

Introduction to Neuroinformatics

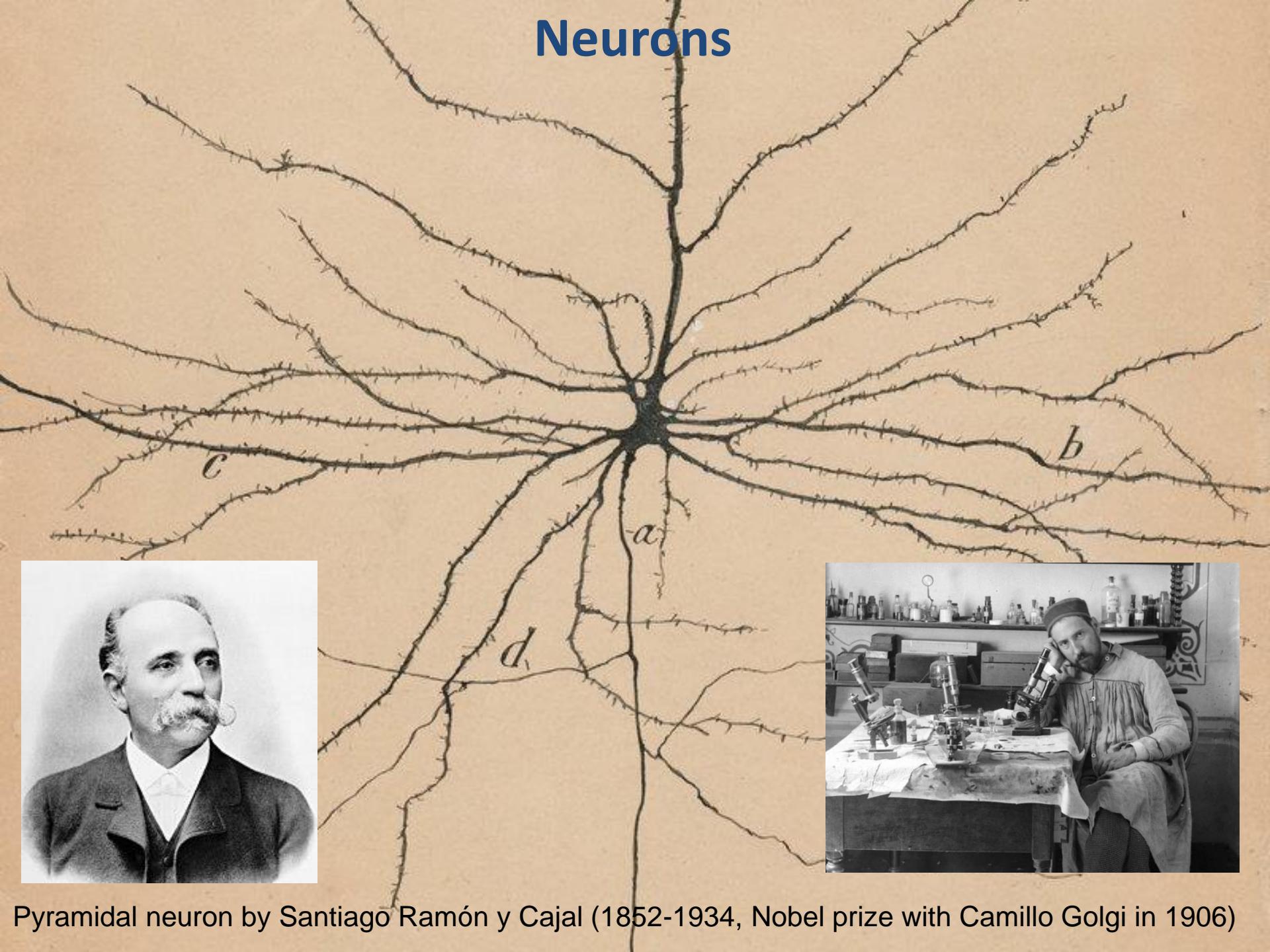
INI 401

Lecture 2: Organization of the Brain

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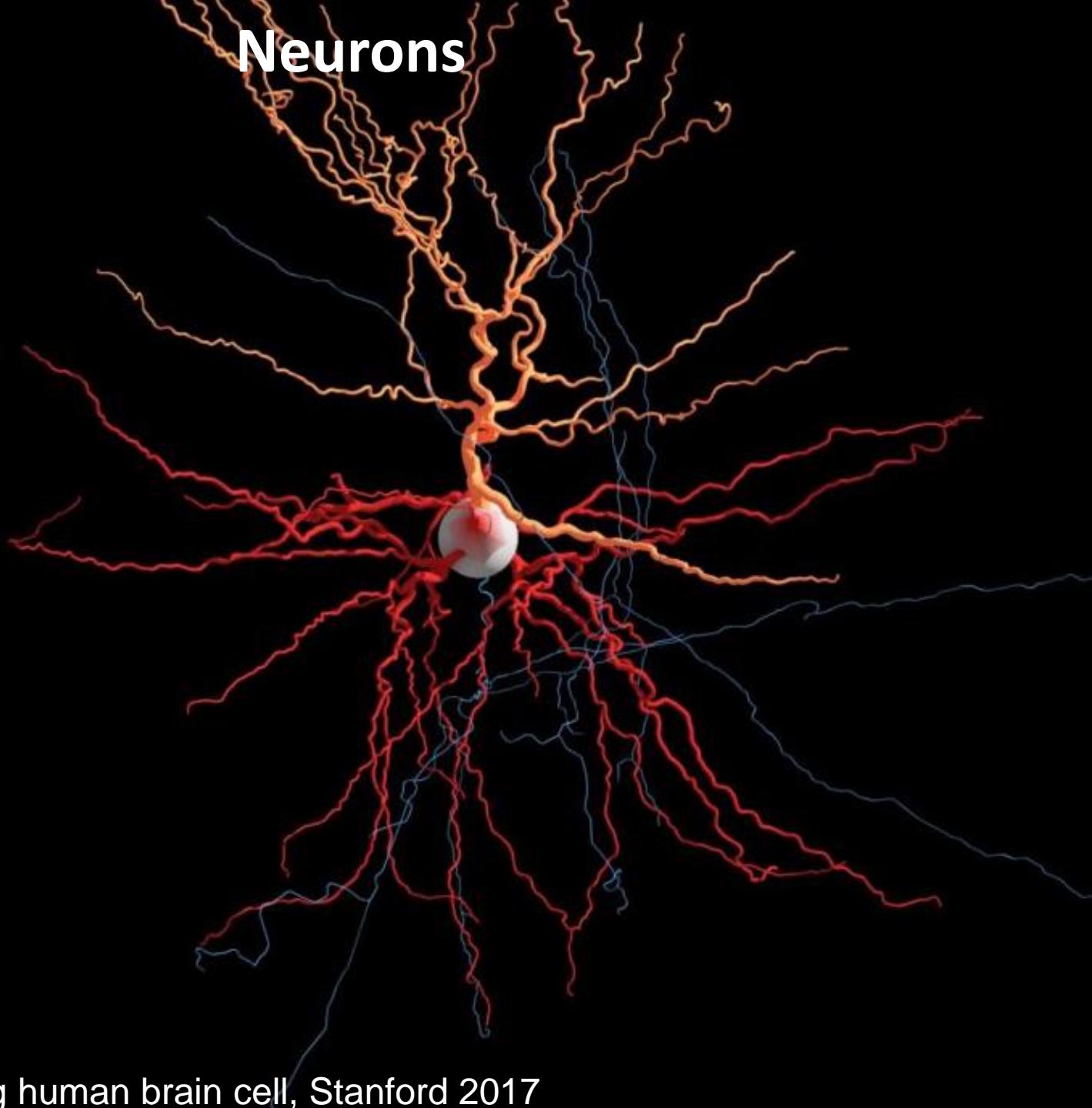
26.9.2019

Neurons



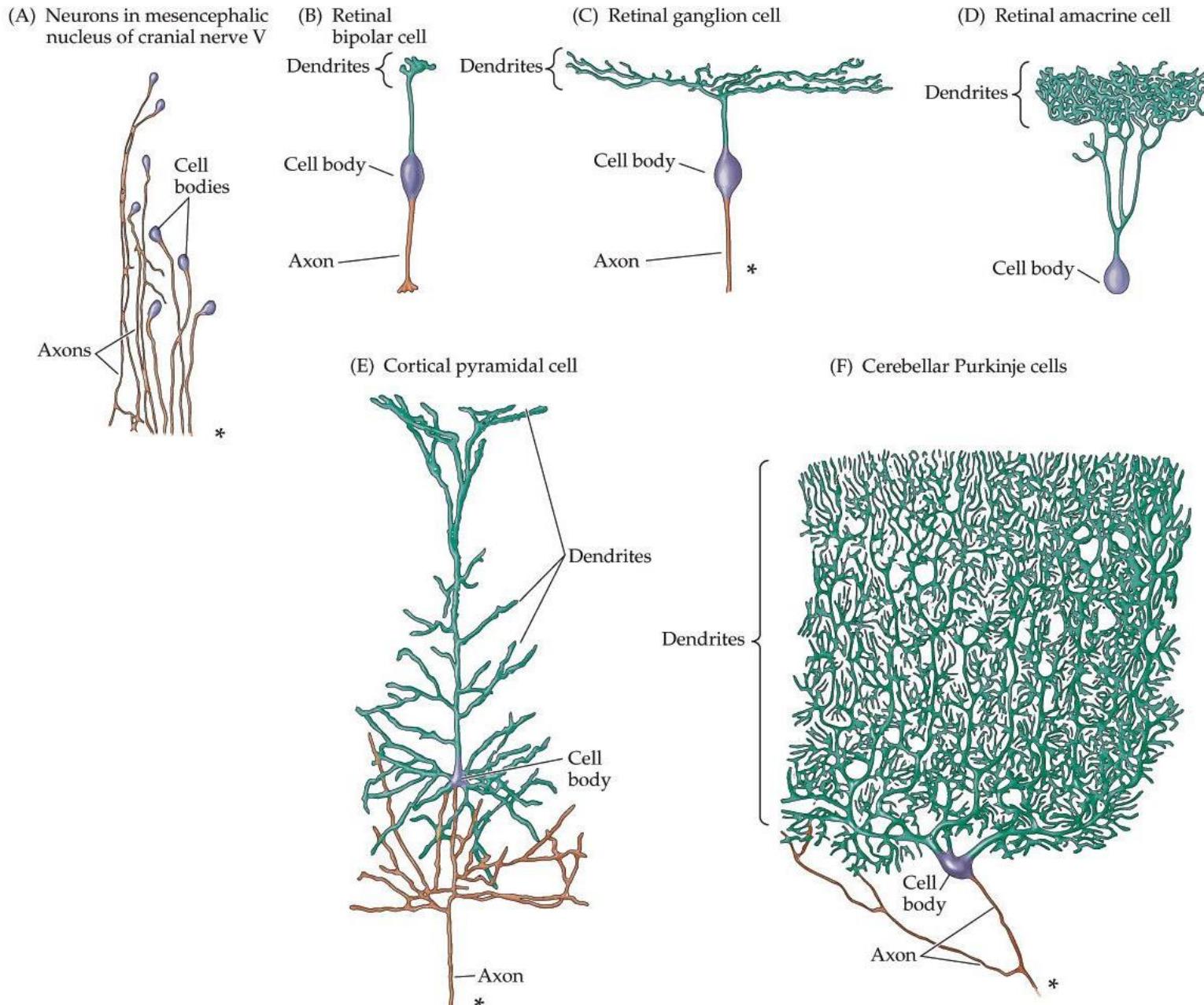
Pyramidal neuron by Santiago Ramón y Cajal (1852-1934, Nobel prize with Camillo Golgi in 1906)

