

BASICS OF NEUROBIOLOGY

**CYTOARCHITECTURE
OF CEREBRAL
CORTEX**

ZSOLT LIPOSITS

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CELLULAR COMPOSITION OF THE CEREBRAL CORTEX

THE CEREBRAL CORTEX CONSISTS OF THE ARCHICORTEX (HIPPOCAMPAL FORMATION), PALEOCORTEX (OLFACTORY AREAS) AND NEOCORTEX

THE NEOCORTEX IS COMPRISED OF SIX SUPERIMPOSED LAYERS. THERE ARE ABOUT 10^{10} NEURONS IN THE CEREBRAL CORTEX

THE CORTEX IS BUILT UP BY PRINCIPAL, PYRAMIDAL NEURONS, INHIBITORY INTER-NEURONS AND GLIA CELLS

THERE ARE VARIATIONS IN THE CYTOARCHITECTURE OF THE CORTEX. THE PRIMARY SENSORY CORTEX IS GRANULAR, THE PRIMARY MOTOR CORTEX IS RATHER AGRANULAR IN NATURE

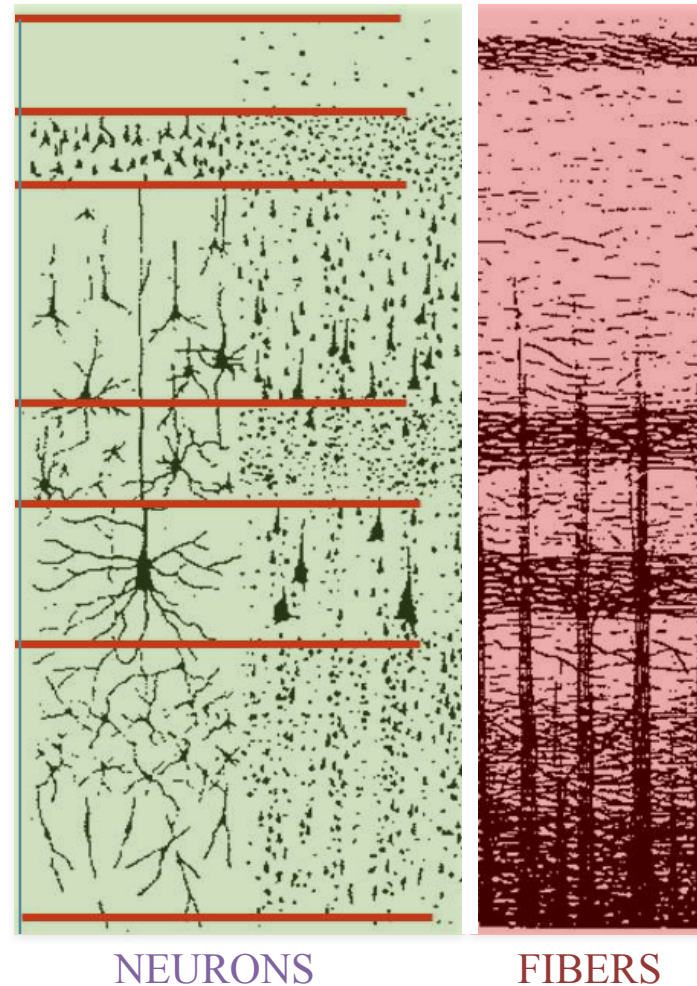
THE INCOMING SUBCORTICAL AND CORTICAL AFFERENTS HAVE SPECIAL TERMINATION PATTERNS. THEY TRANSFER THE INFORMATION TO INTERNEURONS, THAT RELAY IT FURTHER TO PRINCIPAL CELLS

NEURONS INTERACTING LOCALLY ARE ORGANIZED IN COLUMNS CALLED CORTICAL MODULES

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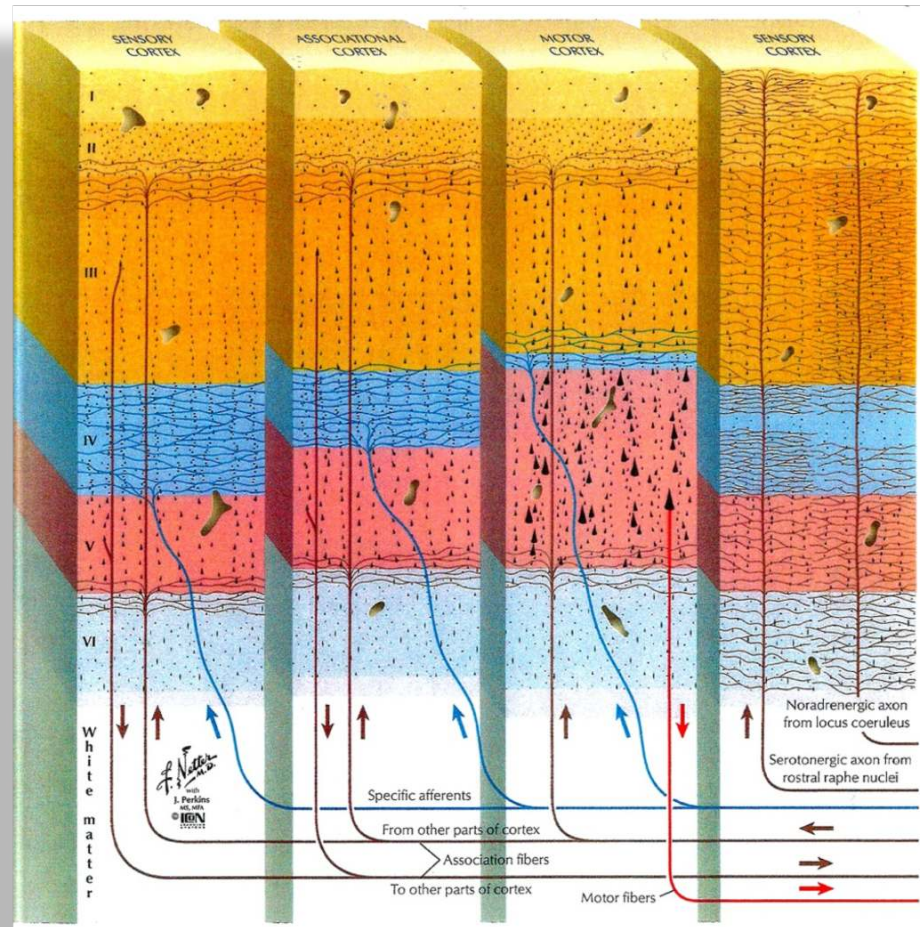
ORGANIZATION OF NEURONS IN CORTICAL LAYERS

1. MOLECULAR LAYER
2. EXTERNAL GRANULAR LAYER
3. EXTERNAL PYRAMIDAL LAYER
4. INTERNAL GRANULE LAYER
5. INTERNAL PYRAMIDAL LAYER
6. MULTIFORM LAYER



