15 - The Central Nervous System (Continued)
Taft College Human Physiology
Cerebrospinal fluid (CSF) is a fluid found inside the brain (ventricles) and spinal cord (central canal) and outside the brain and spinal cord in the meninges.

Functions:
1. **Mechanical protection** of the CNS acting as a shock absorber or cushion.
2. **Chemical protection** to maintain optimal environment for neuron synapses and propagation of action potentials.
3. **Circulates and exchanges nutrients and waste products** between blood and nervous tissue.
4. **Control of breathing at rest** is regulated by CSF pH.
Cerebrospinal fluid (CSF)

- **Hydrocephaly** - ‘water on the brain’.
- CSF is normally drained at a constant rate from the brain. Any obstruction may lead to accumulation with pressure build up in the cranium and **exerts pressure on the brain tissue**.
- In an **infant** with unclosed fontanels, the fluid will escape to **enlarge the head**.
- In **adult**, the cranium is fused and crushing pressure develops that will **damage nervous tissue and cut off blood vessel circulation**.
- A **shunt** can be installed from the ventricles to the subclavian vein or peritoneal cavity to drain the fluid.
Spinal Cord

Basic Structure and Function

Anterior view and transverse section through spinal cord
Basic structure of the spinal cord in cross section.

2 median grooves: A deep anterior (=ventral) median fissure and a shallow posterior (= dorsal) median sulcus. These extend length of cord forming 2 bilaterally symmetrical halves.
The basic structures of the spinal cord show bilateral symmetry, with **white matter** on the outside and **gray matter** on the inside. Note this arrangement of white and gray matter is the **opposite of the brain**.

**Mnemonic:**
- **“H” pattern for horizontal**
- **Carries info vertically**
- **Posterior median sulcus**
- **Anterior median fissure**

**Carries info horizontally**

**White matter**

**Gray matter**
Gray matter “H” pattern or “butterfly” consists of neuron cell bodies, synapses, nonmyelinated neurons (interneurons, neurons that connect sensory and motor neurons = 99% of all neurons).
Important areas of **Gray matter**:

**Dorsal Horn (posterior horn)** – receives **sensory input** into the CNS from PNS (sensory neurons). Contains the terminal boutons of sensory neurons.
Important areas of Gray matter:

**Ventral Horn (anterior horn)** – contains cell bodies of **somatic motor neurons**. Somatic motor neurons originate here and carry **voluntary motor info out** to target (effector) organs.
Gray matter:

**Lateral horn** – smaller lateral protrusion found in thoracic and lumbar levels of spinal cord only. Contains **cell bodies of Sympathetic (Autonomic) motor neurons** that **carry involuntary info out** to smooth muscle, cardiac muscle, and glands.
Gray matter:

**Gray commissure** – horizontal bar connecting the wings of the gray matter. Contains neurons that connect right and left sides.
Central canal – continuous with ventricles of brain and contains cerebrospinal fluid. Canal disappears before adulthood.
By now we should all realize that gray matter consists of:

- Neuron cell bodies
- Areas of synapses
- Non-myelinated neurons

- **Interneurons**, connector neurons, internuncial neurons, or association neurons = neurons between sensory & motor neurons
Spinal Cord – Gray Matter

- Important areas of gray matter
  - **Dorsal horn**
    - Receives *sensory input* from periphery (*sensory info. in*)
  - **Ventral horn**
    - Contains *cell bodies of somatic motor neurons* (*voluntary motor info. out*)
  - **Lateral horn**
    - Contains *cell bodies of Sympathetic motor neurons* of ANS (*involuntary motor info. out*)
  - **Gray commissure**
    - Containing neurons that *connect right and left side of the body*
White Matter (columns) – consists myelinated neurons, therefore white color. Divided by gray matter in three distinct regions (anterior, posterior, lateral) that contain bundles of neurons = tracts.

Key Idea: bundles of neurons in CNS = tracts, In PNS = nerves
White Matter (columns) – consist of:

Ascending tracts – sensory (afferent) info in (and up) to brain.

