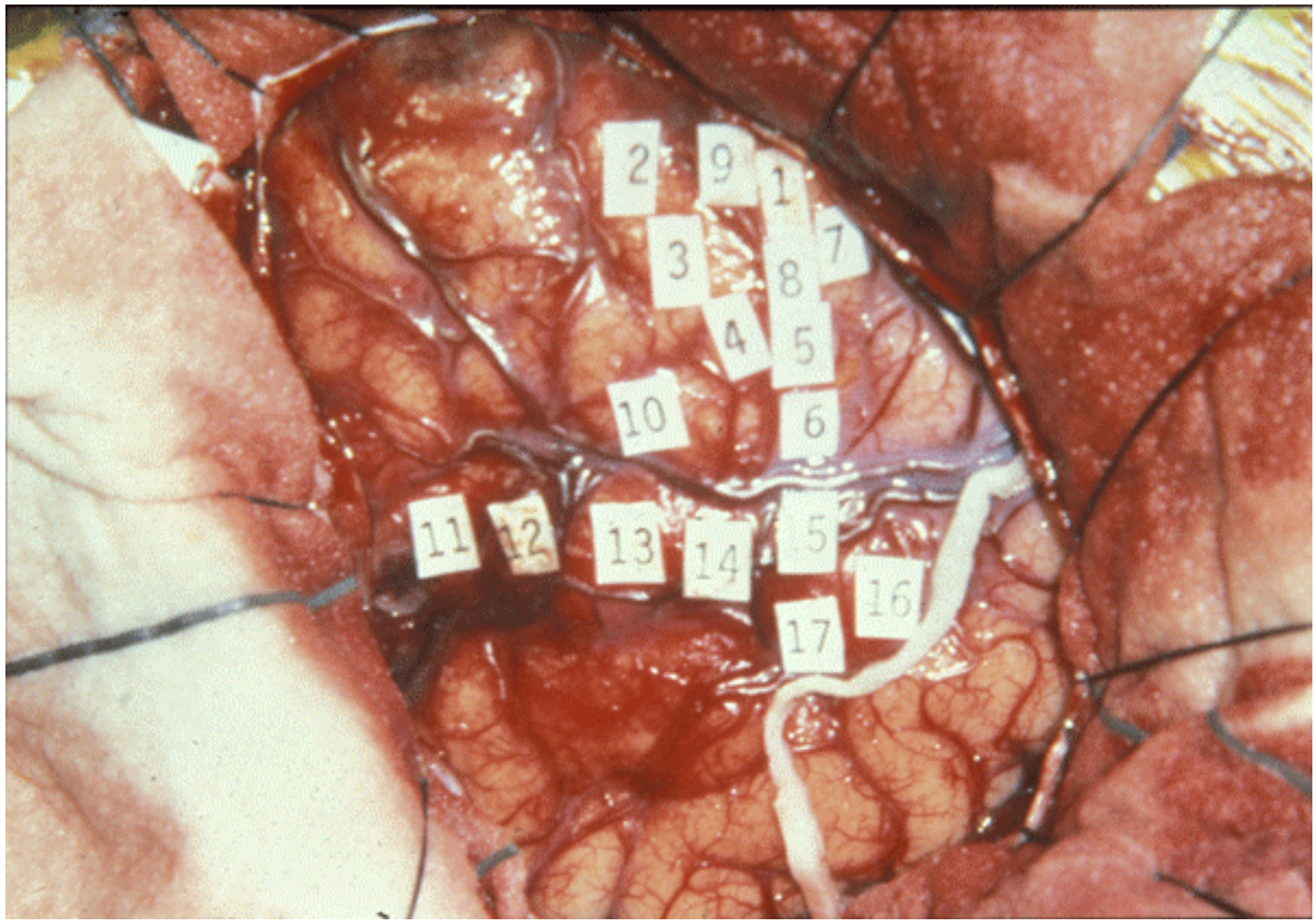
- Penfield showed:
- Point-to-point relations between parts of body and parts of cortex
- Areas with finer discriminative touch, have larger areas of representation on cortex.
- Body represented upside down on postcentral (and precentral) gyrus – largest lips and thumb


CORTEX
HIP
KNEE
ANKLE
TOES
TRUNK
SHOULDER
ELBOW
WRIST
FINGERS
THUMB
NECK
BROW
EYELID
NARES
LIPS
TONGUE
LARYNX
INTERNAL CAPSULE
BASIS PEDUNCULI
III, IV AND VI
PONS
V
VII
IX
X
XI
XII
LATERAL CORTICOSPINAL (CROSSED PYRAMIDAL) TRACT
SPINAL CORD
DECUSSATION OF PYRAMIDS
VENTRAL CORTICOSPINAL (DIRECT PYRAMIDAL) TRACT
HIP
TRUNK
ARM
HAND
FACE
LATERAL ASPECT OF CEREBRAL CORTEX TO SHOW TOPOGRAPHIC PROJECTION OF MOTOR CENTERS
POSTERIOR
VISUAL AND AUDITORY PATH
TEMPOROPONTI PATH
SENSORY PATH
LEG
TRUNK
ARM
FACE
CORTICOSPINAL (PYRAMIDAL) P
FRONTOPONTIN PATH
FRONTOTHALA PATH
ANTERIOR
HORIZONTAL SECTION THROUGH INTERNAL CAPSULE TO SHOW LOCATION OF PRINCIPAL PATHWAYS
DECUSSATION
VENTRAL ASPECT OF BRAIN STEM SHOWING DECUSSATION OF PYRAMIDS

Functional Maps

- We stimulate cortex today to “map” the somatosensory, motor, and language cortex during neurosurgical procedure where
- “eloquent” cortex is involved
- In order to avoid vital areas in area of resected brain tissue.