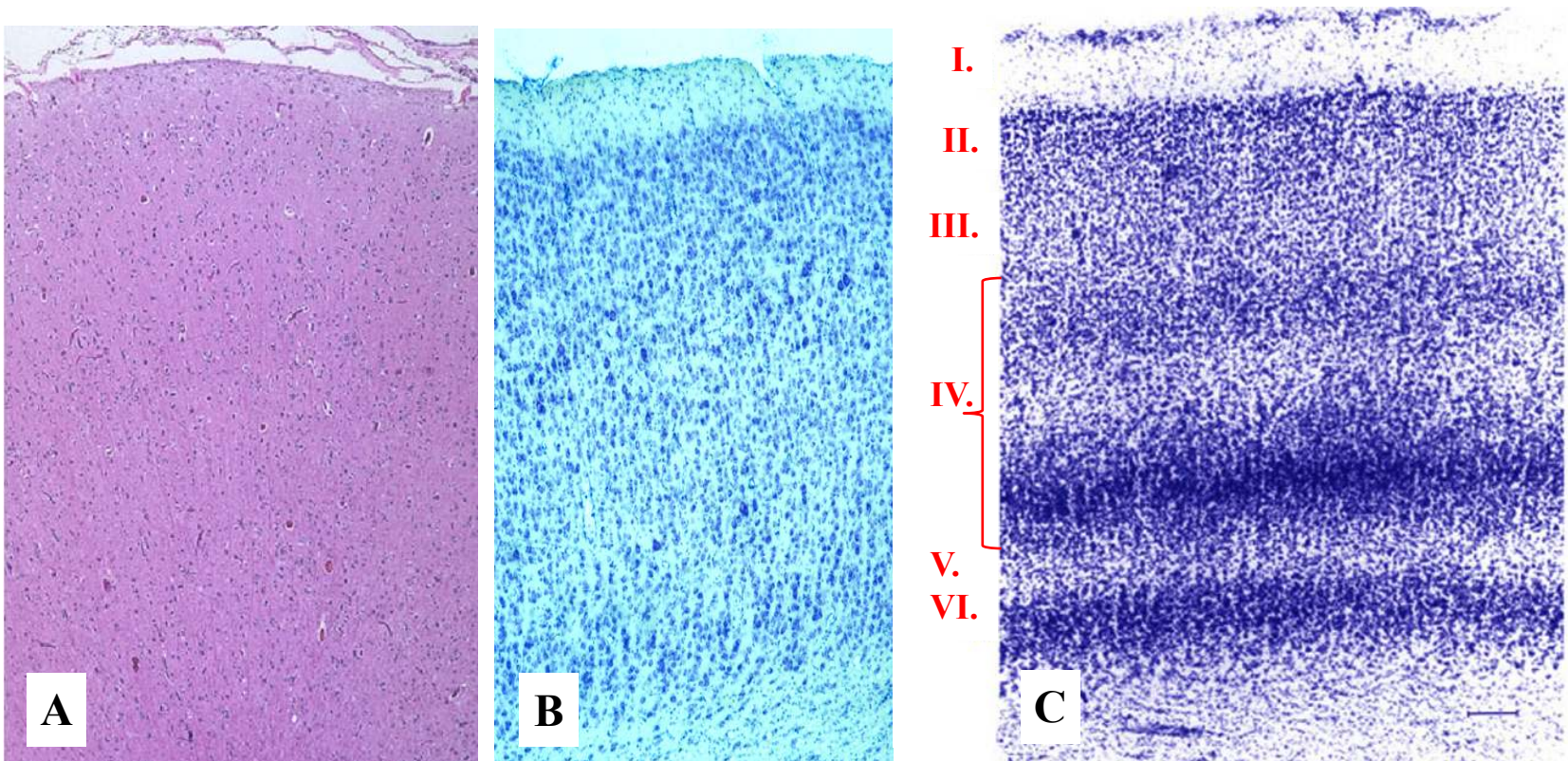
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LAYERS OF THE CEREBRAL CORTEX



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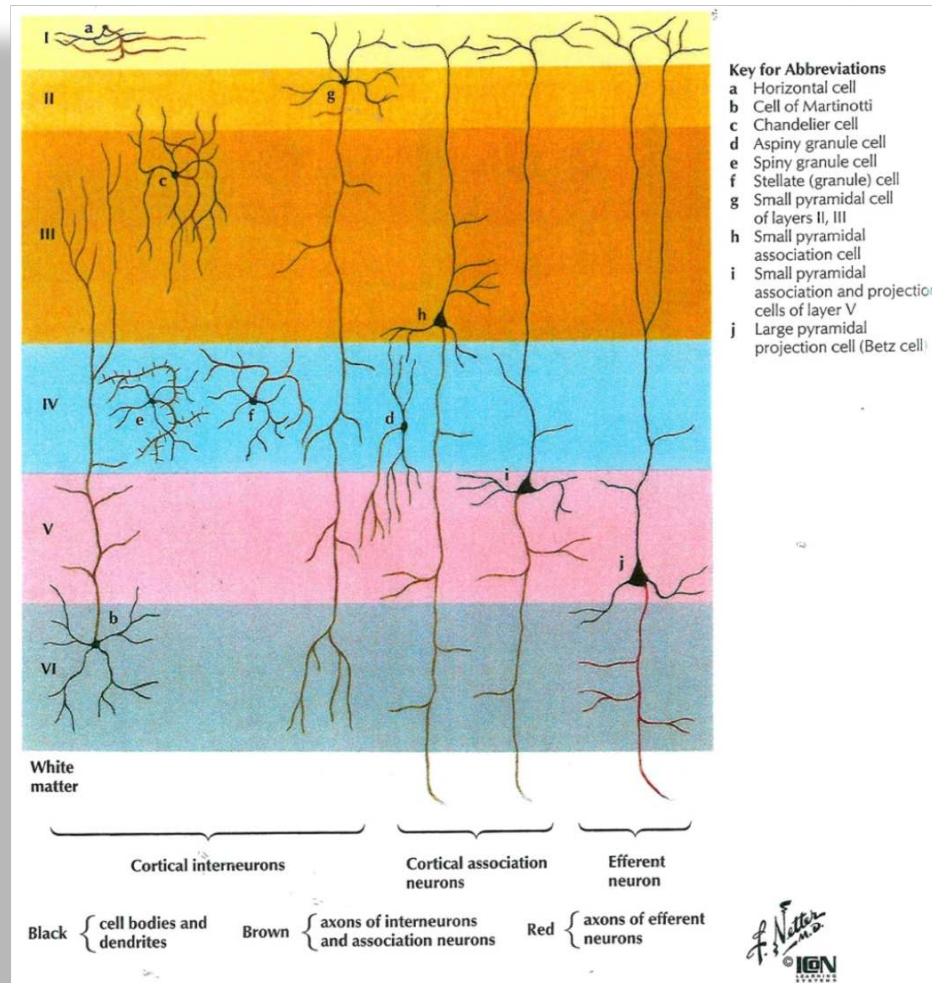
HISTOLOGY OF CEREBRAL CORTEX



