Nervous System
Kristine Krafts, M.D.
Nervous System Lecture Objectives

• Describe the anatomical and functional organization of the nervous system.
• Describe the histologic features of neurons, their processes, and synapses.
• Describe the histologic features and functions of glial cells.
More Nervous System Lecture Objectives

• Describe myelin and its production in the central and peripheral nervous systems.

• Describe the histologic structure and distribution of the meninges.

• Describe the blood-brain barrier.

• Describe the histologic features of nerve fibers in the peripheral nervous system.
Nervous System Lecture Outline

• Organization of the nervous system
• Cells of the nervous system
• Central nervous system
• Peripheral nervous system
Nervous System Lecture Outline

• Organization of the nervous system
Organization of Nervous System

• Central nervous system (CNS) = brain + spinal cord

• Peripheral nervous system (PNS) = peripheral nerves + nerve ganglia (groups of nerve cell bodies outside the CNS)

• Peripheral nervous system has motor and sensory components.
Central nervous system (CNS)
- Cerebrum
- Cerebellum
- Spinal cord

Peripheral nervous system (PNS)
- Cranial nerves
- Spinal nerves
- Ganglia
Nervous System Lecture Outline

• Organization of the nervous system

• Cells of the nervous system
  • Neurons
  • Glial cells
Two Main Cell Types in Nerve Tissue

- Neurons (nerve cells)
- Glial cells
  - Astrocytes
  - Oligodendrocytes
  - Ependymal cells
  - Microglia
  - Schwann cells
Nervous System Lecture Outline

• Organization of the nervous system

• Cells of the nervous system
  • Neurons
Neurons
- **Cell body** maintains the cell; can receive synaptic input
- Tons of **Nissl substance** (rough ER)
- Multiple **dendrites** (receive impulses)
- One **axon** (sends out impulses) – originates at “axon hillock”
- Cytoskeleton contains neurofilaments (for structure) and microtubules (for transport along axons)
Neuron cell body

Large pale nucleus

Nucleolus

Nissl substance
Gorgeous, sexy neuron and neuropil
Gorgeous, sexy J. Crew shimmer net skirt
Lipofuscin

Lipofuscin pigment represents lysosomes with undigested debris.

From the Latin *fuscus* (brown, muddy). As in obfuscate (to make something unclear).
Axons and Dendrites

- Dendrites are multiple and branching. May have “spines” (involved in neuroplasticity).
- Axons are single and branch terminally into “telodendria.”
- Can tell axons from dendrites by looking for the axon hillock, which lacks Nissl substance.
The amount and type of dendritic branching can determine the type of neuron!
The axon hillock (and the axon itself) lacks Nissl substance.
Dendritic spines
Neuron Synapses

Presynaptic axon terminal (terminal bouton)
Contains synaptic vesicles and mitochondria.

Synaptic cleft
Space between pre and postsynaptic structures.

Postsynaptic structure
Dendrite, cell body, axon terminal, or effector cell. Membrane contains ion channels and receptors for neurotransmitters.
Axon of **presynaptic neuron**

- Calcium ($Ca^{2+}$) ions
- Voltage-regulated calcium ($Ca^{2+}$) channel
- Synaptic vesicles containing acetylcholine (ACh)

**Synaptic cleft**

- Acetylcholine binds to receptor protein, causing ion gates to open
- Sodium ($Na^+$) ions

**Postsynaptic neuron**

- Postsynaptic membrane
- Receptor protein

- Mitochondria
- Microtubules of cytoskeleton
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Glial Cells

• 10x more abundant than neurons in brain
• Support and protect neurons
• Five types, each with different functions:
  • Astrocyte
  • Oligodendrocyte
  • Schwann cell
  • Ependymal cell
  • Microglial cell
## Location and Function of Glial Cells

<table>
<thead>
<tr>
<th>Glial cell type</th>
<th>Location</th>
<th>Main functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Astrocyte</td>
<td>CNS</td>
<td>Provides structural support, helps repair cells, participates in blood-brain barrier, provides nutrition</td>
</tr>
<tr>
<td>Oligodendrocyte</td>
<td>CNS</td>
<td>Makes myelin, insulates axons</td>
</tr>
<tr>
<td>Schwann cell</td>
<td>PNS</td>
<td>Makes myelin, insulates axons</td>
</tr>
<tr>
<td>Ependymal cell</td>
<td>CNS</td>
<td>Lines cavities of CNS</td>
</tr>
<tr>
<td>Microglial cell</td>
<td>CNS</td>
<td>Eats up debris and dead cells</td>
</tr>
</tbody>
</table>
Neuropil is a dense network of astrocyte processes, axons, and dendrites in gray matter.
Neuropil and an astrocyte
Astrocytes