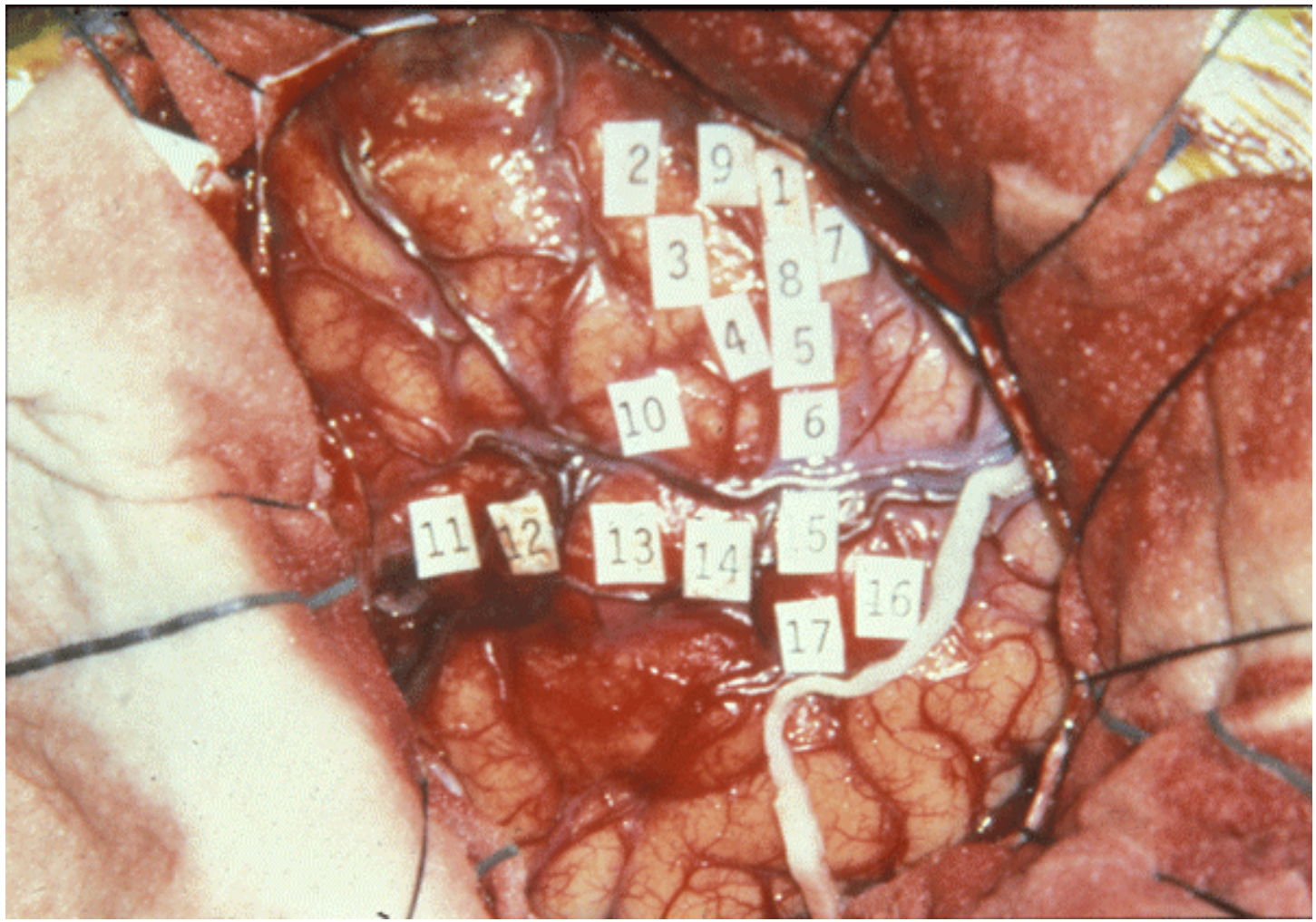
Cortical Stimulation Mapping



Intraoperative Stimulation Mapping

- **SENSORIMOTOR MAPPING**
- **1 = inability to open mouth**
- **2 = funny sensation, L side of mouth**
- **3-6 = Tingling sensations, L side of mouth**
- **7 = drawing up of mouth**
- **8-9 = mouth movements**

Cortical Stimulation Mapping



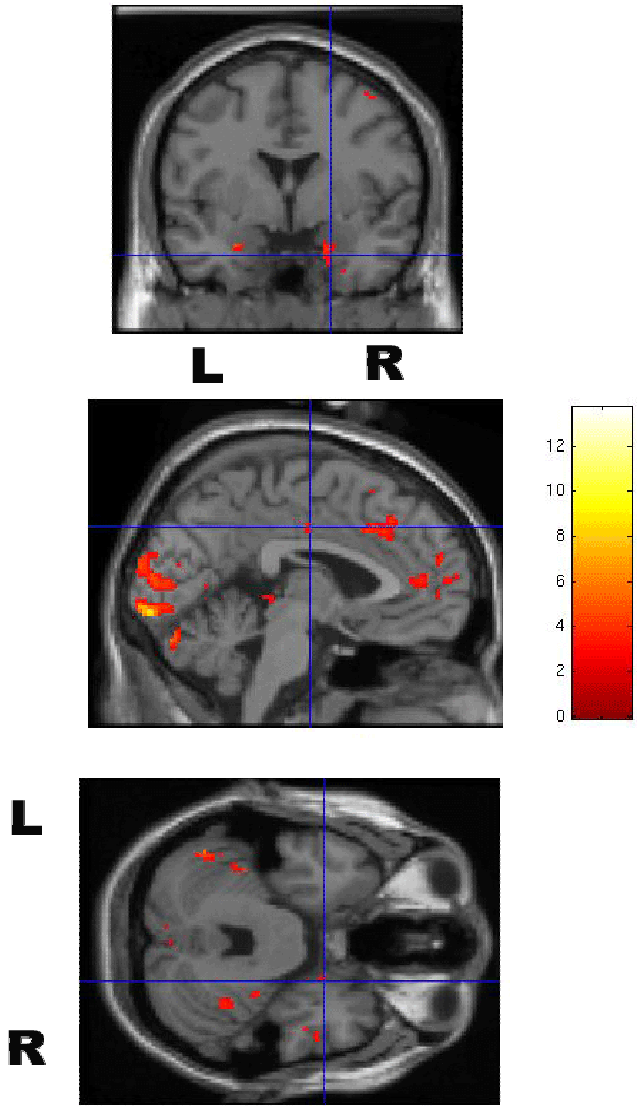
Intraoperative Stimulation Mapping

- SPEECH MAPPING
- 10= cessation of counting
- 11= paraphasia during recitation
- 12= perseveration of recitation
- 13= interruption & repeating phrase
- 14-16 = arrest of recitation
- 17= paraphasia during recitation

Functional Imaging

- Neuroscientists use:
- functional magnetic imaging (fMRI),
- positron emission tomography (PET),
- single-photon emission computed tomography (SPECT), and
- magnetoencphalography (MEG) during experimental tasks to map various cognitive functions.

