Autonomic Nervous System and Visceral Reflexes

• Autonomic Nervous System (ANS)
  – general properties
  – anatomy
• Autonomic Effects on Target Organs
• Central Control of Autonomic Function

General Properties of ANS

• autonomic nervous system (ANS) – a motor nervous system that controls glands, cardiac muscle, and smooth muscle
• Maintains homeostasis
• Primary organs of the ANS
  – viscera of thoracic and abdominal cavities
  – some structures of the body wall
    – cutaneous blood vessels
    – sweat glands
    – piloerector muscles
• carries out actions involuntarily – no intent/awareness
• visceral effectors do not depend on the ANS to function

Divisions of ANS

sympathetic division (Fight or Flight)
  – prepares body for physical activity – exercise, trauma, arousal, competition, anger, or fear
    • increases heart rate, BP, airflow, blood glucose levels, etc.
    • reduces blood flow to the skin and digestive tract
parasympathetic division (Rest and digest)
  – calms many body functions reducing energy expenditure and assists in bodily maintenance
  • digestion and waste elimination

Divisions of ANS

• autonomic tone - balance of the two systems according to the body’s changing needs
  – parasympathetic tone
    • maintains smooth muscle tone in intestines
    • holds resting heart rate down to about 70 – 80 beats per minute
  – sympathetic tone
    • keeps most blood vessels partially constricted and maintains blood pressure

Neural Pathways

• ANS has components in both the central and peripheral nervous systems
  – nuclei in the hypothalamus and other brainstem regions
  – motor neurons in the spinal cord and peripheral ganglia
  – nerve fibers that travel through the cranial and spinal nerves

Somatic versus Autonomic Pathways

• Somatic effectors (skeletal muscles)
  – myelinated preganglionic fiber
  – unmyelinated postganglionic fiber
• Autonomic ganglion
  – visceral effectors (cardiac muscle, smooth muscle, glands)

  Premyelinated cell bodies in gray matter
Sympathetic Nervous System

- Aka thoracolumbar division (T1 – L2)
- relatively short preganglionic and long postganglionic fibers
- preganglionic cell bodies in lateral horns and nearby regions of the gray matter of spinal cord
  - lead to sympathetic chain of ganglia (paravertebral ganglia)

Sympathetic Nervous System

- each paravertebral ganglion is connected to a spinal nerve by two branches – communicating rami (rami communicant)
- preganglionic fibers are small myelinated fibers that travel form spinal nerve to the ganglion via white communicating ramus (myelinated)
- postganglionic fibers leave the ganglion by via gray communicating ramus (unmyelinated)
  - forms a bridge back to the spinal nerve
  - postganglionic fibers extend to target organ

Sympathetic Chain Ganglia

Preganglionic Pathways

3 pathways of preganglionic neurons entering sympathetic chain

Other ganglia of Sympathetic Nervous System

- collateral ganglia (prevertebral ganglia)
- Some preganglionic fibers pass thru sympathetic chain
  - form splanic nerves
  - synapse in collateral (prevertebral ganglia)

contribute to a network called the abdominal aortic plexus
- three major collateral ganglia in this plexus
  - celiac, superior mesenteric, and inferior mesenteric
  - postganglionic fibers accompany these arteries and their branches to their target organs
- solar plexus – collective name for the celiac and superior mesenteric ganglia
  - nerves radiate from ganglia like rays of the sun

Efferent Pathways of sympathetic division
Adrenal Glands

- **two glands** with different functions
  - adrenal cortex (outer layer)
    - secretes steroid hormones
  - adrenal medulla (inner core)
    - **essentially a sympathetic ganglion**
      - stimulated by preganglionic sympathetic neurons that terminate on these cells
    - secretes a mixture of hormones into bloodstream
      - catecholamines - 85% epinephrine (adrenaline) and 15% norepinephrine (noradrenaline)
        - also function as neurotransmitters
  - **sympathoadrenal system** is adrenal medulla and sympathetic nervous system

Parasympathetic Division

- **parasympathetic division** (aka craniosacral division)
  - origin of long preganglionic neurons
    - midbrain, pons, and medulla (III, VII, IX, X)
    - sacral spinal cord segments S2-S4
  - **terminal ganglia** in or near target organs
    - long preganglionic, short postganglionic fibers

Parasympathetic Cranial Nerves

- Oculomotor nerve (III)
  - narrows pupil and focuses lens
- Facial nerve (VII)
  - tear, nasal and salivary glands
- Glossopharyngeal nerve (IX)
  - parotid salivary gland
- Vagus nerve (X)
  - vescera as far as proximal half of colon
    - cardiac, pulmonary, and esophageal plexus

Efferent Pathways

- **form pelvic splanchnic nerves** that lead to the inferior hypogastric plexus
- most form pelvic nerves to their terminal ganglion on the target organs
  - distal half of colon, rectum, urinary bladder, and reproductive organs

Summary of Sympathetic Innervation

- **effectors in body wall** are innervated by sympathetic fibers in spinal nerves
- **effectors in head and thoracic cavity** are innervated by fibers in sympathetic nerves
- **effectors in abdominal cavity** are innervated by sympathetic fibers in splanchnic nerves
Enteric Nervous System

