Lecture Outline: The Nervous System

I. **Nervous System Overview**

A. Control System

1. One of two control systems (nervous and endocrine) out of 11 total organ systems.
2. Controls the other nine organ systems.
3. Each control system also controls the other.
4. Involved in maintaining homeostasis.

B. Signals

1. Both nervous and endocrine systems operate via signals.
2. **Endocrine system** uses only chemical signals (hormones), which are molecules broadcast throughout the body via the bloodstream.
3. **Nervous system** uses two categories of signals:

a. Electrochemical signals (action potentials).

(1) Changes in voltage carried by ions.

(2) Produced and transmitted only by excitable tissues (nervous and muscle tissue).

d. Chemical signals (neurotransmitters).

(1) Released from axon terminals and act locally, not entering the bloodstream.

(2) Can be the same chemical as a hormone, but functional difference in operation.

(3) Require appropriate protein receptors for effect.

C. Major Functions (in order of occurrence)

1. Sensory input: Information coming into the nervous system, specifically toward the central nervous system (CNS).

a. Via sensory neurons using action potentials.

b. Allows CNS to read current values of variables for homeostasis

comparison to a set point.

c. **Sense vs. Sensation**:

(1) Sense/Sensory input: Any information coming toward the CNS, often unconsciously.

(2) Sensation: High-level processing in the brain, leading to conscious awareness.

2. Integration: High-level processing of sensory information in the CNS.
   a. Can be conscious (sensation) or unconscious (e.g., controlling heart beat, digestion).
   b. Determines appropriate changes for homeostasis.
3. Motor output: Information sent from the CNS to target tissues.
   a. "Motor" refers to movement, but not only skeletal muscles.
   b. Can target all three muscle types (skeletal, cardiac, smooth) and glands.
   c. Causes muscles to contract or glands to secrete.

D. Hierarchical Breakdown

1. **Nervous System**
   a. **Central Nervous System (CNS)**: Brain and spinal cord.
   b. **Peripheral Nervous System (PNS)**: Everything else, including cranial and spinal nerves (bundles of neurons).

(1) **Sensory Division (Afferent)**: Carries incoming sensory information toward the CNS.

(2) **Motor Division (Efferent)**: Carries outgoing motor information away from the CNS toward target tissues/effector organs.

1. **Somatic Division**: Controls only skeletal muscles; under voluntary control. Single motor neuron from CNS to muscle.
2. **Autonomic Division**: Controls involuntary actions (cardiac muscle, smooth muscle, glands); behind-the-scenes. Two neurons in series with a synapse: presynaptic and

postsynaptic neurons.

1. **Parasympathetic Division**: Antagonistic to sympathetic; often decreases activity.
2. **Sympathetic Division**: Antagonistic to parasympathetic; often increases activity.

II. **Nervous System Cell Types**

A. Neurons

1. Excitable cells: Able to produce and transmit action potentials and release neurotransmitters.
2. "Business end" of the nervous system, doing the actual controlling.
3. A neuron is an individual cell; a nerve is a bundle of many neurons.
4. Neurons are either sensory or motor; they do not change direction of information.

B. Neuroglia (Glial Cells)

1. Non-excitable cells that support neurons.
2. Do not produce action potentials or neurotransmitters themselves.
3. **Central Nervous System Neuroglia** (found only in brain or spinal cord)

a. **Astrocytes**:

(1) Star-shaped cells with elaborate plasma membranes.

(2) Wrap around capillaries to form and maintain the blood-brain barrier.

(3) Protects CNS by controlling what leaks from bloodstream.

e. **Microglial Cells**:

(1) Smaller than most neuroglial cells.

(2) Act as phagocytes ("cell eaters") to engulf and destroy unwanted substances, protecting neurons.

h. **Ependymal Cells**:

(1) Line interior surfaces of hollow parts of CNS (ventricles in brain, central canal of spinal cord).

(2) Produce and secrete cerebrospinal fluid (CSF) at choroid

plexuses.

k. **Oligodendrocytes**:

(1) Form myelin sheaths around axons of neurons in the CNS.