Neurons

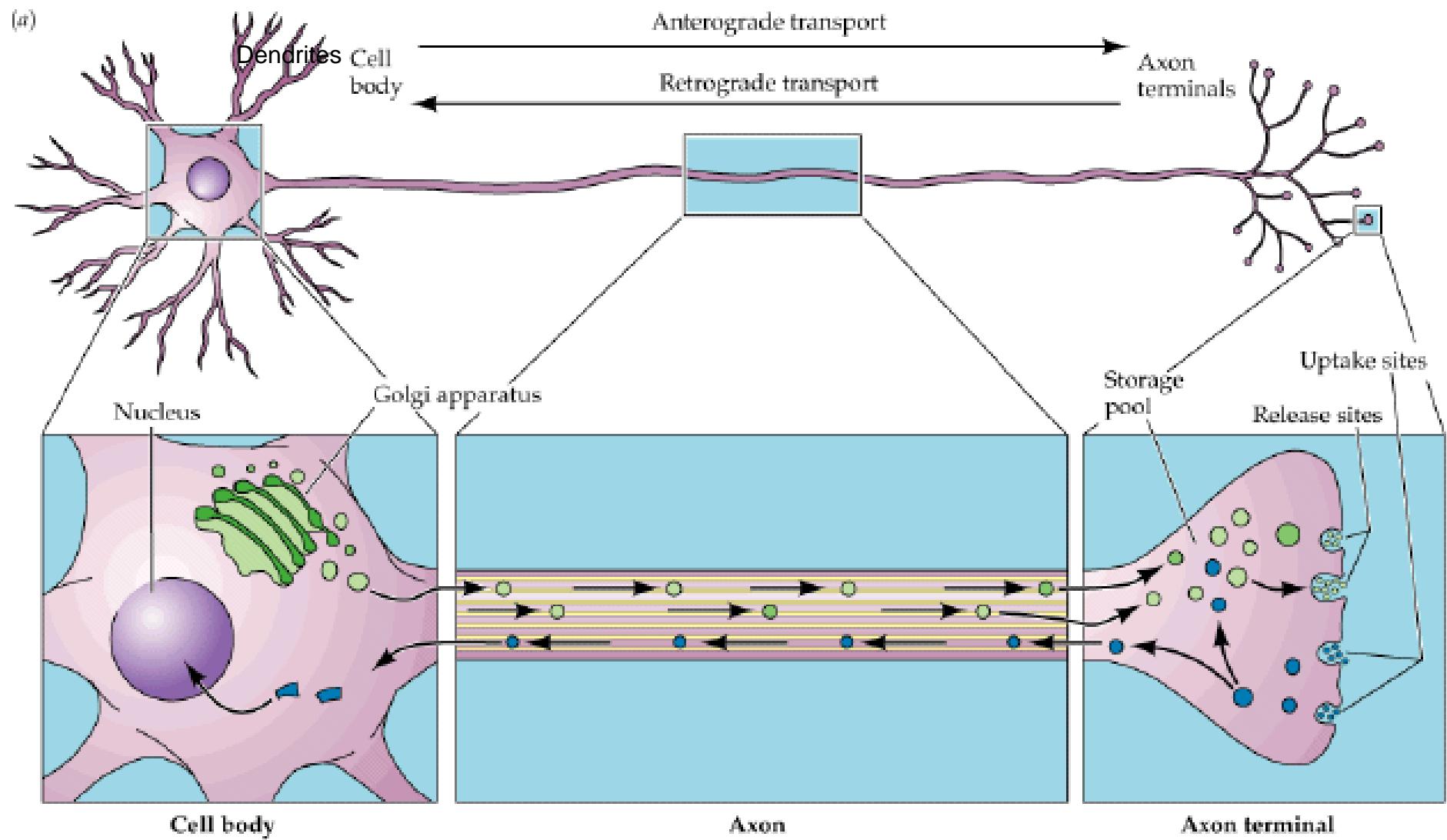


Reconstruction of living human brain cell, Stanford 2017

Types of neurons



Schematic neuron



Terminology

Axon

Boutons

Cleft

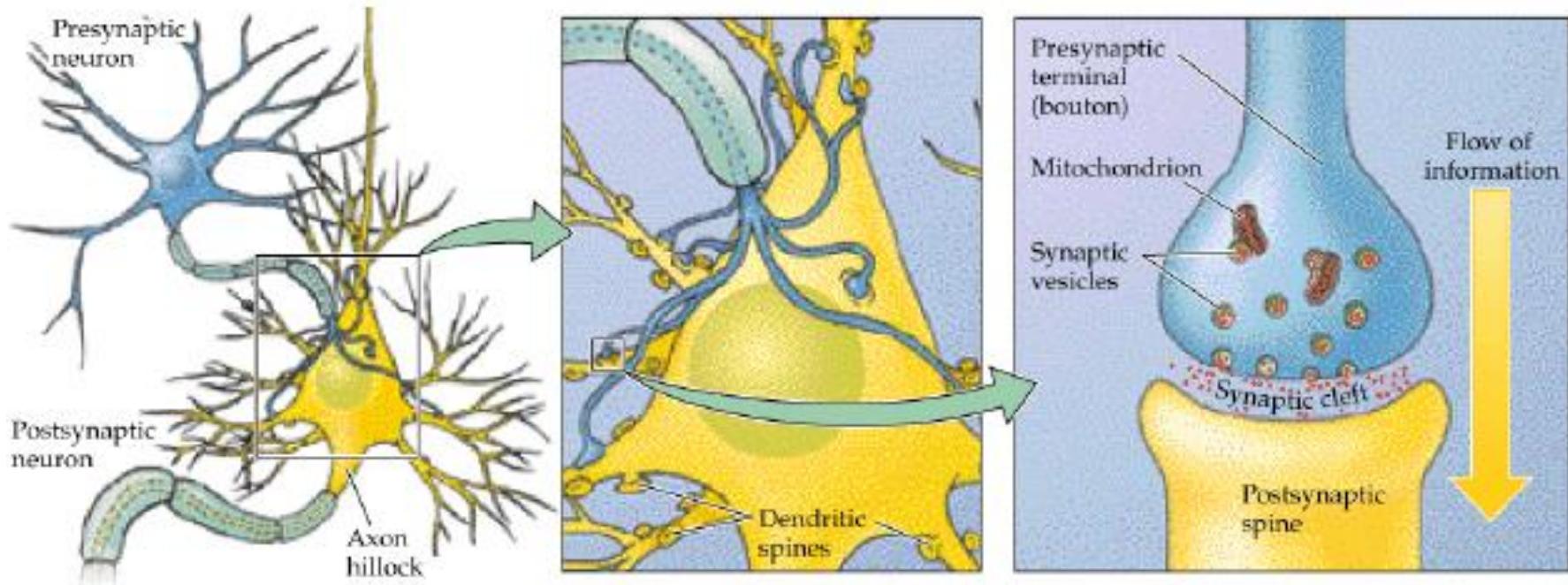
Dendritic spines

Postsynaptic membrane,

Vesicles

Transmitter,

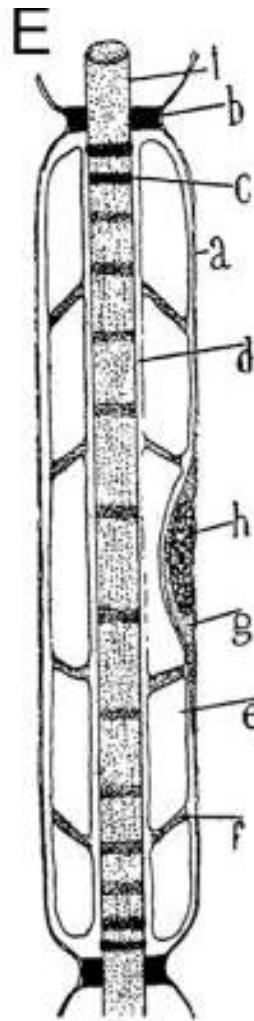
Receptors



Axon

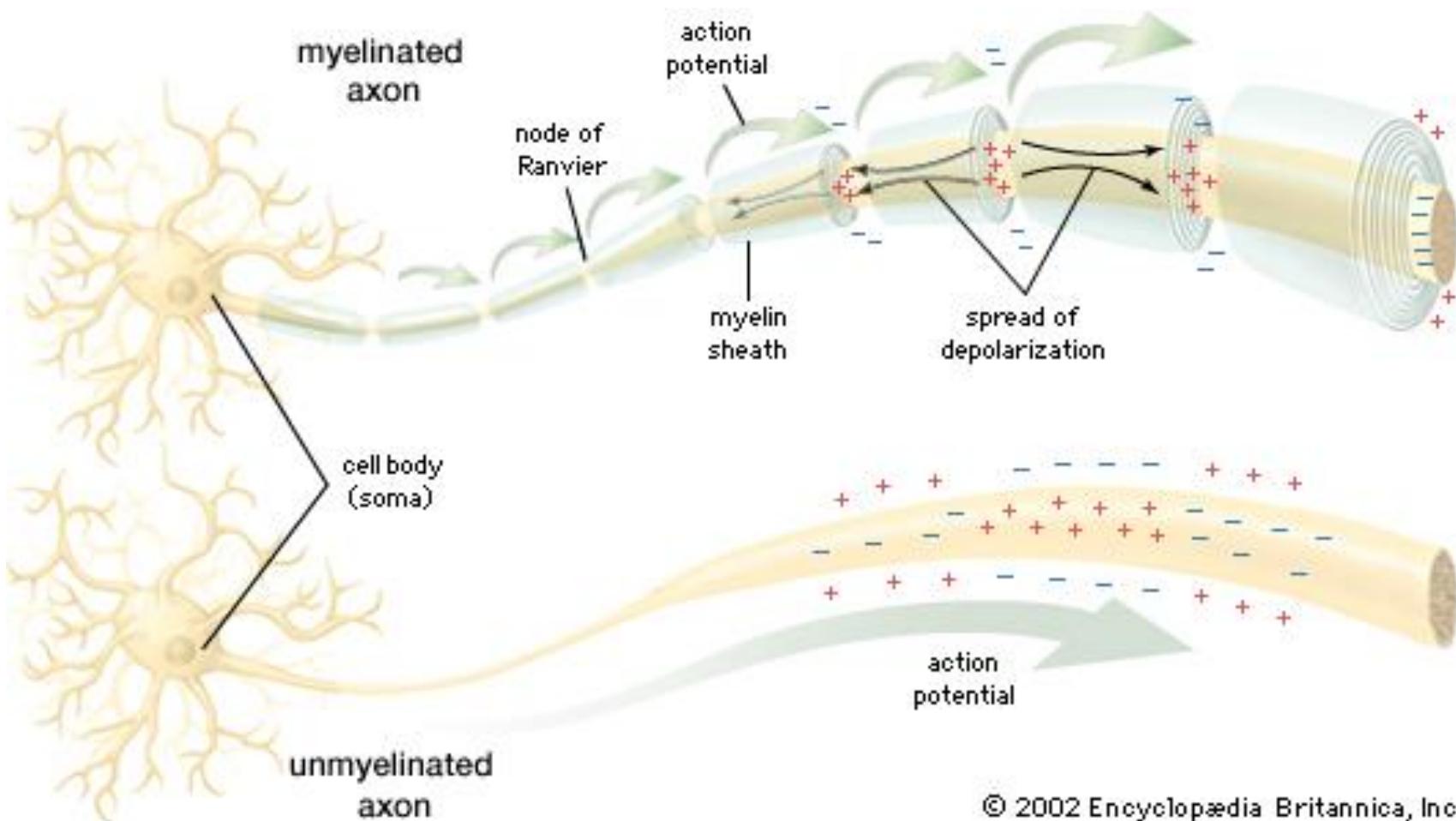


First trans-atlantic telegraph cable, 1858



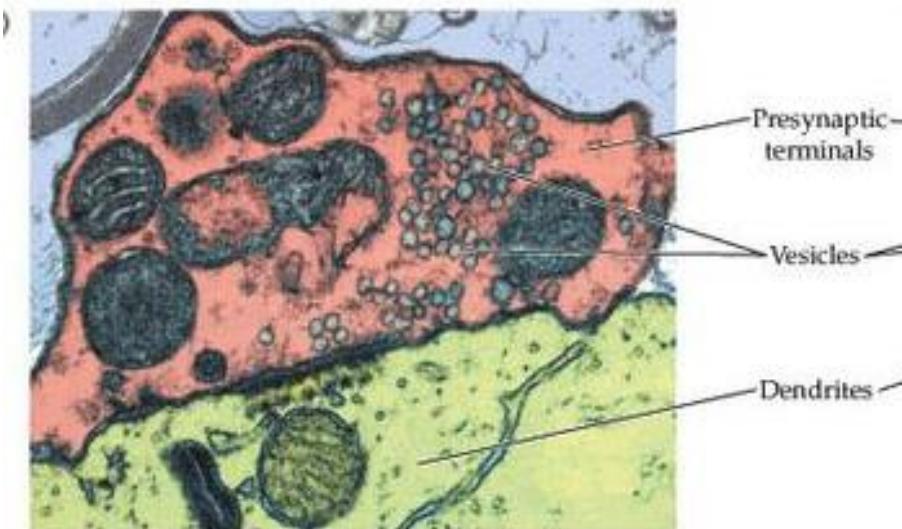
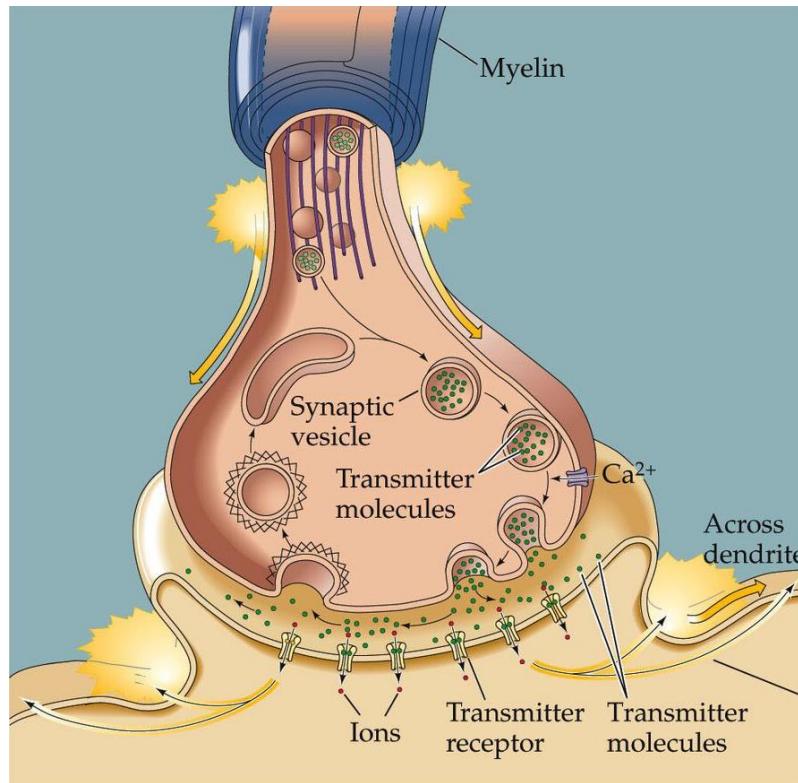
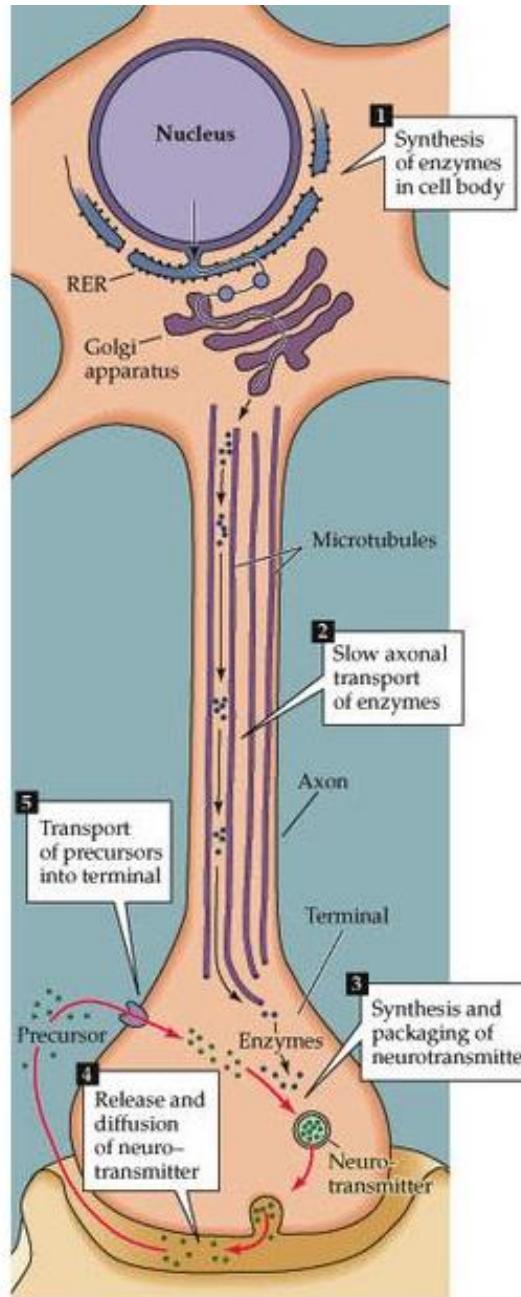
A complete schematic of a peripheral internode
Fig. 88, Cajal, 1909–1911

Axon



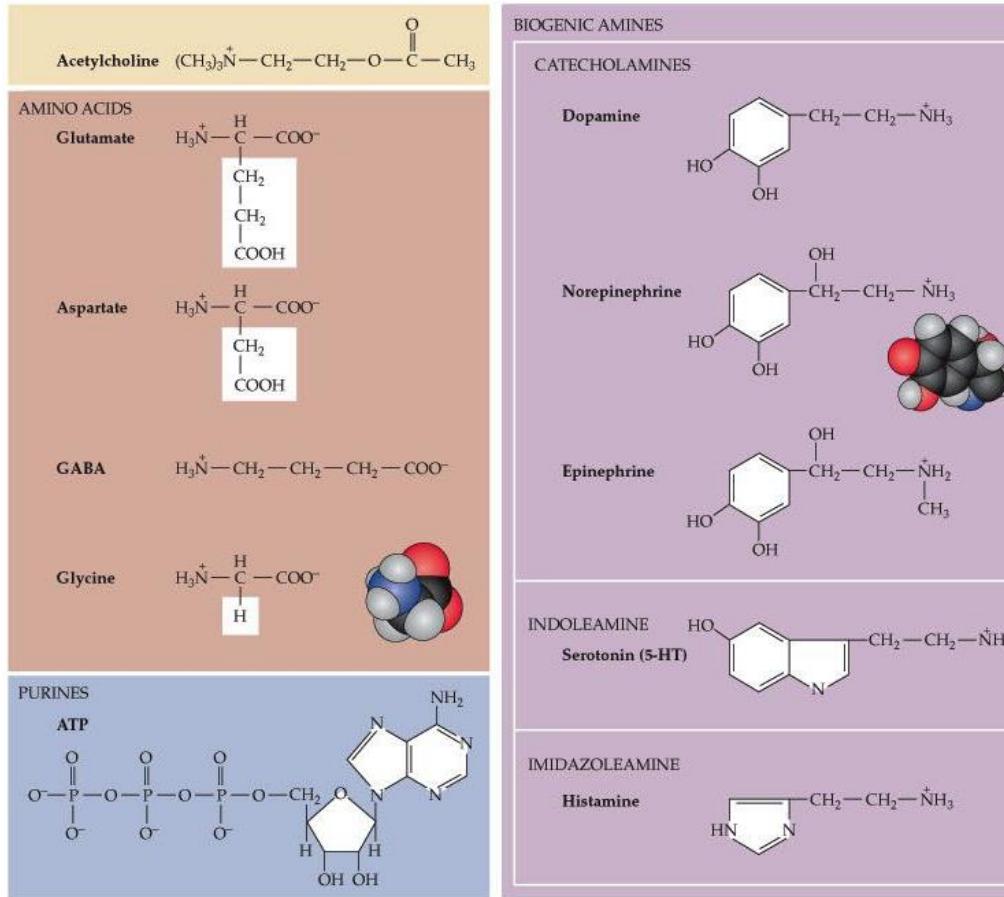
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Vesicles

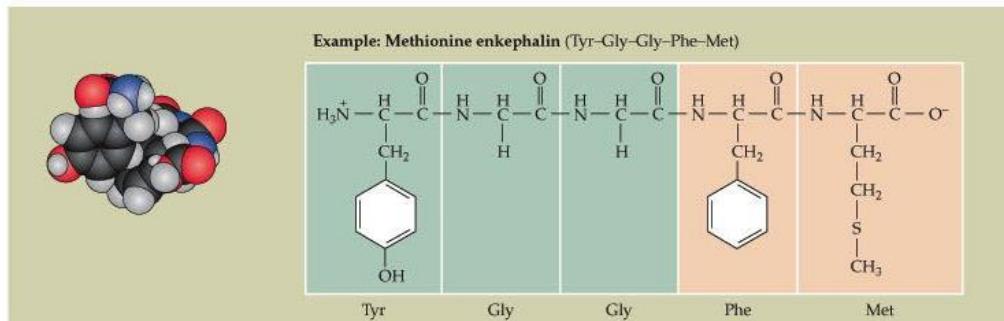


Neurotransmitter

SMALL-MOLECULE NEUROTRANSMITTERS

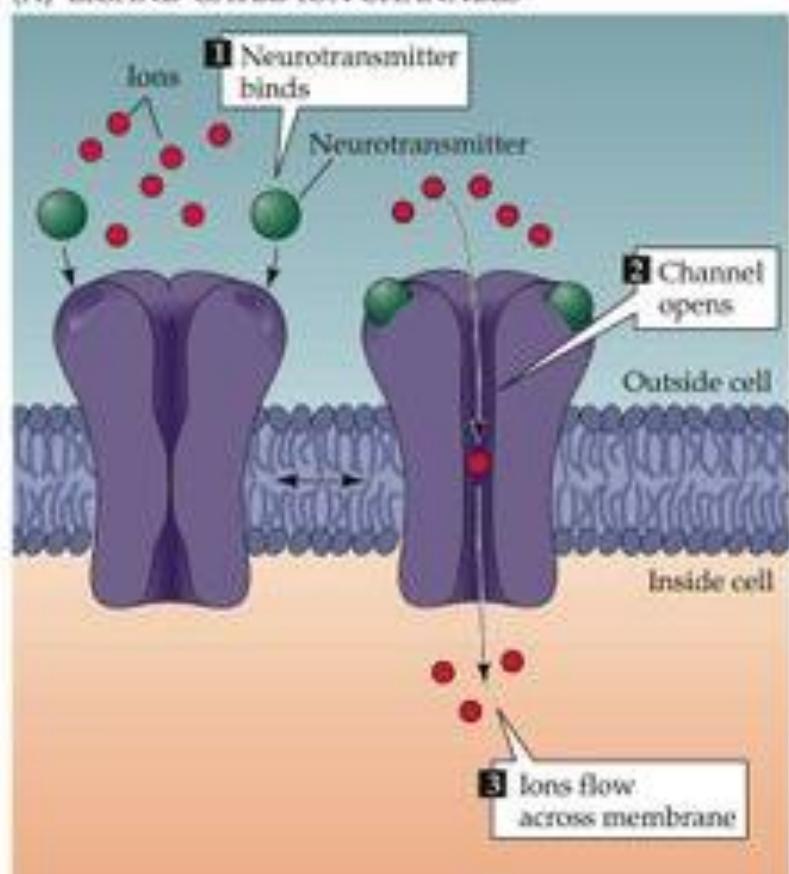


PEPTIDE NEUROTRANSMITTERS (more than 100 peptides, usually 3–30 amino acids long)

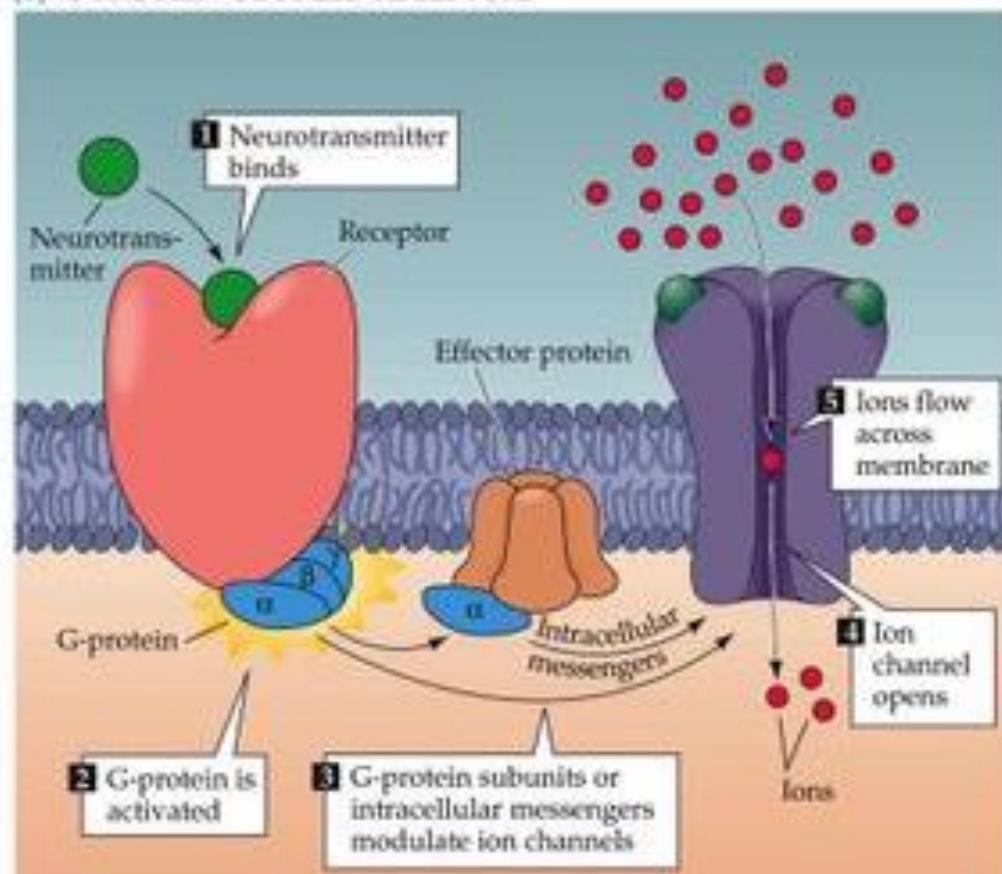


Post-synaptic receptor

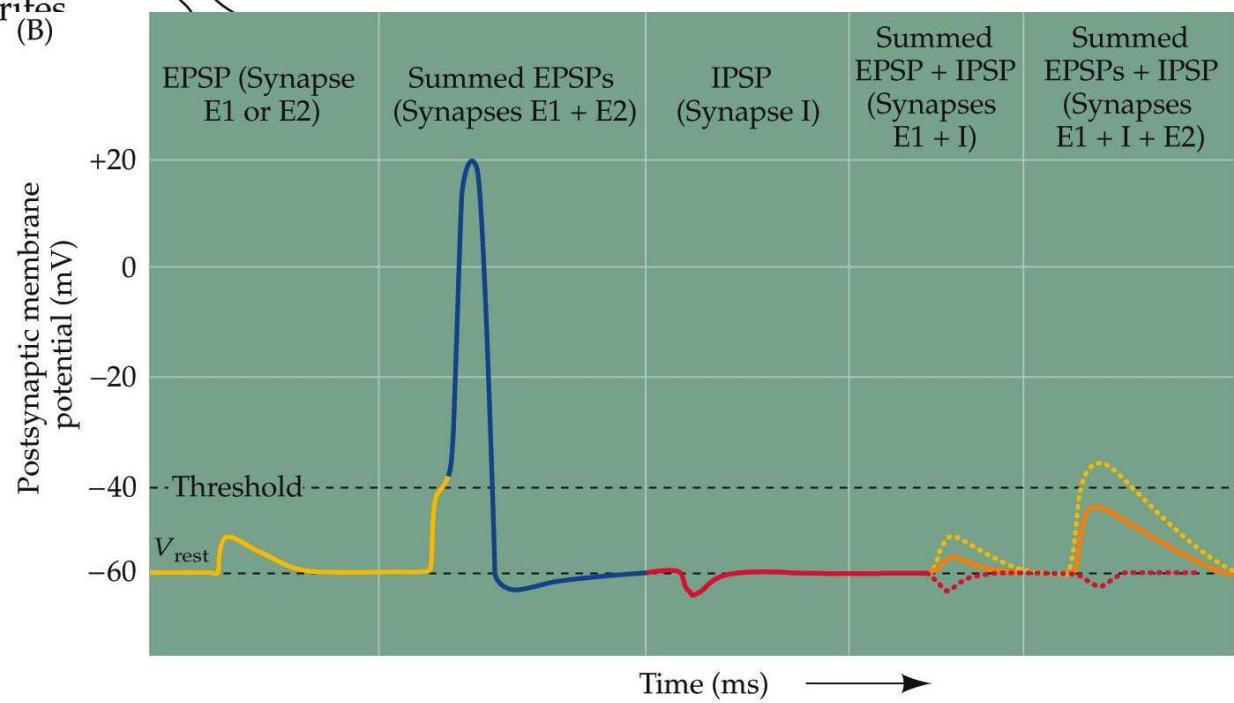
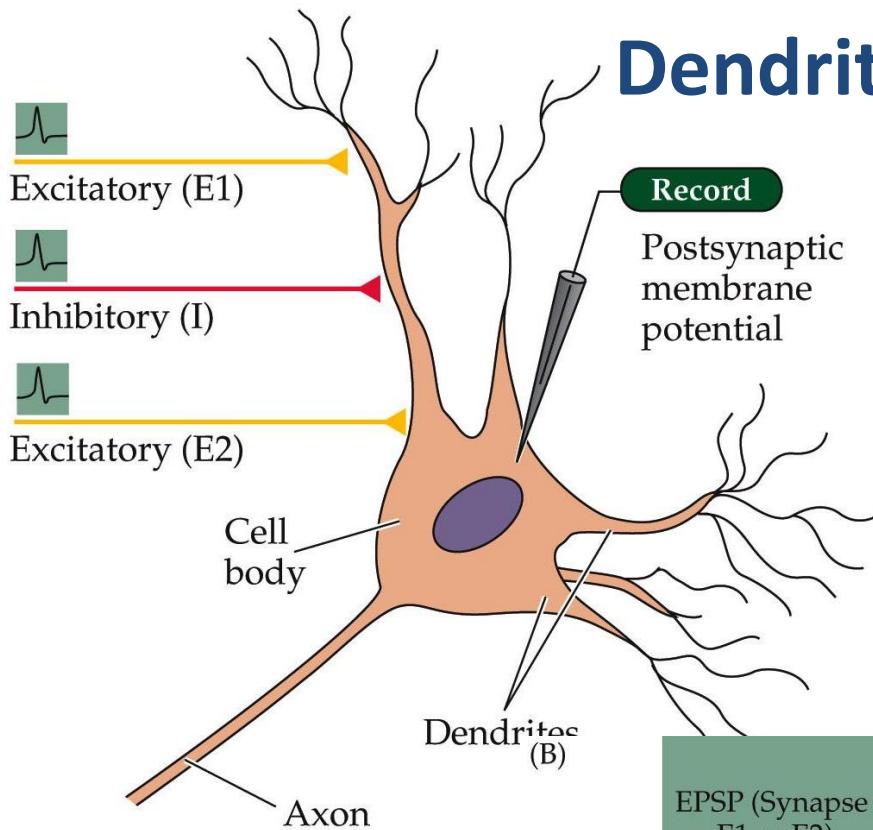
(A) LIGAND-GATED ION CHANNELS