CORTICAL SECTIONS STAINED BY CONVENTIONAL HEMATOXYLIN-EOSIN (A) AND TOLUIDINE BLUE (B). NOTE, THE THICK LAYER IV IN THE VISUAL CORTEX (C)

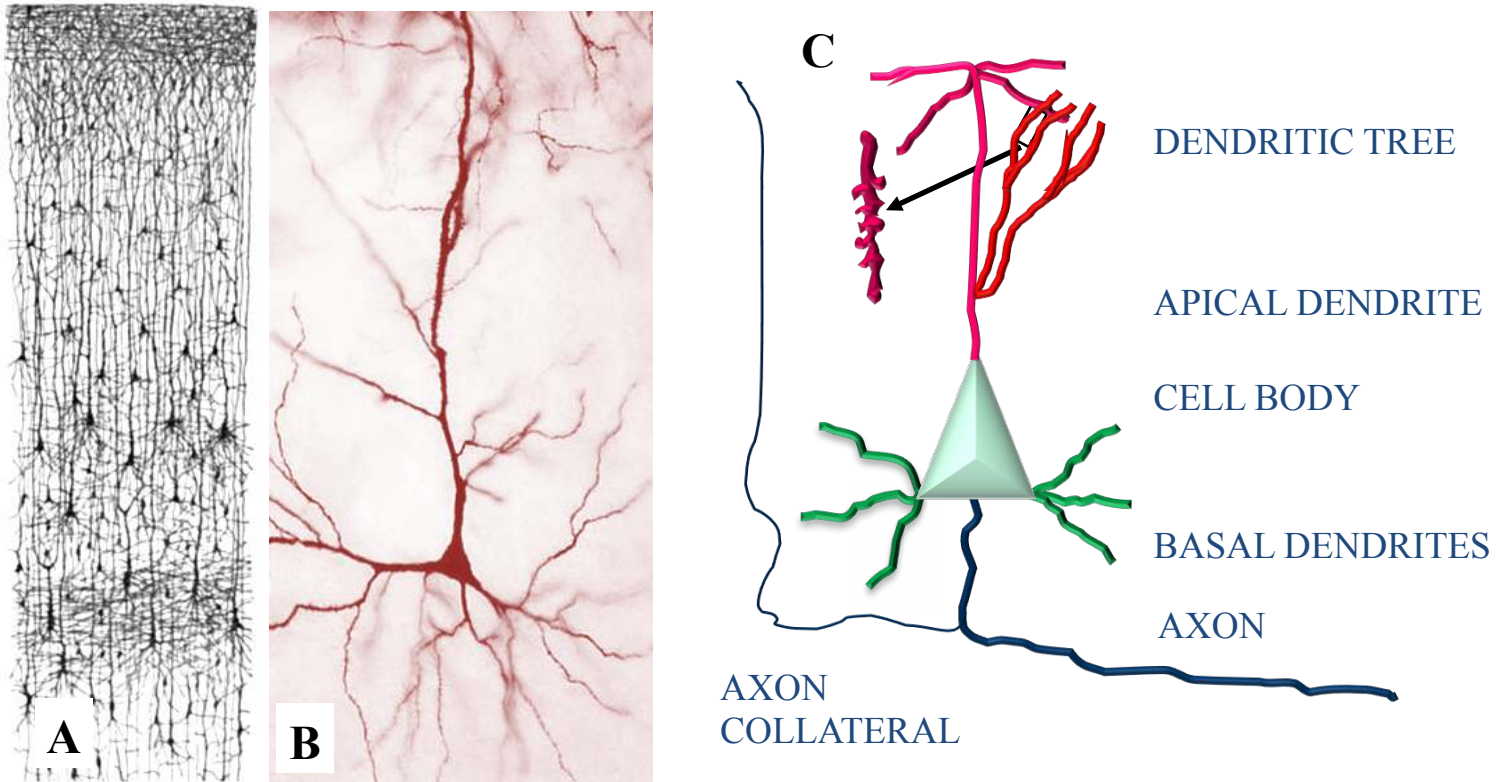
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CELL TYPES OF THE CEREBRAL CORTEX



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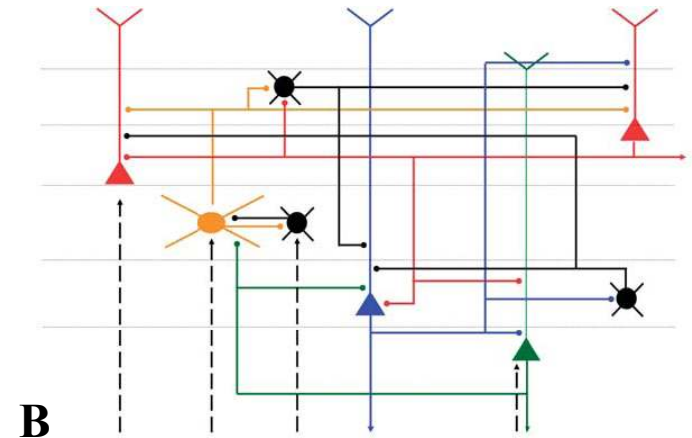
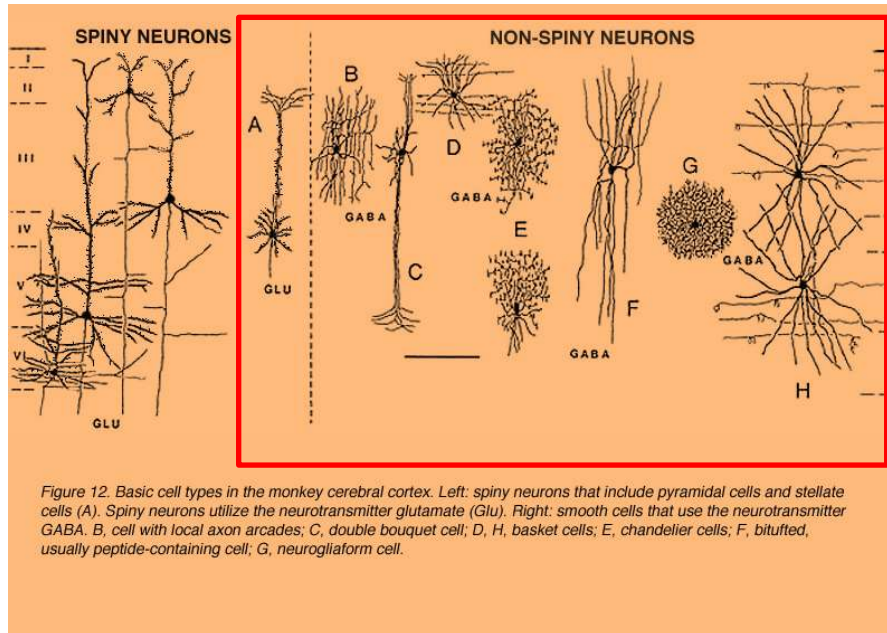
THE PYRAMIDAL NEURON