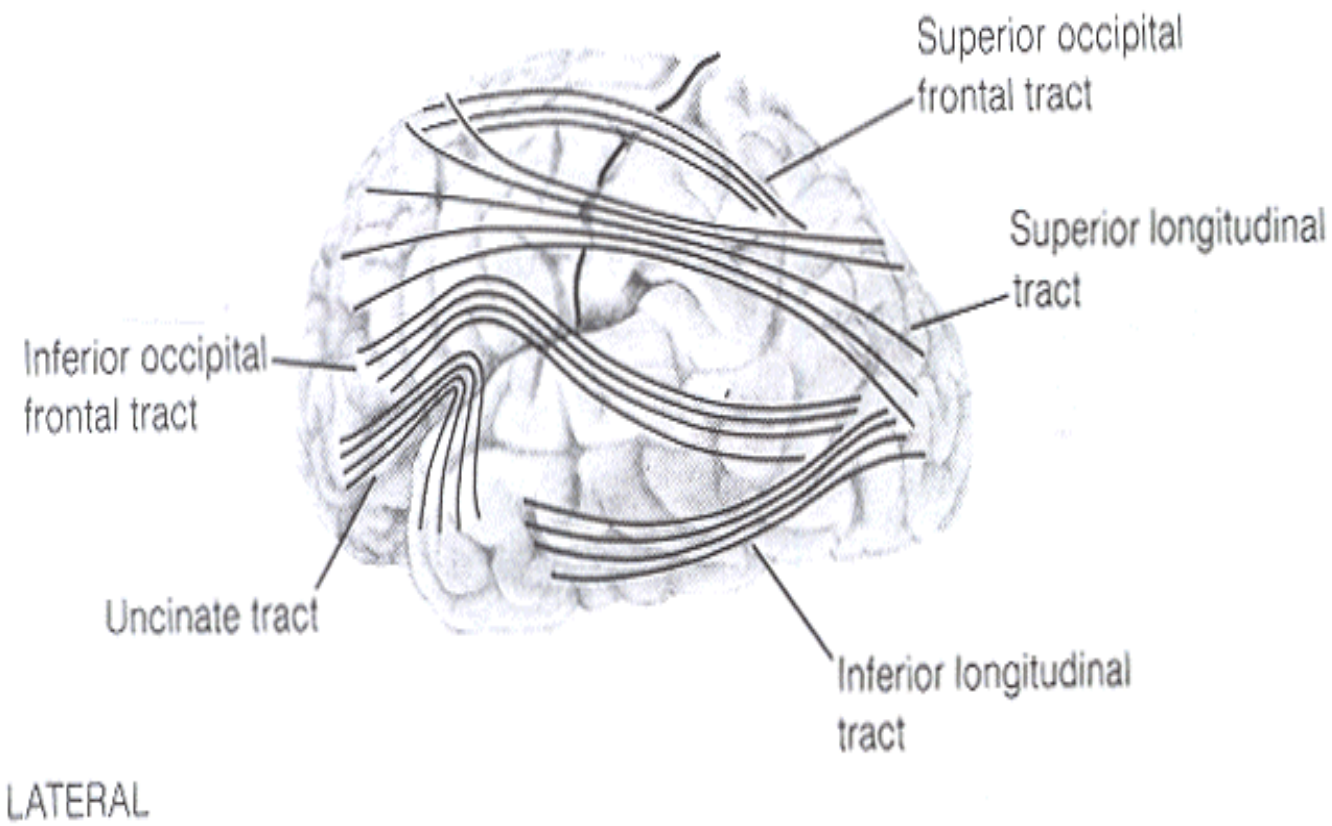
Functional Imaging



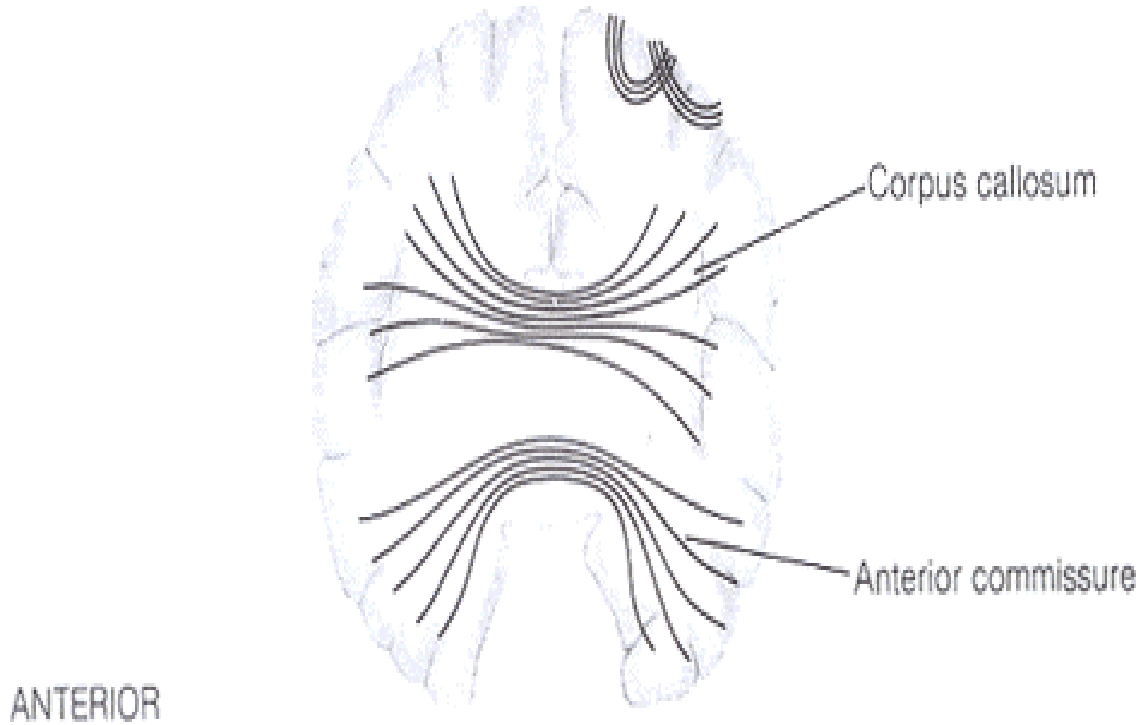
Cortical Connections

- 3 types of axon projections in cortex
- Short connections between 1 gyrus and another (***U-fibers*** or ***arcuate fibers***).
- Longer connections between lobes (named ***fasciculi*** or ***tracts***)
- Interhemispheric connections (***commissures***) between two hemispheres

Lateral Cortico-cortical Connections



Interhemispheric Commissures



Importance of Connections

- Difficult to damage area of cortex without damaging interconnection pathways too.

- Isolated damage to a pathway may result in as severe a deficit as damage to the cortex.

Importance of Connections

- Damage to pathway may cause behavioral deficits similar to that seen

- after damage to functional cortical areas the pathway connects.