Descending tracts – motor (efferent) info out (and down) from brain.
Direction of movement of messages in spinal cord:

- Gray matter – horizontal
- White matter – vertical

Gray matter mnemonic = H pattern for Horizontal
Spinal Cord – White Matter

- White matter
  - Consists of myelinated neurons

- Functions of areas of white matter
  - Ascending tracts
    - Sensory information to brain (in)
  - Descending tracts
    - Motor information from brain (out)
Peripheral Nervous System

• Components:
  1. **Nerves**
     • 12 pair cranial nerves
     • 31 pair spinal nerves
  2. **Ganglia**
     • Aggregations of nerve cell bodies
  3. **Receptors** = Sense organs
     • Exteroreceptors – detect stimuli from outside body
     • Intereceptors – detect stimuli from inside body
PNS consists of nerves that branch out from the CNS and connect to other body parts.

- **Somatic (outer; voluntary)** - nerves that connect CNS to skin and **skeletal muscles** for conscious movement and sensory input.

- **Autonomic (visceral; involuntary)** – connect CNS to visceral organs (**heart, stomach, intestines, glands**) for unconscious activities.
Cranial Nerves

- 12 pair, numbered I-XII from rostral (superior) to caudal (inferior).
- First 2 from forebrain, the rest from the brain stem.
- All serve the neck and head, except the vagus (thoracic and abdomen).

Good News! Already covered on exam 2.
Spinal Nerves

- 31 pairs, each exits spinal cord between vertebrae inferior to vertebra of same number (except C which are above as are 8 total, not 7).

- All Mixed – motor and sensory
  - Afferent – carry sensory info to spinal cord (CNS) from receptors.
  - Efferent – carry motor info out to effector (target) organs
    - Somatic – to skeletal muscles
    - ANS – to smooth muscle, cardiac muscle, glands

- Names = C1-8, T1-12, L1-5, S1-5, CO1
Connection of Spinal Nerves to Spinal Cord

- Each spinal nerve emerges from 2 short roots in spinal cord.
  - Dorsal Root (sensory in only) – note dorsal root ganglion contains cell bodies of sensory neurons which conduct impulses inward from body periphery.
  - Ventral Root (motor out only) – consists of axons from motor neurons whose cell bodies are located in gray matter of spinal cord.
Roots unite to form **spinal nerve** proper which passes through intervertebral foramen and then splits into branches.
• Spinal nerve splits just lateral to intervertebral foramen.
• **Dorsal ramus** (posterior branch); nerve turns posteriorly and innervates muscles and skin of back.
• **Ventral ramus** (anterior branch); main portion continues anteriorly to supply muscles and skin on front and sides of trunk and limbs.
• **Rami communicantes** (communicating rami of ANS)
  – Serves sympathetic motor nerves.
• Rami communicantes consist of white ramus with (myelinated) preganglionic neurons and gray ramus with (nonmyelinated) postganglionic neurons
The ANS *always* displays **two neurons** in the motor pathway from CNS to the effector organ.

- This contrasts with the situation in the somatic-efferent system where there is **one neuron** in the path from CNS to a skeletal muscle effector.

The two ANS neurons are designated the **pre- and post-ganglionic neurons**.
1. **Preganglionic** neurons and fibers
   - Cell body located in the CNS, originates in lateral horn (sympathetic).
   - Its axon may be short (sympathetic), or long (parasympathetic), reaching most of the distance to target organ.
   - And synapses on, the **postganglionic neuron** in ganglia.

2. **Postganglionic** neurons and fibers
   - The cell body is located in an autonomic ganglion (motor ganglion).
   - Axon may be relatively short (parasympathetic), or long (sympathetic).
   - Projects to smooth muscle, cardiac muscle or glands as target organs.
Let’s Draw PNS CNS Connections –
Know functions in red!