AS IT IS SHOWN IN PICTURE **A** DRAWN BY RAMON Y CAJAL, THE CEREBRAL CORTEX IS RICH IN PYRAMIDAL NEURONS OF DIFFERENT SIZES. FIGURE **B** DEPICTS A GOLGI-IMPREGNATED PYRAMIDAL NEURON. NOTE, THE RAMIFICATION OF THE BASAL AND APICAL DENDRITES. FIGURE **C** ILLUSTRATES THE MAIN STRUCTURAL DOMAINS OF THE SPINY, PYRAMIDAL NEURON

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FEATURES OF INTERNEURONS



THERE ARE SEVERAL KINDS OF INHIBITORY INTERNEURONS CLASSIFIED BASED ON THEIR STRUCTURAL, ELECTROPHYSIOLOGICAL AND CHEMICAL PROPERTIES. THE RICH PHENOTYPE OF THEM IS DEPICTED IN FIG A. THE MOST KNOWN REPRESENTATIVES OF INTERNEURONS ARE THE BASKET, CHANDELIER, STELLATE, RETZIUS-CAJAL AND MARTINOTTI CELLS. FOR A DEEPER INSIGHT SEE *NATURE REVIEWS NEUROSCIENCE*, VOLUME 9, 2008, 565. INTERNEURONS ESTABLISH SOPHISTICATED CIRCUITS WITH PRINCIPAL NEURONS (B) AND RELAY THE INFORMATION BROUGHT IN BY SPECIFIC AND NON-SPECIFIC AFFERENTS TO PYRAMIDAL CELLS

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PROPERTIES OF CORTICAL INTERNEURONS

Summary of the the Petilla Interneuron Nomenclature Group

Morphological features

- Soma: shape; size; orientation; other
- Dendrite: arborization polarity; branch metrics; fine structure; postsynaptic element; other
- Axon: initial segment; arbor trajectory; terminal shape; branch metrics; boutons; synaptic targets; other
- Connections: chemical and electrical; source; location and distribution; other

Molecular features

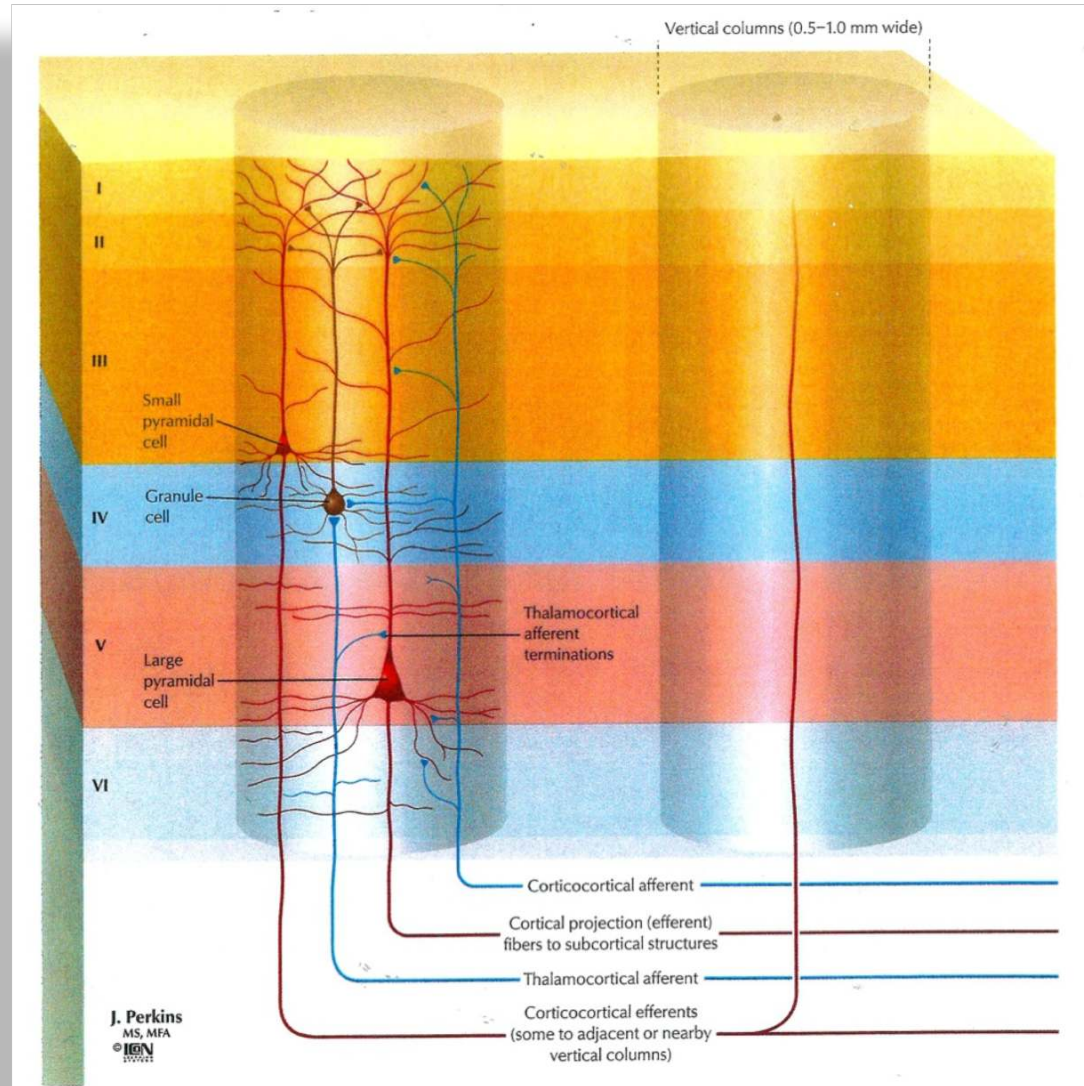
- Transcription factors
- Neurotransmitters or their synthesizing enzymes
- Neuropeptides
- Calcium-binding proteins
- Receptors: ionotropic; metabotropic
- Structural proteins
- Cell-surface markers
- Ion-channels
- Connexins
- Transporters: plasma membrane; vesicular
- Others

Physiological features

- Passive or subthreshold parameters: resting membrane potential; membrane time constants; input resistance; oscillation and resonance; rheobase and chronaxie; rectification
- Action potential (AP) measurements: amplitude; threshold; half-width; afterhyperpolarization; afterdepolarization; changes in AP waveform during train.
- Dendritic back-propagation
- Depolarizing plateaus
- Firing pattern: oscillatory and resonant behaviour; onset response to depolarizing step; steadystate response to depolarizing step
- Response to hyperpolarizing step: rectification; rebound
- Spiking recorded extracellularly: phase relationship to oscillations; functional response specificity; cross-correlation and other dynamics
- Postsynaptic responses: spontaneous and evoked; ratio of receptor subtypes; spatial and temporal summation; short- and long-term plasticity; gap junctions

