Systems Neuroscience
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Pyramidal neuron by Santiago Ramón y Cajal (1852-1934, Nobel prize with Camillo Golgi in 1906)
Reconstruction of living human brain cell, Stanford 2017
Terminology

Axon
Boutons
Cleft
Dendritic spines
Postsynaptic membrane,
Vesicles
Transmitter,
Receptors
Vesicles

From: Purves, Neuroscience, 4th edition
Post-synaptic receptor

From: Purves, Neuroscience, 4th edition
From: Purves, Neuroscience, 4th edition

Dendrites

Excitatory (E1)
Inhibitory (I)
Excitatory (E2)

Cell body
Dendrites
Axon

Record
Postsynaptic membrane potential
Sequence of events

1. Neurotransmitter release
2. Receptor binding
3. Ion channels open or close
4. Conductance change causes current flow
5. Postsynaptic potential changes
6. Postsynaptic cells excited or inhibited
7. Summation determines whether or not an action potential occurs

From: Purves, Neuroscience, 4th edition
Neuronal Networks
Neuronal Networks
Terminology

Central nervous system (CNS) vs Peripheral nervous system
The human brain
The human brain

Human

Elephant

Dolphin

Gorilla

Dog

Macaque

Cat

Mouse

5cm
The human brain
Gross Anatomy: Protection and Sustenance of the Brain

The Skull

- Structure
- Function

[Diagram of the skull with anatomical labels]

face-and-emotion.com/.../physiognomy/cranium.jsp
The Meninges

- Structure
- Function

Gross Anatomy:
Protection and Sustenance of the Brain

From: Purves, Neuroscience, 4th edition
Ventricular system

Central part of left lateral ventricle
Frontal horn of lateral ventricle
Choroid plexus
Interventricular foramen of Monro
Third ventricle
Temporal horn of lateral ventricle
Central canal
Interventricular foramen of Monro
Postcentral gyrus
Frontal horn of lateral ventricle
Third ventricle
Temporal horn of lateral ventricle
Central sulcus
Right lateral ventricle
Left lateral ventricle
Occipital horn of lateral ventricle
Cerebral aqueduct
Fourth ventricle
Central canal
Choroid plexus
Right cerebral hemisphere
Occipital horn of lateral ventricle
Fourth ventricle
Cerebral aqueduct
Left cerebral hemisphere
Central sulcus

From: Purves, Neuroscience, 4th edition
Navigating the Central Nervous System
Navigating the Central Nervous System
Navigating the Central Nervous System

(A)

Superior (above)

Longitudinal axis of the forebrain

Rostral

Anterior (in front of)

Dorsal

Posterior (behind)

Ventral

Inferior (below)

Caudal

Longitudinal axis of the brainstem and spinal cord

From: Purves, Neuroscience, 4th edition
Navigating the Central Nervous System

From: Purves, Neuroscience, 4th edition
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

(A) 18 days

- Ectoderm
- Neural plate
- Mesoderm
- Endoderm
- Notochord
- Primitive streak

(B) 20 days

- Neural plate/tube
- Neural crest
- Pre-somitic mesoderm
- Neural groove
- Floorplate
- Notochord

(C) 22 days

- Neural crest
- Anterior neural fold
- Neural tube
- Neural groove
- Floorplate
- Notochord
- Somite

(D) 24 days

- Sensory ganglion
- Anterior neural fold
- Somites
- Spinal cord
- Rhombencephalon
- Floorplate
- Spinal cord
- Notochord

From: Purves, Neuroscience, 4th edition
Major divisions of the brain

From: Purves, Neuroscience, 4th edition
# Cranial nerves

**TABLE A2** The Cranial Nerves and Their Primary Functions *(Part 1)*

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

*From: Purves, Neuroscience, 4th edition*
Major divisions of the brain

(b) Organization of the adult human brain

- Central nervous system (CNS)
  - Forebrain
    - Telencephalon (cerebral hemispheres)
    - Diencephalon
      - Mesencephalon—Midbrain
      - Metencephalon
        - Cerebellum
        - Pons
      - Myelencephalon—Medulla
  - Hindbrain
  - Spinal cord

(c) Adult brain

Peripheral nervous system
- Somatic (skeletal) nerves
- Autonomic ganglia and nerves
- Sympathetic division
- Parasympathetic division
The Limbic System

Location of Major Limbic System Structures:
- Cingulate gyrus
- Septum
- Fornix
- Olfactory bulb
- Hypothalamus
- Amygdala
- Mammillary body
- Hippocampus
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

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**

**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

(A) Frontal lobe  Central sulcus
  Lateral (Sylvian) fissure  Occipital lobe
  Temporal lobe

(B) Frontal lobe
  Parietal lobe
  Parieto-occipital sulcus
  Occipital lobe
  Temporal lobe

From: Purves, Neuroscience, 4th edition
Cytoarchitecture

(a) Six layers of cortex

(b) A single pyramidal neuron

- Apical dendrite
- Cell body
- Basal dendrites
- Axon

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Franz Joseph Gall (1758-1828)
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.”
Brodmann’s areas

From: Korbinian Brodmann 1909
Brodmann’s areas
Circuits

Superficial layers

Layer IV

Infragranular layers

Lower area

Feedback

Higher area

Feedforward
“Comprehensive” visual circuit

From: Felleman & Van Essen, 1991