- **enteric nervous system** – nervous system of the digestive tract
  - does not arise from the brainstem or spinal cord
  - innervates smooth muscle and glands
- semiautonomous
- has its own reflex arcs
- regulates motility of esophagus, stomach, and intestines and secretion of digestive enzymes and acid
- normal digestive function also requires regulation by sympathetic and parasympathetic systems

Neurotransmitters and Receptors

- how can different autonomic neurons have different effects? constricting some vessels but dilating others
  - effects determined by types of neurotransmitters released and types of receptors found on target cells
- 2 fundamental reasons:
  - sympathetic and parasympathetic fibers secrete different neurotransmitters
  - target cells respond to the same neurotransmitter differently depending upon the type of receptor they have for it
    - all autonomic fibers secrete either acetylcholine or norepinephrine
    - there are 2 classes of receptors for each of these neurotransmitters

Acetylcholine (ACh)

- ACh is secreted by all preganglionic neurons in both divisions and the postganglionic parasympathetic neurons
  - cholinergic fibers
  - any receptor that binds it is called cholinergic receptor
- 2 types of cholinergic receptors
  - muscarinic receptors
    - all cardiac muscle, smooth muscle, and gland cells have muscarinic receptors
    - excitatory or inhibitory due to subclasses of muscarinic receptors
  - nicotinic receptors
    - on all ANS postganglionic neurons, and at neuromuscular junctions of skeletal muscle
    - excitatory when ACh binding occurs

Norepinephrine (NE)

- NE is secreted by nearly all sympathetic postganglionic neurons
  - called adrenergic fibers
  - receptors for it called adrenergic receptors
    - alpha-adrenergic receptors
      - usually excitatory
      - 2 subclasses use different second messengers ($\alpha_1$ & $\alpha_2$)
    - beta-adrenergic receptors
      - usually inhibitory
      - 2 subclasses with different effects, but both act through cAMP as a second messenger ($\beta_1$ & $\beta_2$)

Overview

- **autonomic effects on glandular secretion** are often an indirect result of their effect on blood vessels
  - vasodilation – increased blood flow – increased secretion
  - vasoconstriction – decreased blood flow – decreased secretion
- **sympathetic effects tend to last longer** than parasympathetic effects
  - ACh released by parasympathetics is broken down quickly at synapse
  - NE by sympathetic is reabsorbed by nerve, diffuses to adjacent tissues, and much passes into bloodstream
- many substances released as neurotransmitters that modulate ACh and NE function
  - sympathetic fibers also secrete enkephalin, substance P, neuropeptide Y, somatostatin, neurotensin, or gonadotropin-releasing hormone
  - parasympathetic fibers stimulate endothelial cells to release the gas, nitric oxide – causes vasodilation by inhibiting smooth muscle tone
    - function is crucial to penile erection - means of action of Viagra

Figure 15.8
Dual Innervation

- dual innervation - most viscera receive nerve fibers from both parasympathetic and sympathetic divisions
  - antagonistic effect – oppose each other
  - cooperative effects – two divisions act on different effectors to produce a unified overall effect
- both divisions do not normally innervate an organ equally
  - digestion, heart rate

Dual Innervation of the Iris

![Image of the iris with dual innervation labels]

Figure 15.9

Without Dual Innervation

- some effectors receive only sympathetic fibers
  - adrenal medulla, arrector pili muscles, sweat glands and many blood vessels
- control of blood pressure and routes of blood flow
- sympathetic vasomotor tone - a baseline firing frequency of sympathetics
  - keeps vessels in state of partial constriction
  - increase in firing frequency - vasoconstriction
  - decrease in firing frequency - vasodilation
  - can shift blood flow from one organ to another as needed
- sympathetic division acting alone can exert opposite effects on the target organ through control of blood vessels
  - during stress
    - blood vessels to muscles and heart dilate
    - blood vessels to skin constrict

Sympathetic and Vasomotor Tone

- sympathetic division prioritizes blood vessels to skeletal muscles and heart in times of emergency
- sympathetic vasoconstrict to minimize bleeding if injury occurs during stress or exercise
Control of Autonomic Function

- **ANS** regulated by several levels of CNS
  - **cerebral cortex** has an influence — anger, fear, anxiety
    - powerful emotions influence the ANS because of the connections between our limbic system and the hypothalamus
  - **hypothalamus** - major visceral motor control center
    - nuclei for primitive functions — hunger, thirst, sex
  - **midbrain, pons, and medulla oblongata** contain:
    - nuclei for cardiac and vasomotor control, salivation, swallowing, sweating, bladder control, and pupillary changes
  - **spinal cord reflexes**
    - defecation and micturition reflexes are integrated in spinal cord
    - we control these functions because of our control over skeletal muscle sphincters...

Visceral Reflexes

- **visceral reflexes** - unconscious, automatic, stereotyped responses to stimulation involving visceral receptors and effectors and somewhat slower responses
- **visceral reflex arc**
  - **receptors** — nerve endings that detect stretch, tissue damage, blood chemicals, body temperature, and other internal stimuli
  - **afferent neurons** — leading to the CNS
  - **interneurons** — in the CNS
  - **efferent neurons** — carry motor signals away from the CNS
  - **effectors** — that make adjustments
- **ANS modifies effector activity**

Visceral Reflex to High BP