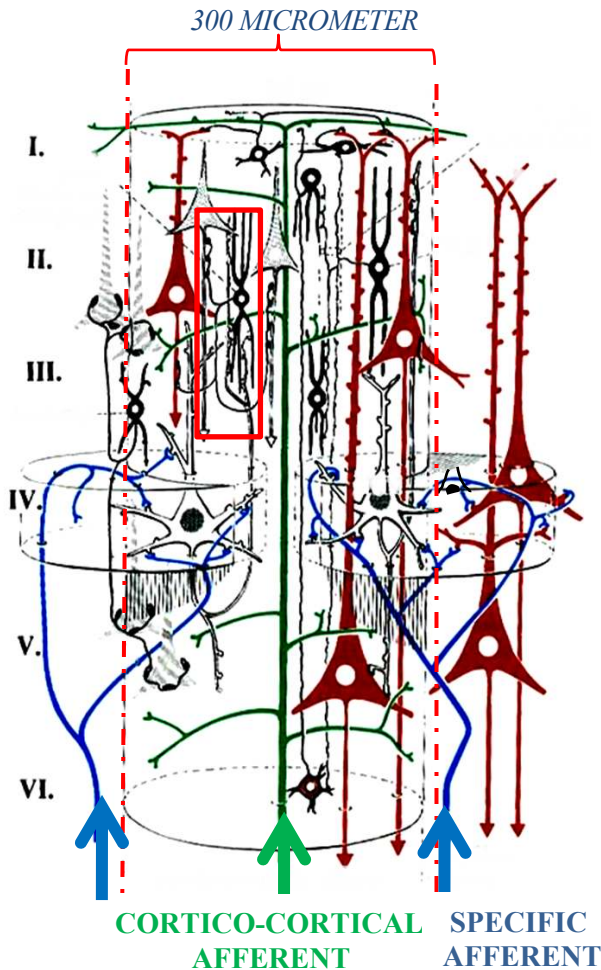
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CORTICAL COLUMNS



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NEURONAL ASSEMBLY OF A CORTICAL MODULE



THE CORTICAL COLUMN IS ABOUT 300 MICROMETER WIDE AND HAS THE HEIGHT OF THE CORTEX (2.5-3 mm). EACH HOSTS ABOUT FIVE THOUSAND NEURONS. THERE ARE APPROXIMATELY 2×10^6 CORTICAL MODULES IN HUMANS. THE SYSTEM SPECIFIC AFFERENTS AND THE CORTICO-CORTICAL AFFERENTS FEED THE CORTICAL COLUMNS. THE FORMER FIBERS TERMINATE IN THE MIDDLE AREA, THE LATTER ONES IN THE SUPERFICIAL ZONE OF THE COLUMN. A FEW KINDS OF INTERNEURONS ARE SHOWN IN SOLID BLACK IN THE ORIGINAL FIGURE OF J. SZENTÁGOTHAÏ. A CHANDELIER CELL IS ENFRAMED. THEIR AXONS FORM AXO-AXONIC CONNECTIONS WITH PYRAMIDAL NEURONS. AT THE TOP AND THE BASE OF THE COLUMN THE EXCITATION SPREADS Laterally, WHILE IN THE MIDDLE PART THE LATERAL INFORMATION FLOW IS LIMITED. THE OUTFLOW FROM THE COLUMN IS EXECUTED BY AXONS OF PYRAMID CELLS. LAYER III CELLS PROJECT TO CORTICAL REGIONS AS ASSOCIATIVE AND COMMISSURAL FIBERS, WHILE THE LARGE BETZ PYRAMIDAL NEURONS OF LAYER V ESTABLISH THE DESCENDING CONNECTIONS

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COMMUNICATION AMONG CORTICAL MODULES

