Tips

- Use the Study Guide (SG) to follow the lectures
  - Lectures will be posted after class
- Reading the SG before class will be helpful
- Use the textbook to supplement lectures/SG
The Nervous System

Neurons and the Nervous Impulse
The Nervous System

- Cooperates with endocrine system
- Senses environment
- Responds to changes in environment
- Maintains homeostasis
- The nervous system is responsible for all our behaviors, memories, and movements
Functions of the Nervous System

1. **Sensory input**
   - Information gathered by sensory receptors about internal and external changes

2. **Integration**
   - Interpretation of sensory input

3. **Motor output**
   - Activation of effector organs (muscles and glands) produces a response
Figure 11.1

Sensory input

Motor output

Integration
Organization

Central Nervous System
  1. Brain
  2. Spinal Cord

Peripheral Nervous System
  1. Afferent (sensory)
  2. Efferent (motor)
     a. Somatic
     b. Autonomic
        i. Sympathetic
        ii. Parasympathetic
Major Structures of the Nervous System

CNS: Brain
Spinal cord

PNS:
- Cranial nerves
- Spinal nerves
- Ganglia
- Enteric plexuses in small intestine
- Sensory receptors in skin

Figure 12.01 Tortora - PAP 12/e
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Figure 11.2
Central nervous system (CNS)
- Brain and spinal cord
- Integrative and control centers

Peripheral nervous system (PNS)
- Cranial nerves and spinal nerves
- Communication lines between the CNS and the rest of the body

Sensory (afferent) division
- Somatic and visceral sensory nerve fibers
- Conducts impulses from receptors to the CNS

Motor (efferent) division
- Motor nerve fibers
- Conducts impulses from the CNS to effectors (muscles and glands)

Somatic nervous system
- Somatic motor (voluntary)
- Conducts impulses from the CNS to skeletal muscles

Autonomic nervous system (ANS)
- Visceral motor (involuntary)
- Conducts impulses from the CNS to cardiac muscles, smooth muscles, and glands

Somatic nervous system
- Motor fiber of somatic nervous system
- Conduction of impulses from the CNS to skeletal muscles

Sympathetic division
- Mobilizes body systems during activity

Parasympathetic division
- Conserves energy
- Promotes housekeeping functions during rest

Structure
- Sensory (afferent) division of PNS
- Motor (efferent) division of PNS

Function
- Skin
- Stomach
- Skeletal muscle
- Heart
- Bladder

Motor fiber of somatic nervous system
- Sympathetic motor fiber of ANS
- Parasympathetic motor fiber of ANS
Histology of Nervous Tissue

- **Two principal cell types**
  1. Neurons = excitable cells that transmit electrical signals
  2. Accessory cells (Neuroglia) = non-excitatable supporting cells
Neurons

- Individual nerve cells
- **Nerves** are parallel bundles of neurons carrying impulses

Types:
- Sensory (afferent)
- Motor (efferent)
- Association (interneurons)
Neuron Structure

- Body
- Dendrites
- Axons
Figure 11.4 Structure of a motor neuron.

- **Dendrites**: Receptive regions
- **Cell body**: Biosynthetic center and receptive region
- **Axon**: Impulse generating and conducting region
- **Nucleus**
- **Nissl bodies**
- **Axon hillock**
- **Neurilemma**
- **Node of Ranvier**
- **Impulse direction**
- **Schwann cell**: One internode
- **Axon terminals**: Secretory region
- **Dendritic spine**
Special Characteristics of Neurons

- Long lived
- Amitotic
- High metabolic rate
- Excitable
Neuroglia

- Neuroglia
- About %50 of cellular mass of nervous system
- Do not conduct impulses
- Most retain capacity to divide
- Different types found in PNS and CNS
Neuroglia of Central Nervous System

- Astrocytes
- Oligodendrocytes
- Microglial cells
- Ependymal cells
Astrocytes

- Most abundant of CNS neuroglia
- Contact blood vessels
- Blood Brain Barrier regulates passage of molecules
Astrocytes are the most abundant of CNS neuroglia. Provide most structural support.
Astrocytes
Oligodendrocytes

- Branched cells
- Processes wrap CNS nerve fibers, forming insulating myelin sheaths
Oligodendrocytes have processes that form myelin sheaths around CNS nerve fibers.
Oligodendrocytes
Ependymal Cells

- Line the central cavities of the brain and spinal column
- Form cerebrospinal fluid
- Separate the CNS interstitial fluid from the cerebrospinal fluid in the cavities
Ependymal cells line cerebrospinal fluid-filled cavities.
Microglia

- Small, ovoid cells with thorny processes
- Migrate toward injured neurons
- Phagocytize microorganisms and neuronal debris

- Add these to your list!
(b) Microglial cells are defensive cells in the CNS.
Neuroglia of PNS

- **Satellite cells**
  - Surround neuron cell bodies in the PNS
- **Schwann cells**
  - Surround peripheral nerve fibers and form myelin sheaths
  - Vital to regeneration of damaged peripheral nerve fibers
Satellite cells and Schwann cells (which form myelin) surround neurons in the PNS.
More on Schwann cells...

- Myelin Sheath
- Neurilemma
- Nodes of Ranvier
Structure of a Multipolar Neuron

(a) Parts of a motor neuron

(b) Motor neuron

Figure 12.02  Tortora  - FAP 12/e
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A Schwann cell envelopes an axon.

The Schwann cell then rotates around the axon, wrapping its plasma membrane loosely around it in successive layers.