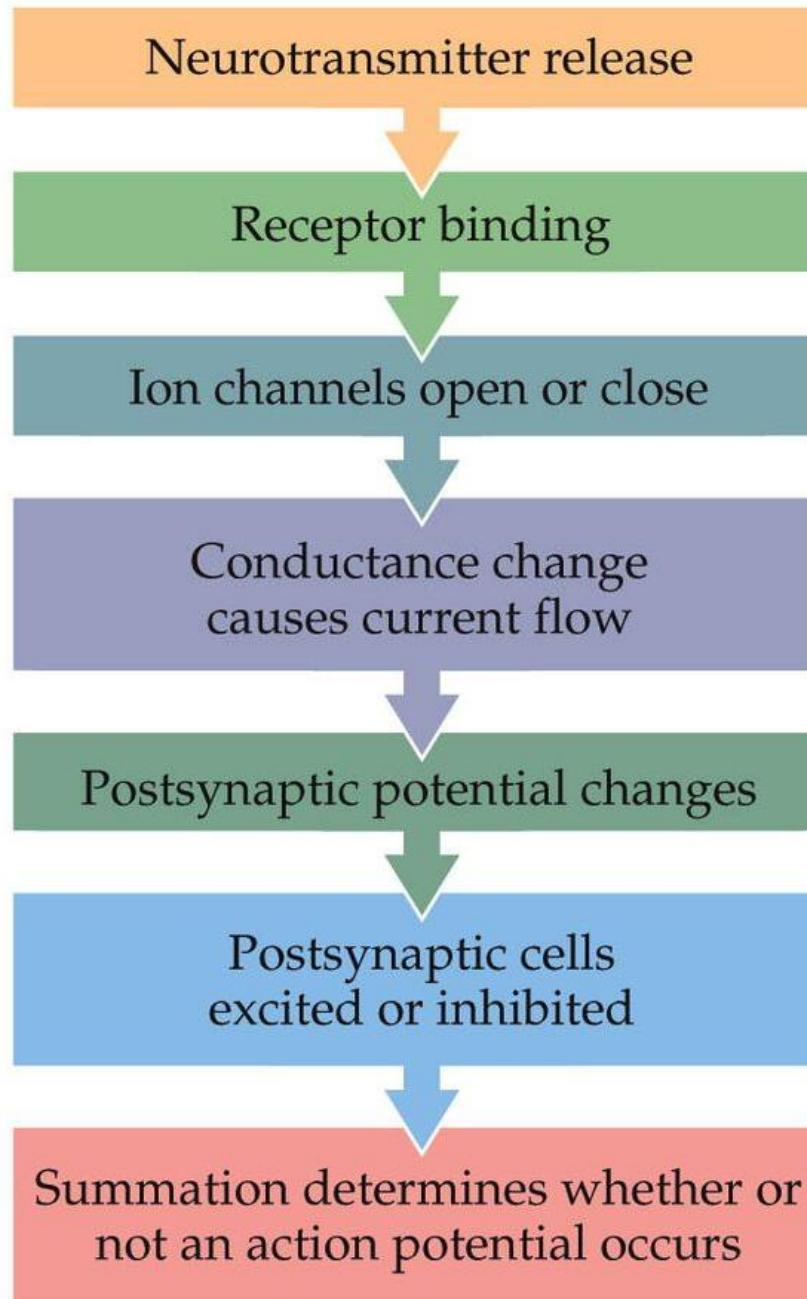
(B) G-PROTEIN-COUPLED RECEPTORS



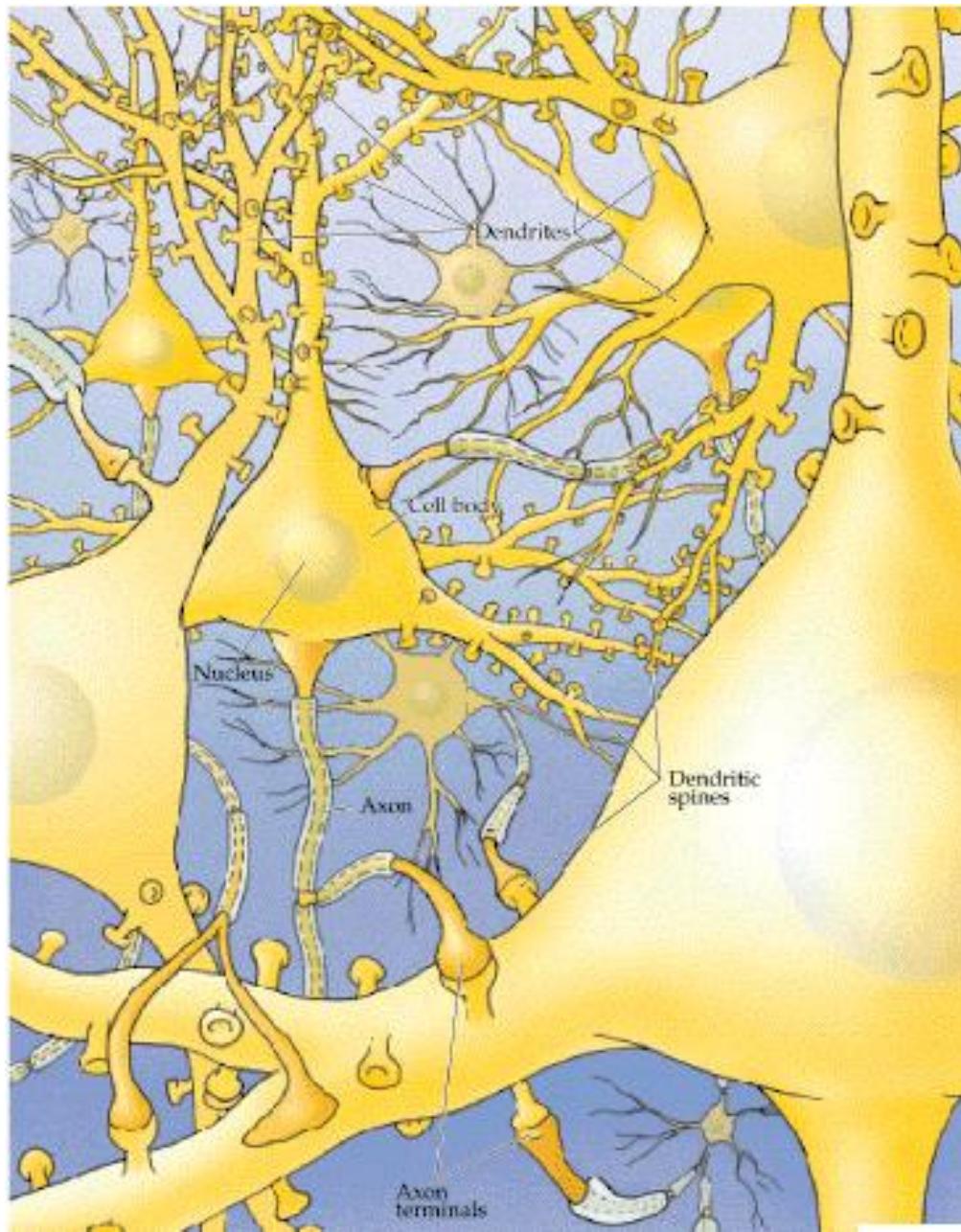
Dendrites



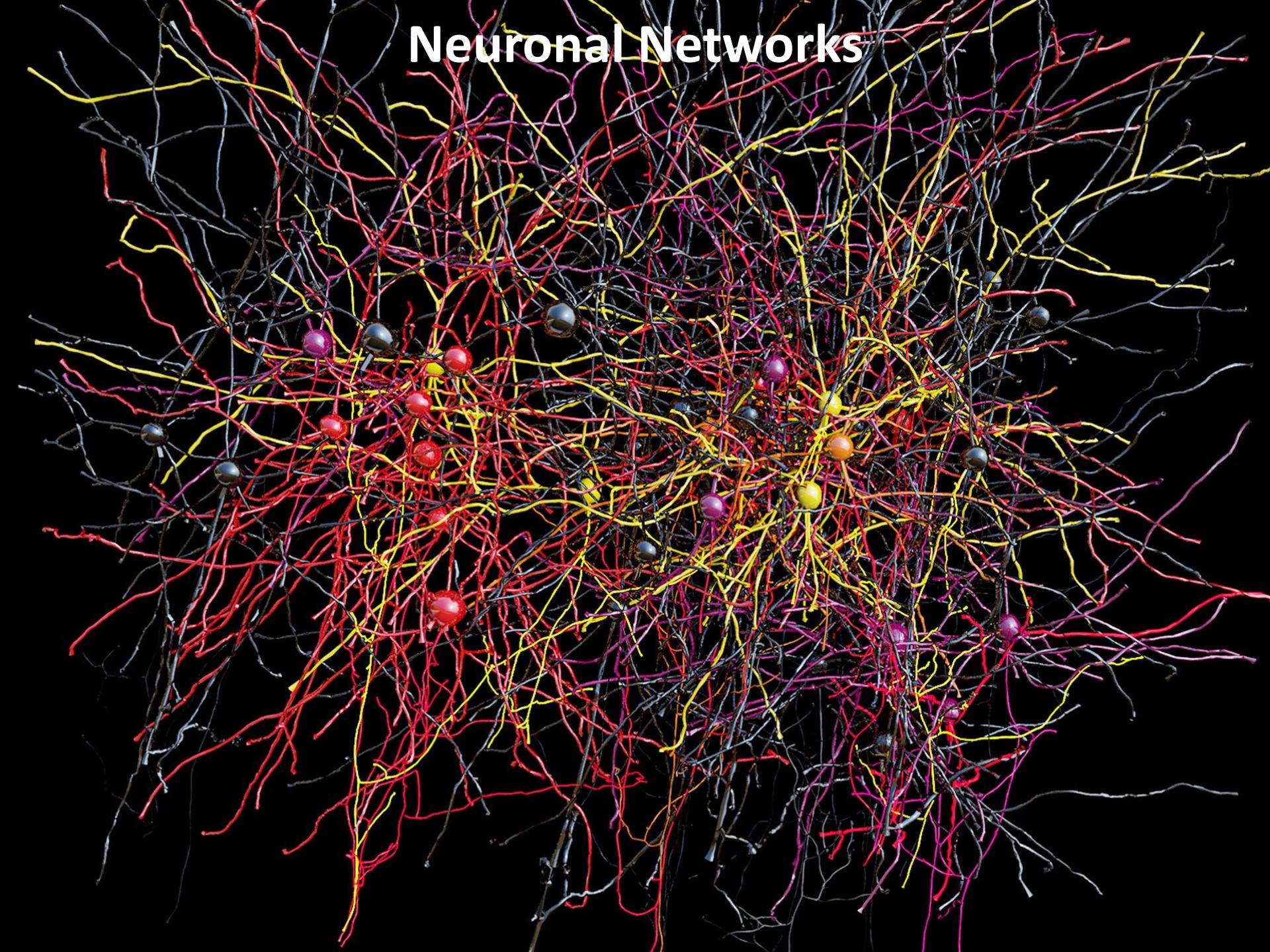
Sequence of events



Neuronal Networks

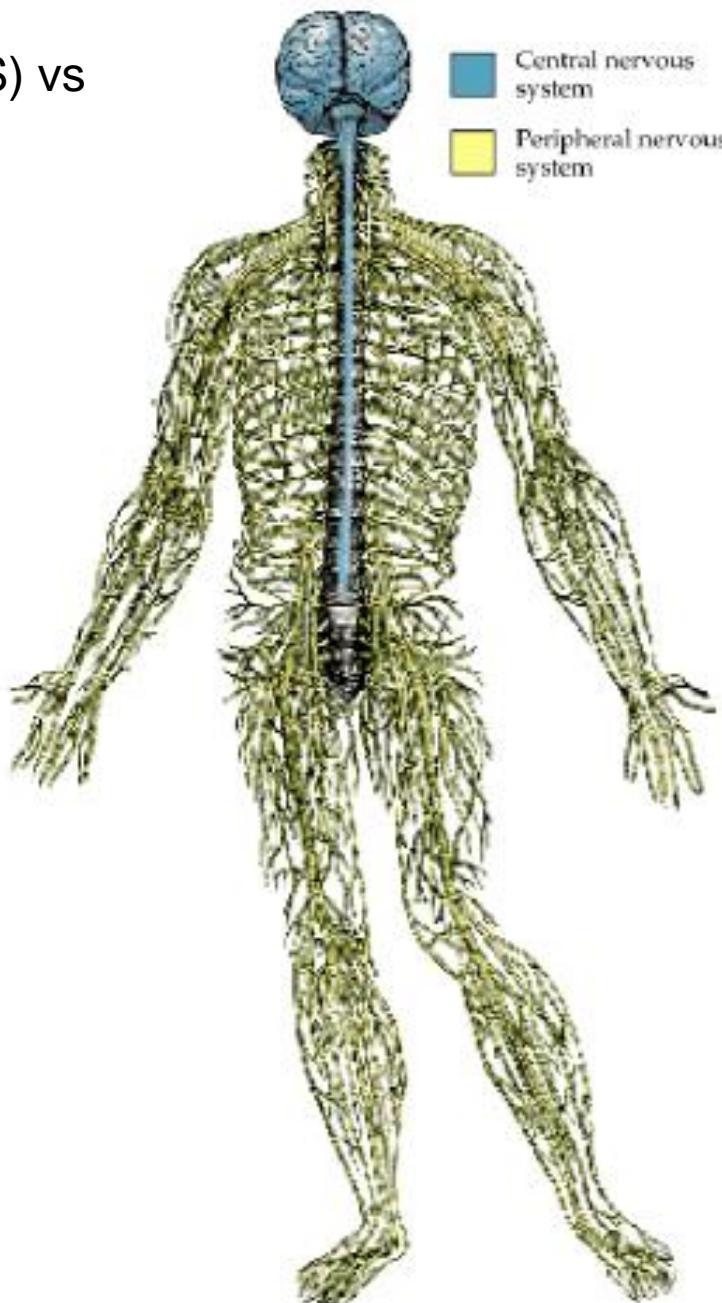


Neuronal Networks



Terminology

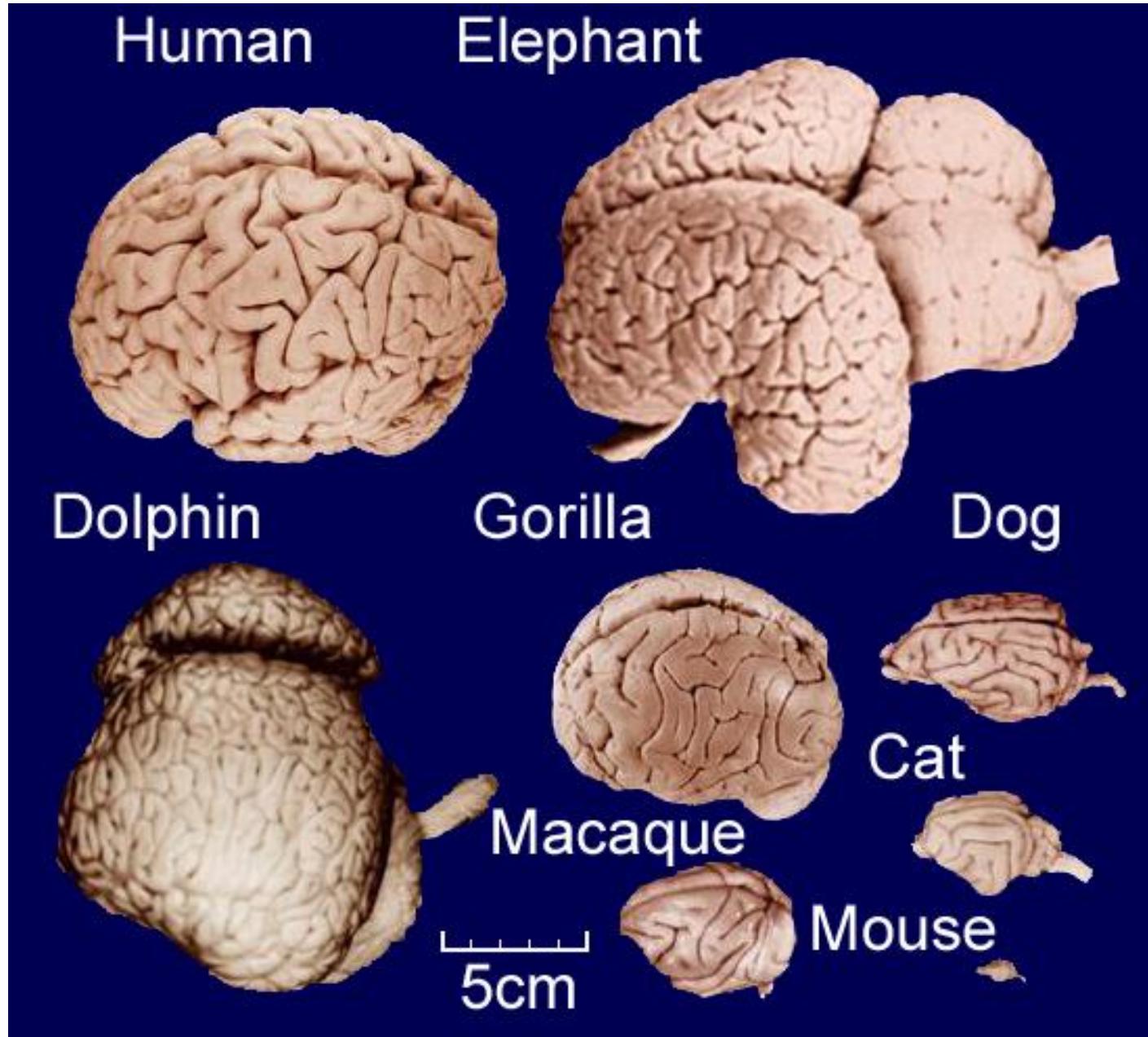
Central nervous system (CNS) vs
Peripheral nervous (PNS)