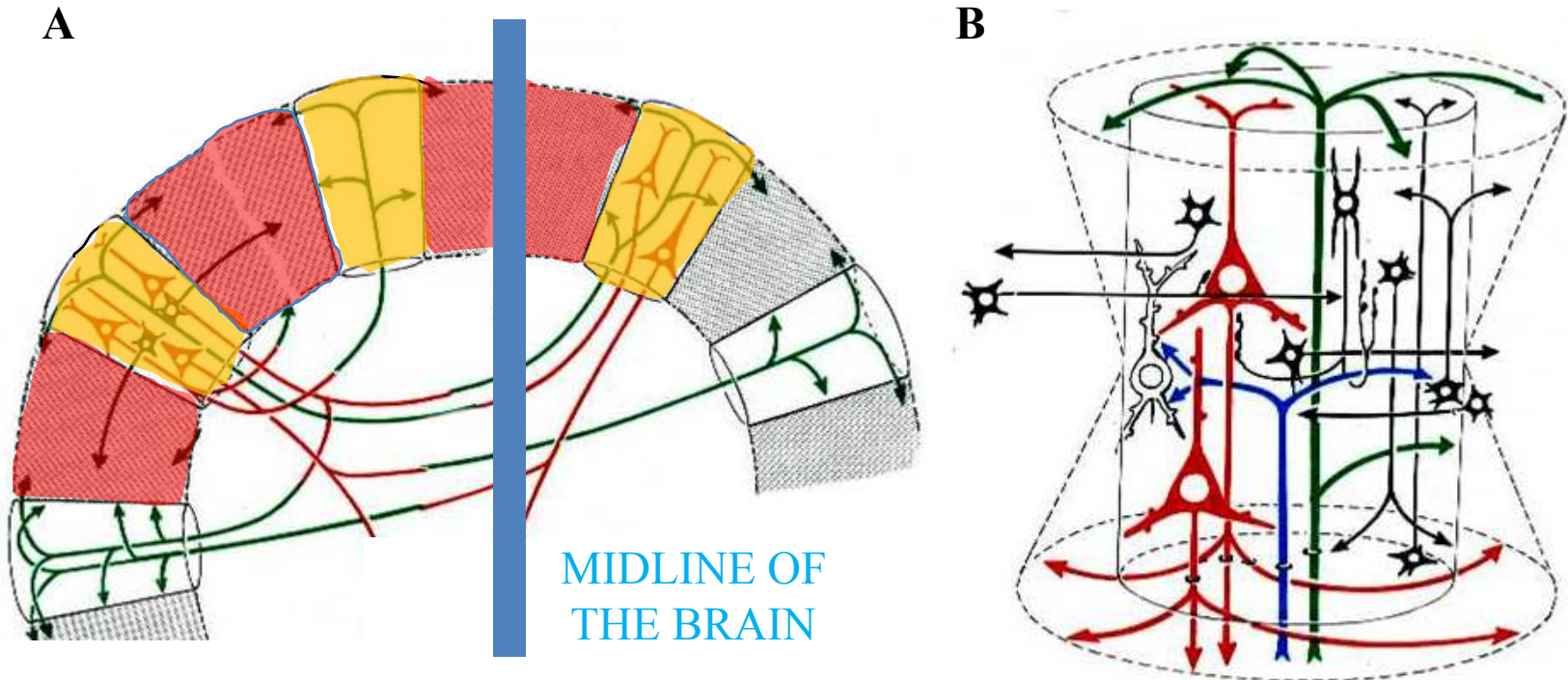
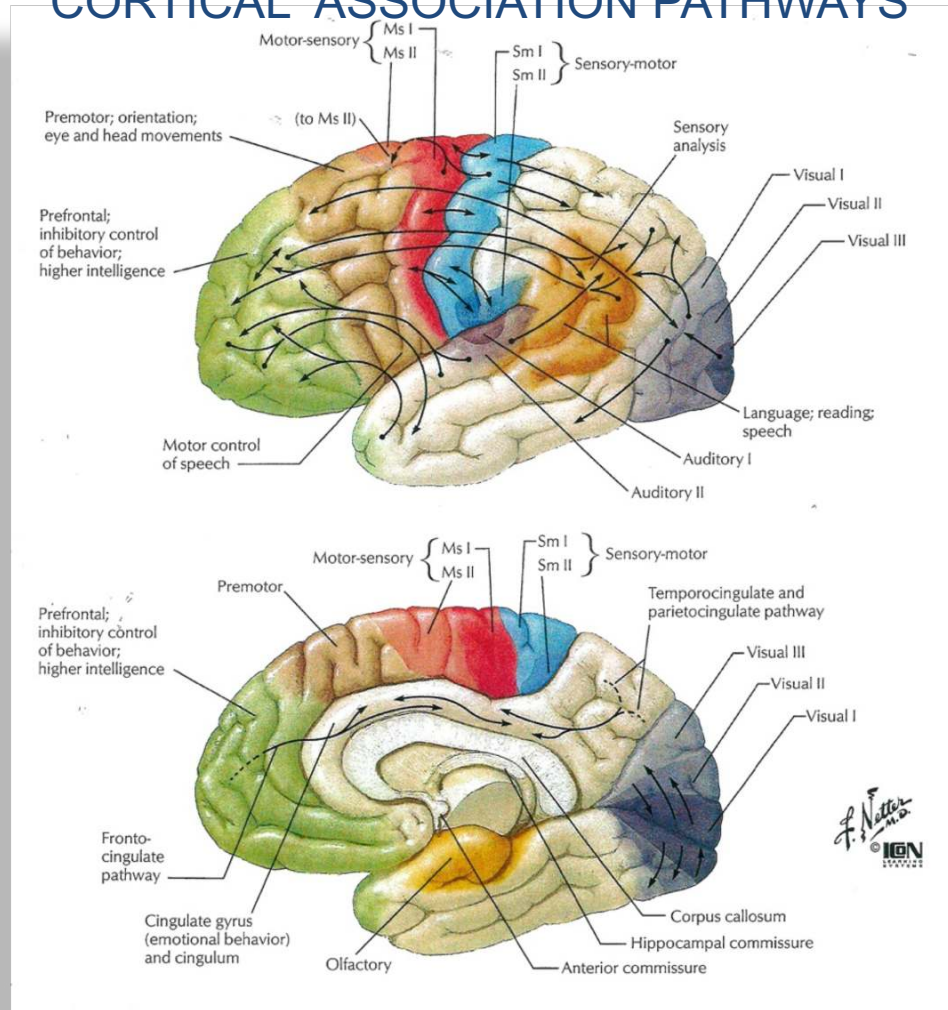


FIGURE A SHOWS THE IPSI- AND CONTRALATERAL CONNECTIONS OF MODULES ESTABLISHING CORTICO-CORTICAL NETWORKS. INHIBITORY NEURONS OF ACTIVE CORTICAL COLUMNS (HIGHLIGHTED IN YELLOW) ARE SURROUNDED BY INACTIVE ONES (RED HIGHLIGHT). THE COLLATERAL INHIBITION IS DUE TO BASKET CELLS. FIGURE B DEPICTS THE PROPOSED FUNCTIONAL SHAPE (DASHED LINE) OF THE MODULE

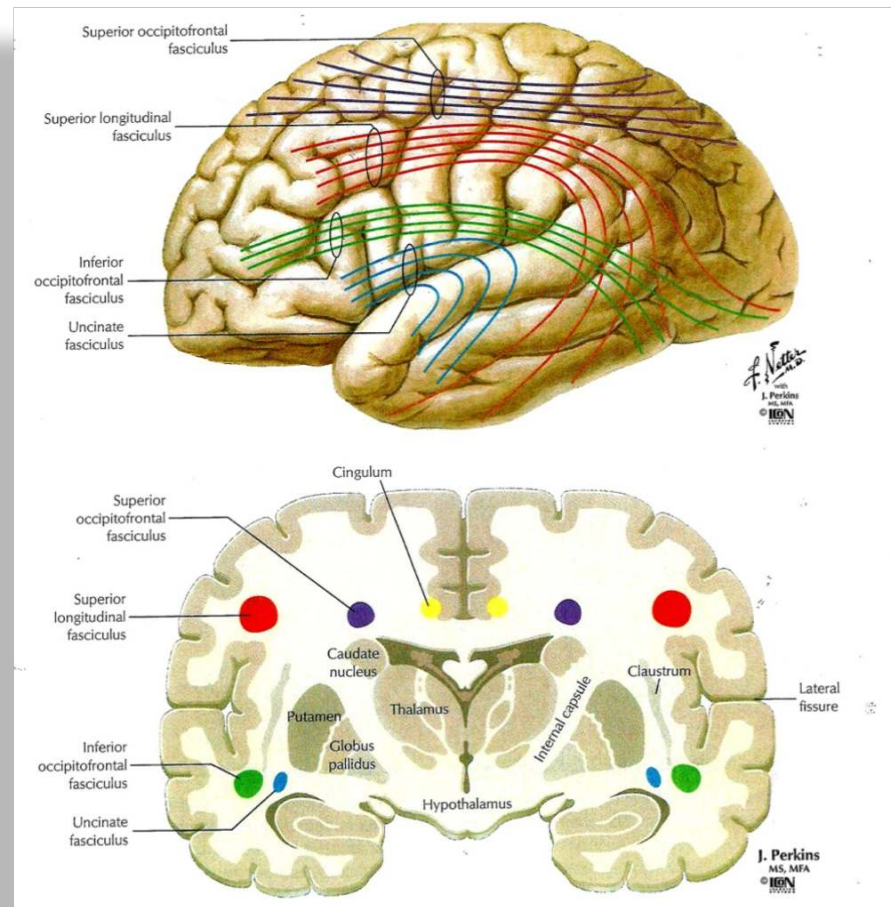
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CORTICAL ASSOCIATION PATHWAYS

