CHAPTER 7: NERVOUS SYSTEM

- Organization
- Nervous tissue
- Central nervous system
- Peripheral nervous system
- Developmental aspects
The nervous system is the master controlling and communicating system of the body.

Three overlapping functions:

- **Sensory input**, both internal and external, via sensory receptors. Gathered information from the environment = stimuli.
- **Integration** is the process of interpreting sensory input and deciding what to do about it.
- **Motor output**, the response, from either a muscle or gland, to the sensory input.
- Example and endocrine system
Organization of the Nervous System

- Structural Classification (all organs):
  - 1. **central nervous system (CNS)** – brain and spinal column; integration central
  - 2. **peripheral nervous system (PNS)** – spinal and cranial nerves; sensory and motor neurons
Organization of the Nervous System

- Functional Classification (classifying PNS):

  1. **Sensory (afferent) division**: sensory receptors → nerve fibers
     1. A. **somatic sensory fibers**: from skin, skeletal muscle and joints
     2. B. **visceral sensory fibers**: from visceral organs like intestines and blood vessels.
Functional Classification (classifying PNS): 

2. Motor (efferent) division: CNS → effector organs (muscles and glands)
   - A. Somatic (voluntary) nervous system: controls skeletal muscles, although reflexes are involuntary they are still controlled by this system.
   - B. Autonomic (involuntary) nervous system: controls smooth and cardiac muscles and glands (sympathetic and parasympathetic systems). See page 204
Structure and Function of Nervous Tissue

- Nervous tissues have two types of cells:
  - Neurons and supporting cells

- Supporting cells in the CNS are called **neuroglia** ("nerve glue") AKA glia and have many different types and functions.
  - They cannot transfer nerve impulses.
  - Continually go through mitosis.
Structure and Function of Nervous Tissue

- **Neuroglia Types**
  - **1. astrocytes:**
    - Star shaped cells
    - Almost half of neural tissue
    - Anchor and brace neurons to capillaries
    - Protect neurons from toxins in the blood
    - Act as chemical vacuums in the brain by picking up excess ions and neurotransmitters.
Structure and Function of Nervous Tissue

- **Neuroglia Types**
  - 2. microglia
    - Spiderlike
    - Phagocytes (cell eaters) that dispose of dead brain cells, bacteria and toxins in the CNS.
## Structure and Function of Nervous Tissue

### Neuroglia Types

3. Ependymal cells

- Ciliated cells
- Line cavities of the brain and spinal cord
- Circulates the cerebrospinal fluid and cushions brain and spinal cord.

![Ependymal cells](image.png)
Structure and Function of Nervous Tissue

- **Neuroglia Types**
  - 4. oligodendrocytes
    - Flat extensions
    - Wrap and cover neural fibers
    - Fat insulation
    - AKA myelin sheaths
Structure and Function of Nervous Tissue

- PNS supporting cells
  - 1. schwann cells
    - Form the myelin sheaths on neurons
  - 2. satellite cells
    - Protective, cushioning cells
Structure and Function of Nervous Tissue

- Neurons!
  - Nerve cells that
    - A. transmit nerve impulses
    - B. Stop dividing in childhood

  - 1. anatomy
  - 2. classification
  - 3. physiology
Structure and Function of Nervous Tissue

Anatomy

- Neuron (AKA nerve cell) have 2 main parts –
  - A. cell body
  - B. slender processes
Structure and Function of Nervous Tissue

- **Cell body** – the metabolic center of the neuron, holds organelles (no centrioles)
  - Rough ER (AKA nissl substance) maintain shape
  - Neurofibrils also maintain shape
Structure and Function of Nervous Tissue

- **Slender processes**
  - Length = microscopic to 3-4 feet
  - **Dendrites** move neural impulses toward the cell body. Many, short
  - **Axons** move neural impulses away from the cell body. One, can be long. Come from the axon hillock. Can branch off (collateral branch). Have many axon terminals
Structure and Function of Nervous Tissue

- Axon terminals: many vesicles that contain neurotransmitters (like acetyl choline).
- Synaptic cleft: tiny gap between axon and dendrite of the next neuron.
- Synapse: functional junction
Structure and Function of Nervous Tissue

- **Myelin**: white-ish, lipid substance; protection of axon and increases speed of neural transmission.
- **Schwann cells**: PNS axons are wrapped with these special cells.
- **Myelin sheath**: the wrapped membranes around the axon, made of many Schwann cells.
- **Neurilemma**: outside part of Schwann cells.
- **Nodes of Ranvier**: gaps between myelin sheaths.