(2) Myelin makes white matter appear white.

(3) Speed up propagation of action potentials (insulation).

(4) Oligo means "more than one but not many"; one oligodendrocyte covers parts of multiple axons.

4. **Peripheral Nervous System Neuroglia** (found only outside CNS)

a. **Schwann Cells (Neurolemmocytes)**:

(1) Form myelin sheaths around axons of neurons in the PNS.

(2) Unlike oligodendrocytes, one Schwann cell covers only part of one axon.

(3) Myelinated axons have gaps called Nodes of Ranvier, which are necessary for faster action potential propagation.

e. **Satellite Cells**:

(1) Cover the cell bodies of neurons.

(2) Least understood function.

III. **Signal Transmission**

A. Resting Membrane Potential

1. All living cells have a voltage difference across their plasma membrane.
2. More positive charge outside, more negative charge inside.
3. Caused by continuous operation of sodium-potassium exchange pumps, creating unequal distribution of ions (charge gradient).

B. Action Potentials (Electrochemical Signals)

1. Drastic, temporary change in membrane voltage.
2. **Generation**:

a. Triggered by opening of voltage-gated sodium ion channels in the neuron membrane.

b. Sodium ions (positive charge) rush into the cell, making the interior

less negative/more positive.

3. **Propagation**:
    a. Chain reaction where one action potential causes the next one beside it.
    b. Travels down the axon without diminishing in strength.
    c. Myelination significantly increases propagation speed by allowing "jumping" between Nodes of Ranvier.
4. **Recovery**:
    a. After action potential, sodium-potassium pumps re-establish resting membrane potential.
    b. Allows for subsequent action potentials (e.g., continuous muscle contraction).

C. Synapses

1. Site of communication between two excitable cells (neuron to neuron, or neuron to muscle/gland).
2. Components: Presynaptic cell (upstream neuron), synaptic cleft (extracellular fluid space), postsynaptic cell (downstream neuron/ muscle/gland).
3. **Neurotransmitter Release** (Chemical Signal)
    a. Action potential reaches axon terminal of presynaptic neuron.
    b. Causes opening of voltage-gated calcium ion channels.
    c. Calcium ions (higher concentration outside) flow into the axon terminal.
    d. Incoming calcium ions directly trigger exocytosis of neurotransmitter-filled vesicles.
    e. Neurotransmitters are released into the synaptic cleft.
4. **Neurotransmitter Binding and Ion Channels**
    a. Neurotransmitters diffuse across synaptic cleft and bind to specific protein receptors on the postsynaptic membrane.
    b. Binding causes a conformational (shape) change in the receptor protein.

c. This shape change opens chemically-gated ion channels in the postsynaptic membrane.

d. Ions (e.g., sodium) flow through these channels into the postsynaptic cell, causing a voltage change.

e. In a postsynaptic neuron, if enough sodium ions enter, it generates a new action potential, continuing the signal.

5. **Neurotransmitter Removal**

a. Neurotransmitters must be removed from receptors/synaptic cleft to allow precise signaling and relaxation.

b. Enzymes (proteins) degrade neurotransmitter molecules, preventing them from staying bound to receptors indefinitely.

c. Once released, the receptor returns to its original shape, closing the channel and allowing the postsynaptic cell to recover to resting potential.

IV. **Brain Anatomy**

A. Major Subdivisions

1. **Cerebrum**: Largest, most conspicuous part; responsible for higher functions ("the brain" in common terms).

a. Features gyri (ridges) and sulci (grooves/valleys).

b. Divided into lobes (e.g., occipital, temporal, parietal, frontal) named after overlying cranial bones.

c. Central sulcus: Major groove dividing anterior (motor) and posterior (sensory) processing areas.

(1) Precentral gyrus: Primary motor area (anterior to central sulcus).

(2) Postcentral gyrus: Primary somatic sensory area (posterior to central sulcus).

f. Hemispheres: Right and left halves, divided by longitudinal fissure.

(1) Not divided by motor/sensory function; both hemispheres have both.