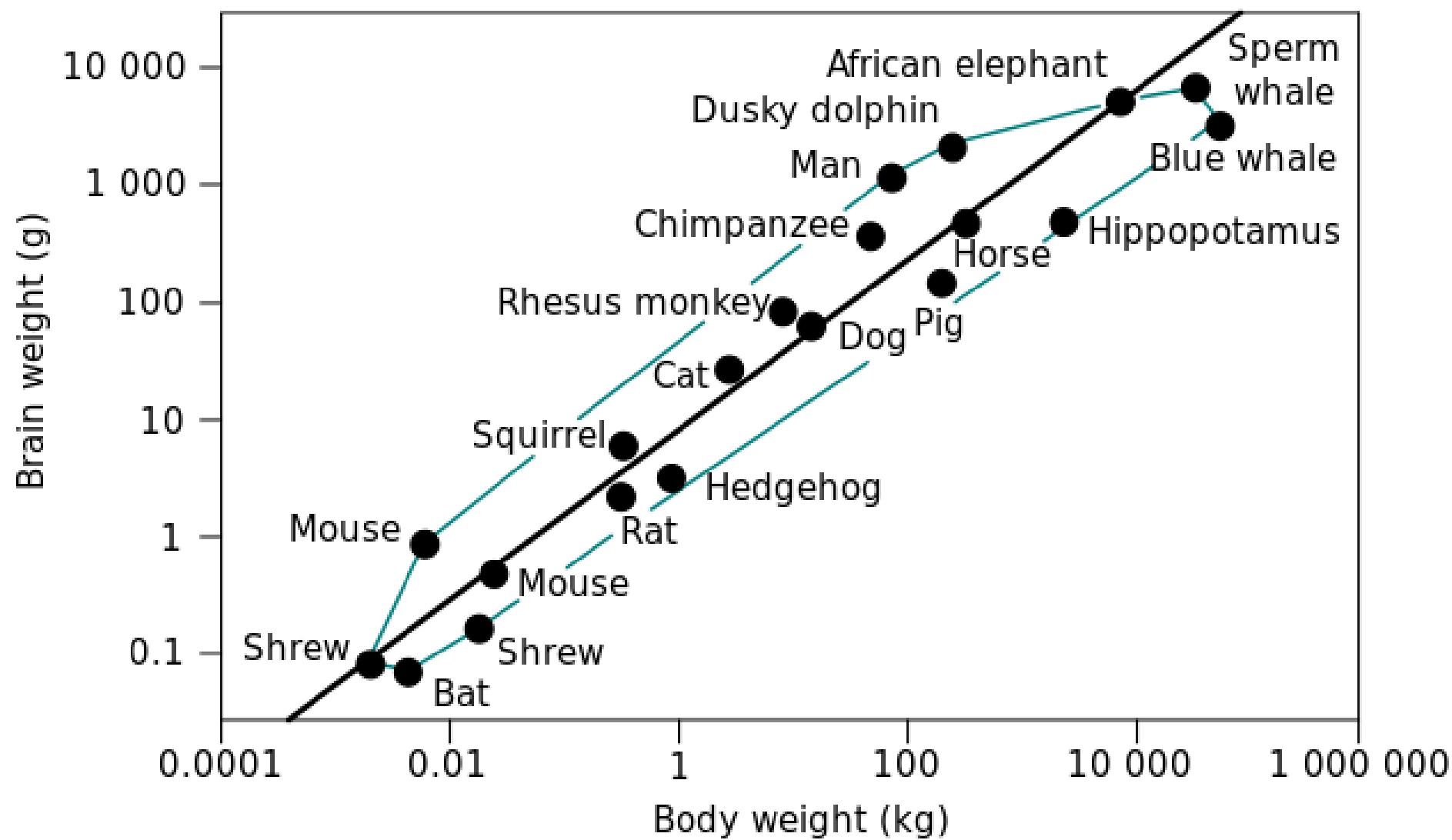
The human brain



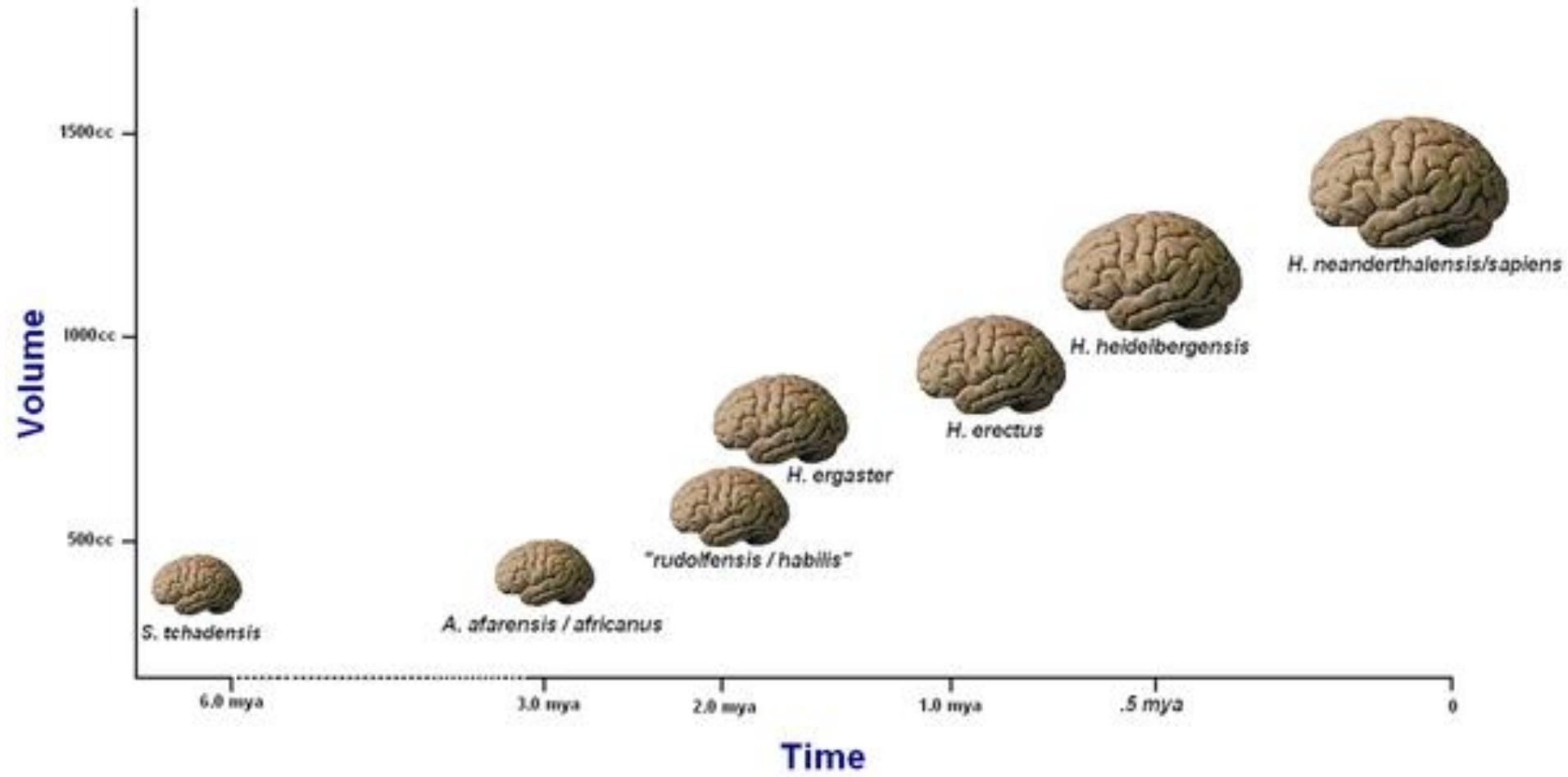
The human brain



The human brain



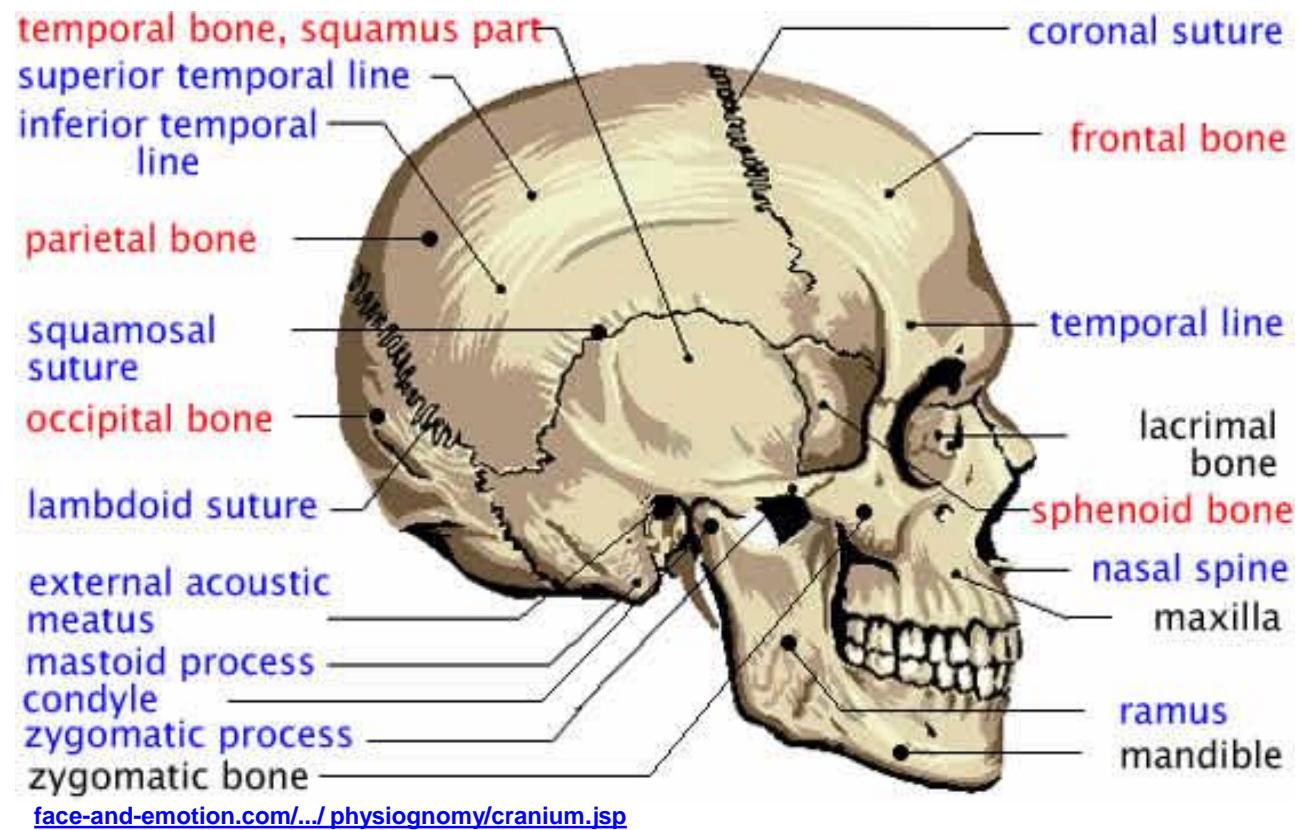
The human brain



Gross Anatomy: Protection and Sustenance of the Brain

The Skull

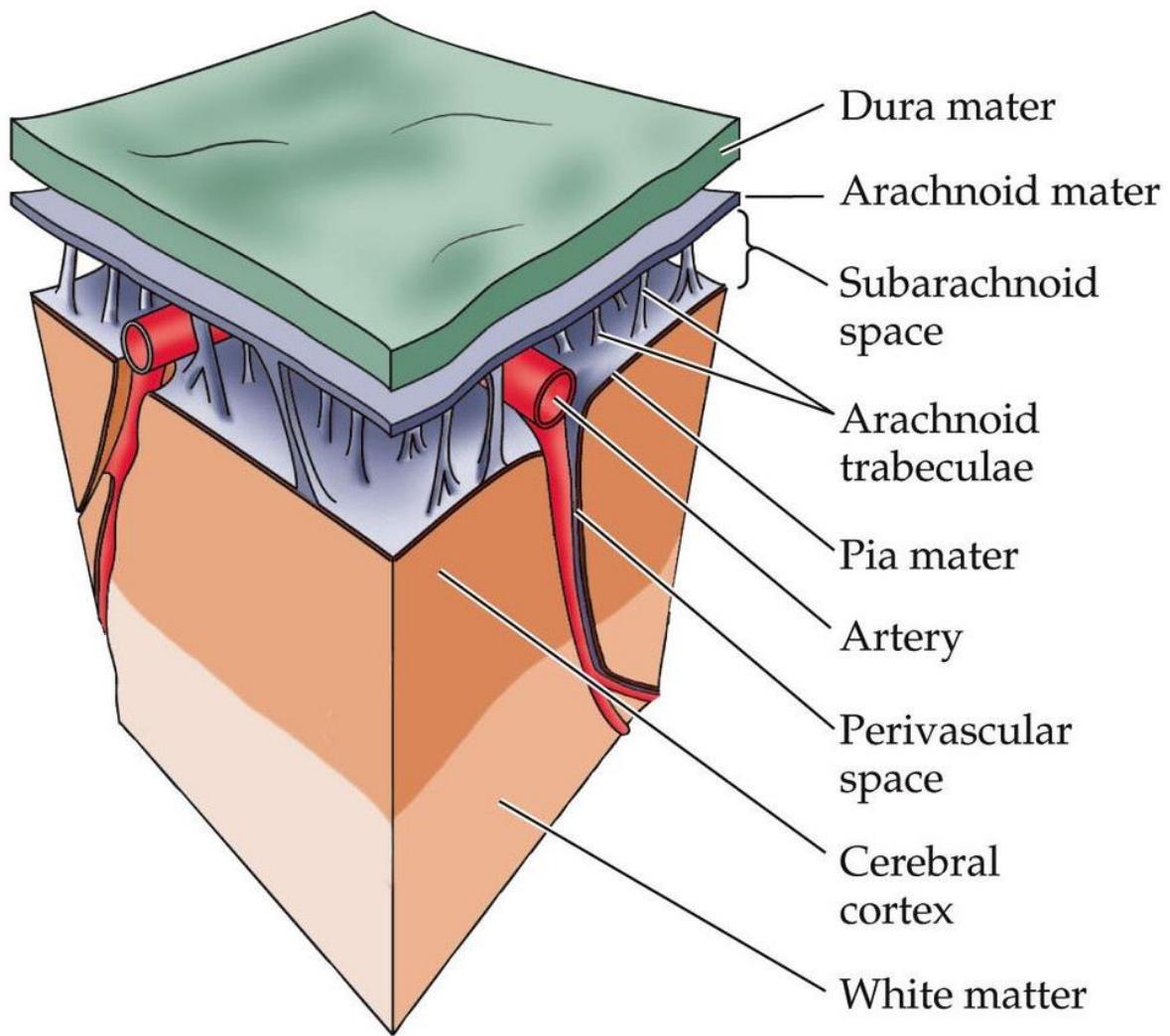
- Structure
- Function



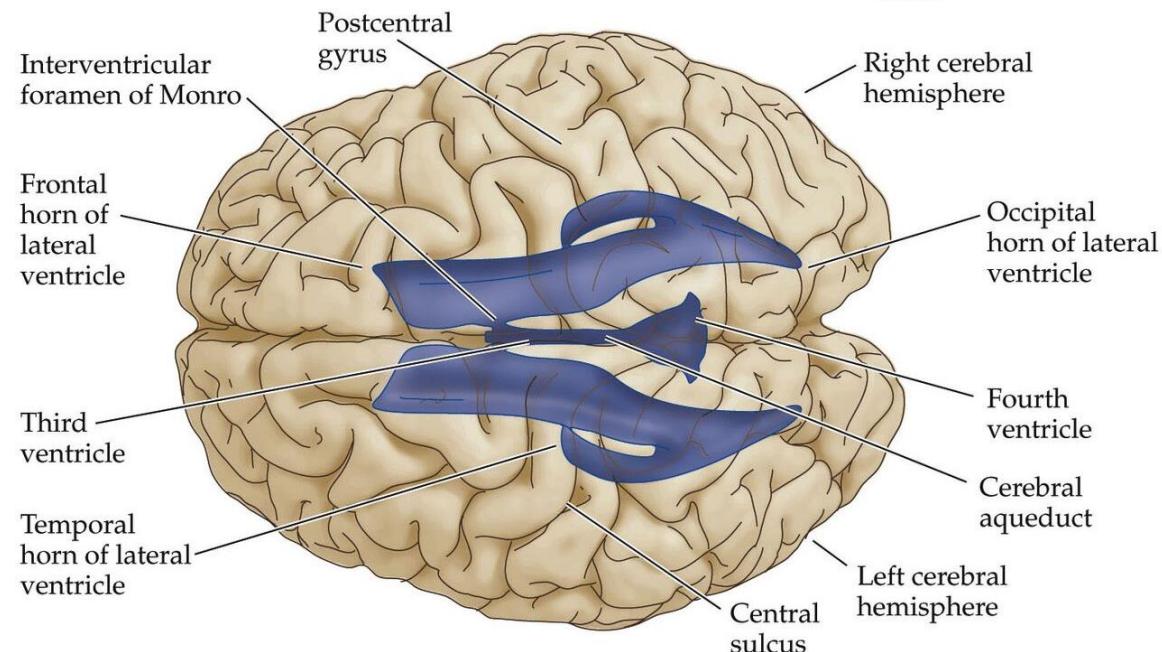
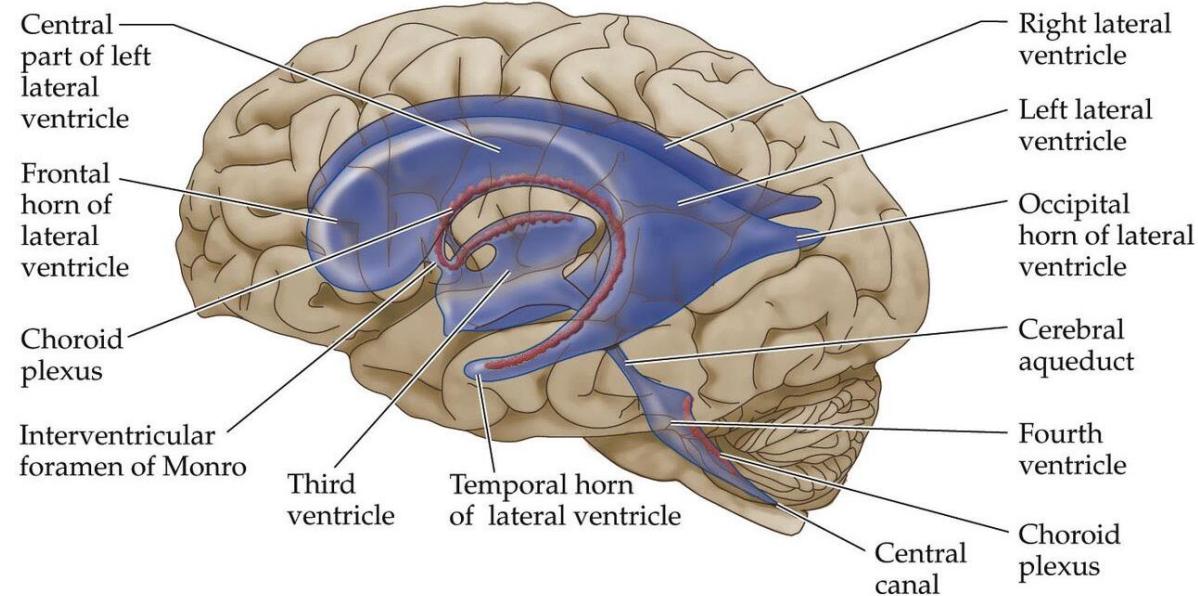
Gross Anatomy: Protection and Sustenance of the Brain

The Meninges

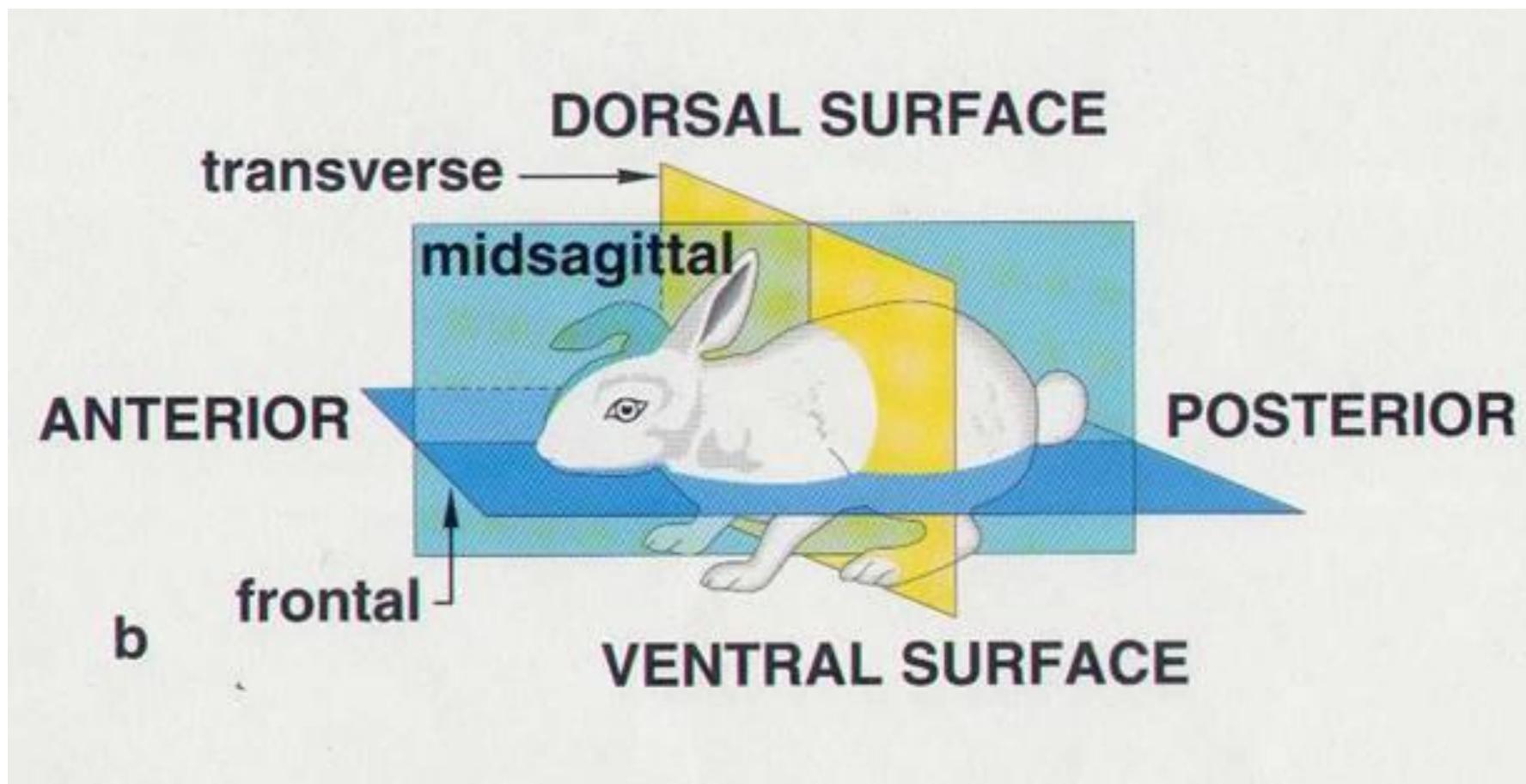
- Structure
- Function



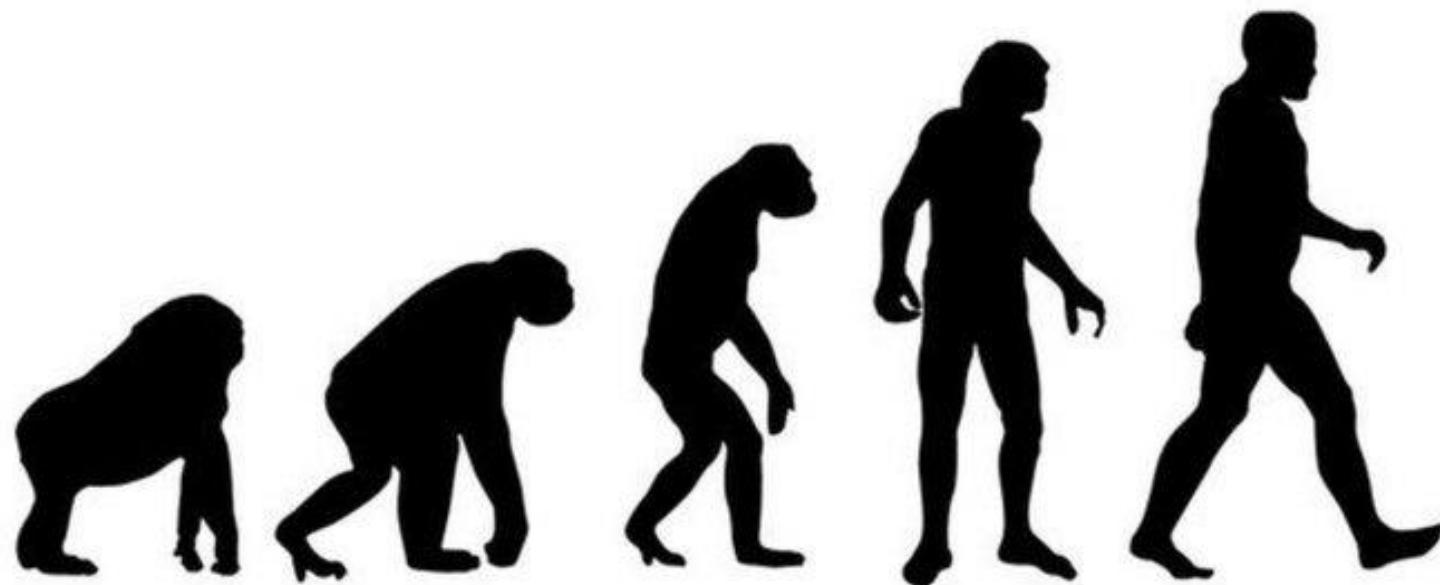
Ventricular system



Navigating the Central Nervous System

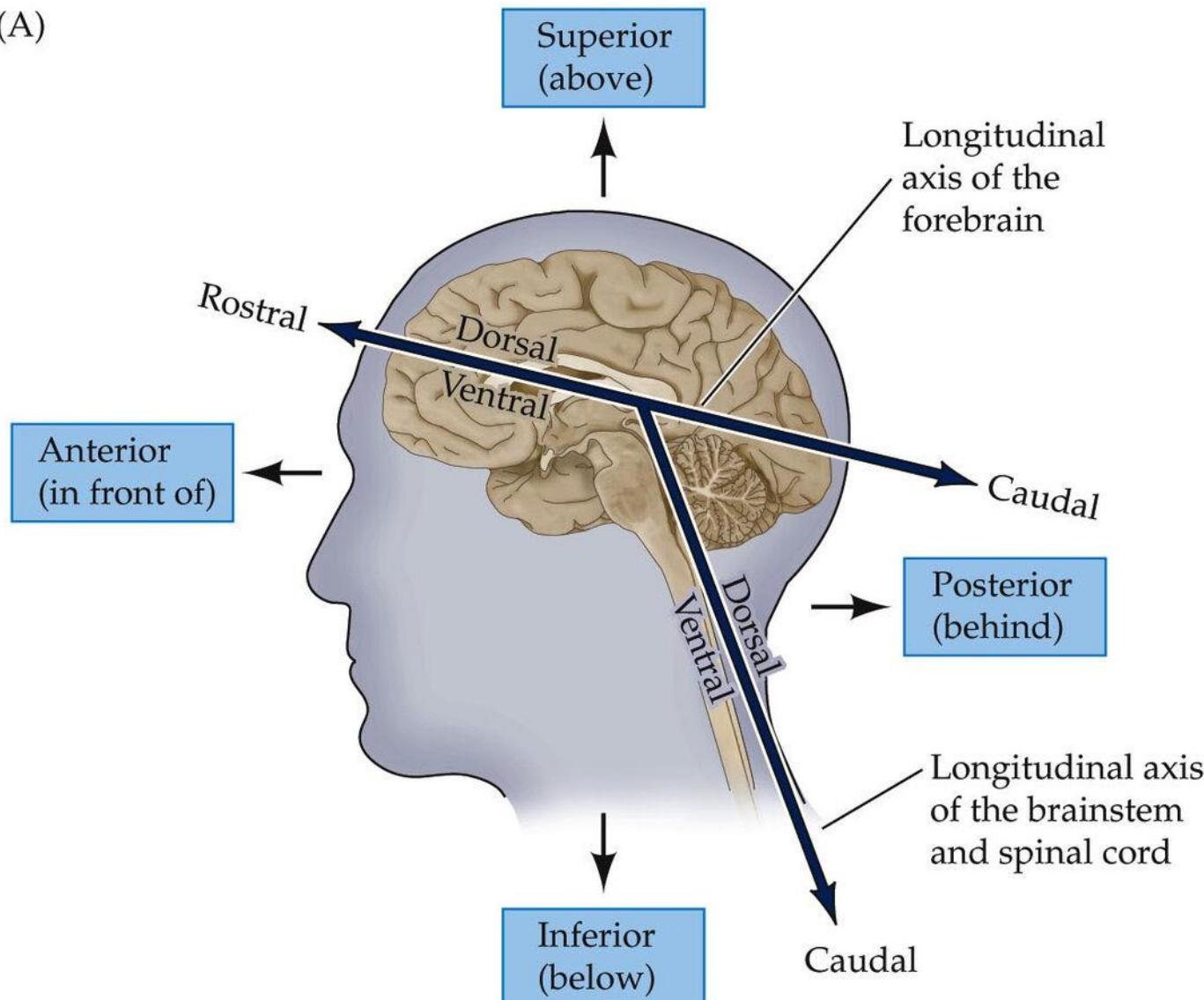


Navigating the Central Nervous System

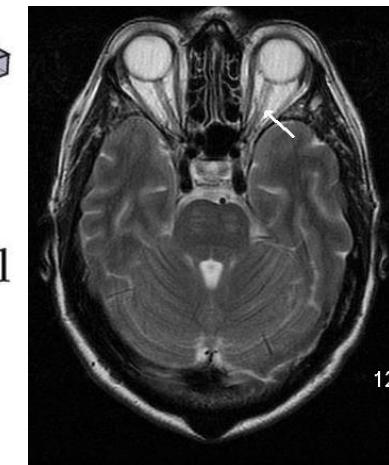
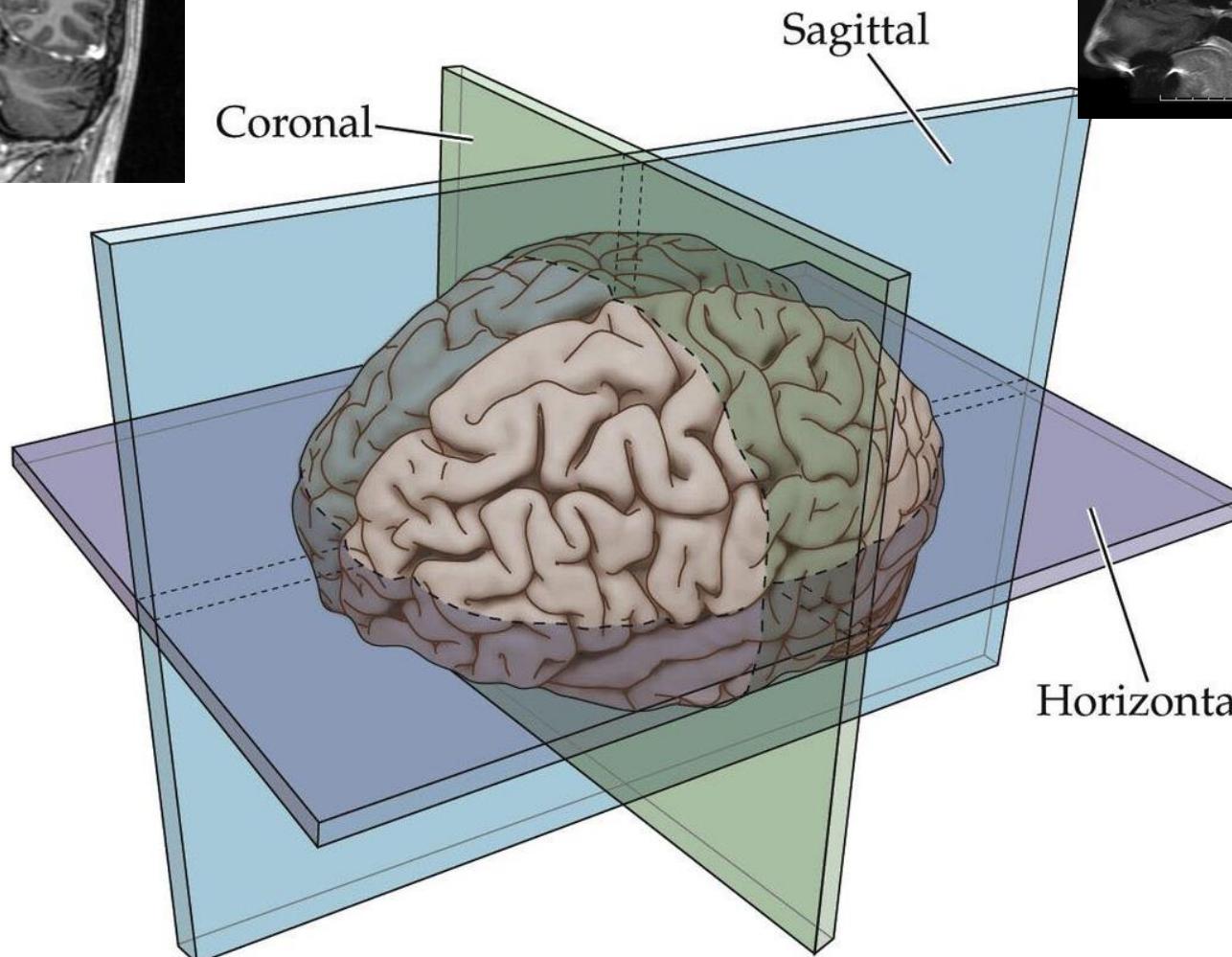
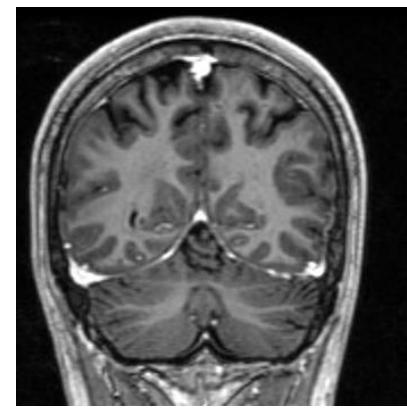


Navigating the Central Nervous System

(A)



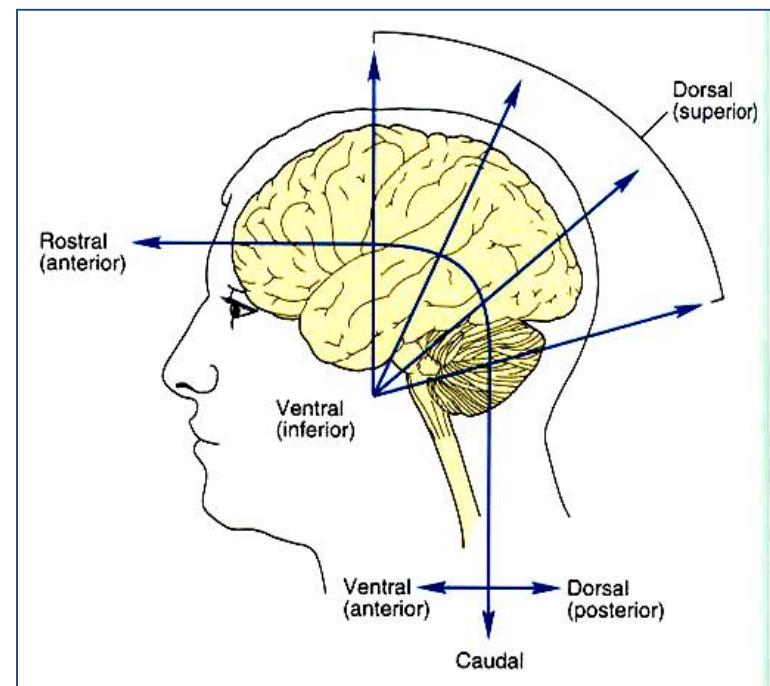
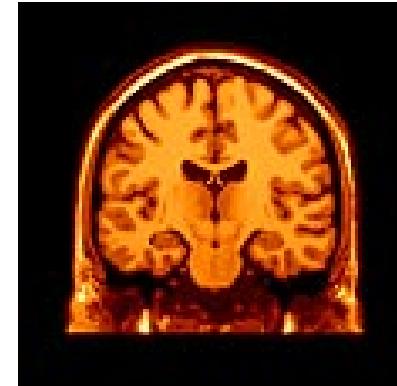
Navigating the Central Nervous System