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Homeostatic imbalance: Multiple Sclerosis (MS)

Myelin sheaths around axons are destroyed and harden creating scleroses. This causes the current to short-circuit. People lose the ability to control their muscles. This is an autoimmune disease where the protein component of the sheath is attacked.
Structure and Function of Nervous Tissue

CNS
Nuclei: clusters of cell bodies
Tracts: bundles of nerve fibers
gray matter: unmyelinated neurons
(brain)
white matter: myelinated neurons
(spine)

PNS
Ganglia: clusters of cell bodies
Nerves: bundles of nerve fibers
Classification of Neurons

- Functional or Structural

1. Functional:
   - Groups neurons according to the direction of the nerve impulse relative to the CNS.
     - **Motor (efferent) neurons:** carry impulses away from CNS
       - All cell bodies are in CNS
     - **Association (interneuron) neurons:** connect motor and sensory neurons
       - All cell bodies are in CNS
     - **Sensory (afferent) neurons:** “to go toward” the CNS
       - Are found in ganglions
       - Are associated with receptors (cutaneous, proprioceptors)
Classification of Neurons

2. Structural Classifications: based on the number of processes extending from the cell body

   a. **multipolar neuron**: all motor and association neurons

   b. **bipolar neurons**: one axon and one dendrite; rare in adults, some sense organs (eye, ear); only sensory neurons

   c. **unipolar neurons**: only one single process from cell body; very short; branch into proximal and distal fibers; distal fibers become dendrites; proximal fibers become axons; sensory neurons in PNS ganglia
Neurons have two major functional properties:

A. irritability: respond to stimuli and convert it to a nerve impulse.

B. conductivity: transmitting the impulse to other neurons, muscles, or glands.
I. Irritability

- Polarized: resting (inactive) plasma membrane.
- Depolarized: change in the polarity of the neuron’s membrane. (sound, light, neurotransmitters)
Physiology

- 1. Irritability
  - Action potential: when depolarization is great enough to cause a chain reaction. (all-or-none)
  - Action potential = nerve impulse
I. Irritability

- Repolarization: back to resting state; no impulse until this is established!
- Polarization restored by sodium/potassium pumps that use ATP energy.
Physiology

I. Irritability

Saltatory conduction: (dance or leap) impulse across myelinated axons.
II. Conductivity

- NOT electrical!
- Chemical neurotransmitters flow across synaptic cleft.
- Electrochemical event!

- Example of radio, light
Open channel
Neurotransmitters open channels in the target cell to let charged particles through.
Homeostatic Imbalance

- Items that block sodium ion permeability:
  - Alcohol
  - Sedatives
  - Anesthetics
  - Cold
  - Continuous pressure
Reflex Arc

- Reflex arc: Neural pathways in which reflexes occur.
- Reflex: rapid, predictable, involuntary responses to stimuli.
- 5 basic elements of a reflex arc –
  - 1. receptor
  - 2. Sensory neuron
  - 3. integration center (association neuron in spinal cord)
  - 4. motor neuron
  - 5. effector (muscle or glands)
Reflex Arc

- Two types of reflexes: Autonomic & Somatic reflexes

- 1. Autonomic reflexes: regulate activity of smooth muscle, the heart and glands.
  - Examples: salivary gland, pupil dilation, digestion, elimination, blood pressure, sweating
Reflex Arc

- Two types of reflexes: Autonomic & Somatic reflexes

- 2. Somatic reflexes: all reflexes that stimulate skeletal muscle.
  - Examples: knee jerk, withdrawal reflex, startle

  - Reflexes are used as a pre-test for impending neurological disorders.
Central Nervous System