The Schwann cell cytoplasm is forced from between the membranes. The tight membrane wrappings surrounding the axon form the myelin sheath.
The Nervous Impulse

- Dependent upon a resting potential across the cell membrane
- Active transport carriers (Sodium/Potassium pump)
- Polarization of neuron
- Impulse results from depolarization
Factors that contribute to resting membrane potential

Figure 12.14 Tortora - PAP 12/e
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Finally, let’s add a pump to compensate for leaking ions. 

**Na**<sup>+</sup>-**K**<sup>+</sup> ATPases (pumps) maintain the concentration gradients, resulting in the resting membrane potential.

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**The concentrations of Na**<sup>+</sup> and K**<sup>+</sup> on each side of the membrane are different.**

The Na**<sup>+</sup> concentration is higher outside the cell.

The K**<sup>+</sup> concentration is higher inside the cell.

**The permeabilities of Na**<sup>+</sup> and K**<sup>+</sup> across the membrane are different.**

Suppose a cell has only K**<sup>+</sup> channels...

K**<sup>+</sup> loss through abundant leakage channels establishes a negative membrane potential.

Now, let’s add some Na**<sup>+</sup> channels to our cell...

Na**<sup>+</sup> entry through leakage channels reduces the negative membrane potential slightly.

Finally, let’s add a pump to compensate for leaking ions. 

Na**<sup>+</sup>-K**<sup>+</sup> ATPases (pumps) maintain the concentration gradients, resulting in the resting membrane potential.
The Nervous Impulse

- Polarization
- Depolarization
- Hyperpolarization

*Polarity is dependent upon channels within the membrane (K⁺ and Na⁺)*
(a) **Depolarization**: The membrane potential moves toward 0 mV, the inside becoming less negative (more positive). This increases the probability of nerve impulse production.
(b) Hyperpolarization: The membrane potential increases, the inside becoming more negative. This decreases the probability of nerve impulse production.
Membrane Channels

- Chemically gated (ligand gated)
- Voltage gated
(a) Chemically (ligand) gated ion channels open when the appropriate neurotransmitter binds to the receptor, allowing (in this case) simultaneous movement of Na\(^+\) and K\(^+\).

(b) Voltage-gated ion channels open and close in response to changes in membrane voltage.
The Graded Potential

- Short lived, localized changes in membrane potential due to stimulation
- Channels open
- Ions flow
- Short distance signals
- May be depolarization or hyperpolarization events
(a) **Depolarization:** A small patch of the membrane (red area) has become depolarized.
(b) *Spread of depolarization:* The local currents (black arrows) that are created depolarize adjacent membrane areas and allow the wave of depolarization to spread.
(c) **Decay of membrane potential with distance:** Because current is lost through the “leaky” plasma membrane, the voltage declines with distance from the stimulus (the voltage is *decremental*). Consequently, graded potentials are short-distance signals.
Action Potential

- Long distance signal
- Initiated by *sufficient* depolarization at site of graded potential
- Involves opening of *voltage gated* channels
- Does not decrease in strength with distance
- All or none phenomenon
- Also called a nerve impulse
Figure 11.4  Structure of a motor neuron.
The events

1. **Resting state**
   - Sodium channel
   - Potassium channel
   - Activation gates
   - Inactivation gate

2. **Depolarization**
   - Sodium ions (Na⁺) enter the cell
   - Potassium ions (K⁺) exit the cell

3. **Repolarization**
   - Sodium ions (Na⁺) exit the cell
   - Potassium ions (K⁺) enter the cell

4. **Hyperpolarization**
   - Sodium ions (Na⁺) exit the cell
   - Potassium ions (K⁺) exit the cell

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The big picture

1. Resting state
2. Depolarization
3. Repolarization
4. Hyperpolarization

Figure 11.11 (1 of 5)
Conduction Velocity

- Axon diameter
- Degree of myelination
Myelinated Neurons

- Nodes of Ranvier
- Saltatory conduction
(a) In a **bare plasma membrane** (without voltage-gated channels), as on a dendrite, voltage decays because current leaks across the membrane.

(b) In an **unmyelinated axon**, voltage-gated Na\(^+\) and K\(^+\) channels regenerate the action potential at each point along the axon, so voltage does not decay. Conduction is slow because movements of ions and of the gates of channel proteins take time and must occur before voltage regeneration occurs.

(c) In a **myelinated axon**, myelin keeps current in axons (voltage doesn’t decay much). APs are generated only in the nodes of Ranvier and appear to jump rapidly from node to node.
2b. should read....
“...and also use considerably LESS energy.”
Refractory Period

- Neuron cannot respond to a second stimulus
  - During repolarization
- Limits number of impulses per second
Figure 11.14

Stimulus

Absolute refractory period

Relative refractory period

Membrane potential (mV)

+30

0

-70

Time (ms)

0 1 2 3 4 5

Depolarization (Na\(^+\) enters)

Repolarization (K\(^+\) leaves)

After-hyperpolarization

Stimulus
Stimuli that Initiate Action Potentials

Sensory Neurons
- Light
- Heat
- Chemicals
- Mechanical energy

Motor and Association Neurons
- Chemical stimuli from other neurons

Threshold stimulus always required
Coding for Stimulus Intensity

- All Action Potentials are independent of stimulus strength
- CNS must discern strong from weak signals to initiate appropriate response
- Stimulus intensity is coded for by *frequency* of action potentials
Questions?

- Homework due in lab
  - Lab Exercise 17 pg.’s 265-266 #1-10
- Please bring your Physio-Ex CD to lab