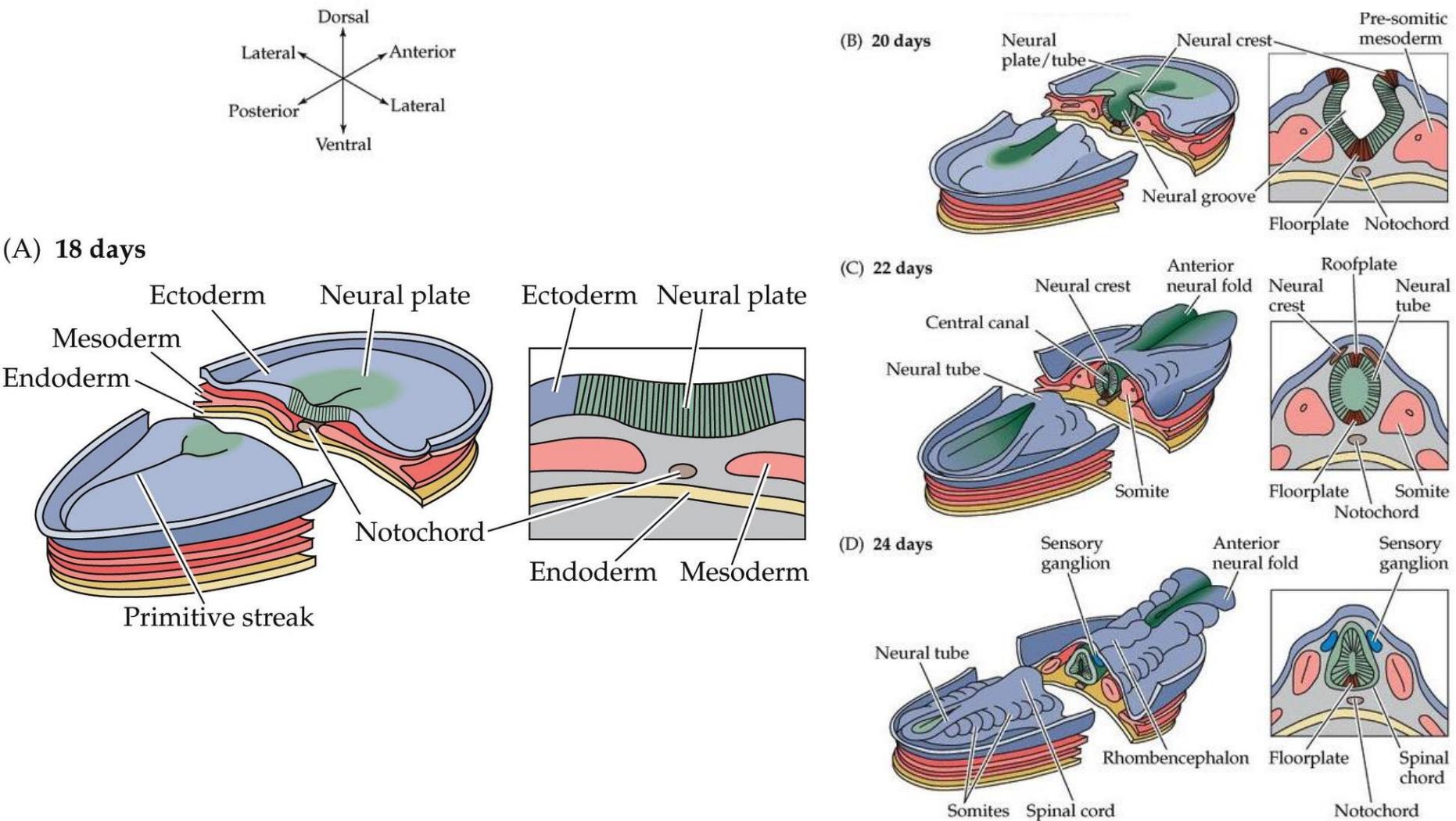
Navigating the Central Nervous System

Directions of Orientation in the CNS

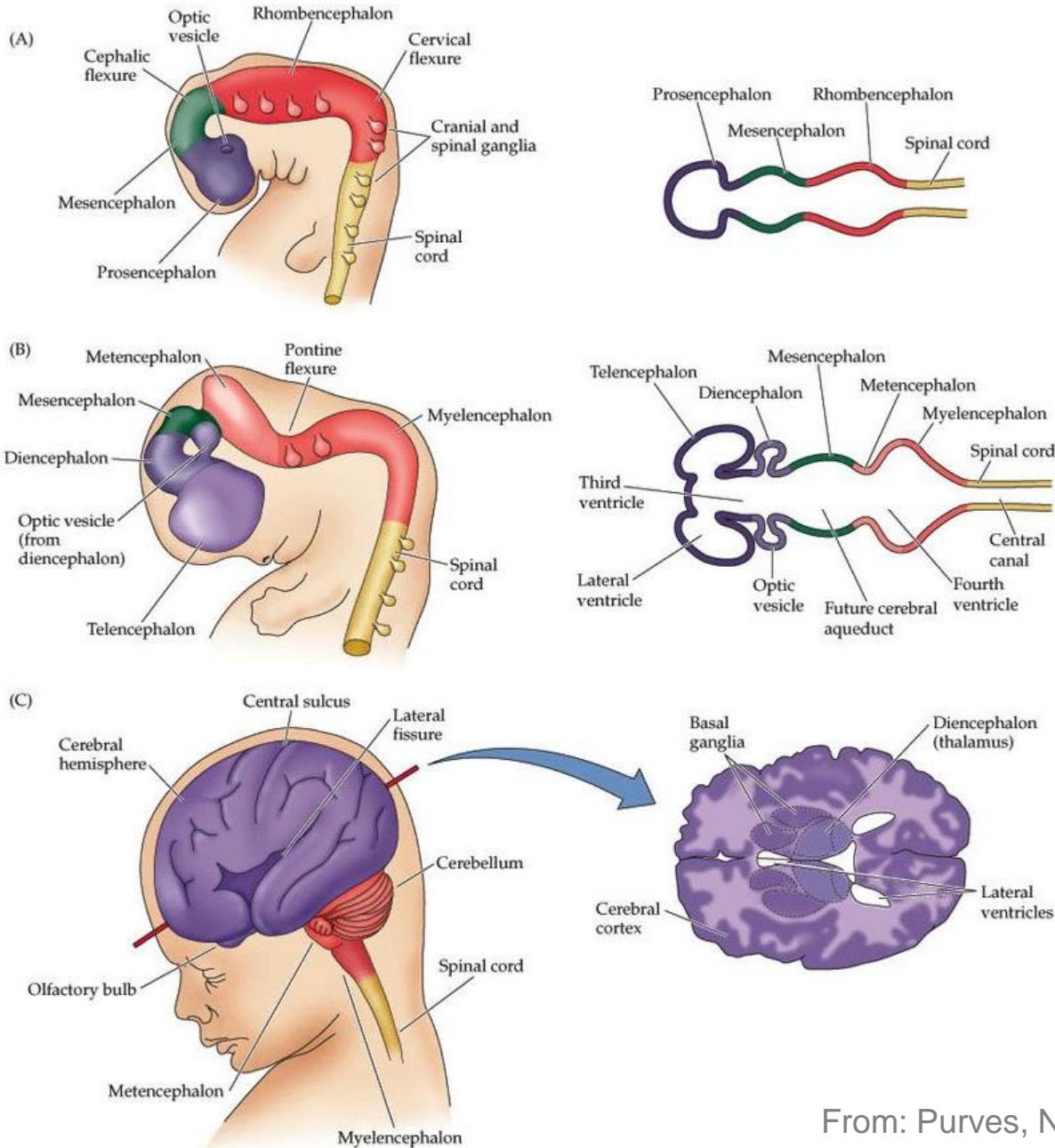
- Anterior: Toward the front or front end
- Posterior: Toward the back or back end
- Inferior: Toward the bottom of the body, or below
- Superior: Toward the top of the head/body, or above
- Medial: Toward the middle/midline
- Lateral: Away from the middle/midline, toward the side
- Rostral: Toward the nose
- Caudal: Toward the tail/rear
- Proximal: Near the trunk or center
- Distal: Away from the center
- Dorsal:Toward the back
- Ventral: Toward the belly
- Ipsilateral: On the same side
- Contralateral: On the opposite side
- Bilateral: On both sides
- Unilateral: On one side



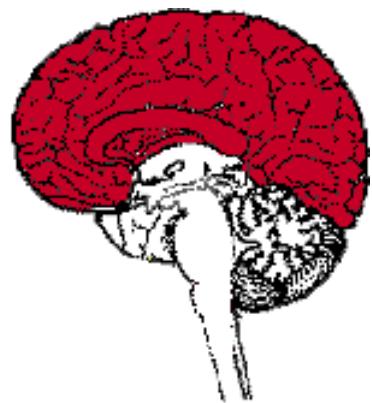
Neural development



Neural development



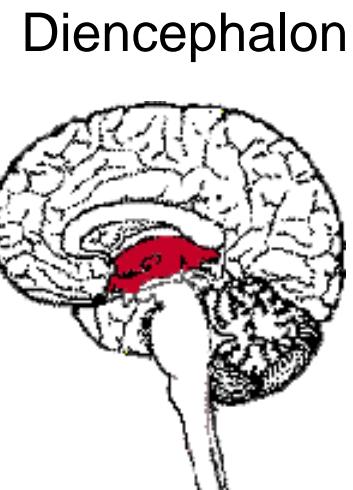
Major divisions of the brain



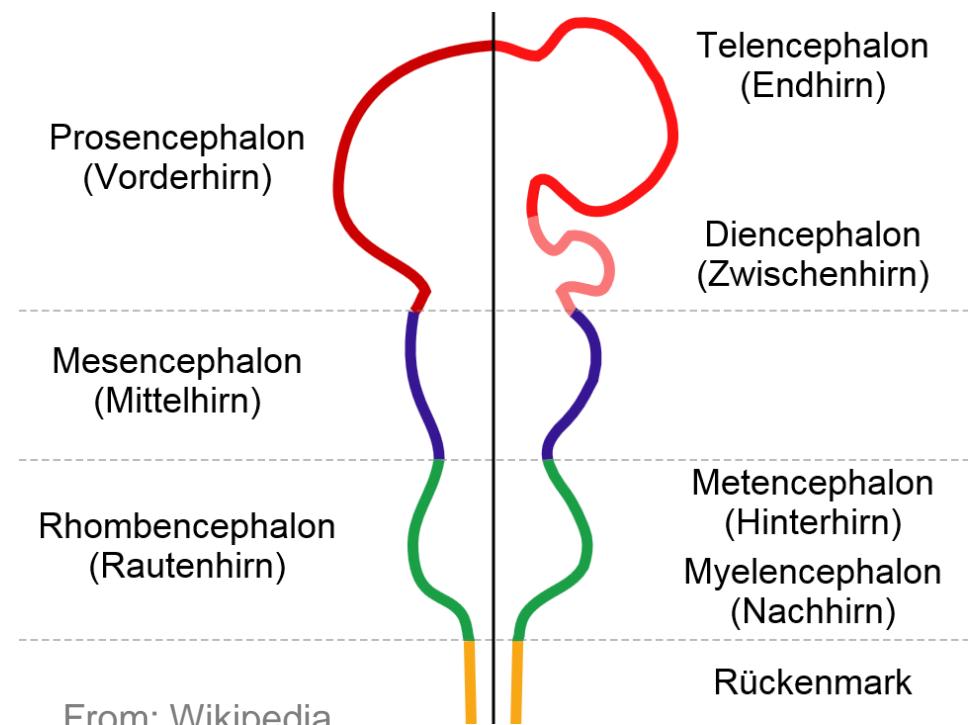
Telencephalon

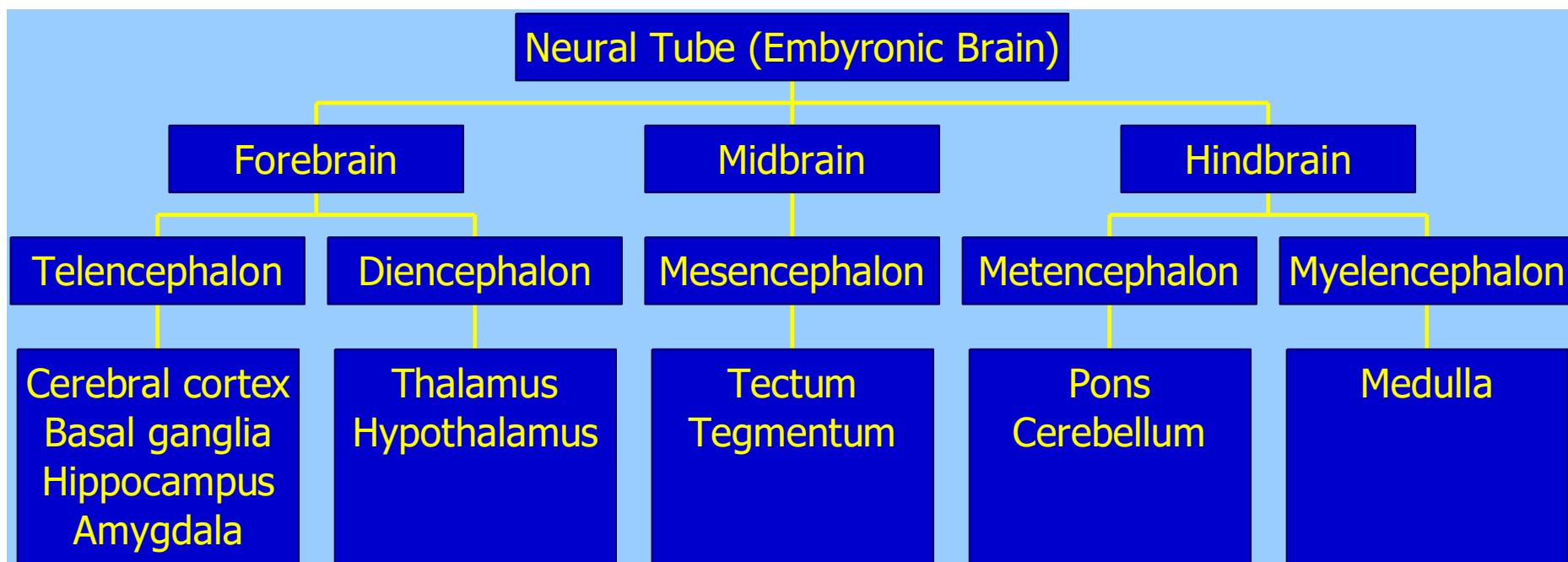
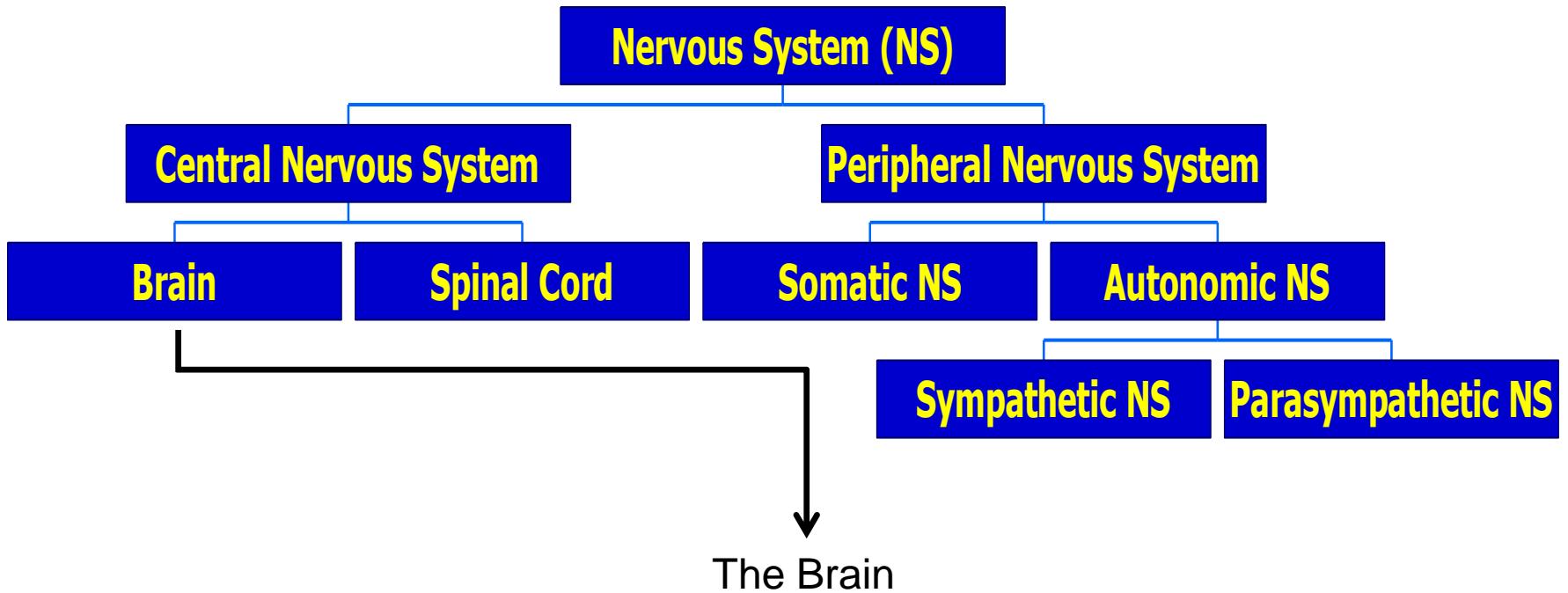
Mesencephalon

Myelencephalon

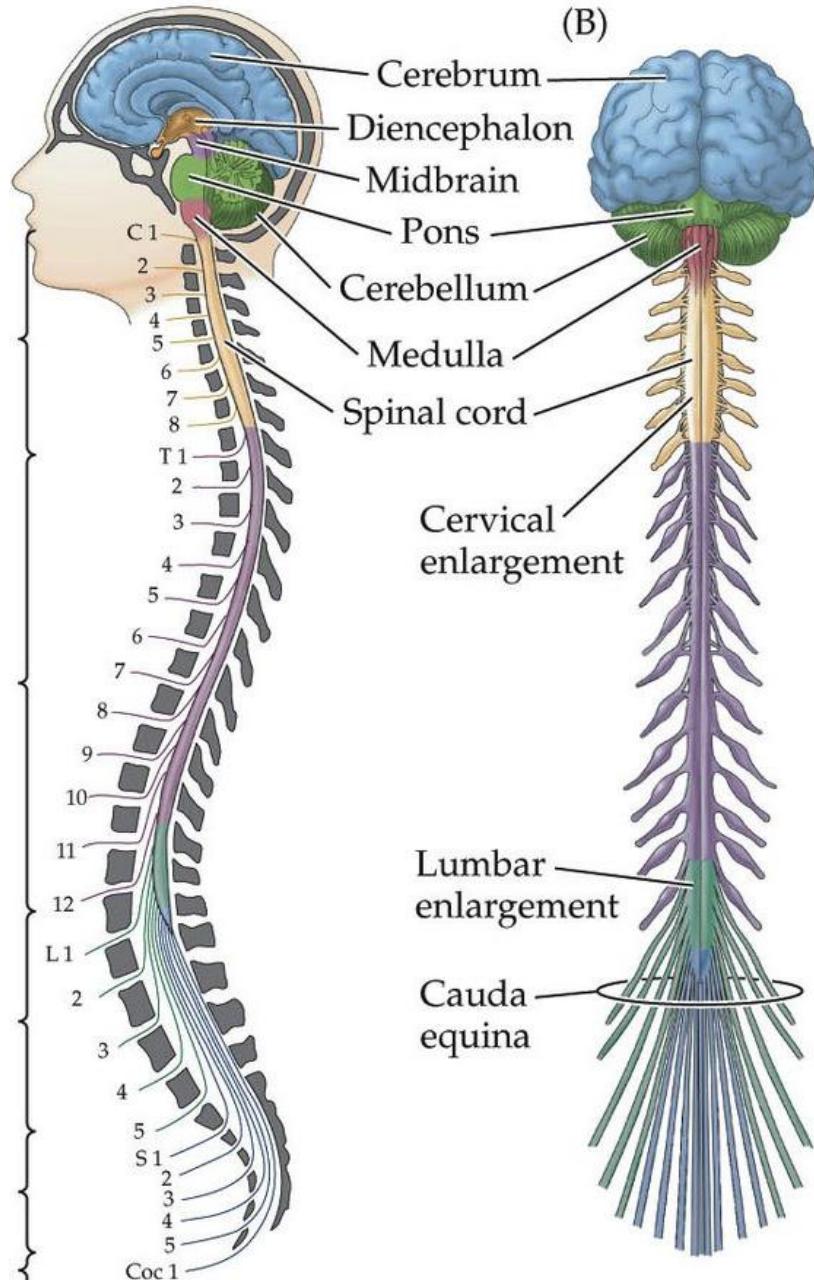


Metencephalon

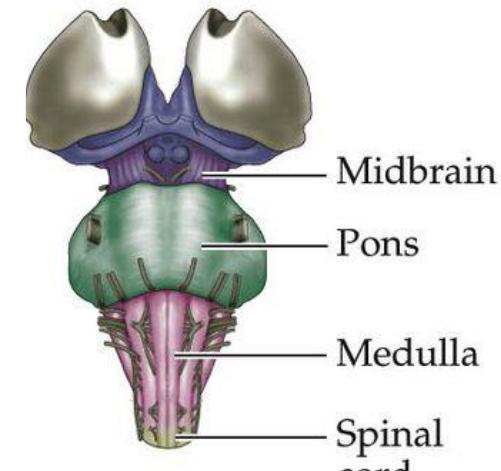
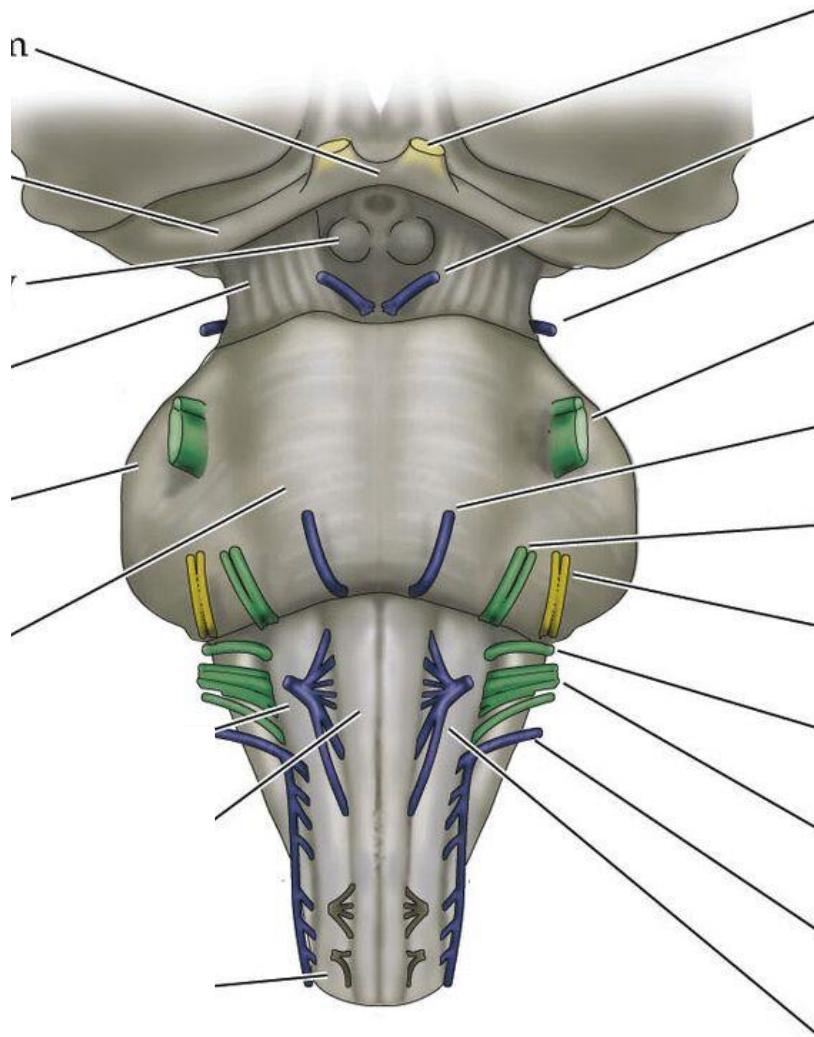