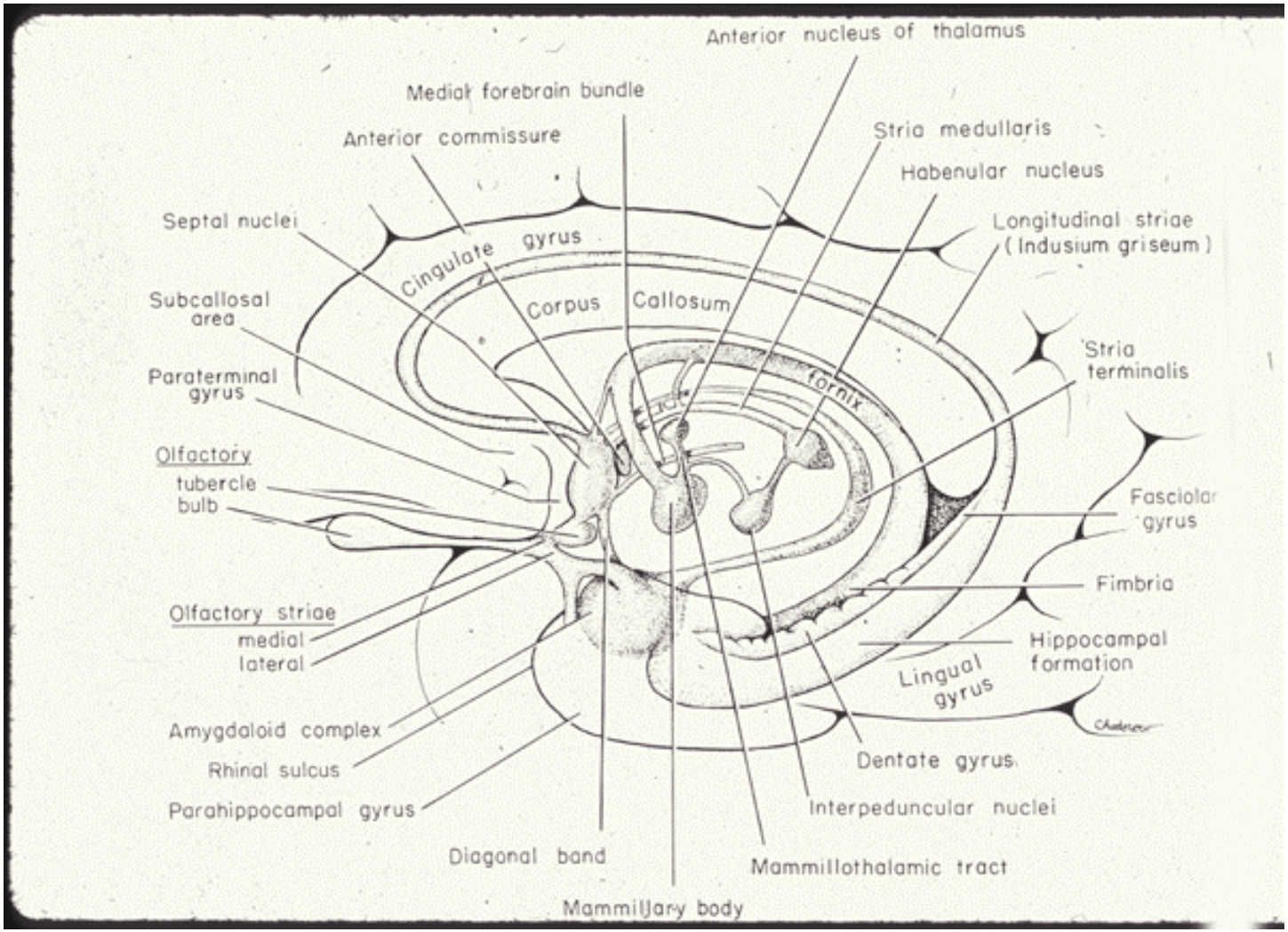
Limbic Lobe

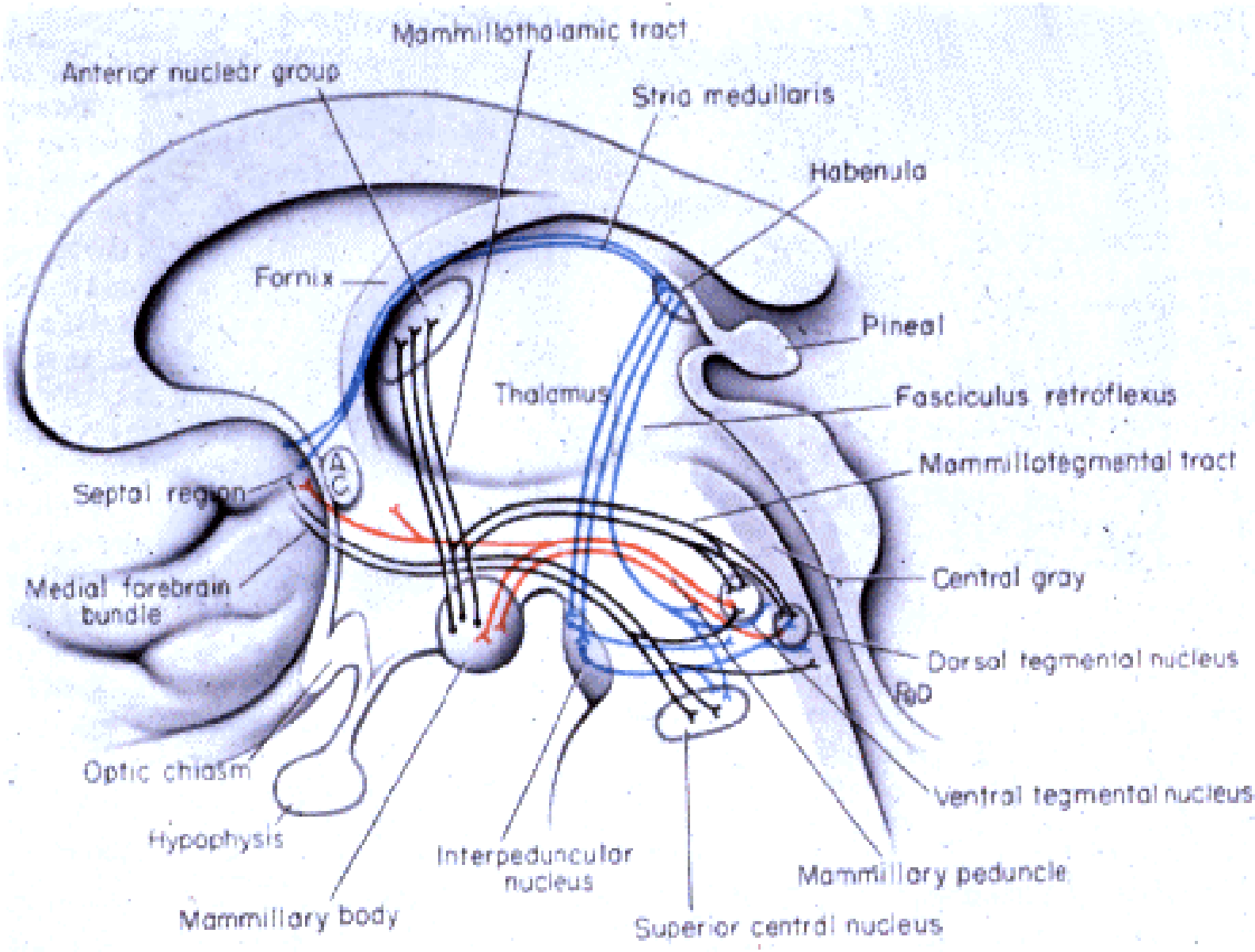
- Middle brain layer sandwiched between new brain (cortex) and old brain (diencephalon)
- First developed in reptiles/amphibians
- Major functions are related to
- Emotion and
- Memory

Limbic Lobe Structures

- Major Structures:
- Amygdala
- Hippocampus
- Septal nuclei
- Cingulate gyrus (and cingulum bundle)
- Papez (1937) “limbic system” or circuit “produces emotions”

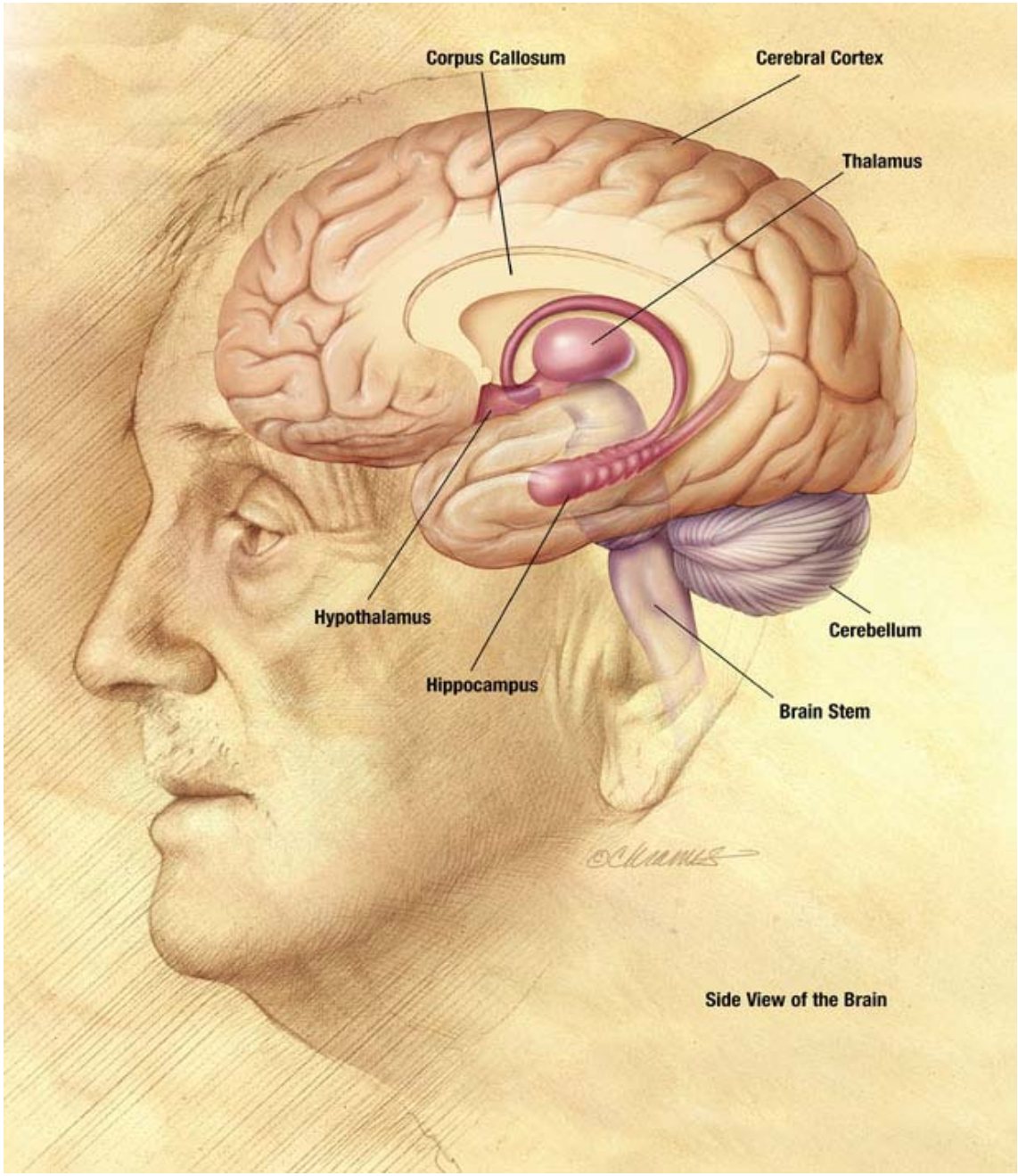
Limbic Lobe Structures




Mammillothalamic tract
Anterior nuclear group
Stria medullaris
Habenula
Fornix
Pineal
Thalamus
Fasciculus retroflexus
Mammillotegmental tract
Septal region
Medial forebrain bundle
Central gray
Dorsal tegmental nucleus
RaD
Optic chiasm
Ventral tegmental nucleus
Hypophysis
Interpeduncular nucleus
Mammillary peduncle
Mammillary body
Superior central nucleus