2. Gray matter H Pattern – carries info horizontally.
3. Dorsal (posterior) root – contains sensory neurons that carry sensory info to CNS.
4. Dorsal (posterior) root ganglion – aggregation of sensory nerve cell bodies.
5. Receptor (Sense organ) – detects stimuli.
6. Afferent (sensory neuron) – carries sensory info to CNS.
7. Ventral (anterior) root – contains motor neurons that carry motor info from CNS.
8. Spinal Nerve – contains sensory and motor neurons that carry sensory info to CNS and motor info out from CNS.
10. Efferent somatic neuron – carries voluntary motor info from CNS to skel muscle.
14. Efferent presynaptic sympathetic neuron - carries involuntary info from CNS to Symp ganglion.
15. Gray ramus – contains sympathetic postganglionic neurons, carries involuntary info from Symp ganglion to target organ.
16. Efferent postsynaptic sympathetic neuron - carries involuntary info from Symp ganglion to target organ.
17. Interneuron #1 – carries sensory info to brain via ascending tracts.
18. Interneuron #2 – carries info from one side to another.
19. Interneuron #3 – carries info from sensory neuron to efferent somatic neuron on same side.
20. Interneuron #4 – carries motor info from brain via descending tracts to efferent somatic neuron.
1. Spinal nerve
2. Dorsal root ganglion
3. Dorsal root
4. Ventral root
5. Ventral ramus
6. Dorsal ramus
7. White ramus
8. Gray ramus
9. Sympathetic ganglion chain

A. Gray matter
B. White matter
C. Anterior median fissure
Segmental Distribution of Spinal Nerves

- **Dermatomes** - each pair of spinal nerves supplies a particular area of body skin.
- Dermatomes = Areas of skin innervated by single spinal segment (nerve).
- Dermatome map help localize sites of injury to the spinal cord. Significant **overlap** occurs (about 50% on trunk) so damage to 1 spinal nerve will not cause total loss of sensation to an area.
- To cause a regional area of anesthesia, 3 adjacent spinal nerves would need to be blocked.
Autonomic Nervous System

- No conscious control over therefore called *involuntary* nervous system.
ANS consists of motor neurons that serve:

1. Cardiac muscle
2. Smooth muscle
   - Viscera (respiratory, digestive, excretory and genital organs)
   - Blood vessels
3. Glands
   - Salivary glands, Adrenal gland, Lacrimal glands
# Differences Between Somatic and Autonomic Nervous Systems

<table>
<thead>
<tr>
<th>Control</th>
<th>Somatic</th>
<th>Autonomic</th>
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<tbody>
<tr>
<td>Voluntary</td>
<td>Voluntary</td>
<td>Involuntary</td>
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<tr>
<td>Effector organs</td>
<td>Skeletal Muscle</td>
<td>Smooth &amp; cardiac muscle, glands</td>
</tr>
<tr>
<td># of neurons</td>
<td>1</td>
<td>2</td>
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<tr>
<td>spinal cord to effector</td>
<td>1st Spinal cord to ganglia = preganglionic (presynaptic)</td>
<td>2nd Ganglia to effector = postganglionic (postsynaptic)</td>
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<tr>
<td>Myelination</td>
<td>All myelinated</td>
<td>½ myelinated</td>
</tr>
<tr>
<td>Neurotransmitter</td>
<td>All secrete ACh</td>
<td>Most secrete ACh</td>
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<tr>
<td></td>
<td></td>
<td>Parasympathetic – all secrete ACh</td>
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<tr>
<td></td>
<td></td>
<td>Sympathetic - All preganglionic secrete ACh</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Most postganglionic secrete NE</td>
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2 Divisions of the Autonomic Nervous System

Afferent Division (sensory division)  Efferent Division (motor division)

Sympathetic "Stress"  Parasympathetic "Calm"

Involuntary or Voluntary Control

Autonomic  Somatic
Parasympathetic Division
( = Craniosacral Division)

- Preserves normal resting functions (rest and digest division).
- Protects and preserves resources.
- Most active under ordinary, restful (calm) conditions.
- Postganglionic neuron secretes acetylcholine.
- Preganglionic neuron is long, postganglionic fibers are short.
Parasympathetic Division

Craniosacral Out Flow

- Cranial Parasympathetic Outflow
  - Via Cranial nerves: III, VII, IX, and X.

