Autonomic Nervous System (ANS)

Learn and Understand:

Divisions of the ANS

- Sympathetic division
- Parasympathetic division
- **Dual innervation**
  - ~ All visceral organs served by both divisions, usually cause opposite effects
- Dynamic antagonism between two divisions maintains homeostasis
- Most spinal and many cranial nerves contain both somatic and autonomic fibers

Features of the Autonomic Nervous System

- Motor neurons innervating smooth and cardiac muscle and glands – ensuring optimal support for daily activities
- Unconscious regulation – involuntary, visceral
- Target tissues stimulated or inhibited
- Two synapses from brain to effector – preganglionic neuron - > autonomic ganglion - > postganglionic neuron - > effector
- Neurotransmitters Utilized: Acetylcholine by preganglionic neurons and ACh or norepinephrine by postganglionic neurons
- Post-synaptic receptors: varies with synapse and neurotransmitter, nicotinic, muscarinic, adrenergic
Table 14.1 Anatomical and Physiological Differences Between the Parasympathetic and Sympathetic Divisions

<table>
<thead>
<tr>
<th>CHARACTERISTIC</th>
<th>PARASYMPATHETIC</th>
<th>SYMPATHETIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Origin</td>
<td>Cranial (parasympathetic)</td>
<td>Spinal (sympathetic)</td>
</tr>
<tr>
<td>Location of ganglia</td>
<td>Superior to the organ served</td>
<td>inferior to the organ served</td>
</tr>
<tr>
<td>Degree of branching of postganglionic fibers</td>
<td>Moderate</td>
<td>Minimal</td>
</tr>
<tr>
<td>Neurotransmitters</td>
<td>Acetylcholine (ACh)</td>
<td>Norepinephrine (NE)</td>
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</tbody>
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**Neurotransmitters**

- **Cholinergic fibers** release neurotransmitter ACh
  - All ANS preganglionic axons
  - All parasympathetic postganglionic axons at effector synapse

- **Adrenergic fibers** release neurotransmitter NE
  - Most sympathetic postganglionic axons
  - Exception: sympathetic postganglionic fibers secrete ACh at sweat glands
Comparison of motor neurons in the somatic and autonomic nervous systems.

<table>
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<tr>
<th>Central Nervous System</th>
<th>Peripheral Nervous System</th>
<th>Effector Organs</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single neuron from CNS to effector organs</td>
<td>Heavily myelinated axon</td>
<td>Skeletal muscle</td>
<td>Stimulatory</td>
</tr>
</tbody>
</table>

**SOMATIC NERVOUS SYSTEM**

- Single neuron from CNS to effector organs
- Heavily myelinated axon
- Acetylcholine (ACh)

**AUTONOMIC NERVOUS SYSTEM**

- Two-neuron chain from CNS to effector organs
- Lightly myelinated preganglionic axons
- Nonmyelinated postganglionic axon
- Epinephrine and norepinephrine

**Location of ANS Receptors**

- Nicotinic receptors found on:
  - Sarcolemma of skeletal muscle cells (Chapter 9) at NMJ
  - All postganglionic neurons (sympathetic and parasympathetic)
  - Hormone-producing cells of adrenal medulla

- Effect of ACh at nicotinic receptors is always stimulatory
  - Opens ion channels, depolarizing postsynaptic cell

**Nicotinic Receptors**
Muscarinic Receptors

• Found on
  – All effector cells stimulated by postganglionic cholinergic fibers

• Effect of ACh at muscarinic receptors
  – Can be either inhibitory or excitatory
  – Depends on receptor type of target organ

Adrenergic Receptors

• Two major classes
  – Alpha (α) (subtypes α₁, α₂)
  – Beta (β) (subtypes β₁, β₂, β₃)

• Effects of NE depend on which subclass of receptor predominates on target organ

Sympathetic (Thoracolumbar) Division

• Preganglionic neurons are in spinal cord segments T₁ – L₂
  – Form lateral horns of spinal cord

• Preganglionic fibers pass through white rami communicantes and enter sympathetic trunk (chain or paravertebral) ganglia
Role of the Sympathetic Division

• Mobilizes body during activity; "fight-or-flight" system
• Exercise, excitement, emergency, embarrassment
  – Increased heart rate; dry mouth; cold, sweaty skin; dilated pupils
• During vigorous physical activity
  – Shunts blood to skeletal muscles and heart
  – Dilates bronchioles
  – Causes liver to release glucose

