Introduction to the Nervous System and Nerve Tissue

Three Basic Functions
1. Sensory Functions: Sensory receptors detect both internal and external stimuli.
   Functional unit: Sensory or Afferent Neurons
2. Integrative Functions: CNS integrates sensory input and makes decisions regarding appropriate responses
   Functional Unit: Interneurons or Association Neurons of the Brain and Spinal cord
   Functional Unit: Motor or Efferent Neurons
Organization of the Nervous System
to supply the three basic functions

1. SENSORY RECEPTOR
   (responds to a stimulus by producing a generator or receptor potential)

2. SENSORY NEURON
   (axon conducts impulses from receptor to integrating center)

3. INTEGRATING CENTER
   (one or more regions within the CNS that relay impulses from sensory to motor neurons)

4. MOTOR NEURON
   (axon conducts impulses from integrating center to effector)

5. EFFECTOR
   (muscle or gland that responds to motor nerve impulses)

Introduction to the Nervous System
and Nerve Tissue

Brain
Cranial nerves
Spinal cord
Spinal nerves
Ganglia
Peripheral nerves
Sensory receptors in skin
Entopic plexuses in small intestine

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Introduction to the Nervous System and Nerve Tissue

Organization of the CNS

**Gray Matter:** Contains neuron cell bodies

**White Matter:** Contains cell extensions organized into tracts
Organization of the CNS

Organization of a Nerve of the PNS
Introduction to the Nervous System and Nerve Tissue

Structure of a Neuron

Dendrites: Carry nerve impulses toward cell body. Receive stimuli from synapses or sensory receptors.

Cell Body: Contains nucleus and nissl bodies, a form of rough endoplasmic reticulum.

Axon: Carry nerve Impulses away from the cell bodies. Axons interact with muscle, glands, or other neurons.

Multipolar “Motor” Neuron
Multipolar “Motor” Neuron

Histology Lab Part 6: Slide 3

Multipolar “Motor” Neuron
Introduction to the Nervous System and Nerve Tissue

Types of Neurons

(a) Multipolar neuron
(b) Bipolar neuron
(c) Unipolar neuron
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Types of Interneurons

(a) Purkinje cell  
(b) Pyramidal cell

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Introduction to the Nervous System and Nerve Tissue

Types of Supportive Cells of the PNS

1. Schwann cells that form the myelin sheath

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Types of Supportive Cells of the PNS

1. Schwann cells that form the myelin sheath

Introduction to the Nervous System and Nerve Tissue

Types of Supportive Cells of the PNS

1. Satellite cells associated with sensory neuron cell bodies
Introduction to the Nervous System and Nerve Tissue

Types of Supportive Cells of the PNS

1. Satellite cells associated with sensory neuron cell bodies

Histology Lab Part 6: Slide 9

Introduction to the Nervous System and Nerve Tissue

Types of Supportive Cells of the CNS (Neuroglia)

1. Oligodendrocytes: form the myelin sheath of the CNS

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Types of Supportive Cells of the CNS (Neuroglia)

2. Astrocytes: Help form the blood-brain barrier, support the appropriate chemical environment for neurons.

3. Microglia: Phagocytes in the CNS that engulf microbes and cellular debris.
Introduction to the Nervous System and Nerve Tissue

Types of Supportive Cells of the CNS (Neuroglia)

4. Ependymal Cells: Form blood-brain barrier in the brain ventricles and central canal of spinal cord. Produce cerebrospinal fluid and assist in its circulation.

Nervous System Physiology:
Distribution of Ions between ECF and ICF
Nervous System Physiology:
Nerve Conduction Occurs because of Changes in Membrane Potential

![Diagram showing nerve conduction](image)

Key:
- Resting membrane potential
- Voltage-gated Na⁺ channel activation gates are open
- Voltage-gated K⁺ channels are in the resting state and voltage-gated K⁺ channels are closed
- Stimulus causes depolarization to threshold
- Voltage-gated Na⁺ channel activation gates are open
- Voltage-gated K⁺ channels are open; Na⁺ channels are inactivating
- Voltage-gated K⁺ channels are still open; Na⁺ channels are in the resting state
- Absolute refractory period
- Relative refractory period

Nervous System Physiology:
Types of Channel Proteins

![Diagram showing types of channel proteins](image)

- Voltage-gated K⁺ channel closed
- Voltage-gated K⁺ channel open
- Acetylcholine
- Cation channel closed
- Cation channel open
- Change in membrane potential
- Chemical stimulus
- Extracellular fluid

(a) Voltage-gated ion channel
(b) Ligand-gated ion channel
Nervous System Physiology:
Mechanism that creates an Action Potential

1. Resting state:
Voltage-gated Na⁺ channels are in a closed state and voltage-gated K⁺ channels are closed.

4. Repolarization continues:
Voltage-gated Na⁺ channels are in a closed state and voltage-gated K⁺ channels are closed.

3. Depolarizing phase:
Depolarization is toward threshold (about −55 mV and opens Na⁺ channels.)
The result is an "upward" change in membrane potential until its polarity is reversed.