- Objectives:
  - Embryonic development
  - Functional anatomy of the brain
  - Protection of the CNS
  - Brain dysfunctions
  - Spinal cord anatomy and physiology
Central Nervous System

Embryonic Development

- The CNS begins as a neural tube which extends the dorsal median plane of the embryo.
- In four weeks the anterior end expands and we have the beginnings of brain formation!
- The posterior end becomes the spinal cord.
- The central canal forms four ventricles (or chambers) that will be discussed later.
Central Nervous System

Functional Anatomy of the Brain

- Our three pound brain is broken down into four major regions:
  - Cerebral hemispheres
  - Diencephalon
  - Brain stem
  - Cerebellum
Central Nervous System

1. Cerebral Hemispheres (pair)

- Largest and most superior part of brain
  - Gyri: elevated ridges of brain tissue
  - Sulci: shallow grooves (many)
  - Fissure: deeper grooves (fewer); these separate the regions (ex: longitudinal fissure)
  - Lobes: areas on the brain surface separated by fissures and named by their cranial bones.
Central Nervous System
Somatic sensory area (parietal lobe): sensory receptors like pain, temperature, and touch, but not special sense, are interpreted here. These are crossed pathways.

Special sensory areas include:
- Occipital lobe – vision
- Auditory area (temporal lobe) – sound
- Olfactory area (deep temporal lobe) – smell
- Gustatory area (lateral parietal lobe) - taste
Central Nervous System

- **Primary motor area** (frontal lobe): allows us to consciously move skeletal muscle.
- Pyramidal (corticospinal) tract: formed from the axons of the motor area; crossed pathways like the somatic sensory area.
- Specialized motor areas include:
  - Broca’s area (lateral frontal lobe of one side) – motor speech
  - Anterior frontal lobe – language comprehension, reasoning
  - Temporal & frontal lobes – memories
  - Speech area (where temporal, occipital, and parietal lobes meet) – sound out words
Central Nervous System
Central Nervous System

Grey Matter vs. White Matter

1. Grey matter: cell bodies, outermost area of the cerebrum (cerebral cortex)
   - Basal Nuclei – grey matter buried deep in the cerebrum, regulate voluntary motor activity

2. White matter: fiber tracts, deep within the cerebrum
   - Corpus Callosum – type of white matter, large fiber tract, connects hemispheres physically and communicatively (yes, I made that word up!)
Central Nervous System

Homeostatic Imbalance

- Basal nuclei damage leads to individuals who have difficulty walking or carrying out simple voluntary activities.
  - Huntington’s disease (late onset, behavioral)
  - Chorea (large jerking motions)
  - Parkinson’s disease (shaking)
Central Nervous System

2. Diencephalon

- AKA inner brain: sits on top of brain stem deep inside the cerebral hemispheres.

- Made of three parts
  - a. Thalamus: sensory impulses pass through and are relayed to the sensory cortex; can determine pleasant or unpleasant senses.
  - c. Epithalamus: have pineal body (regulate sleep) and choroid plexus (form cerebrospinal fluid)
Central Nervous System
3. Brain Stem

- About the size of a three inch thumb; articulates with the spinal cord; pathways for tracts; control involuntary actions like breathing.

- Has three sections:
  - Midbrain: contain cerebral peduncles (tracts) and corpora quadrigemina (sight and hearing reflexes).
  - Pons: ("bridge") fiber tracts, control breathing.
  - Medulla oblongata: fiber tracts, regulate visceral activities like heart rate, vomiting, blood pressure.
Central Nervous System

Midbrain

Pons

Medulla Oblongata
4. Cerebellum

- Two hemispheres, outer grey matter cortex and inner white matter; voluntary activity
  - Skeletal muscle activity, balance, equilibrium.
  - Fibers from eyes and inner ear meet here.
  - “automatic pilot”: regulates the brain’s desire and what is really happening with the body.
Protecting the CNS

- The 4 CNS protective barriers include:
  - 1. the skull and vertebrae*
  - 2. the meninges
  - 3. cerebrospinal fluid
  - 4. blood-brain barrier
Protecting the CNS

1. skull and vertebral column — duh!