Clinical Correlations

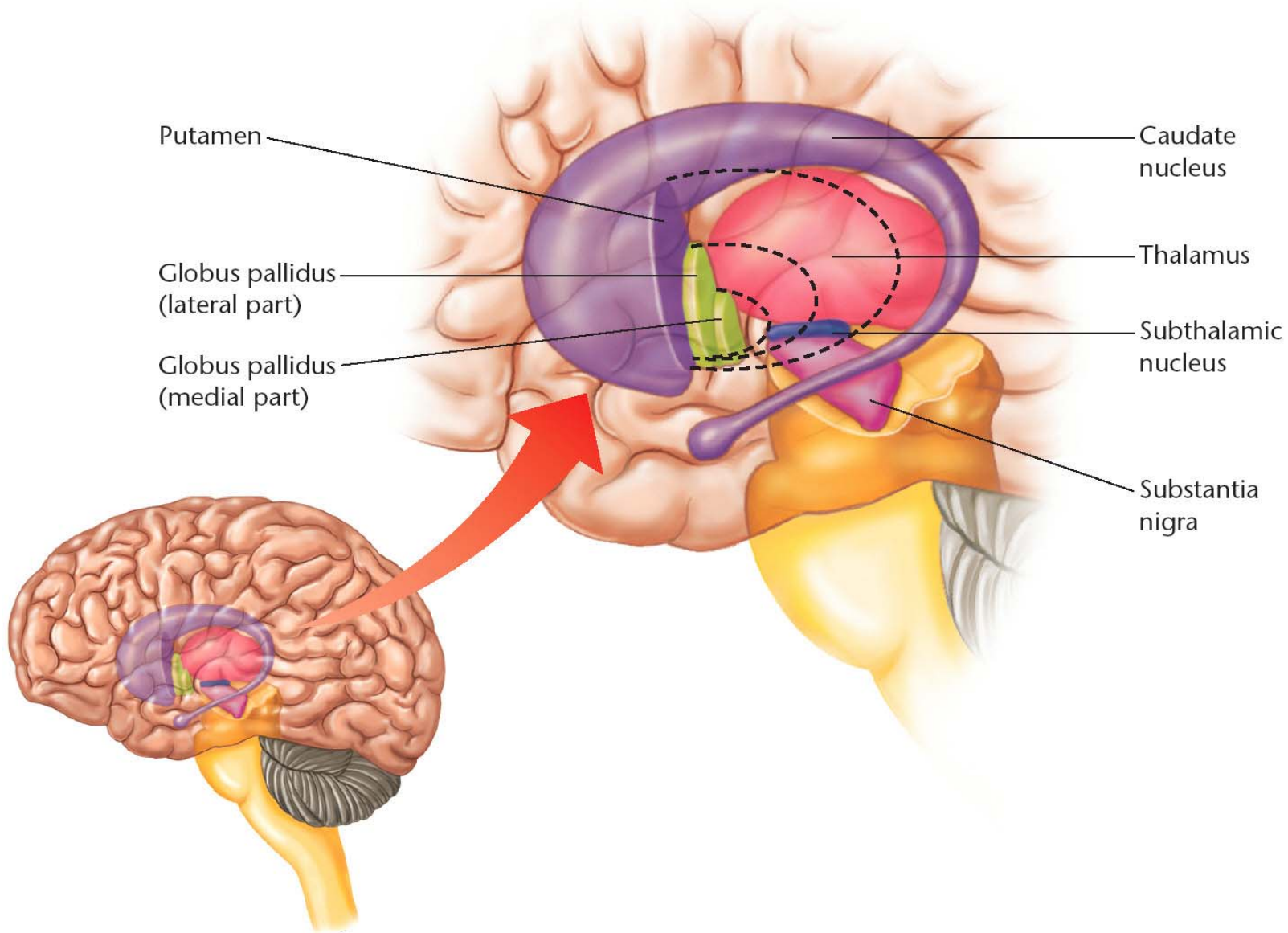
- Hippocampus – learning and memory disorders
- Amygdala – fear, aggression, fight or flight, adds “emotional tone”
- Cingulate gyrus – motivation, drive; lesions = akinetic mutism, reduced drive
- Septal area – “pleasure center;” mediator of self-stimulation, self-reward.



Side View of the Brain

Basal Ganglia

- Group of nuclei lying deep beneath anterior regions of cortex
- Caudate nucleus (tailed nucleus)
- Putamen (shell)
- Globus pallidus (pale globe)
- Amygdala (almond)
- Substantia nigra in midbrain


Putamen
Caudate nucleus
Thalamus
Globus pallidus (lateral part)
Globus pallidus (medial part)
Subthalamic nucleus
Substantia nigra

Basal Ganglia Circuits

- Caudate receives input from all areas of cortex projects to
- Putamen and globus pallidus to
- Thalamus (VA / VL). From thalamus to
- Motor areas of cortex.

Basal Ganglia

Basal Ganglia Circuits

- Caudate/putamen = neostriatum
- Reciprocal connections with midbrain, esp. substantia nigra.
- Substantia nigra provides dopamine (DA) to basal ganglia.
- When DA is lost, motor disorder called Parkinson's disease results.

Functions of Basal Ganglia

- Damage causes changes in posture, muscle tone, and abnormal movements
- E.g., twitches, jerks, tremors.
- Important in sequencing movements into a smooth progression.
- Also thought to support habit (procedural) learning.

Thalamus

- Group of relay nuclei deep within center of brain.
- All sensory projections synapse in thalamus en route to cortex (except olfaction).
- ***Lateral geniculate body*** (LGB) receives input from retina – projects to visual cortex (Brodmann's area 17) in occipital lobe.

Thalamic Connections

- ***Medial geniculate body*** (MGB) receives auditory projections – projects to primary auditory cortex (transverse gyri of Heschl, Brodmann's area 41, 42).

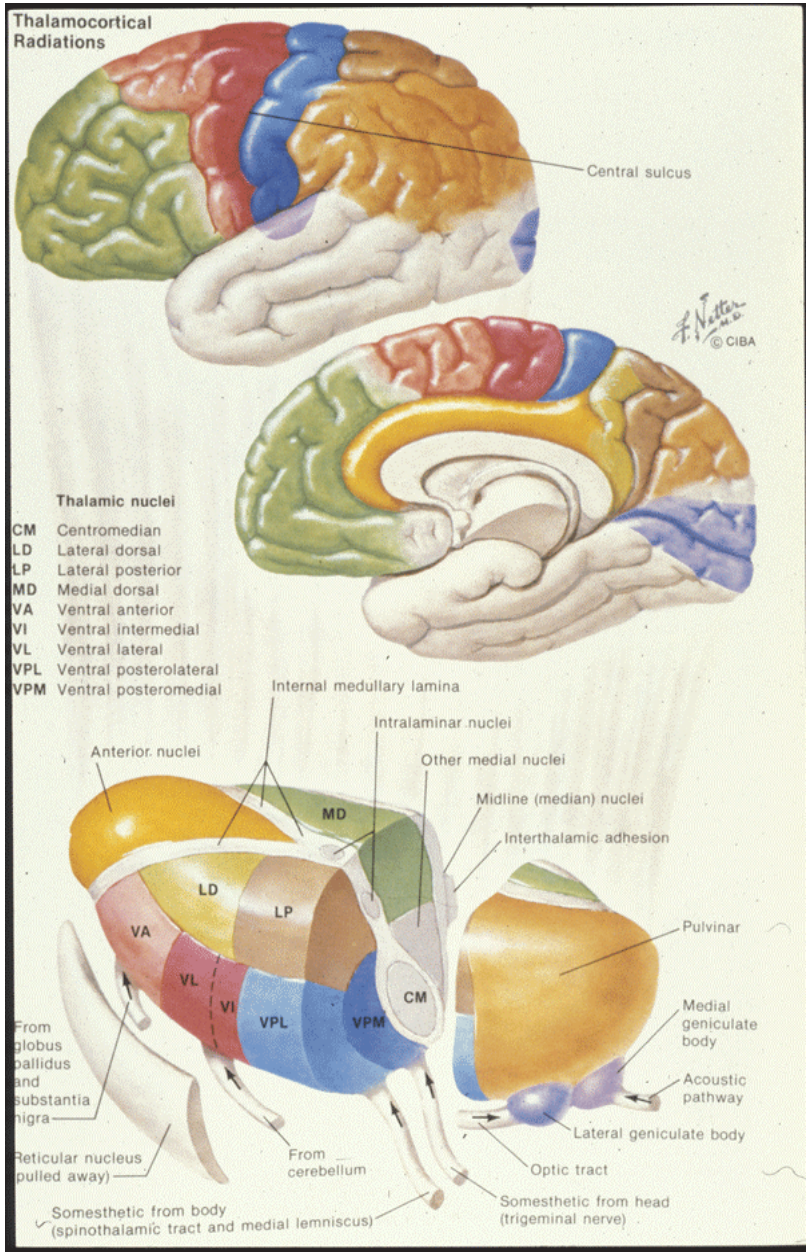
- Posterior areas of cortex send projects to and receives input back from ***pulvinar.***

Thalamic Connections

- ***Ventral posterior lateral*** (VPL) nucleus receives touch, pressure, pain and temperature input from body – projects to somatosensory cortex (Brodmann's areas 3,1,2).
- Limbic system projects to frontal lobe through ***dorsomedial*** (DM) nucleus.