Major divisions of the brain



Cranial nerves

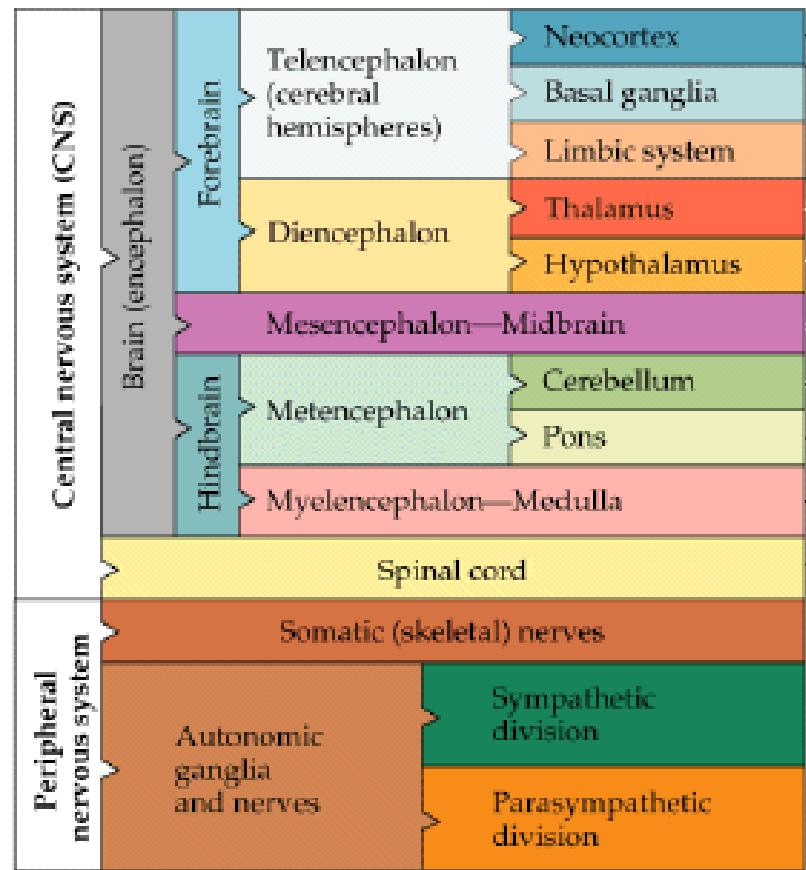


Cranial nerves

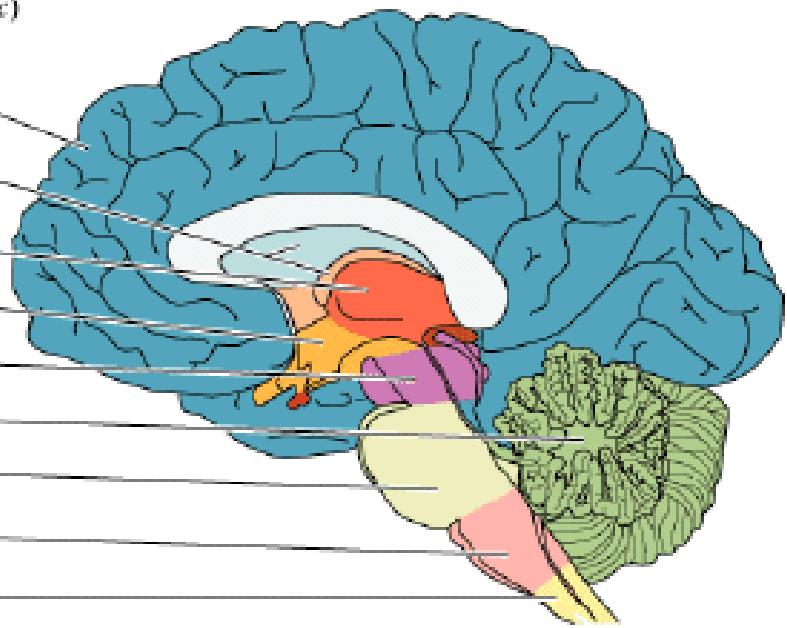
Cranial nerve	Name	Sensory and/or motor	Major function
I	Olfactory nerve	Sensory	Sense of smell
II	Optic nerve	Sensory	Vision
III	Oculomotor nerve	Motor	Eye movements; pupillary constriction and accommodation; muscles of eyelid
IV	Trochlear nerve	Motor	Eye movements
V	Trigeminal nerve	Sensory and motor	Somatic sensation from face, mouth, cornea; muscles of mastication
VI	Abducens nerve	Motor	Eye movements
VII	Facial nerve	Sensory and motor	Controls the muscles of facial expression; taste from anterior tongue; lacrimal and salivary glands
VIII	Vestibulocochlear (auditory) nerve	Sensory	Hearing; sense of balance
IX	Glossopharyngeal nerve	Sensory and motor	Sensation from pharynx; taste from posterior tongue; carotid baroreceptors
X	Vagus nerve	Sensory and motor	Autonomic functions of gut; sensation from pharynx; muscles of vocal cords; swallowing
XI	Spinal accessory nerve	Motor	Shoulder and neck muscles
XII	Hypoglossal nerve	Motor	Movements of tongue

Major divisions of the brain

(b) Organization of the adult human brain

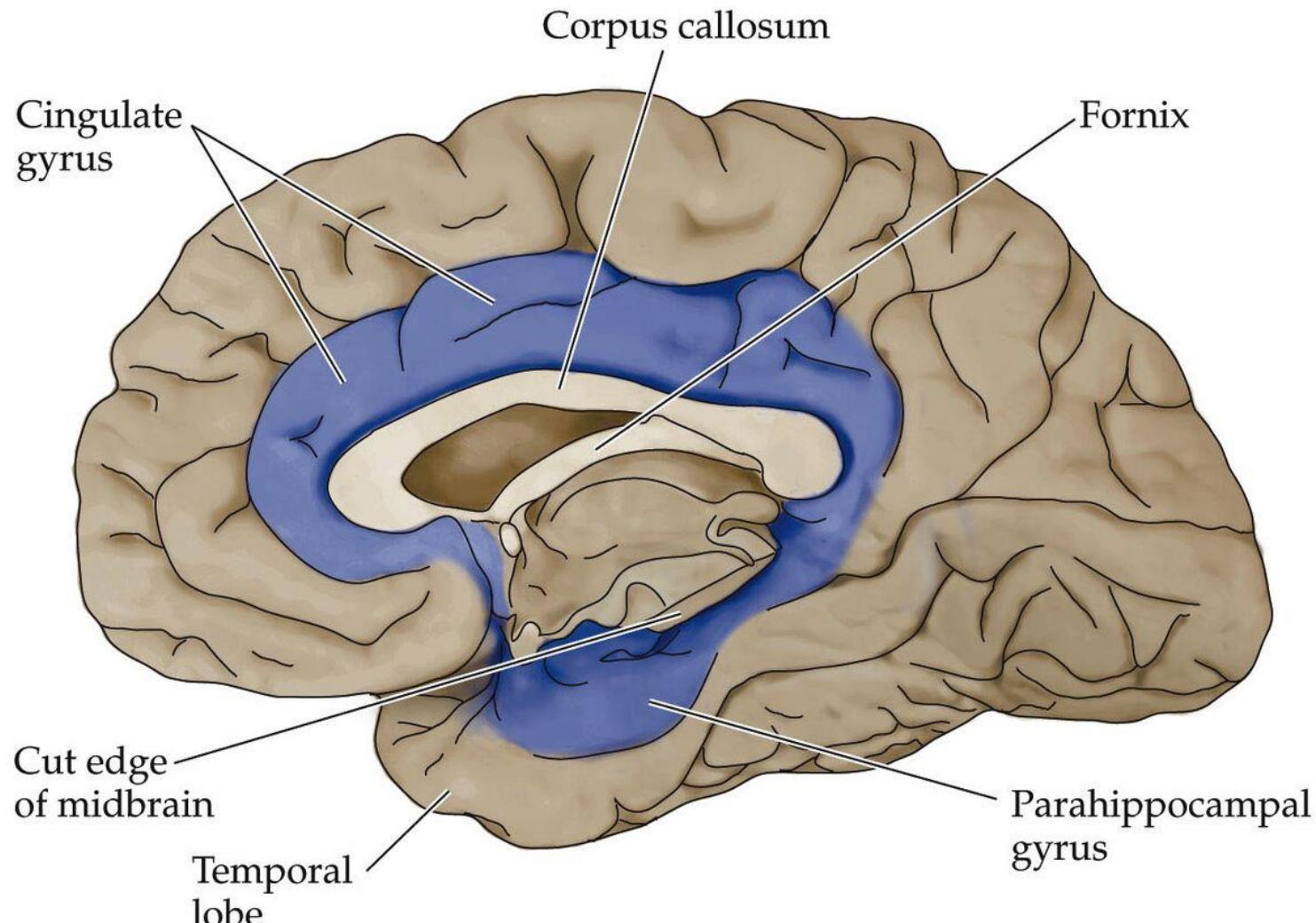


(c)



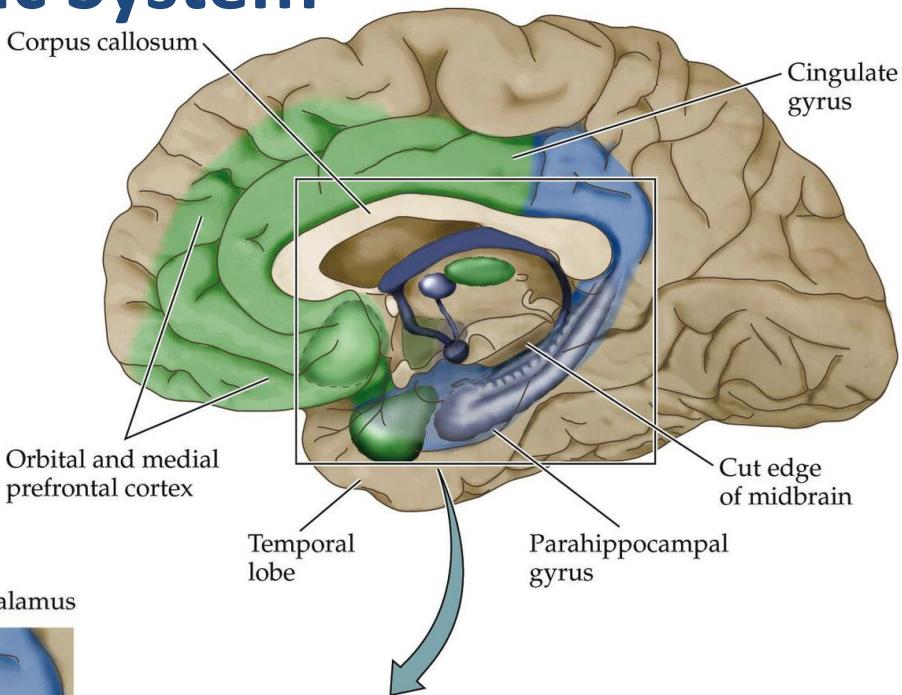
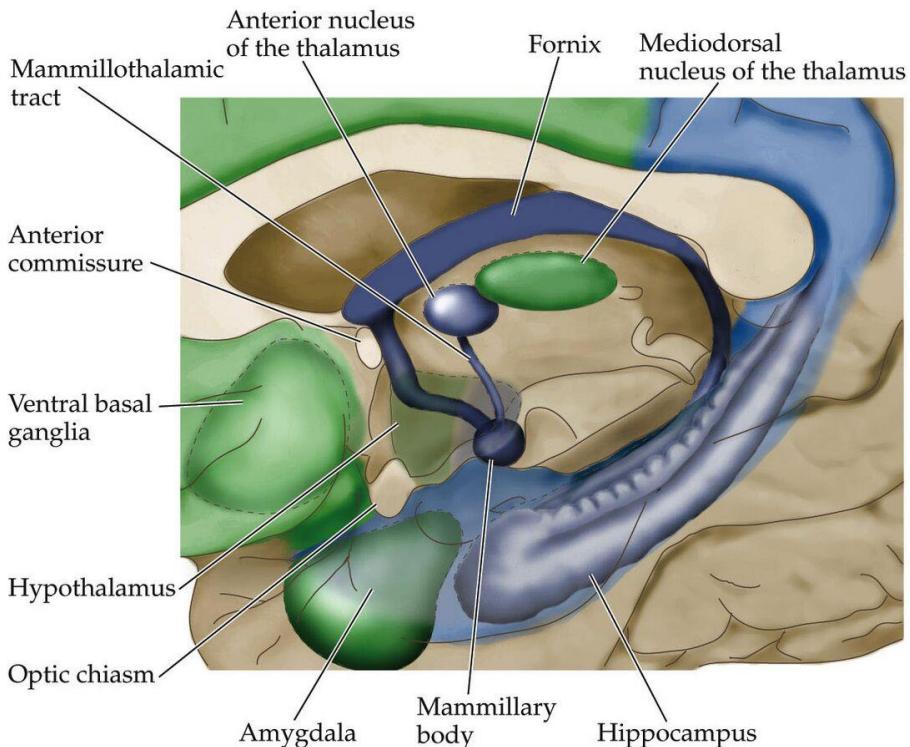
Adult brain

The Limbic System



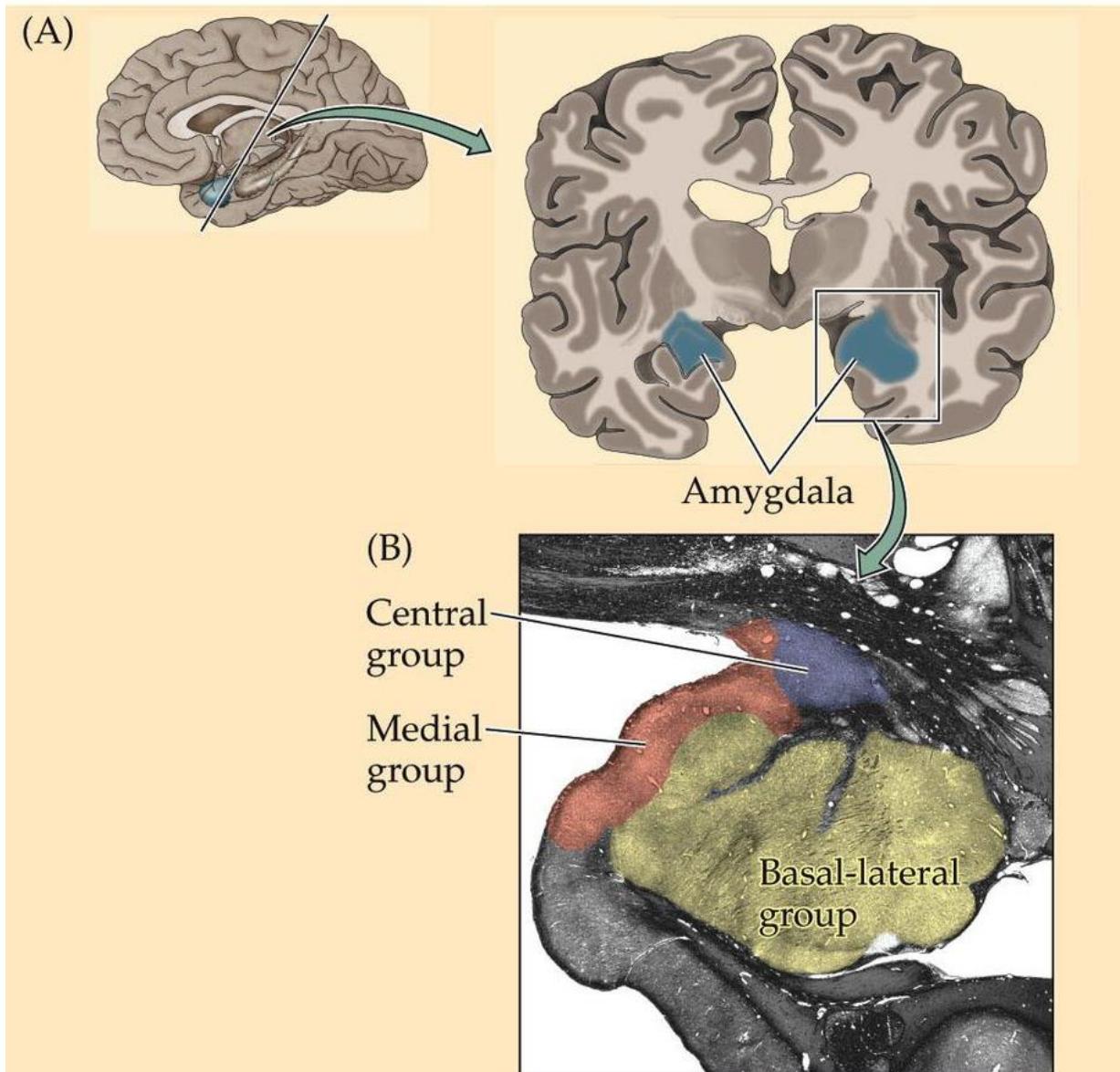
Brocas Limbic Lobe

The Limbic System



Papez circuit & modern conception of limbic system

The Limbic System



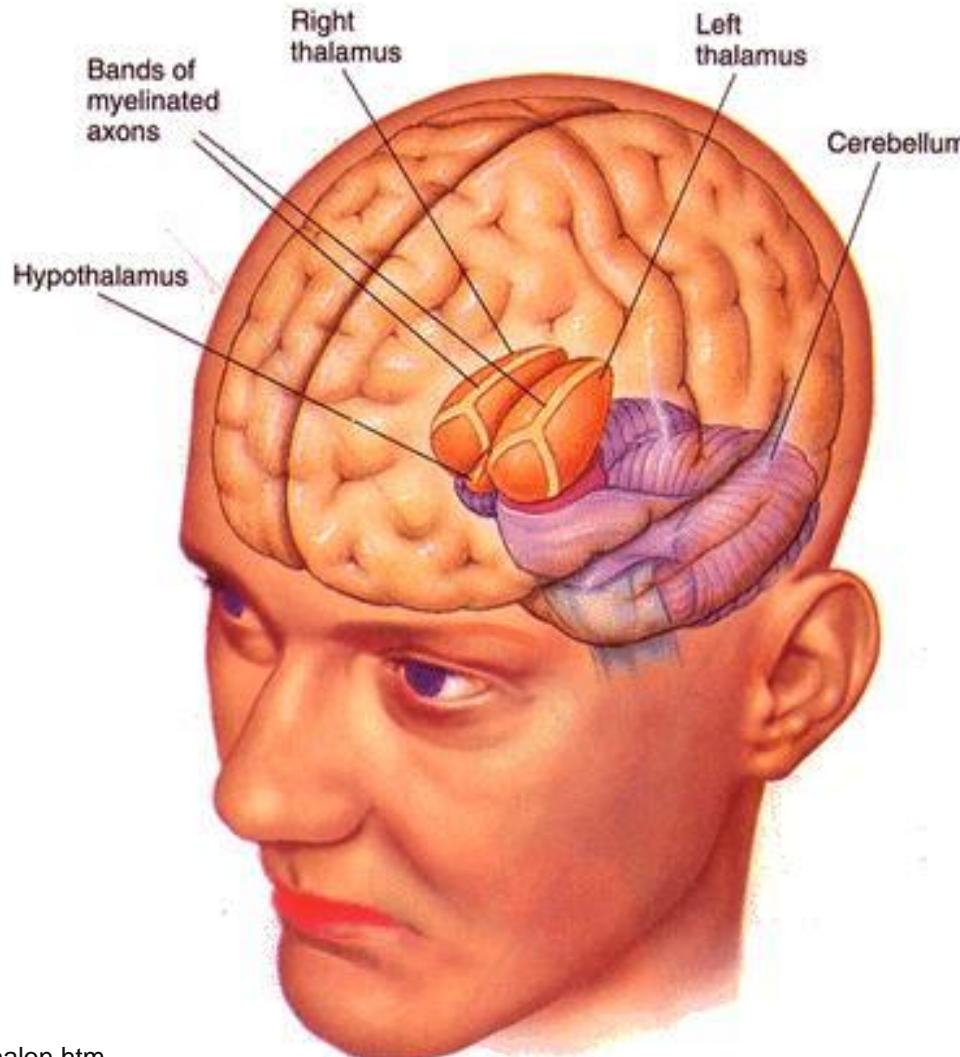
Papez circuit & modern conception of limbic system

The Limbic System

- Broca's "limbic lobe"
- Papez (1937) more precisely defined it
- Structure
 - Structures on medial and basal surfaces of cerebral hemispheres
 - Cingulate gyrus + parahippocampal gyrus + hippocampal formation + fornix + amygdala + septum + mammillary bodies
 - Anatomic circuits include basolateral circuit and the Papez circuit
- Function
 - Emotional expression
 - Memory acquisition
 - Fear conditioning
 - Violence and aggression

Hypothalamus and Thalamus

► Human Diencephalon



Hypothalamus and Thalamus

Upper Brain Stem: Diencephalon

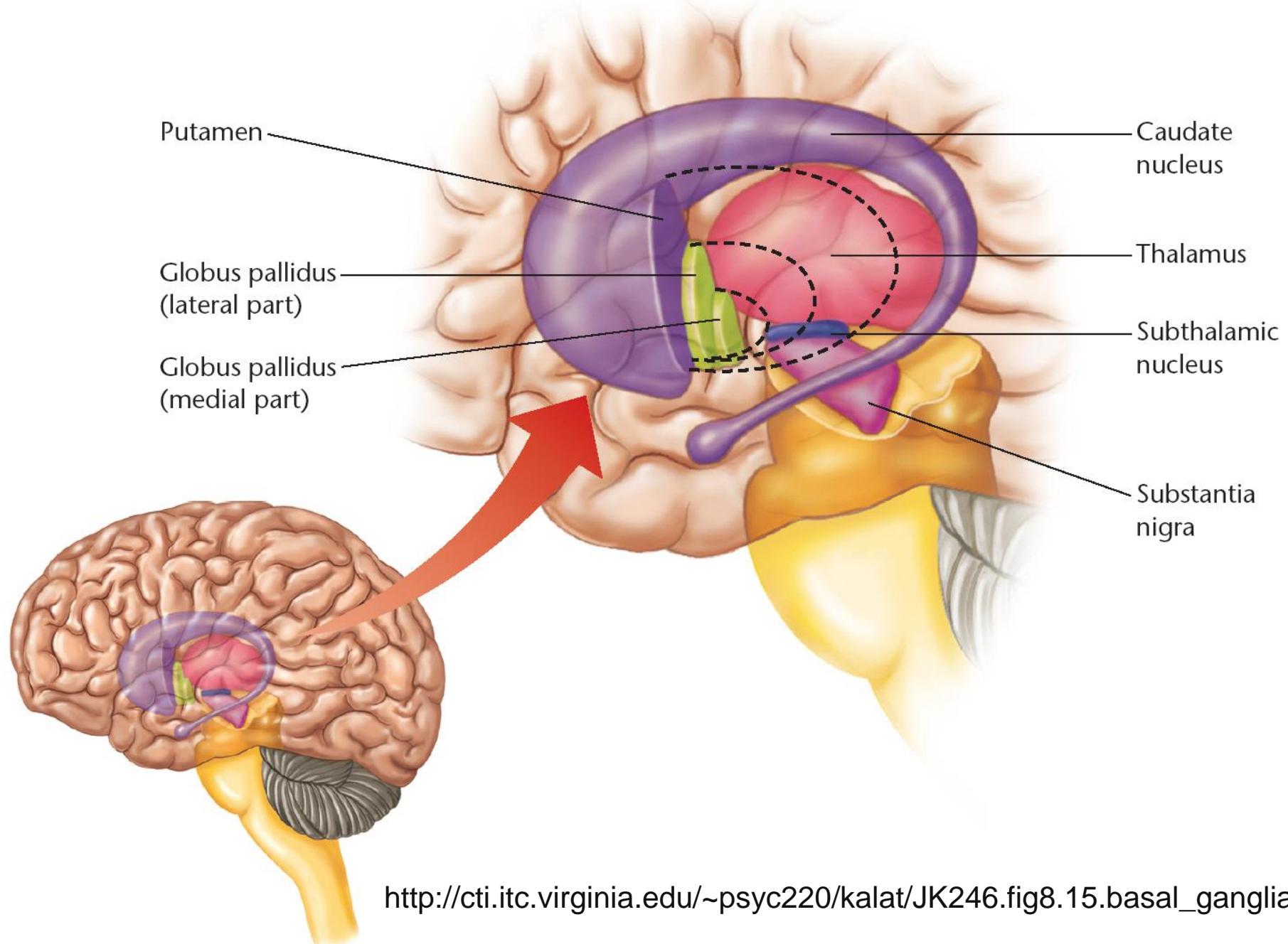
- Thalamus
 - Structure
 - Relatively large
 - Two symmetric large nuclei
 - All thalamic nuclei receive ascending and descending input
 - Many projections
 - Function
 - Relay station
 - Domain-specific information processing