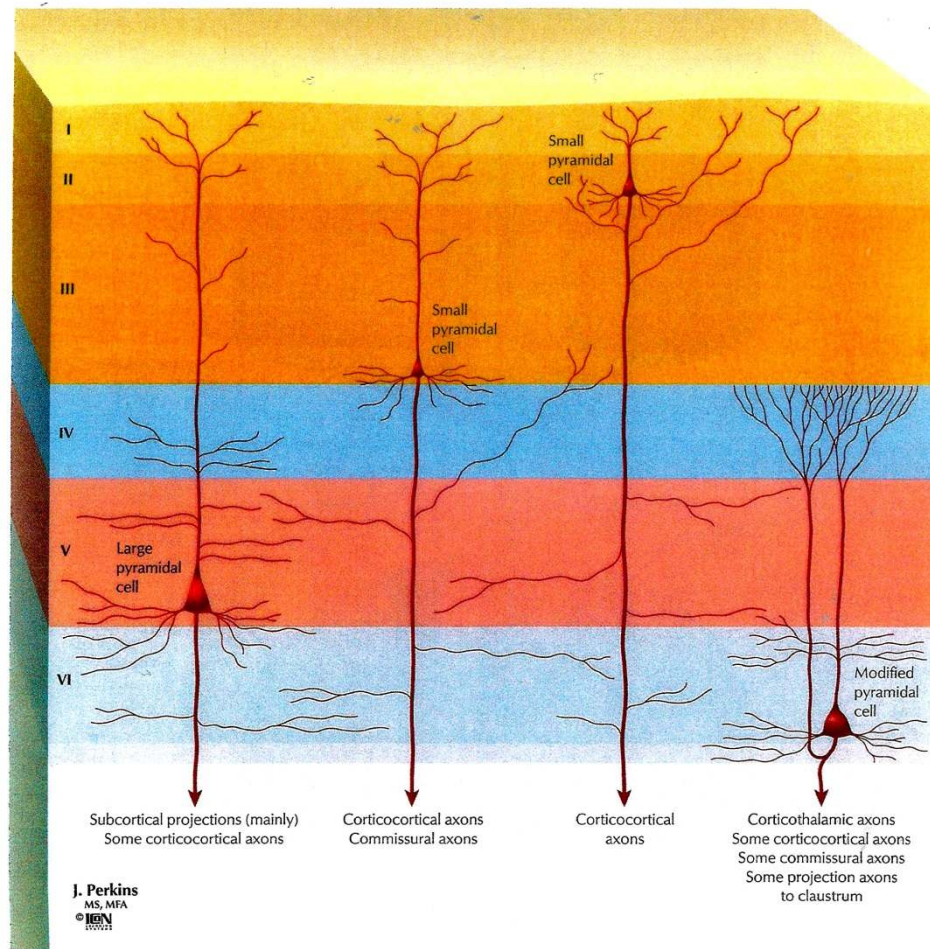


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ASSOCIATIVE PATHWAYS WITHIN THE CEREBRAL CORTEX



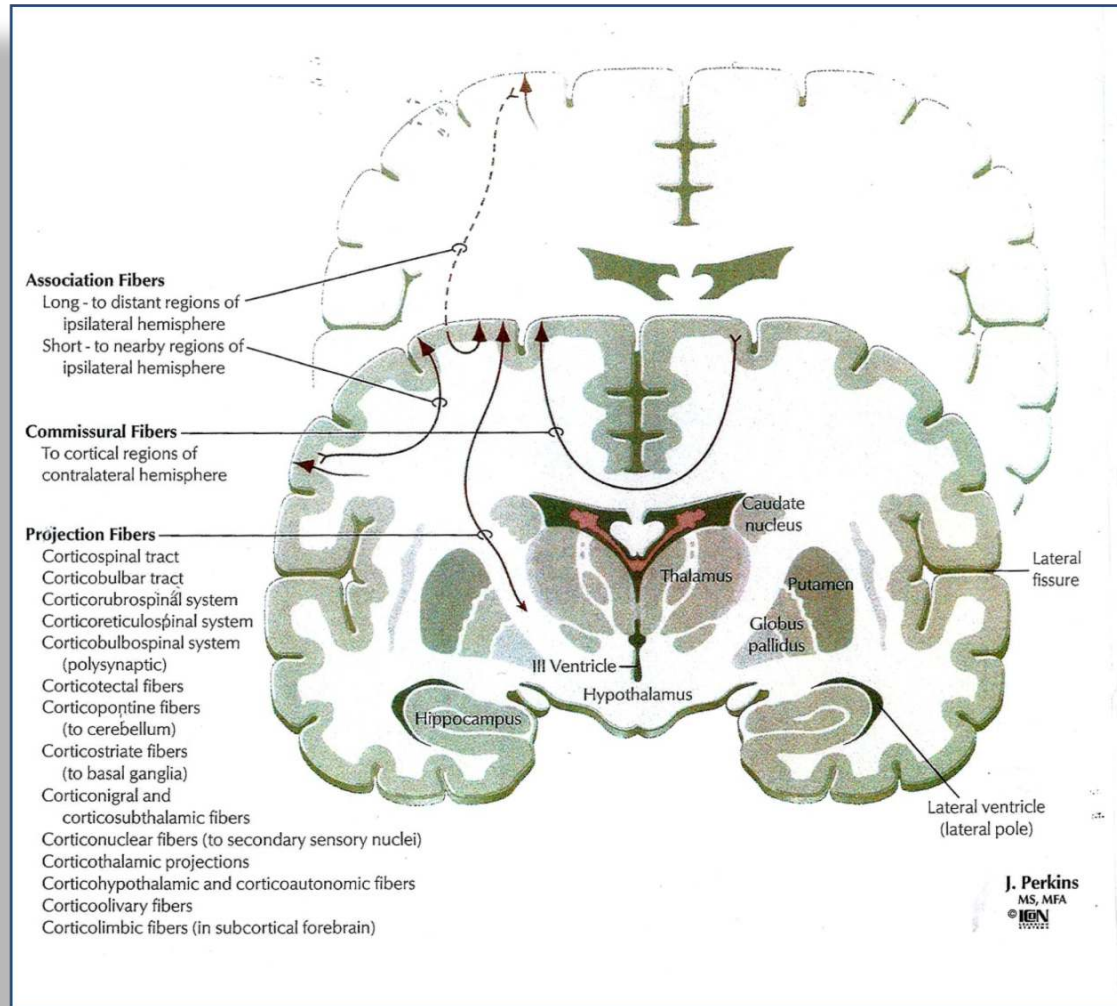
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EFFERENT NEURONS OF THE CORTEX

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EFFERENT PATHWAYS OF THE CORTEX