Thalamic Connections

- Other limbic projections pass through mammillary bodies to ***anterior*** nucleus to cingulate gyrus.
- Basal ganglia project to motor cortex through the ***ventral anterior*** nucleus (VA).
- Cerebellum projects to motor cortex through the ***ventral lateral*** nucleus (VL).


Thalamocortical Radiations
Central sulcus
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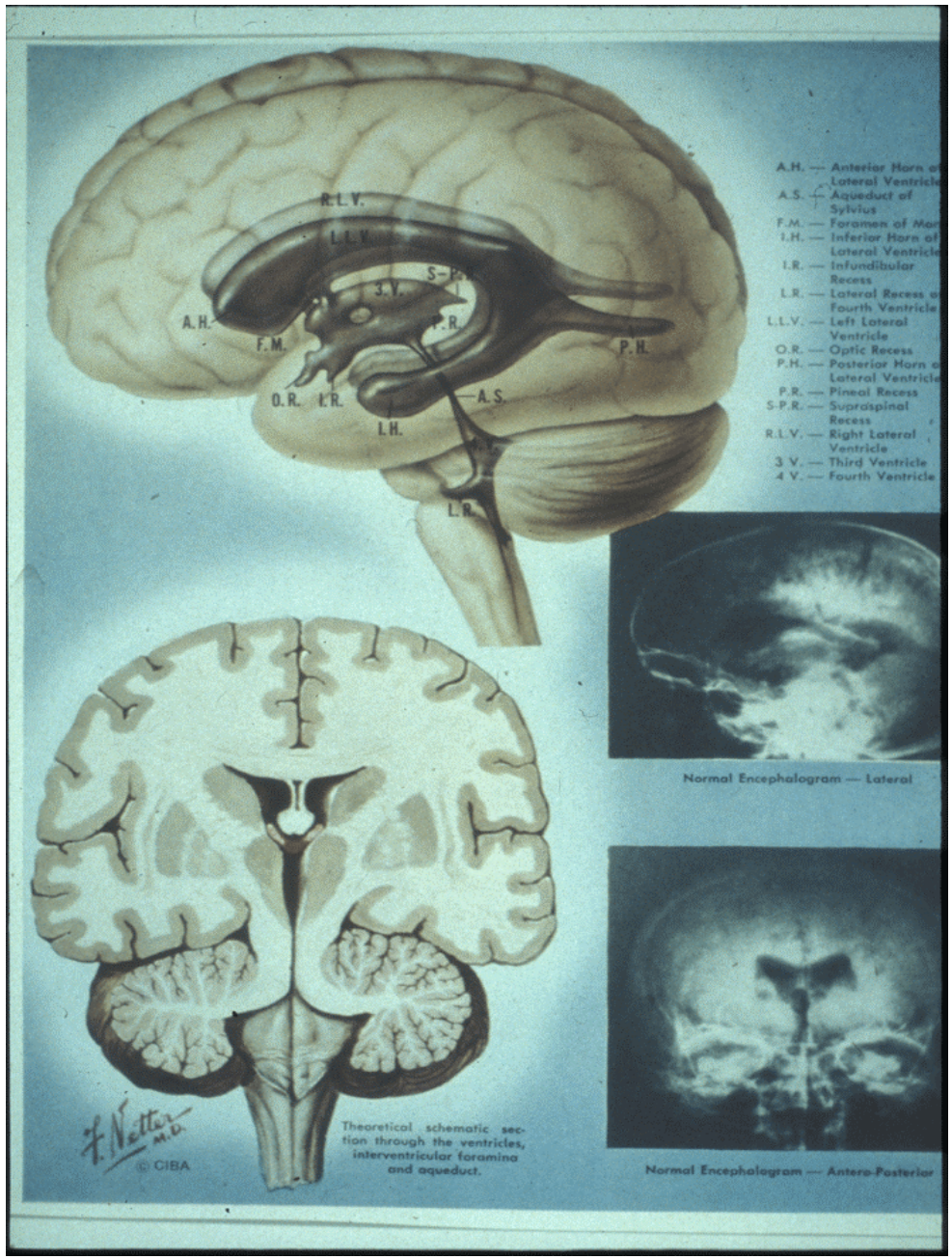
Thalamic nuclei
CM Centromedian
LD Lateral dorsal
LP Lateral posterior
MD Medial dorsal
VA Ventral anterior
VI Ventral intermedial
VL Ventral lateral
VPL Ventral posterolateral
VPM Ventral posteromedial
Internal medullary lamina
Intralaminar nuclei
Anterior nuclei
Other medial nuclei
Midline (median) nuclei
Interthalamic adhesion
MD
LD
LP
VA
VL
VI
VPL
VPM
CM
Pulvinar
Medial geniculate body
Acoustic pathway
Lateral geniculate body
Optic tract
From globus pallidus and substantia nigra
Reticular nucleus (pulled away)
From cerebellum
Somesthetic from head (trigeminal nerve)
Somesthetic from body (spinothalamic tract and medial lemniscus)

Crossed Brain

- Each cerebral hemisphere responds to sensory stimulation from the contralateral side of body
- And controls musculature on contralateral side of body.
- Vision and audition also cross.
- Olfaction does not.

Crossed Brain

- Because of this “crossed” arrangement of the nervous system
- There are many crossings, or ***decussations***, of sensory & motor fibers.
- Damage to one side of brain
- Causes sensory & motor impairments to the opposite side of body.


R.L.V.
L.L.V.
S-P.R.
3.V.
A.H.
F.M.
P.R.
P.H.
O.R.
I.R.
A.S.
I.H.
L.R.
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
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S-P.R. — Supraspinal Recess
R.L.V. — Right Lateral Ventricle
3 V. — Third Ventricle
4 V. — Fourth Ventricle
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Theoretical schematic section through the ventricles, interventricular foramina and aqueduct.
Normal Encephalogram — Lateral
Normal Encephalogram — Antero-Posterior

The Ventricles

- Embryonic nervous system consisted of a neural tube.
- Central core of the brainstem & brain remain hollow.

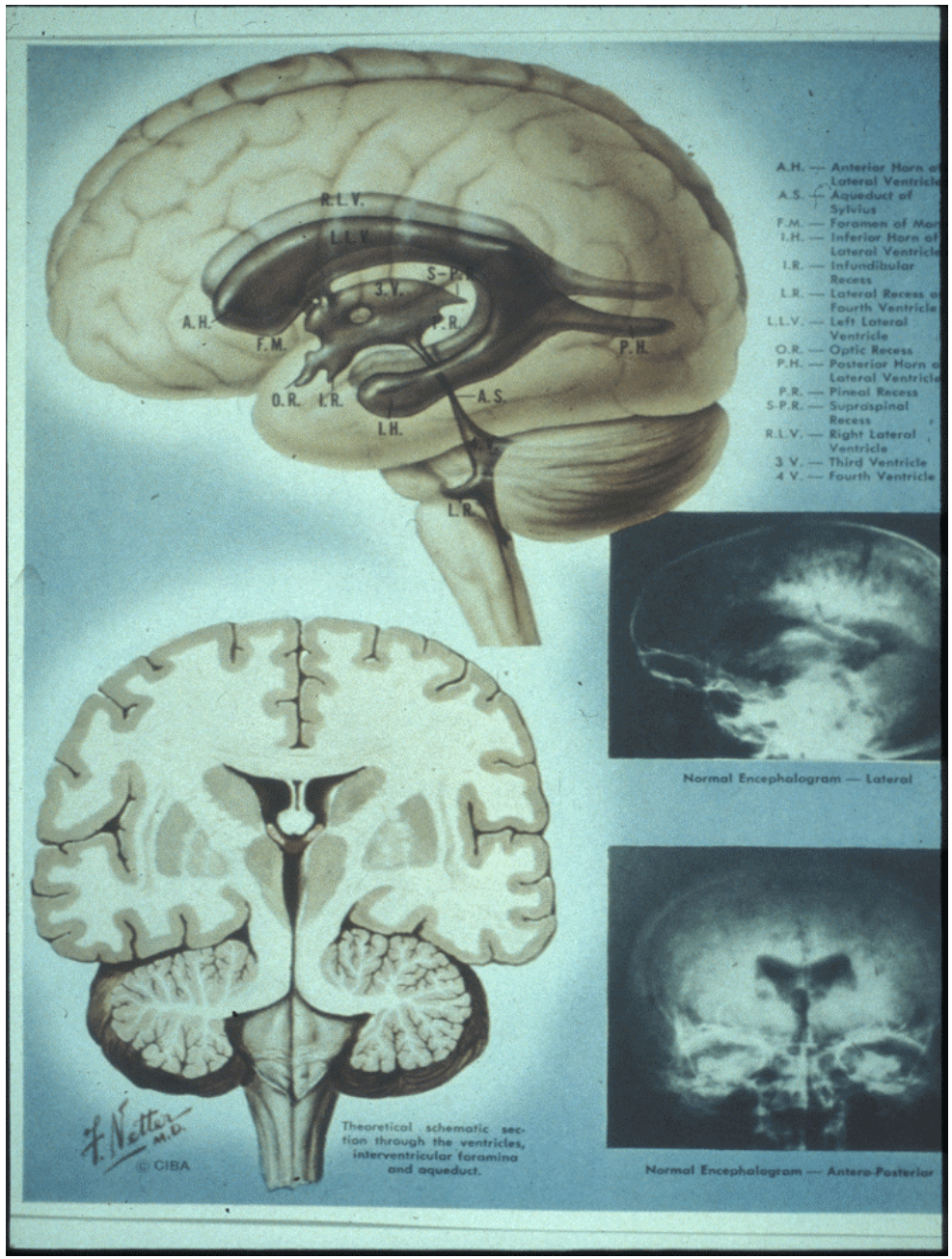
- This cavity is filled with ***cerebrospinal fluid (CSF)***.