Hypothalamus and Thalamus

Upper Brain Stem: Diencephalon

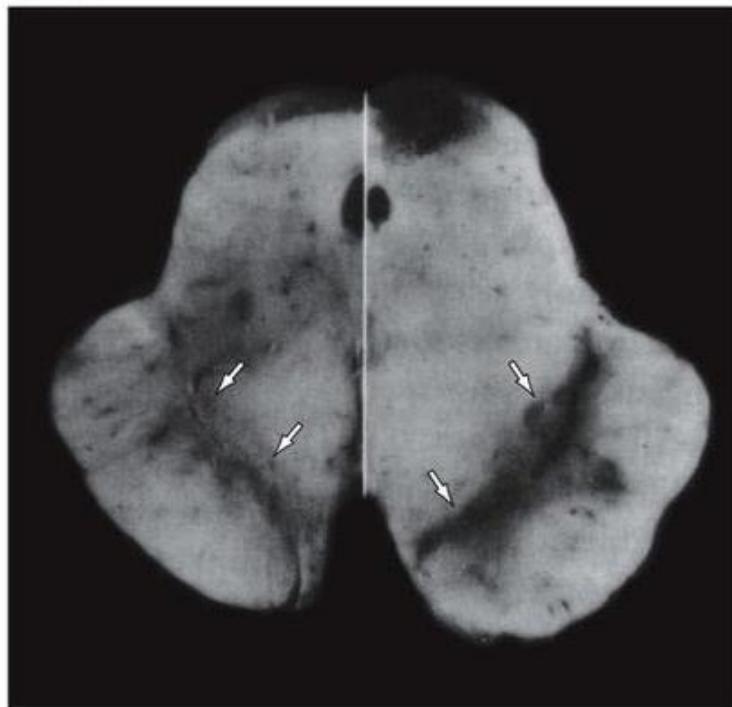
- Hypothalamus
 - Structure
 - Very small
 - Contains an important collection of nuclei
 - Function
 - Controls autonomic mechanisms

Basal Ganglia

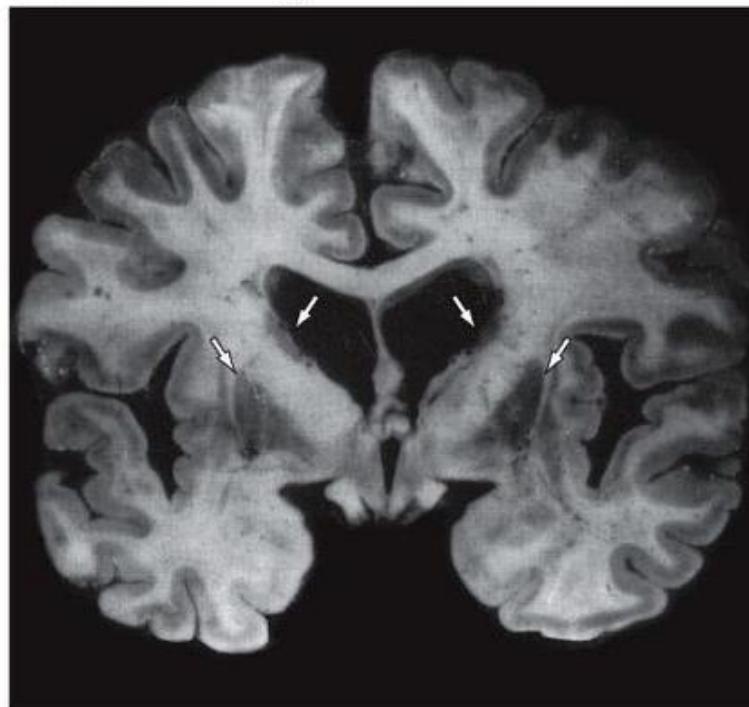


Basal Ganglia

(A) Parkinson's disease



(B) Huntington's disease



Basal Ganglia

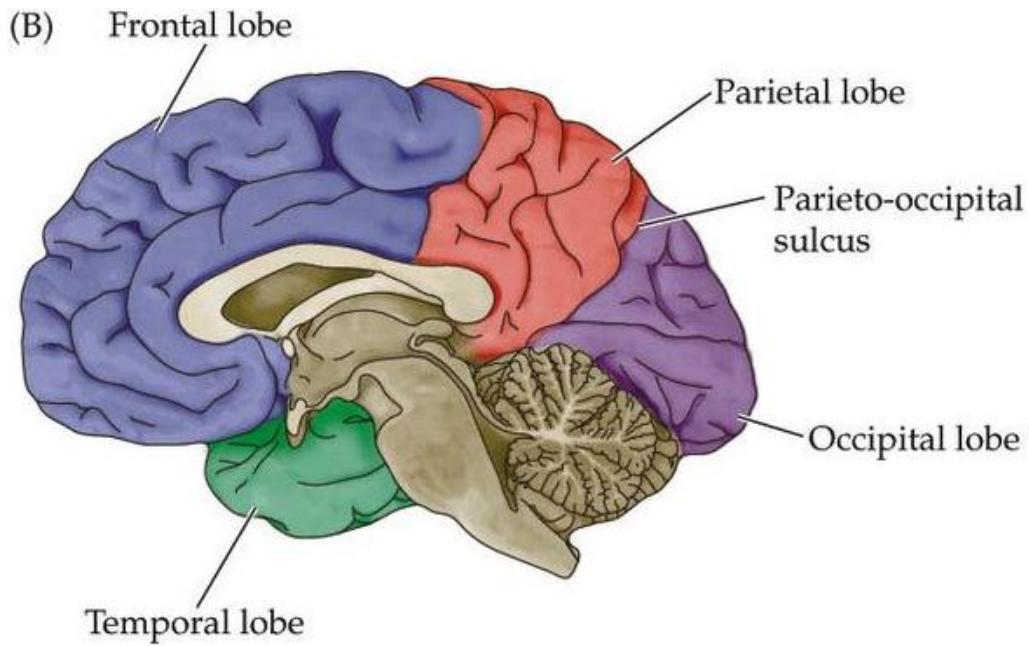
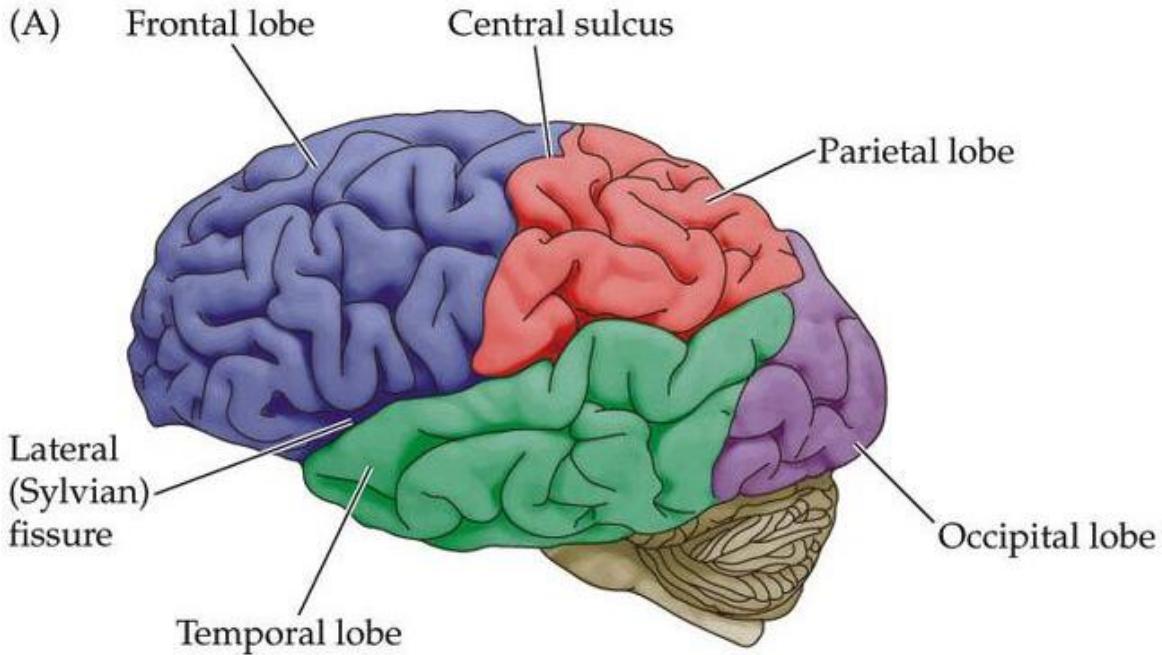
<https://radiopaedia.org/cases/deep-brain-stimulation-for-parkinson-disease>



Basal Ganglia

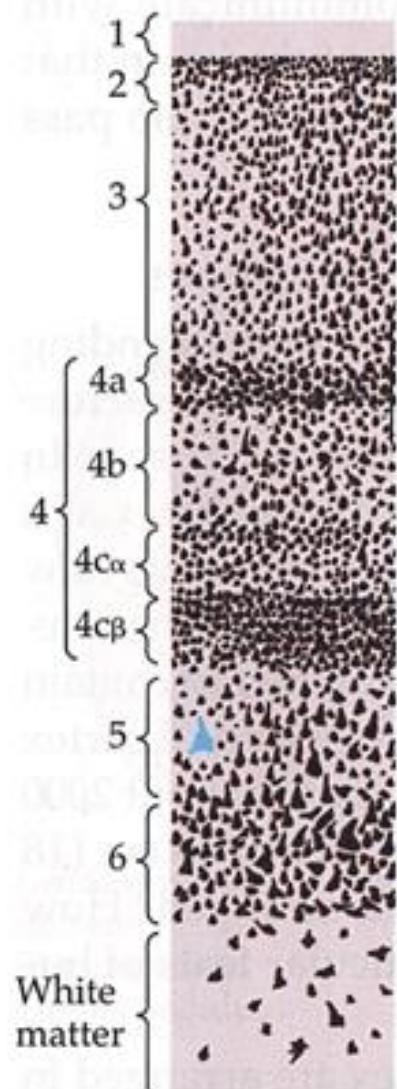
- Structure
 - Collection of nuclei embedded deep within cortex
 - Partially surround the thalamus
 - Sensory projections to cerebrum
 - Efferents to other nervous system structures
 - Caudate nucleus + putamen + globus pallidus + substantia nigra + subthalamic nucleus
- Function
 - Regulate voluntary movement
 - Integrative or just a relay station?
- Pathology
 - Movement disorders (e.g. Parkinson's)

Lobes of cerebral cortex



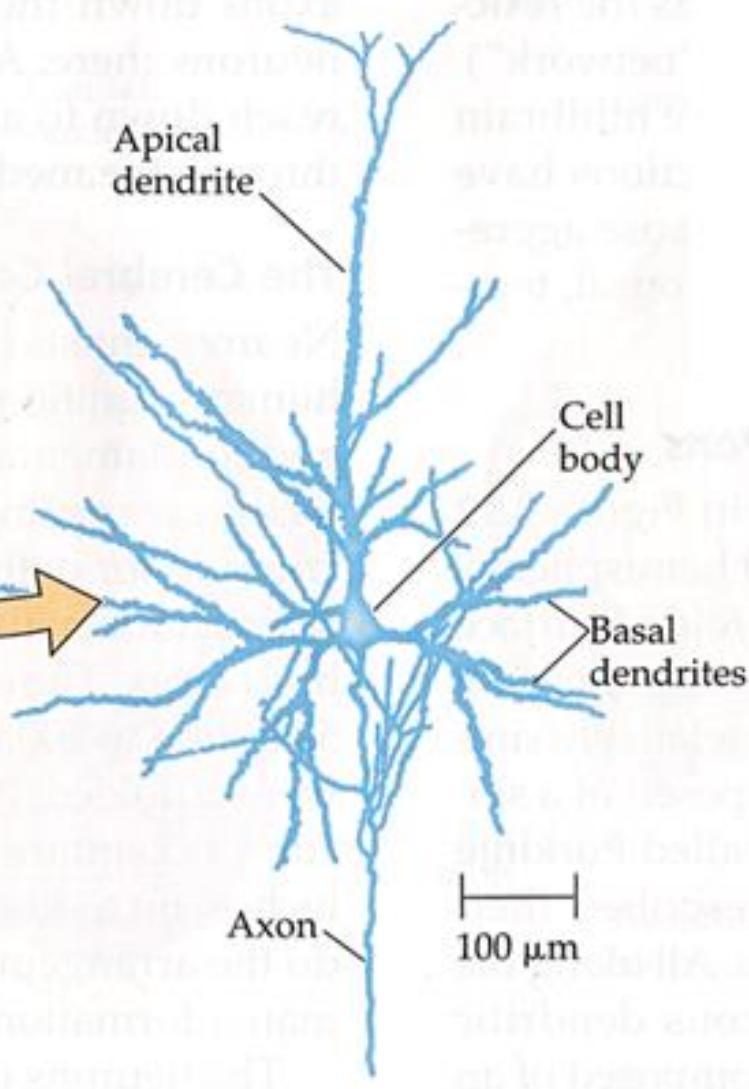
Cytoarchitecture

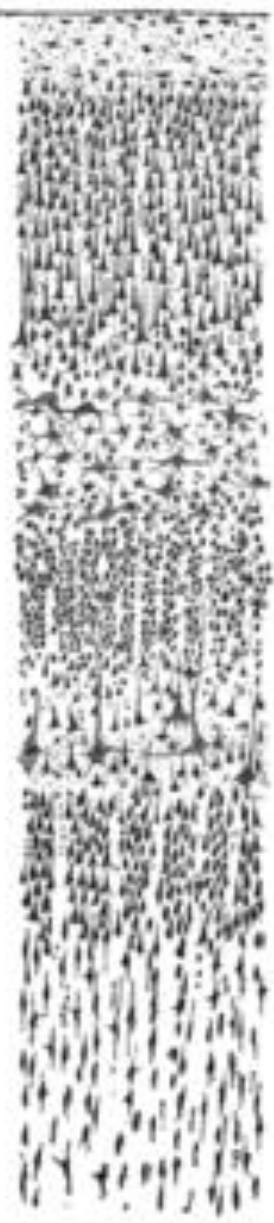
(a) Six layers of cortex



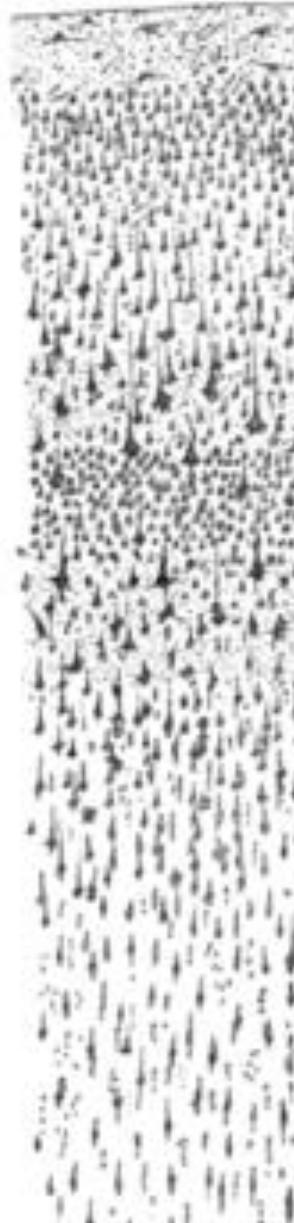
400 μm

(b) A single pyramidal neuron

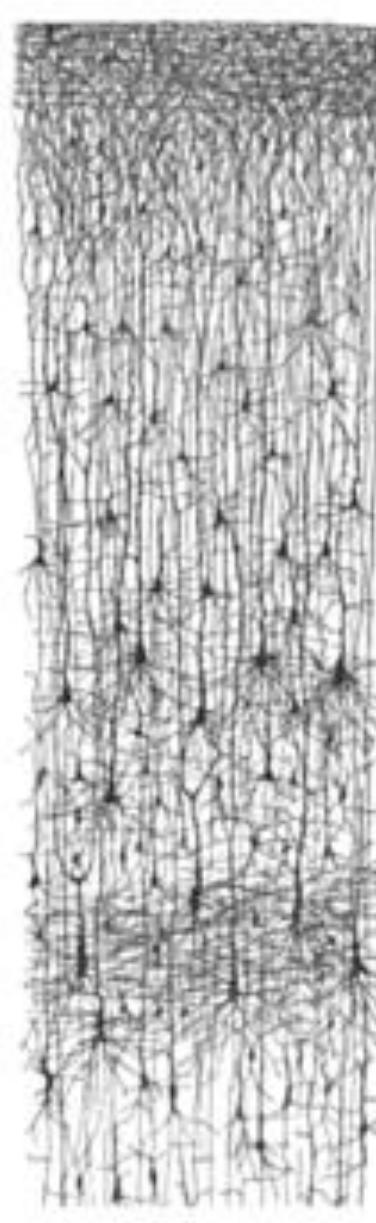




Adult visual Cx

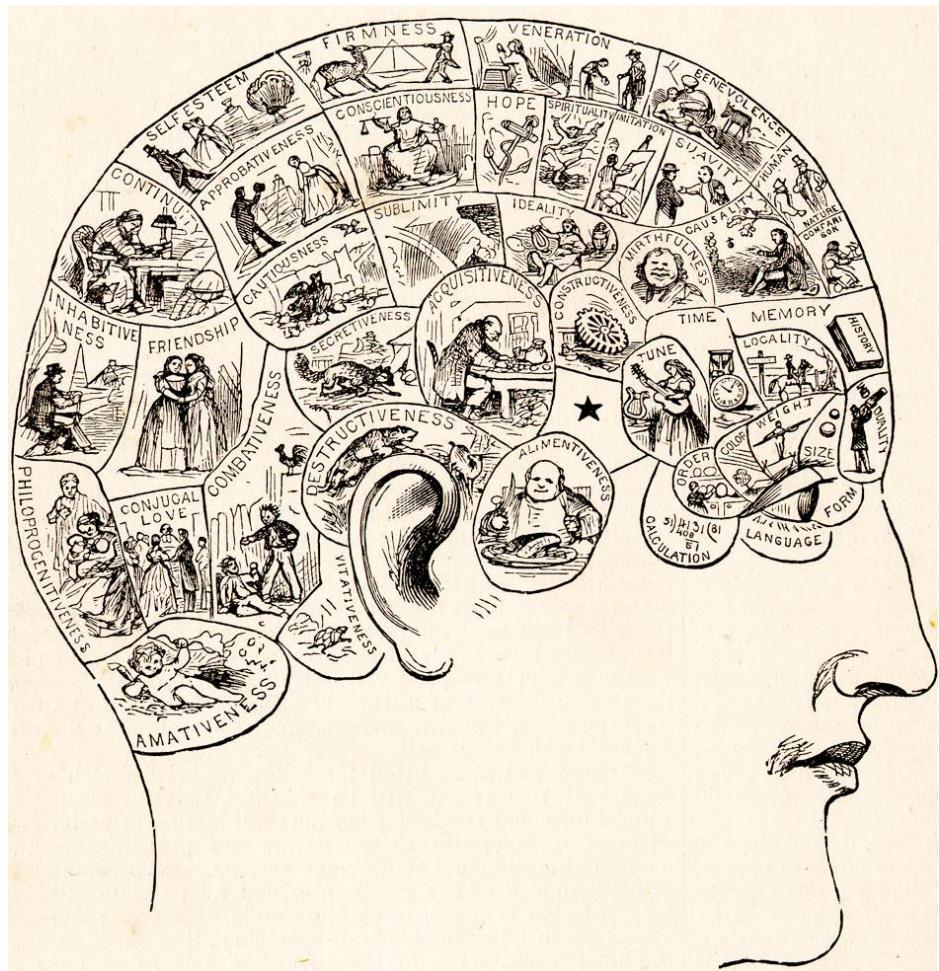
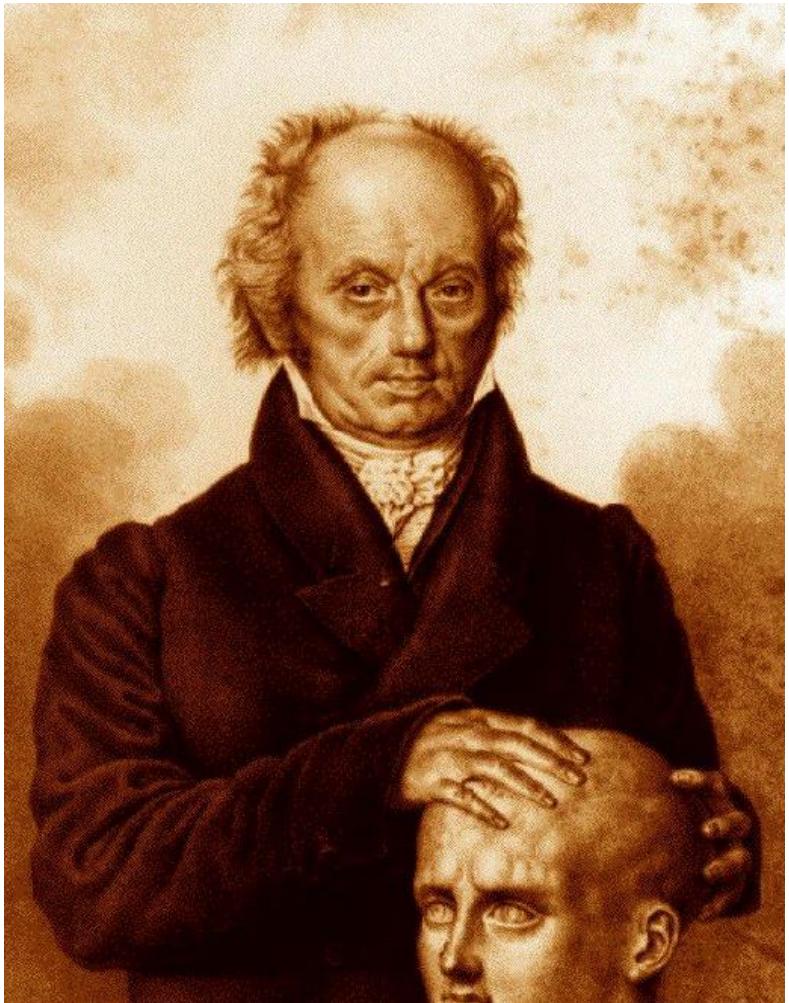


Adult motor Cx



1.5 months Cx

Cortical areas



Franz Joseph Gall (1758-1828)