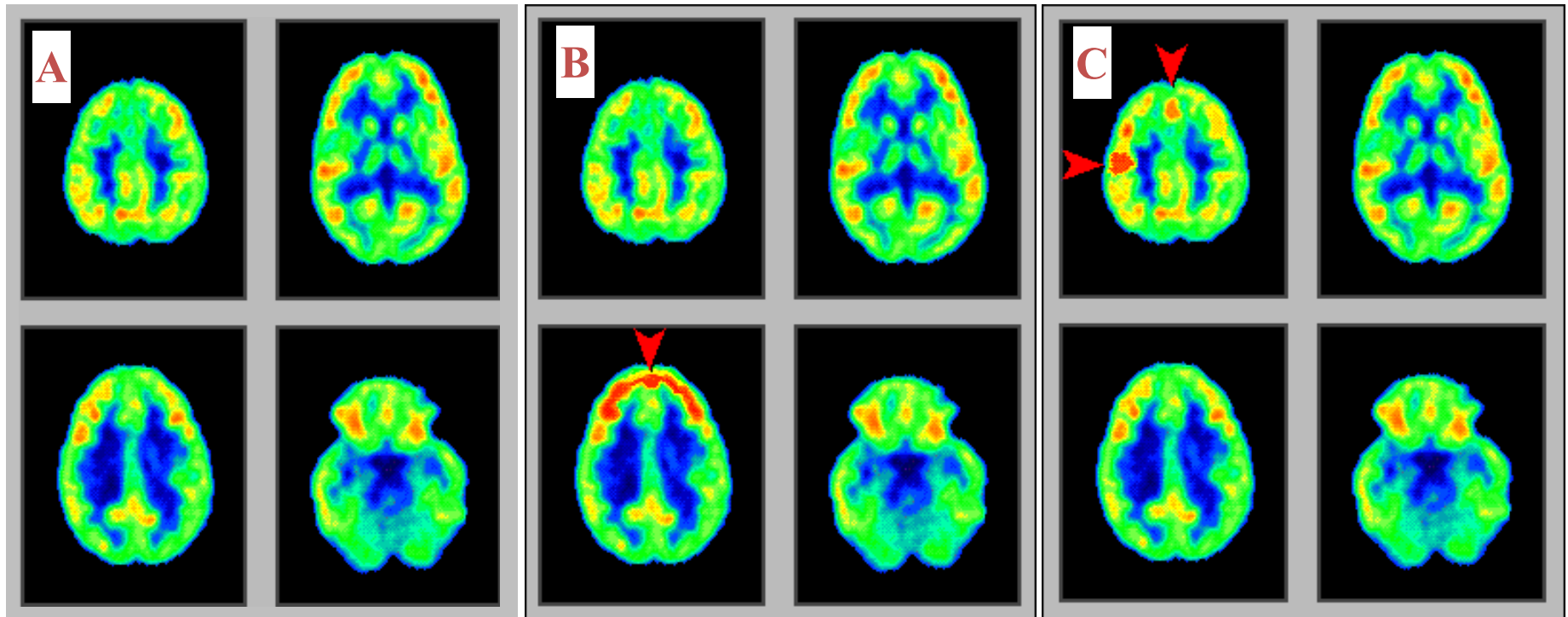
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DIFFERENT FUNCTIONAL OUTPUTS OF CORTICAL MODULES OF DIFFERENT BRAIN REGIONS

CORTICAL AREA	FUNCTION
PREFRONTAL CORTEX	PROBLEM SOLVING, EMOTION, COMPLEX THOUGHT
MOTOR ASSOCIATION CORTEX	COORDINATION OF COMPLEX MOVEMENT
PRIMARY MOTOR CORTEX	INITIATION OF VOLUNTARY MOVEMENT
PRIMARY SOMATOSENSORY CORTEX	RECEIVES TACTILE INFORMATION FROM THE BODY
SENSORY ASSOCIATION AREA	PROCESSING OF MULTISENSORY INFORMATION
VISUAL ASSOCIATION AREA	COMPLEX PROCESSING OF VISUAL INFORMATION
VISUAL CORTEX	DETECTION OF SIMPLE VISUAL STIMULI
WERNICKE'S AREA	LANGUAGE COMPREHENSION
AUDITORY ASSOCIATION AREA	COMPLEX PROCESSING OF AUDITORY INFORMATION
AUDITORY CORTEX	DETECTION OF SOUND QUALITY (LOUDNESS, TONE)
MOTOR SPEECH CENTER (BROCA'S AREA)	SPEECH PRODUCTION AND ARTICULATION

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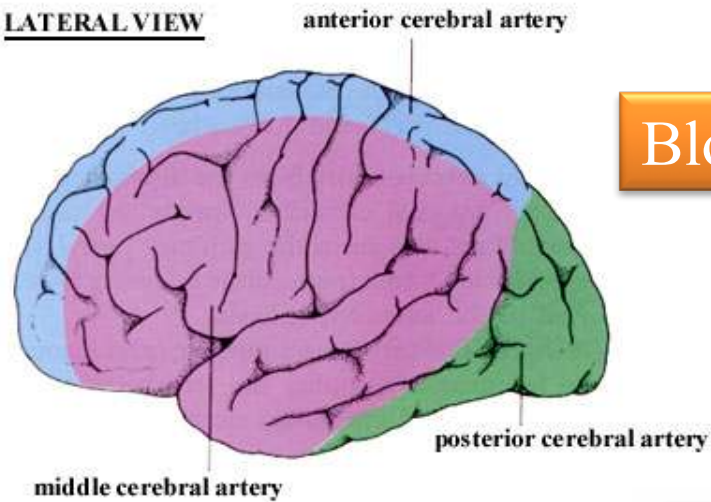
LOCALIZATION OF CORTICAL FUNCTIONS



NON-INVASIVE, RADIOLOGICAL IMAGING TECHNIQUES (PET, FMRI) ALLOW THE LOCALIZATION OF SPECIFIC BRAIN FUNCTIONS IN WELL-DEFINED REGIONS. THE SCANS SHOW BRAIN ACTIVITIES UNDER NORMAL (A), THINKING (B) AND SOMATIC MOTOR (C) CONDITIONS

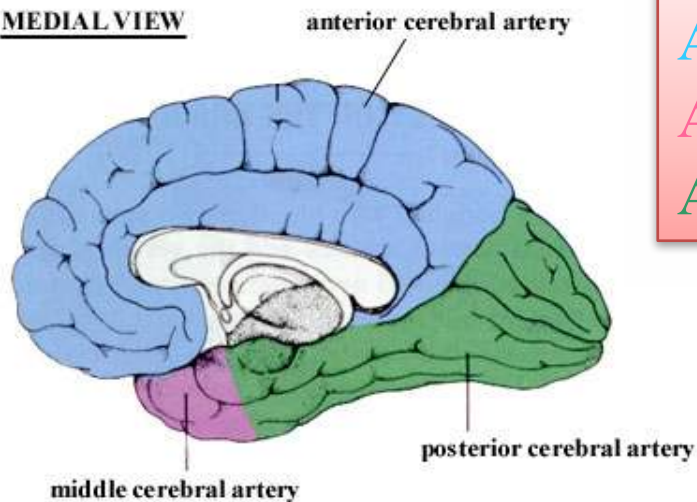
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LATERAL VIEW



Blood supply of the cerebral cortex

MEDIAL VIEW



ARTERIA CEREBRI ANTERIOR
ARTERIA CEREBRI MEDIA
ARTERIA CEREBRI POSTERIOR