Nervous System Physiology:
Two Mechanisms of Action Potential
Conduction along a neuron

(a) Continuous conduction

(b) Saltatory conduction

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Types of Nerve Fibers

- “A” fibers: Largest diameter myelinated fibers with the fastest saltatory conduction (12-130 m/sec) and a brief absolute refractory period. Axons of motor neurons and axons of sensory neurons that conduct touch, pressure, and thermal sensations. (GSSN)

- “B” fibers: Intermediate diameter myelinated fibers
  With slower saltatory conduction than “A” fibers and longer absolute refractory periods. Dendrites of visceral sensory neurons and axons of presynaptic neurons of the ANS.

- “C” fibers: Smallest diameter unmyelinated fibers with slow continuous conduction (.5 – 2 m/sec.) and the longest absolute refractory periods. Axons of some somatic sensory neuron that carry pain, touch, pressure and thermal sensation, neuron that carry visceral pain sensations, and postsynaptic neurons of the ANS.
Comparison of Graded versus Action Potentials

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Graded</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Origin</td>
<td>Dendrites and cell bodies</td>
<td>Trigger Zone 1st Node of Ranvier</td>
</tr>
<tr>
<td>Channels</td>
<td>Ligand-gated or mechanical</td>
<td>Voltage-gated</td>
</tr>
<tr>
<td>Conduction</td>
<td>Nonpropagated continuous</td>
<td>Propagated saltatory</td>
</tr>
<tr>
<td>Amplitude</td>
<td>Varies depending on strength of stimulus</td>
<td>All-or-None</td>
</tr>
<tr>
<td>Duration</td>
<td>Long- several msec. to minutes</td>
<td>Short- .5 – 2msec.</td>
</tr>
<tr>
<td>Polarity</td>
<td>Hyperpolarized or depolarized</td>
<td>Depolarized</td>
</tr>
<tr>
<td>Refractory period</td>
<td>No refractory period summation can occur</td>
<td>Absolute refractory period no summation</td>
</tr>
</tbody>
</table>

Nervous System Physiology:
Communication between neurons at a synaptic junction

1. Electrical Synapses: Communication via gap junctions between smooth muscle, cardiac muscle, and some neurons of the CNS. Provide fast, synchronized, and two-way transmission of information.

2. Chemical Synapses: Communication via chemical neurotransmitters that diffuse across a synaptic cleft. Provides slow one-way information flow.
Nervous System Physiology: Communication between neurons at a synaptic junction

1. Action potential arrives at a synaptic end bulb.
2. Depolarization of membrane causes the opening of Ca2+ channels.
3. Increase in (Ca2+) inside of presynaptic neuron triggers exocytosis of neurotransmitter
4. Neurotransmitter diffuses across synaptic cleft and binds to receptor (ligand-gated channel) on postsynaptic neuron

Nervous System Physiology: Communication between neurons at a synaptic junction

5. Na+ channels open causing a depolarization (Na+ channels) EPSP (excitatory postsynaptic potential) or a hyperpolarization (Cl- channels) IPSP (inhibitory postsynaptic potential) of the postsynaptic neuron.
6. If depolarization reaches a threshold, an action potential is generated on the postsynaptic neuron.
Nervous System Physiology:
Communication between neurons
at a synaptic junction

Neurotransmitters
1. Acetylcholine: Found in the PNS and CNS. EPSP and in parasympathetic neurons IPSP.

2. Amino Acids: Glutamate and Aspartate produce EPSP’s in the CNS. \( \text{Gamma-Aminobutyric Acid (GABA)} \) produces IPSP’s in the CNS. Valium enhances the action of GABA.
Nervous System Physiology:
Communication between neurons at a synaptic junction

**Neurotransmitters**

3. Biogenic Amines:
Norepinephrine and epinephrine produce EPSP’s in the sympathetic system. Serotonin controls mood and induction of sleep.


5. Neuropeptides:
Substance P: Enhances perception of pain.
Endorphins: inhibit pain by blocking release of Substance P

6. ATP-Adenosine 5’-triphosphate
Between taste buds and nerves that carry taste sensations —Finer et. al. Science vol 310, 2005
Nervous System Physiology:
Communication between neurons at a synaptic junction

Types of Neural Circuits
Brain Waves

- Alpha waves: (8 – 13 Hz) Occur when a person is awake, resting, mind wandering and eyes closed. Recorded in the parieto-occipital area.
- Beta waves: (14 -30 Hz) Become accentuated during mental activity and sensory stimulation. Recorded in the frontal to parietal regions.
Brain Waves

- Theta waves: (4 - 7 Hz) Normal in children and drowsy or sleeping adults. Predominant waves in awake adults suggest emotional stress or brain disorders.
- Delta waves: (< 3.5 Hz) High-amplitude wave. Infants exhibit these waves when awake and adults exhibit them in deep sleep. Increased delta waves in awake adults indicate serious brain damage.