• Most numerous of all the glial cells
• Contain bundles of intermediate filaments called glial fibrillary acid protein (GFAP)
• Bind to capillaries and neurons using little “end feet.” Important in blood-brain barrier.
• Provide structural and metabolic support for neurons.
• Proliferate after injury to form a “scar.”
Astrocyte foot processes bind to capillaries and neurons.
Oligodendrocytes produce myelin in the CNS.
Oligodendrocytes are smaller and darker than astrocytes.
Schwann Cells

Schwann cells produce myelin in the PNS.
Ependymal cells

- Line central canal of spinal cord and ventricles of brain.
- Cuboidal to low columnar, with cilia and microvilli.
- In roof of ventricles, become connected with capillary loops, forming the choroid plexus.
- Ependymal cells of the choroid plexus produce CSF by transporting and secreting materials derived from adjacent capillaries.
Ependymal cells
Microglial cells
Microglia

- Small cells with short irregular processes.
- Migrate throughout neuropil, secrete cytokines, and act as immune defender cells.
- Originate from monocytes and have similar phagocytic functions.
Nervous System Lecture Outline

• Organization of the nervous system
• Cells of the nervous system
  • Central nervous system
    • Spinal cord
    • Cerebrum
    • Cerebellum
    • Meninges
Gross anatomy of brain
Gross anatomy of brain
Gray Matter and White Matter

- **Gray matter** contains neuron cell bodies, dendrites, unmyelinated axons, glial cells and synapses
- **White matter** contains myelinated axons and oligodendrocytes
- Brain: gray matter outside (and way deep inside), white matter inside
- Spinal cord: white matter outside, gray matter inside
• Cerebral cortex has 6 poorly-defined layers.
• Pyramidal neurons are the most abundant neurons in the cerebral cortex.
• This is a section from gray matter which is on the outside.

• Note long dendrites of pyramidal neurons extending toward surface of cortex.

• This is a silver stain which really highlights neural cells.
Cerebellum

Three layers of gray matter:

1. **Molecular layer.**
   Outermost layer. Contains granular cell axons, Purkinje dendrites, and glial cells.

2. **Purkinje cell layer.**
   Middle layer. Contains large, prominent “Purkinje” neurons.

3. **Granular layer.**
   Innermost layer. Contains very small neurons.

White matter is on the inside.
Cerebellum: gray matter layers
Meninges

Three layers; surround brain and spinal cord.

Dura mater ("tough mother")
Outermost layer. Dense connective tissue.

Arachnoid ("spider-like")
Middle layer. Two parts: one is in contact with dura mater. Other contains trabeculae (like spider legs) which connect arachnoid with pia.

Pia mater ("tender mother")
Innermost layer. Loose connective tissue lining surface of brain.
Blood-Brain Barrier

- Prevents passage of some drugs and toxins from blood into CNS tissue
- Exists because capillaries in brain are less permeable than capillaries elsewhere.
  - Brain capillaries have tight (occluding) junctions between endothelial cells.
  - Astrocyte foot processes surround capillaries and form part of barrier.
Blood-Brain Barrier

1. Astrocyte foot processes
2. Endothelial cell tight junctions
Spinal Cord Cross Section

Gray matter inside

White matter outside

P

A
Spinal Cord

White matter: myelinated axons and oligodendrocytes.

Gray matter: neurons and glial cells.
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Main Components of the Peripheral Nervous System

• **Nerves.** Bundle of nerve fibers (axons) surrounded by glial cells (Schwann cells) and connective tissue.

• **Ganglia.** Collections of neuron cell bodies.

• **Specialized nerve endings.** Structures that perform special tasks, like responding to vibration.
Schwann cells

- Schwann cells surround and form myelin around PNS axons.
- Small axons are have a Schwann cell but are not myelinated.
- Large axons have myelin.
Schwann Cell Myelinating an Axon
Nodes of Ranvier are breaks in myelin sheath. Action potentials jump between nodes.
Nerve Fibers are Grouped into Nerve Bundles

- **Epineurium.** Outer dense connective tissue fibrous coat surrounding nerve bundles and spaces between nerve fibers.

- **Perineurium.** Surrounds each fiber bundle or fascicle. Cells of perineurium joined by tight junctions to prevent passage of most molecules.

- **Endoneurium.** Surround each axon and its Schwann cell.
Epineurium (E) and perineurium (P) surround nerve bundles (N)
Epineurium, perineurium and endoneurium
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