2. meninges (linings) — made of connective tissue
   A. dura mater ("tough mother") hard, thick layer over brain
   B. arachnoid mater (spider) thin, soft layer over brain
   C. pia mater ("gentle mother") thin, soft layer that clings tightly to the brain and spinal cord
   D. subarachnoid space — between arachnoid and pia mater which contain cerebrospinal fluid.
Protecting the CNS

- **Homeostatic Imbalance**
  - *Meningitis*: an inflammation of the meninges caused by bacterial or viral infection that can be transferred to nervous tissue.
  - *Encephalitis*: brain inflammation.
3. Cerebrospinal Fluid (CSF)

- Similar to blood plasma (less protein, more vitamin C, different ions).
- Formed from the blood in the choroid plexuses in the midbrain (see fig 7.17 page 222).
- CSF is constantly moving around the brain and spinal cord being absorbed and created at a constant rate to ensure correct pressure. (about 150 mL or half a cup)
- Imbalances: lumbar tap and hydrocephalus
Protecting the CNS

4. The Blood-Brain Barrier

- Composed of the least permeable capillaries.
- Only water, glucose, essential amino acids can pass.
- Urea, toxins, proteins and most drugs can’t pass.
- Potassium and unessential proteins are pumped out.
- Fat soluble compounds and respiratory gases diffuse through all membranes easily.
- Astrocytes help.
Brain Dysfunctions

- See “Closer Look” on page 242.
- Concussion: slight brain injury, no permanent damage.
- Contusion: marked tissue damage, may result in coma.
- Cerebral edema: swelling of the brain from injury (cerebrospinal fluid build up or hemorrhage)
Spinal Cord

- About 17 inches long (see page 227)
- Reflex center; communications moving both directions.
- Extends through the foramen magnum in skull to the first or second lumbar vertebrae. At the end it forms the cauda equina.
- Protected by bones, meninges and cerebrospinal fluid.
- 31 pairs of spinal nerves exit through the spine
Spinal Cord

- **Grey Matter**
  - Looks like a butterfly with posterior and anterior horns with a central canal filled with CSF.
  - Dorsal (posterior) horn has association neurons.
  - Dorsal root: sensory neuron fibers.
  - Ventral (anterior) horn has motor neuron cell bodies.
  - Ventral root: motor neuron fibers.
  - The roots fuse to form the spinal nerves.
Spinal Cord
Spinal Cord

- **Homeostatic imbalance:**
  - **Flaccid paralysis** caused by ventral root damage.
    - Can’t get nerve impulse back to the muscles.
Spinal Cord

- White matter
  - Myelinated fiber tracts; outside part of spinal cord
  - Has three sections (posterior, lateral, anterior columns)
  - Posterior column: ascending tracts carrying sensory input.
  - Lateral and anterior tracts contain ascending and descending motor tracts.
Peripheral Nervous System

Objectives:
- Structure of nerves
- Cranial nerves
- Spinal nerves & nerve plexuses
- Autonomic nervous system
- Nervous system development
Peripheral Nervous System

Structure of a nerve

- **Endoneurium**: connective tissue wrapped around myelinated axon.
- **Fascicle**: bundle of axons
- **Perineurium**: connective tissue wrapped around a fascicle.
- **Nerve**: bundle of fascicles and blood vessels.
- **Epineurium**: connective tissue wrapped around a nerve.
Peripheral Nervous System
Naming nerves:

- **Mixed nerves** — nerves that carry both sensory and motor nerves; transmissions travel in both directions; all spinal nerves are mixed; most cranial nerves, too.

