Autonomic Nervous System (ANS)

Learn and Understand:

• What appears to be two separate systems actually work together to maintain homeostasis under varying conditions.
• Receptors on the membranes of ANS effectors vary, APs reaching an effector may not stimulate it to action.
• Speed of AP transmission in the ANS is slower than the SMS.
• Another link between nervous and endocrine systems demonstrated.

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

Divisions of the ANS

• Sympathetic division
• Parasympathetic division
• Dual innervation
  – Almost all visceral organs served by both divisions, usually causing opposite effects
• Dynamic antagonism between two divisions maintains homeostasis
• Most spinal and many cranial nerves contain both somatic and autonomic fibers
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 nerves (except splanchnic nerves), thoracic and lumbar</td>
<td>Thoracic and lumbar nerves</td>
</tr>
<tr>
<td>Location of ganglia</td>
<td>Posterior surface of spinal cord or extracranial organs</td>
<td>Posterior surface of spinal cord or extracranial organs</td>
</tr>
<tr>
<td>Relative length of preganglionic and postganglionic fibers</td>
<td>Short, long</td>
<td>Short, long</td>
</tr>
<tr>
<td>Fiber components</td>
<td>Gray and white matter components</td>
<td>Gray and white matter components</td>
</tr>
<tr>
<td>Neurotransmitters</td>
<td>Acetylcholine</td>
<td>Norepinephrine</td>
</tr>
<tr>
<td>Functional role</td>
<td>Vascular smooth muscle, cardiac muscle, and glands</td>
<td>Adrenergic receptors</td>
</tr>
</tbody>
</table>

**ANS Neurotransmitters**

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

<table>
<thead>
<tr>
<th>SOMATIC NERVOUS SYSTEM</th>
<th>AUTONOMIC NERVOUS SYSTEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single neuron from CNS to effector organs</td>
<td>Two-neuron chain from CNS to effector organs</td>
</tr>
<tr>
<td>Heavily myelinated axon</td>
<td>Lightly myelinated preganglionic axon</td>
</tr>
<tr>
<td>Skeletal muscle</td>
<td>Blood vessel</td>
</tr>
<tr>
<td>Acetylcholine (ACh)</td>
<td>Acetylcholine (ACh)</td>
</tr>
<tr>
<td>Stimulatory</td>
<td>Stimulatory or inhibitory, depending on neurotransmitter and receptors on effector organs</td>
</tr>
</tbody>
</table>

**Location of ANS Receptors**

- Open Na⁺ gates causing EPSP
- Excitatory or inhibitory
- α and β receptors located on effector membranes – stimulatory or inhibitory

**ANS Receptors: Nicotinic**

- 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

**ANS Receptors: Muscarinic**

- Found on
  - Smooth muscle (e.g., in gut), glands, cardiac muscle
  - Stimulatory or inhibitory, depending on neurotransmitter and receptors on effector organs

**ANS Receptors: Adrenergic**

- Found on
  - Adrenal medulla
  - Heart
  - Stimulatory or inhibitory, depending on neurotransmitter and receptors on effector organs

**ANS Receptors: Cholinergic**

- Found on
  - Autonomic ganglia
  - Stimulatory or inhibitory, depending on neurotransmitter and receptors on effector organs

**ANS Receptors: Cholinergic**

- Found on
  - Autonomic ganglia
  - Stimulatory or inhibitory, depending on neurotransmitter and receptors on effector organs
ANS Receptors: Muscarinic

- 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

ANS Receptors: Adrenergic

- 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
Spinal cord
Dorsal root
Ventral root
Rib
Sympathetic trunk ganglion
Sympathetic trunk
Ventral ramus of spinal nerve
Gray ramus communicans
White ramus communicans
Thoracic splanchnic nerves
(a) Location of the sympathetic trunk

Figure 14.5a  Sympathetic trunks and pathways.

Thoracic splanchnic nerves
Preganglionic cell bodies in lateral horns of spinal cord T1-L2
Preganglionic axons pass through ventral roots to white rami communicantes to the retroperitoneal sympathetic chain ganglia

Figure 14.6 Sympathetic (Thoracolumbar) division of the ANS.

Routes of Sympathetic Axons

Sweat glands, arrector pili muscles, blood vessels in skin

Thoracic organs:
Heart via the cardiac plexus
Thyroid gland and the skin
Lungs and esophagus
Routes of Sympathetic Axons

Abdominal and pelvic organs
Adrenal glands only

Roles 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

Roles of the Sympathetic Division:
Sympathetic Tone

• Sympathetic division helps control blood pressure, even at rest
• Vascular system ~ almost entirely innervated by sympathetic fibers
  – Exception: blood vessels serving erectile tissue
  – Sympathetic tone (vasomotor tone)
    • Keeps blood vessels in continual state of partial constriction
    • 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
Unique Roles of the Sympathetic Division

• Adrenal medulla, sweat glands, arrector pili muscles, and kidneys receive only sympathetic fibers

• 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

Sympathetic 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
- Hypothalamic Centers
  - 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 system allows cortical influence on ANS
  – Stress can influence organ function
• 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