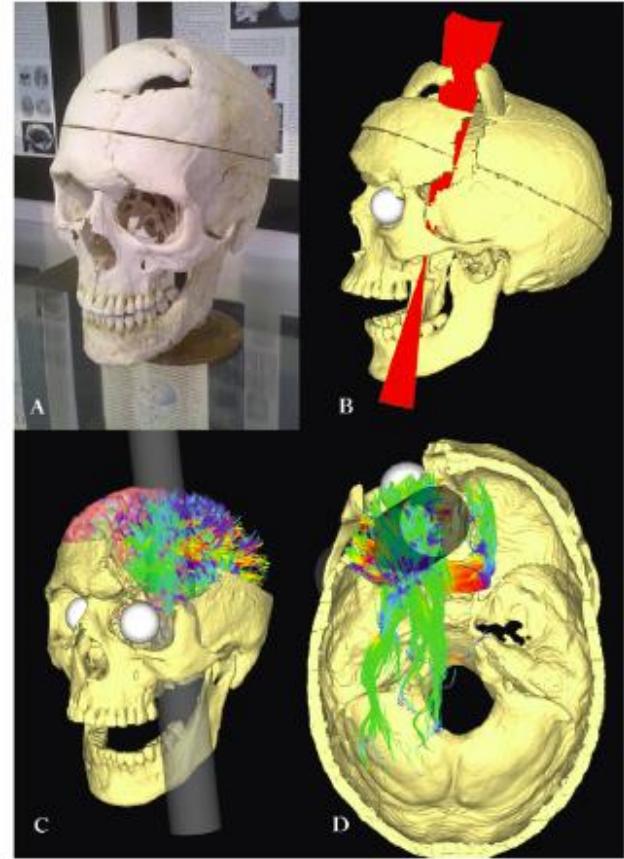
Cortical areas



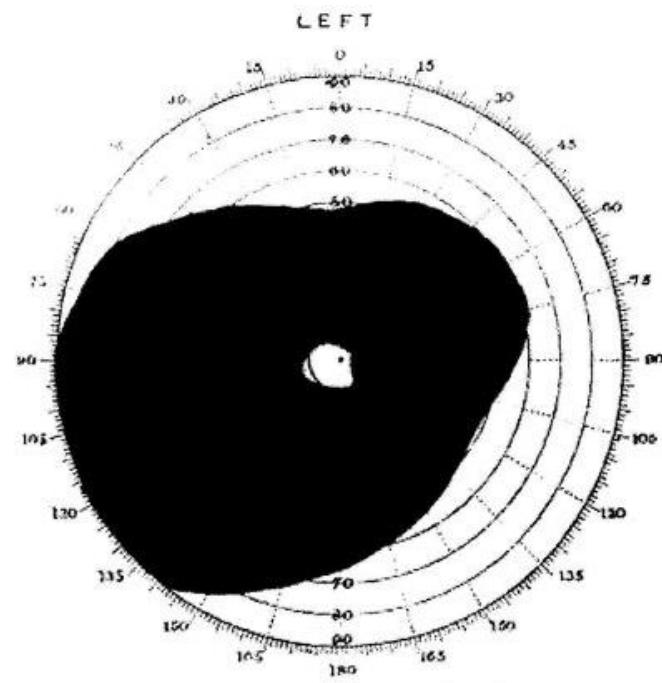
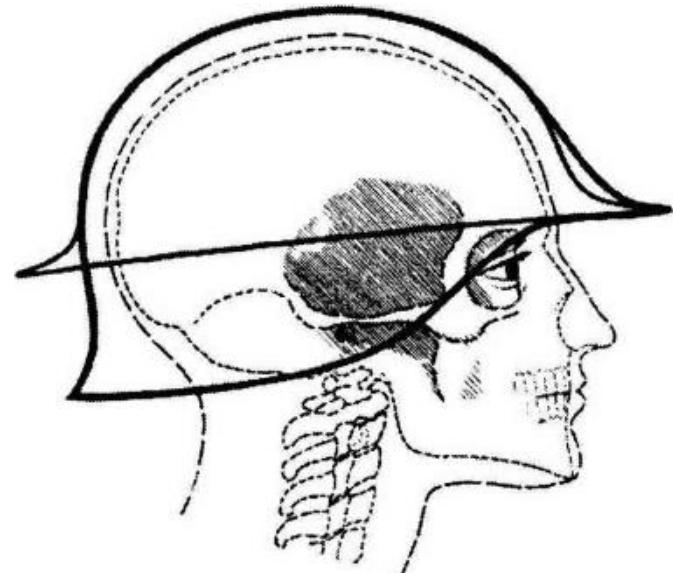
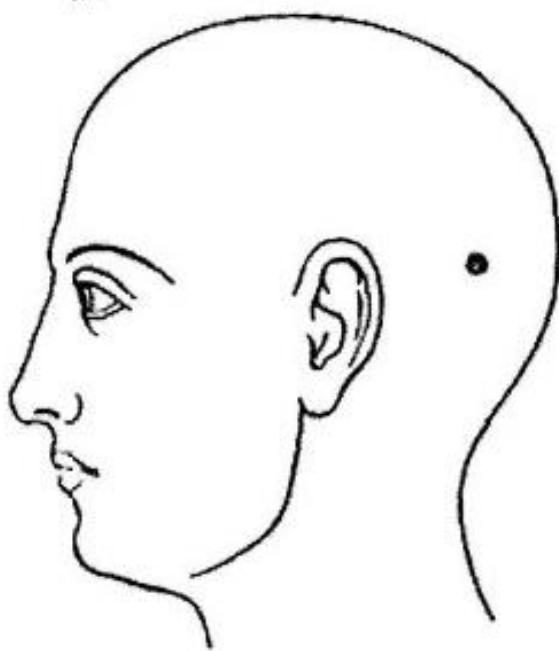
Phineas Gage (1823–1860)

Accident in 1848 destroyed left frontal lobe

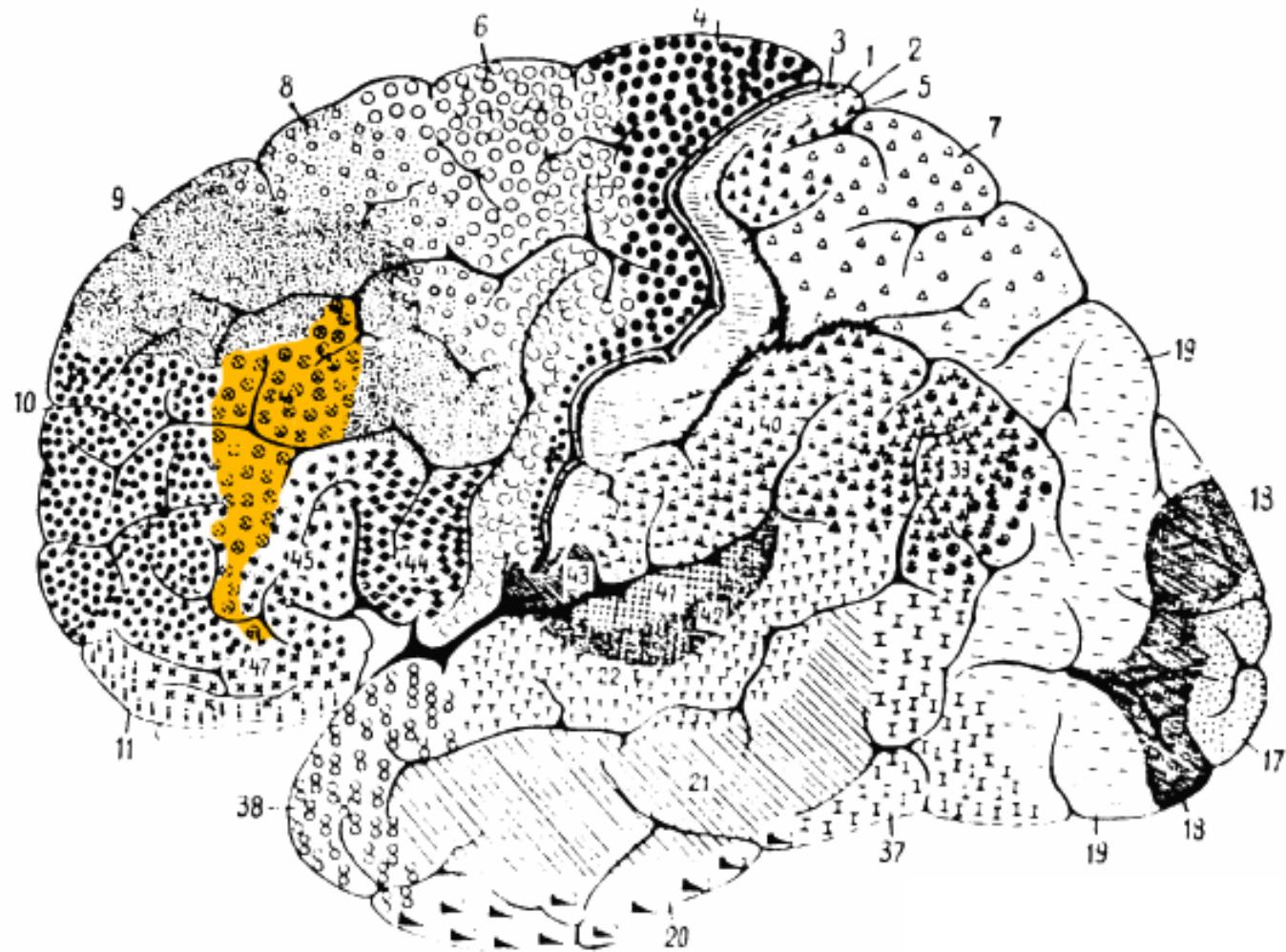
„The equilibrium or balance, so to speak, between his intellectual faculties and animal propensities, seems to have been destroyed.”



Cortical areas

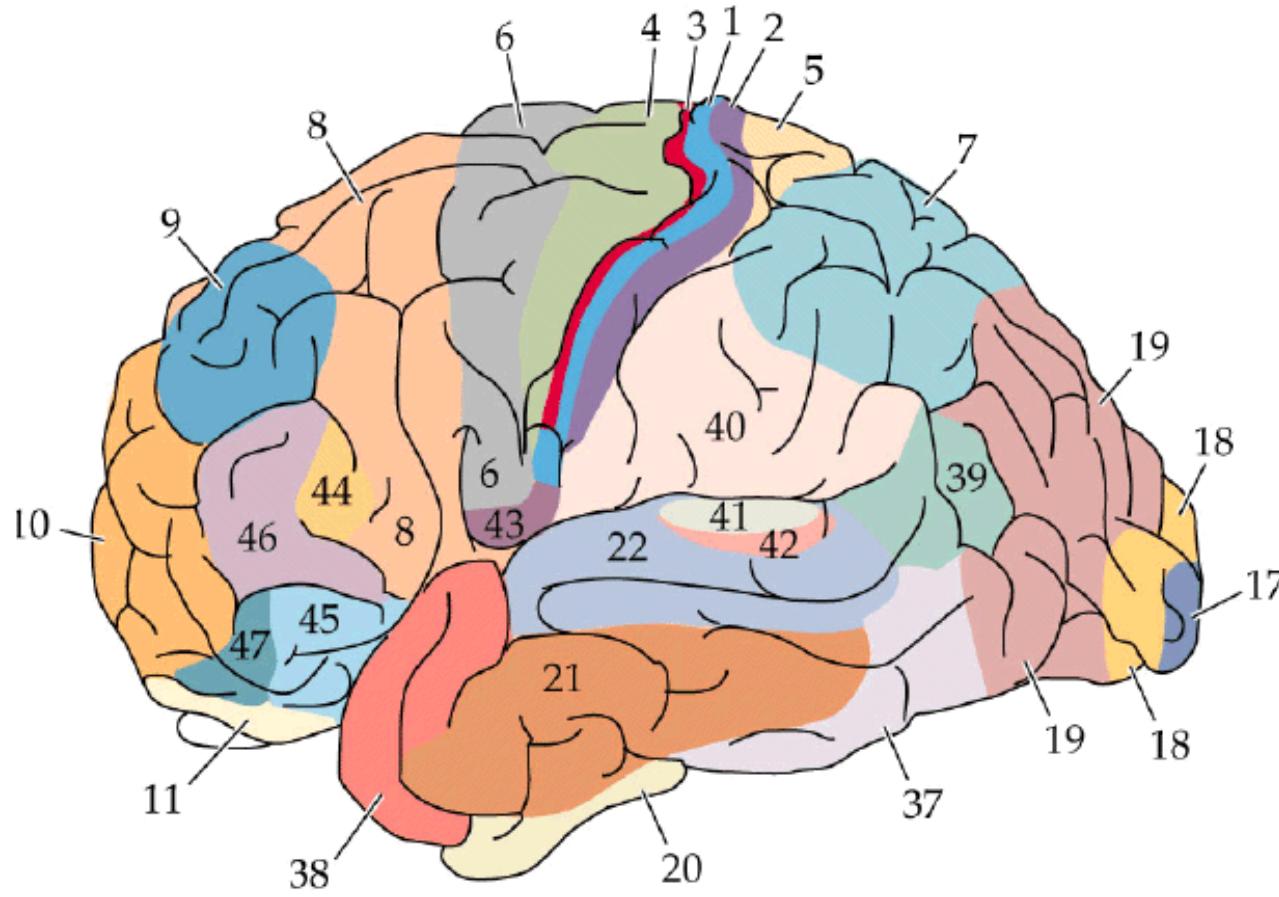


Brodmann's areas (BA)



From: Korbinian Brodmann 1909

Brodmann's areas (BA)



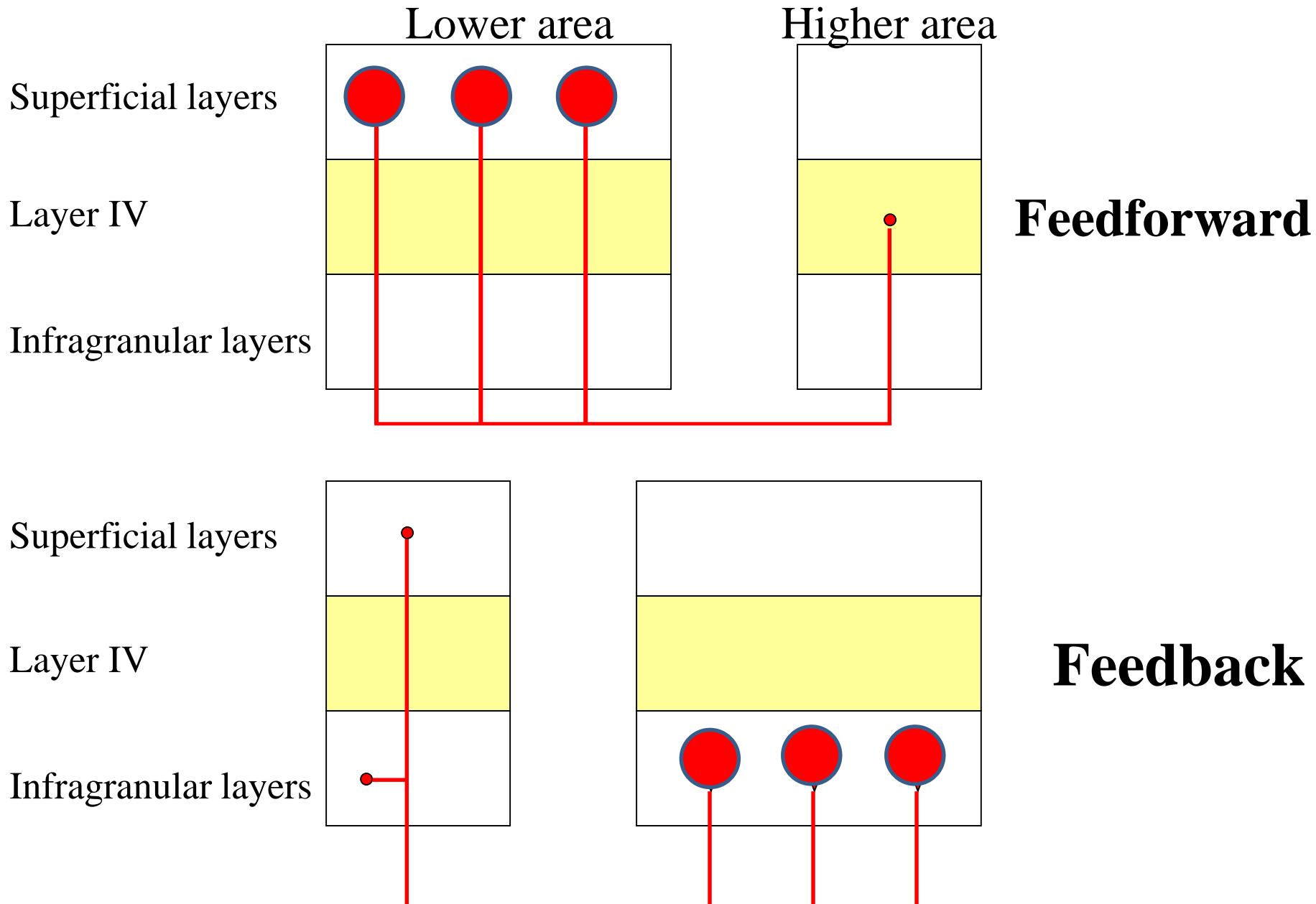
BA 1-3: primary somatosensory cortex

BA 4: Motorcortex

BA 22: Wernicke area

BA 17: primary Visual cortex

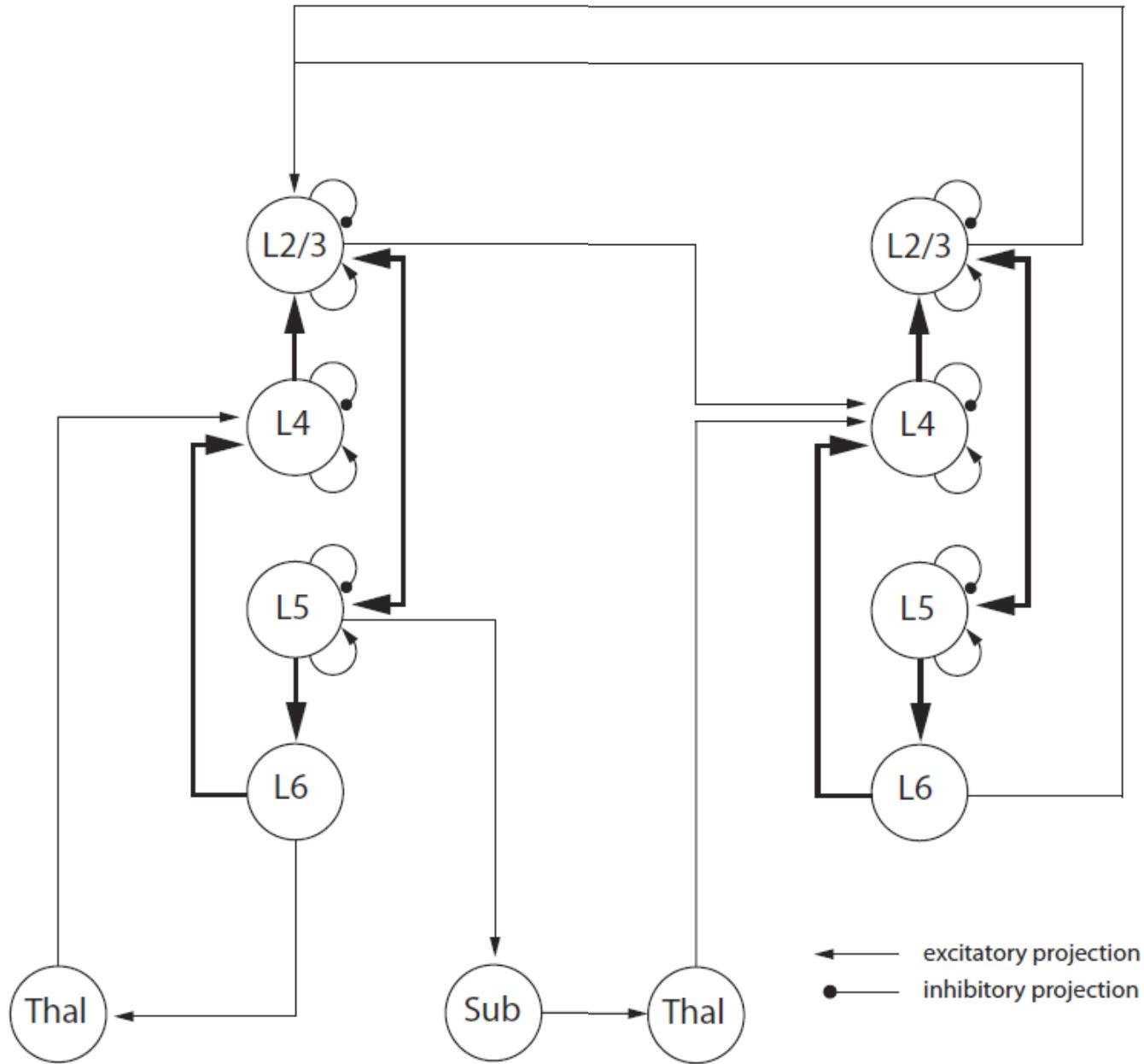
Circuits



Area A

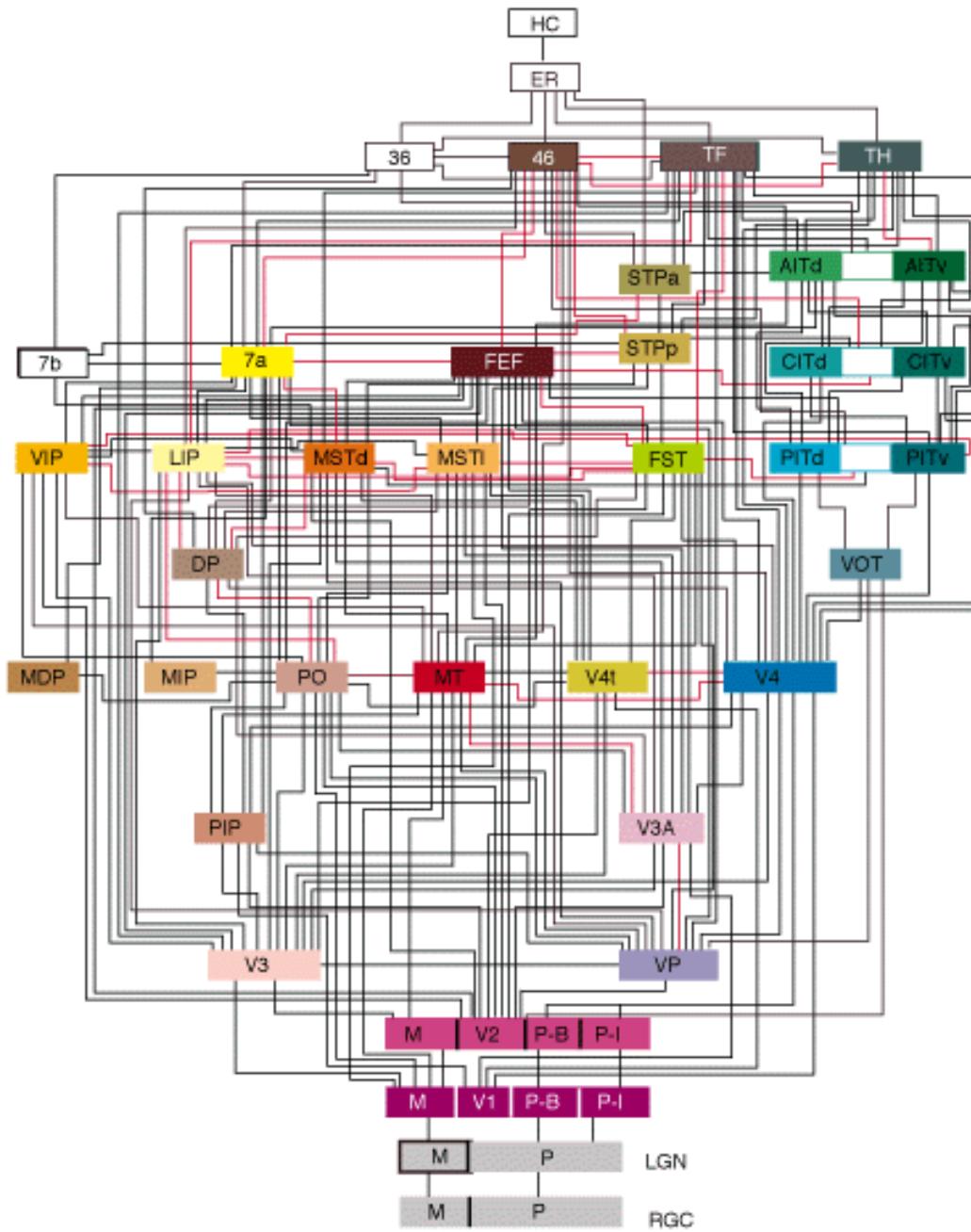
Circuits

Area B



From: Da Costa & Martin, 2010

“Comprehensive” visual circuit



From: Felleman & Van Essen, 1991

Brain of a white-collar worker

Feuillet et al. 2009, Lancet