The Ventricles

- ***Cerebrospinal fluid (CSF)*** is produced by ***choroid plexus***
- (specialized cluster of glial cells lying inside the cavity).
- Some areas of cavity are enlarged
- Called ***ventricles***.

The Ventricles

- In mammals = 4 ventricles.
- ***Lateral ventricles (I & II)***
- ***Third ventricle*** (III) – ventricle in the diencephalon
- ***Fourth ventricle*** (IV) – lies between brainstem and cerebellum.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Theoretical schematic section through the ventricles, interventricular foramina and aqueduct.
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Function of Cerebral Ventricles

- Serves as a hydraulic buffer to protect tissue by absorbing blows to head.
- Dissemination of chemicals to intercellular spaces of brain.
- Bath or sink function – drains off metabolic wastes from the brain.

CSF Flow

- Cerebrospinal fluid (CSF) is made continually.
- Colorless solution of sodium chloride & other salts.
- Flows from the ventricles into the ***subarachnoid space***
- Circulates around the brain
- Absorbed by venous sinuses of dura mater.

CSF Obstruction

- If CSF outflow is blocked, ***hydrocephalus*** results.
- Ventricles enlarge in response to increased CSF pressure
- Produce an enlarged skull in infants.
- Increased intracranial pressure and herniation, if not treated, in adults.

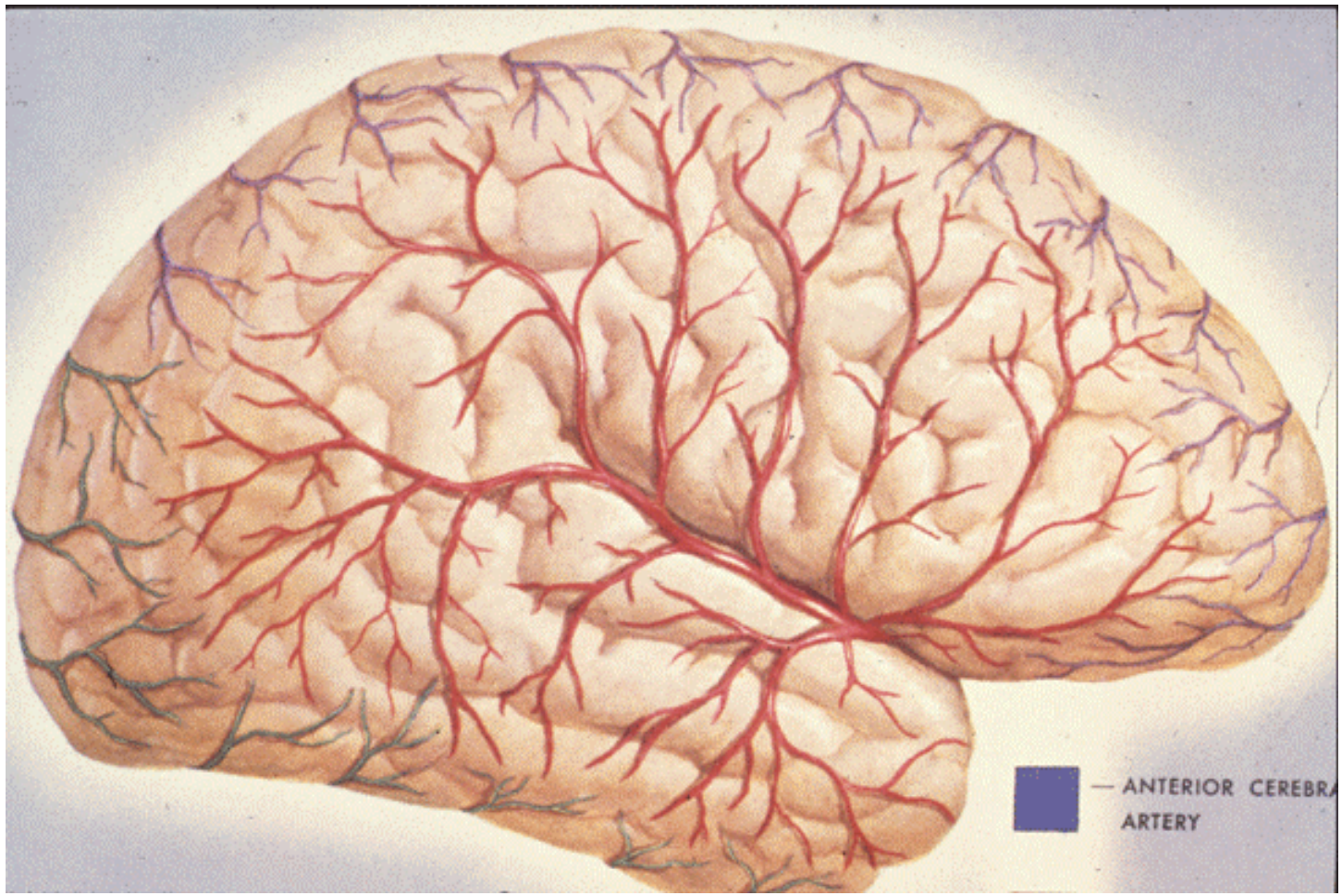
Hydrocephalus

- Treated by neurosurgical placement of a tube into the lateral ventricle to drain off excess CSF.
- Tube called a ***shunt***
- Usually drains into the abdominal cavity called a ***ventriculo-peritoneal shunt***.
- Shunts are vulnerable to infection.

Blood Supply to Brain

- Two major pairs of arteries supply the brain
- ***Internal carotid arteries*** - anterior 2/3^{rds} of brain (80%); predominantly cerebral in distribution.
- ***Vertebral arteries*** merge into ***basilar artery*** on ventral brainstem (pons) – posterior 1/3rd of brain; predominantly cerebellar & brainstem in distribution.