- Sacral Parasympathetic Outflow
  - Via Spinal nerves: S2-S4
Sympathetic Division
(Thoracolumbar Division)

- More extensive than parasympathetic system with a sympathetic ganglia chain.
- Increases utilization of body resources = Fight or Flight Division
- Postganglionic fibers secrete norepinephrine.
- Short preganglionic neuron, long postganglionic neuron.
- The E division: emergency, exercise, excitement, and embarrassment.
Thoracolumbar Outflow

- Spinal nerve outflow
- Thoracic- T1 - T12
- Lumbar- L1 - L2

- Sympathetic trunk (sympathetic chain), formed by paired ganglia

- Preganglionic neurons originate in lateral horn of spinal cord.
Sympathetic vs. Parasympathetic

- The 2 ANS divisions generally act as antagonists, one will activate, the other inhibit most organs.
  - These 2 divisions will provide a **double innervation (dual innervation)** for most body organs.
  - Example: heart and respiratory rate
    - **Parasympathetic** (acetylcholine) will slow them down.
    - **Sympathetic** (norepinephrine) will speed them up.
- Both systems are usually operating with one exerting more influence depending upon the situation.
Not all organs of ANS receive dual innervation!!

• The **sympathetic division** provides **single innervation** to these organs (unopposed activities):
  
  1. **Adrenal gland**- 20% NE, 80% epinephrine. Epinephrine enhances sympathetic response via the circulatory system.
  
  2. **Sweat glands** (sweat under stress) and arrector pili muscles in skin (hair raising experience).
  
  3. **Spleen and kidney**
  
  4. **Blood vessels of skin and skeletal muscle.**
<table>
<thead>
<tr>
<th></th>
<th>Sympathetic (stress, excitement)</th>
<th>Parasympathetic (calm, rest)</th>
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</thead>
<tbody>
<tr>
<td>Iris pupil (eye)</td>
<td>dilates</td>
<td>constricts</td>
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<tr>
<td>Respiratory rate</td>
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<td>decreases</td>
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<tr>
<td>Bronchioles</td>
<td>dilates</td>
<td>constricts</td>
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<tr>
<td>Heart rate</td>
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<td>decreases</td>
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<tr>
<td>Cardiac output</td>
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<td>decreases</td>
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<td>Blood vessels:</td>
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<tr>
<td>coronary</td>
<td>dilates</td>
<td>constricts</td>
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<tr>
<td>skeletal</td>
<td>dilates</td>
<td>none – no innervation</td>
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<tr>
<td>intestines</td>
<td>constriction</td>
<td>dilates</td>
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<tr>
<td>skin</td>
<td>constriction</td>
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<td>Stomach &amp; intestinal</td>
<td>decreases</td>
<td>increases</td>
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<tr>
<td>activity</td>
<td></td>
<td></td>
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<tr>
<td>Sex organs</td>
<td>ejaculation (orgasm)</td>
<td>erection (vasodilation)</td>
</tr>
</tbody>
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Drug Effects on the ANS

Amphetamines
- “speed, uppers” - mimics epinephrine.

Nicotine
- Nicotine found in tobacco but not naturally in humans.
- Binds to receptors (nicotinic) on all postganglionic neurons (cell bodies and dendrites) both parasympathetic and sympathetic, hormone producing cells of adrenal medulla, and motor end plates of skeletal muscle (somatic division). It stimulates them all.
Drug Effects on the ANS

**Muscarine**

- A drug from toadstools that **mimics the actions of ACh** on a class of ACh receptors (muscarinic).
- Generally **excites the parasympathetic system and the sweat glands and blood vessels in skeletal muscles** which **lowers heart and respiration** which can ultimately lead to death.
- **Lomotil** - Blocks action of ACh and slows down intestinal activity. Used for diarrhea.
Drug Effects on the ANS

**Atropine**

- **Counteracts muscarine. Blocks parasympathetic effects by blocking ACh receptors.** So, acts to inhibit the parasympathetic response: reduce secretions (dry mouth, decreased sweating), relax smooth muscle in GI tract (constipation), dilate pupils, tachycardia.

- Used by ophthalmologist to dilate the pupils for exam.

- Pre-op drug to suppress salivation and respiratory secretions during surgery.
Drug Effects on the ANS

Beta blockers

- There are 2 major classes of NE receptors: alpha and beta.
- Beta blockers block the beta receptors and prevent those organs from showing sympathetic effects.
- Beta blockers are used to lower blood pressure, but avoids side effects and does not interfere with other sympathetic activities.
Drug Effects on the ANS

**Ritalin**
- Drug to slow down hyperkinetic children.
- An *amphetamine* like drug. Amphetamines have **opposite effects on children** than on adults.
- Ritalin will speed up adults and is abused that way.

**Decongestants**
- “Dristan” & “Contac” act like amphetamines