2. **Cerebellum**: Second largest part; "little brain" due to similar wrinkled appearance.

    a. Crucial for "muscle memory" and fine motor control, smoothing out movements.
3. **Thalamus**: "Switchboard" for almost all sensory information processing before reaching cortex.
4. **Hypothalamus**: Located inferior ("hypo") to the thalamus.
    a. Overlaps anatomically/physiologically with nervous and endocrine systems.
    b. Contains neurons that control hormone release from the pituitary gland.
5. **Brain Stem**: Inferior part of the brain.
    a. Includes Pons (larger bulge) and Medulla Oblongata (smaller, inferior bulge).
    b. Medulla Oblongata marks the official end of the brain, continuous with spinal cord.

B. Cerebral Cortex

1. Superficial part of the cerebrum.
2. Different regions devoted to different functions (e.g., visual area, olfactory area).
3. **Somatotopy ("Homunculus")**: Mapping of body parts onto the cerebral cortex.
    a. Distorted human representation reflects amount of brain power (neurons) devoted to a body part for sensation or motor control.
    b. Hands, face, and tongue have disproportionately large areas.

C. Brain Fiber Types (Neurons)

1. **Association Fibers**: Connect different parts within the same cerebral hemisphere; do not cross over.
2. **Commissural Fibers**: Cross over (decussate) to connect areas in opposite hemispheres.
    a. Bundled commissural fibers form a commissure.
    b. Corpus Callosum: The largest and most conspicuous commissure, connecting the two hemispheres.

3. **Projection Fibers**: Extend from the brain down into the spinal cord; can be very long.

D. Ventricles and Cerebrospinal Fluid (CSF)

1. Hollow, fluid-filled spaces within the brain and spinal cord (central canal).
2. Provide shock absorption and cushioning for the CNS.
3. Four ventricles in the brain (all interconnected):
    a. Two Lateral Ventricles (symmetrical, off-midline).
    b. Third Ventricle (on midline, superior to fourth, between thalamus halves).
    c. Fourth Ventricle (on midline, in brain stem).
4. Central Canal of spinal cord (connected to fourth ventricle).
5. **Cerebrospinal Fluid (CSF)**:
    a. Produced by ependymal cells in choroid plexuses within ventricles.
    b. Circulates through internal cavities and also surrounds the entire brain and spinal cord externally.
    c. Drains into the bloodstream via arachnoid granulations to maintain constant pressure.

V. **Peripheral Nervous System**

A. Structure of Nerves

1. Nerves are bundles of fascicles, and fascicles are bundles of nerve fibers (neurons, primarily axons).
2. Connective tissue wrappings:
    a. Epineurium: Surrounds the entire nerve.
    b. Perineurium: Surrounds each fascicle.
    c. Endoneurium: Surrounds each individual axon (nerve fiber).

B. Cranial Nerves

1. 12 pairs (24 total) of nerves connected directly to the brain.
2. Can be sensory-only (afferent), motor-only (efferent), or mixed (containing both sensory and motor neurons).

C. Spinal Nerves

1. Nerves connected to the spinal cord.
2. Named by region of spinal cord (e.g., cervical, thoracic).
3. All paired (right and left).
4. Form plexuses (web-like networks) in certain regions.
5. Each spinal nerve is a two-way street but composed of one-way neurons:
    a. Posterior (dorsal) root: Bundle of only sensory (afferent) neurons carrying incoming information to CNS.
    b. Anterior (ventral) root: Bundle of only motor (efferent) neurons carrying outgoing information from CNS.
    c. These roots join to form a mixed spinal nerve.

D. Motor Divisions (Revisiting PNS Motor Division)

1. **Somatic Motor Nervous System**:
    a. Targets: All skeletal muscles.
    b. Pathway: Single motor neuron from CNS to skeletal muscle.
2. **Autonomic Nervous System**:
    a. Targets: Cardiac muscle, smooth muscle, glands.
    b. Pathway: Two neurons in series (presynaptic, postsynaptic) with a synapse between them.
    c. Subdivisions (Parasympathetic and Sympathetic) are antagonistic for fine control.