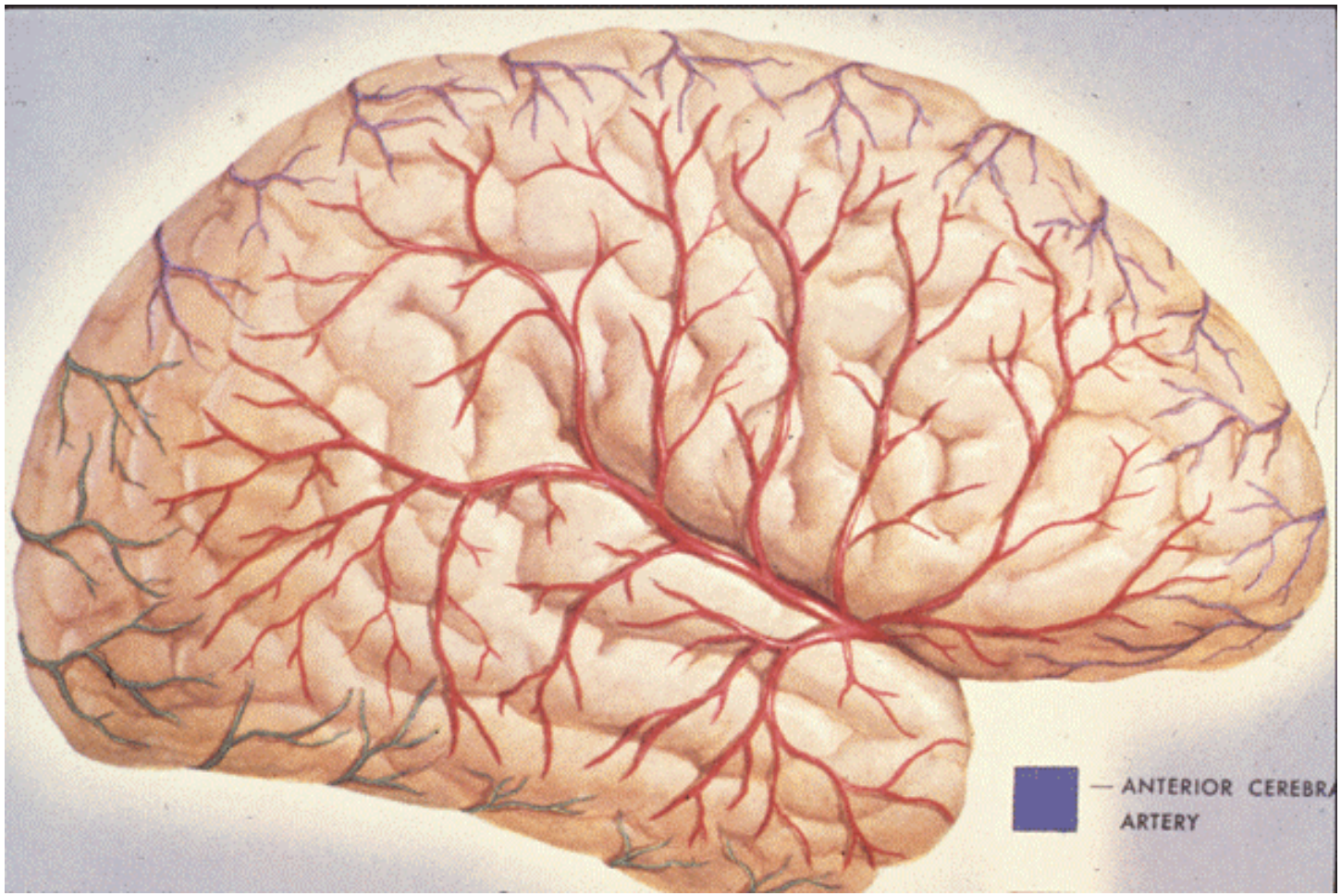
Territory of ACA, MCA & PCA

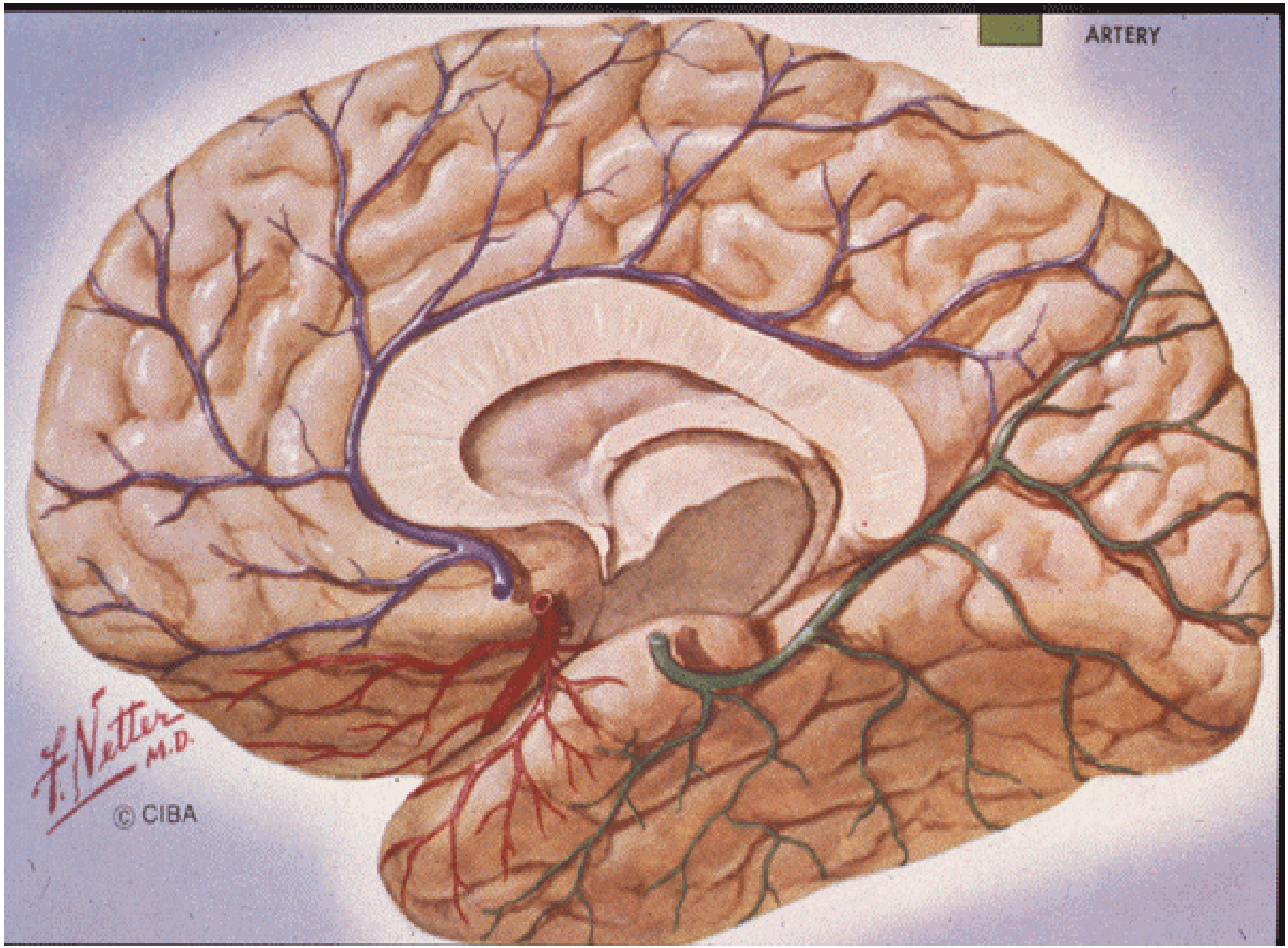


Blood Supply to Brain

- Internal carotid artery (ICA) enters skull at base of brain branches into:
- ***Anterior cerebral artery (ACA)*** and ***middle cerebral artery (MCA)*** which irrigates anterior-lateral and mesial cortex.
- Basilar gives rise to ***posterior cerebral artery (PCA)*** which irrigates occipital lobe and mesial temporal cortex.

Territory of ACA, MCA & PCA




ARTERY
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Stroke

- Disruption of blood flow (ischemia) to the ACA, MCA or PCA will cause a
- Stroke (hypoxic-ischemic cerebrovascular accident) that will result in
- Ischemic necrosis to brain tissues in both cortical and subcortical regions.

Protection of Brain

- Brain & cord protected from injury & infection in 4 ways:
- 1) Brain protected by thick bone, skull; cord encased in interlocking bony vertebrae.
- 2) Within these bony encasements, 3 membranes

Meninges of Brain & Cord

- Outer protective covering = ***dura mater*** (hard mother), a tough double layer of collagenous fiber enclosing CNS in a sack.
- ***Arachnoid*** (spider web)-middle layer-thin sheet of delicate connective tissue.
- ***Pia mater*** (soft mother)-inner layer-membrane of elastic tissue that clings to surface of tissue.

Protection of Brain

- 3) Brain cushioned from shock and sudden changes in pressure by CSF (cerebrospinal fluid).

- 4) Protected from chemical substances circulating in the rest of the body by the ***blood-brain barrier.***

Blood-Brain Barrier

- In brain, capillaries are joined tightly together preventing passage of large molecules.
- In body, capillary membranes have pores allowing substances to pass through.
- Brain capillaries also are covered on outside by a fatty barrier called ***glial sheath***.