- **Afferent nerves** — all sensory nerves; travel toward CNS

- **Efferent nerves** — all motor nerves; travel away from CNS
Peripheral Nervous System

Cranial nerves

- 12 pairs that mainly serve the head and neck areas of the body. (the exception is the vagus nerve)
- They are named by number, course, and function.
- Oh, oh, oh, to touch and feel very good velvet, ah.
- See pages 230 – 232.
Peripheral Nervous System
Peripheral Nervous System

Spinal nerves and nerve plexi

- 31 pairs of spinal nerves from the ventral and dorsal roots of the spinal cord.
- Named from the area the nerve arises (p 233).
- Dorsal and ventral rami: split in the spinal nerve just outside the vertebrae; carry both sensory and motor nerves like the spinal nerves.
- Dorsal rami: smaller, serve skin and muscle.
- Ventral rami: form plexi that serve the sensory and motor aspects of the limbs. (T1-T12 serve the intercostals)
Peripheral Nervous System

- Cervical plexus
- Brachial plexus
- Cervical enlargement
- Intercostal nerves
- Lumbar enlargement
- Lumbar plexus
- Sacral plexus
- Cauda equina
- Cervical nerves $C_1 - C_8$
- Thoracic nerves $T_1 - T_{12}$
- Lumbar nerves $L_1 - L_5$
- Sacral nerves $S_1 - S_5$
- Coccygeal nerve $C_0$

Vertebral body
- Spinal nerve
- Pedicle
- Spinous process
- Spinal cord
Peripheral Nervous System

Nervous System

Central nervous system
- Brain
- Spinal cord

Peripheral nervous system
- Sensory division
  - Visceral sensory division
  - Somatic sensory division
- Motor division
  - Visceral motor division
  - Somatic motor division

Sympathetic division
Parasympathetic division
### Peripheral Nervous System

- **Autonomic Nervous System (ANS):** involuntary motor subdivision (cardiac and smooth muscles and glands)

<table>
<thead>
<tr>
<th>Somatic</th>
<th>vs</th>
<th>Autonomic (Visceral)</th>
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<tbody>
<tr>
<td>- Skeletal muscle</td>
<td></td>
<td>- glands, smooth, cardiac</td>
</tr>
<tr>
<td>- One motor neuron:</td>
<td></td>
<td>- two motor neurons: one in brain, one in PNS</td>
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<tr>
<td>brain to muscle</td>
<td></td>
<td>- Involuntary</td>
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<tr>
<td>- Voluntary</td>
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Peripheral Nervous System

PNS → Efferent Division → Visceral Division → Parasympathetic Division

- Anatomy: Cranial and sacral nerves (preganglionic axon) synapse with their second motor neuron (postganglionic axon). *p 233, 239
- Remember… ganglion means clusters of cell bodies. The terminal ganglion is the group of cell bodies articulated to the postganglionic axon.
- AKA — cholinergic fibers because they use acetylcholine as their neurotransmitter.
- See p 238.
Peripheral Nervous System
Peripheral Nervous System

PNS ➔ Efferent Division ➔ Visceral Division ➔ Parasympathetic Division

- Function: works mostly when body is “at rest”. It controls...
  - Slowing heart rate
  - Increasing digestion
  - Allows urination and defecation
  - Stimulates eyes for close vision

*D division – digestion, defecation, diuresis
Peripheral Nervous System

PNS → Efferent Division → Visceral Division → **Sympathetic Division**

- **Anatomy:** Thoracic and lumbar nerves (preganglionic axon) synapse with their second motor neuron (postganglionic axon).

- **Remember…** ganglion means clusters of cell bodies. The collateral ganglion is the group of cell bodies articulated to the postganglionic axon.

- **AKA** – adrenergic fibers because they use norepinephrine and epinephrine as their neurotransmitters.

- See p 238.
Peripheral Nervous System
Peripheral Nervous System

PNS ➔ Efferent Division ➔ Visceral Division ➔ Sympathetic Division

- Function: the “fight or flight” system; allows us to cope with stressors, major and minor, emotionally and physically.
- It controls...
  - Dilated pupils, bronchioles, skeletal muscle capillaries.
  - Increase heart rate, blood pressure, blood-glucose levels.
  - The adrenal gland produces more hormones.

*E Division – exercise, excitement, emergency & embarrassment
Developmental Aspects of N. S.

- Formed in the first month of gestation.
- Last to mature is the hypothalamus (regulates body temperature).
- No neurons are formed after birth!
- Development includes myelination from the top down (cephalocaudal); neural pathways increase.
- Sympathetic division decreases with age as does oxygen levels leading to senility.
- Alcoholics lose brain size earlier in life and more quickly than others.