Sympathetic Tone

• Sympathetic division controls blood pressure, even at rest
• Vascular system ~ entirely innervated by sympathetic fibers
• Sympathetic tone (vasomotor tone)
  – Keeps blood vessels in continual state of partial constriction

Sympathetic Tone

• Sympathetic fibers fire more rapidly to constrict blood vessels and cause blood pressure to rise
• Sympathetic fibers fire less rapidly to prompt vessels to dilate to decrease blood pressure
• Alpha-blocker drugs interfere with vasomotor fibers
  – Used to treat hypertension
Unique Roles of the Sympathetic Division

- Adrenal medulla, sweat glands, arrector pili muscles, kidneys, and most blood vessels receive only sympathetic fibers
- Sympathetic division controls
  - Thermoregulatory responses to heat
  - Release of renin from kidneys
  - Metabolic effects
    - Increases metabolic rates of cells
    - Raises blood glucose levels
    - Mobilizes fats for use as fuels
Routes of Sympathetic Axons

Sweat glands, arrector pili muscles, blood vessels in skin

Routes of Sympathetic Axons

Abdominal and pelvic organs
Adrenal glands only

Pathways to the Head

• Fibers emerge from T₁ – T₄ and synapse in the superior cervical ganglion
• These fibers
  – Innervate skin and blood vessels of the head
  – Stimulate dilator muscles of the iris
  – Inhibit nasal and salivary glands
  – Innervate smooth muscle of upper eyelid
  – Branch to the heart
Role of the Parasympathetic Division

• Promotes maintenance activities and conserves body energy
  – Directs digestion, diuresis, defecation
• As in person relaxing and reading after a meal
  – Blood pressure, heart rate, and respiratory rates are low
  – Gastrointestinal tract activity high
  – Pupils constricted; lenses accommodated for close vision

Parasympathetic (Craniosacral) Division

• **Long preganglionic fibers** from brain stem and sacrum
  – Extend from CNS almost to target organs
  – Synapse with postganglionic neurons in terminal ganglia close to/within target organs
  – **Short postganglionic fibers** synapse with effectors

Parasympathetic Tone

• Parasympathetic division normally dominates heart, smooth muscle of digestive and urinary tract organs, activate most glands except for adrenal and sweat glands
  – Slows the heart
  – Dictates normal activity levels of digestive and urinary tracts
• The sympathetic division can override these effects during times of stress
• Drugs that block parasympathetic responses increase heart rate and cause fecal and urinary retention
Interactions of the Autonomic Divisions

• Most visceral organs have dual innervation
• Dynamic antagonism allows for precise control of visceral activity
  – Sympathetic division increases heart and respiratory rates, and inhibits digestion and elimination
  – Parasympathetic division decreases heart and respiratory rates, and allows for digestion and discarding of wastes

Cooperative Effects

• Best seen in control of external genitalia
• Parasympathetic fibers cause vasodilation; are responsible for erection of penis or clitoris
• Sympathetic fibers cause ejaculation of semen in males and reflex contraction of a female’s vagina
Localized Versus Diffuse Effects

• Parasympathetic division: short-lived, highly localized control over effectors
  – ACh quickly destroyed by acetylcholinesterase

• Sympathetic division: longer-lasting, bodywide effects
  – NE inactivated more slowly than ACh
  – NE and epinephrine hormones from adrenal medulla prolong effects

Control of ANS Function

• Hypothalamus—main integrative center of ANS activity
• Subconscious cerebral input via limbic system structures on hypothalamic centers
• Other controls come from cerebral cortex, reticular formation, and spinal cord

Hypothalamic Controls

• Control may be direct or indirect (through reticular system)
• Centers of hypothalamus control
  – Heart activity and blood pressure
  – Body temperature, water balance, and endocrine activity
  – Emotional stages (rage, pleasure) and biological drives (hunger, thirst, sex)
  – Reactions to fear and "fight-or-flight" system
Cortical Controls

- Connections of hypothalamus to limbic lobe allow cortical influence on ANS
- Voluntary cortical control of visceral activities is possible
  - Biofeedback
    - Awareness of physiological conditions with goal of consciously influencing them
    - Biofeedback training allows some to control migraines and manage stress