CHAPTER 14: THE AUTONOMIC NERVOUS SYSTEM AND HOMEOSTASIS

MODULE 14.1 OVERVIEW OF THE AUTONOMIC NERVOUS SYSTEM

OVERVIEW OF THE AUTONOMIC NERVOUS SYSTEM

Autonomic nervous system (**ANS**) is involuntary arm of **peripheral nervous system** (**PNS**); also known as *visceral motor division*

- Divided into two separate divisions, **sympathetic** and **parasympathetic** nervous systems; constantly work <u>together</u> to maintain *homeostasis*
- Oversees most *vital functions* including heart rate, blood pressure, and digestive and urinary processes autonomously <u>without</u> *conscious control*

FUNCTIONS OF THE ANS AND VISCERAL REFLEX ARCS

ANS manages vital process through a series of events called **visceral reflex arcs**, in which a *sensory stimulus* leads to a predictable *motor response*; following events summarize these reflexes (**Figure 14.1**):

- Sensory signals from viscera and skin are sent by *afferent sensory neurons* to brain or spinal cord where they are integrated by CNS

FUNCTIONS OF THE ANS AND VISCERAL REFLEX ARCS

- Next, motor impulses from CNS are sent out via *efferent neurons* in cranial and spinal nerves; usually lead to **autonomic ganglia** in PNS
- Lastly, autonomic ganglia send impulses via <u>other</u> *efferent neurons* to various target organs where they trigger a motor response
- Visceral reflex arcs provide another example of **Cell-Cell Communication Core Principle**

COMPARISON OF SOMATIC AND AUTONOMIC NERVOUS SYSTEMS

- Main *differences* between motor divisions of PNS (**Figure 14.2**):
  - Recall that **somatic motor division** neurons innervate skeletal muscle; leads to voluntary muscle contractions, initiated consciously (**Figure 14.2a**)
  - **Autonomic motor division** neurons innervate smooth muscle cells, cardiac muscle cells, and glands; produce *involuntary* actions

COMPARISON OF SOMATIC AND AUTONOMIC NERVOUS SYSTEMS

- Main differences (continued):
  - ANS motor neurons do <u>not</u> *directly* innervate their target like somatic motors neurons; require a two-neuron circuit (**Figure 14.2b**):
    - **Preganglionic neuron** – initial efferent neuron; cell body resides within *CNS*; all axons release *acetylcholine*
    - **Postganglionic neuron** – cell body resides in *autonomic ganglion* in PNS; axons travel to target cells; trigger specific changes (inhibitory or excitatory responses) by releasing <u>either</u> *acetylcholine* or *norepinephrine*

DIVISIONS OF THE ANS

Main *structural* and *functional* differences between sympathetic and parasympathetic nervous systems include:

- **Sympathetic nervous system** – preganglionic axons are usually *short* and postganglionic axons are usually *long*
- **Parasympathetic nervous system** – preganglionic parasympathetic axons are *long* while postganglionic axons are *short*

DIVISIONS OF THE ANS

- **Sympathetic nervous system** exhibits following characteristics (**Figure 14.3**):
  - Preganglionic cell bodies originate in *thoracic* and upper *lumbar* spinal cord giving rise to name, **thoracolumbar division**
  - **Sympathetic ganglia** are generally located *near spinal cord*, where preganglionic axons synapse with postganglionic neuron cell bodies; postganglionic axons proceed to target

DIVISIONS OF THE ANS

- **Sympathetic nervous system** characteristics (continued):
  - "**Fight or flight**" division of ANS; prepares body for *emergency situations*
  - Vital role in maintenance of homeostasis when body is engaged in *physical work*
  - Mediates body's responses to *emotion*

DIVISIONS OF THE ANS

- **Parasympathetic nervous system** exhibits following characteristics:
  - Preganglionic cell bodies are located within nuclei of several cranial nerves in *brainstem* and *sacral region* of spinal cord giving rise to name, **craniosacral division**
  - **Cranial nerves** innervate structures of *head* and *neck*, *thoracic viscera*, and <u>most</u> *abdominal viscera*

DIVISIONS OF THE ANS

- **Parasympathetic nervous system** characteristics (continued):
  - **Sacral nerves** innervate structures within *pelvic cavity*
  - Cell bodies of postganglionic neurons are usually located *near target organ*; requires only a short axon to make connection
  - "**Rest and digest**" division; role in *digestion* and in maintaining body's homeostasis at *rest*

DIVISIONS OF THE ANS

- **Balance between parasympathetic and sympathetic nervous systems**: actions of parasympathetic division directly *antagonize* those of sympathetic division; together, maintain a delicate *balance* to ensure that homeostasis is preserved

MODULE 14.2 THE SYMPATHETIC NERVOUS SYSTEM

GROSS AND MICROSCOPIC ANATOMY OF SYMPATHETIC NERVOUS SYSTEM

"Fight or flight system" – anatomical features are summarized as follows (**Figures 14.4**, **14.5**):

- **Sympathetic chain ganglia** – where most of postganglionic cell bodies are found; run down both sides *parallel* with vertebral column (**Figure 14.4**); "chainlike" appearance (hence name)
  - Section of chain that extends above thoracic spinal cord terminates in **superior cervical ganglion**
  - Section of chain that extends below lumbar spinal cord terminates in **inferior sacral ganglion**

GROSS AND MICROSCOPIC ANATOMY OF SYMPATHETIC NERVOUS SYSTEM

- **Preganglionic neurons** originate in lateral horns of *thoracic* and *lumbar* spinal cord; exit with axons of lower motor neurons via *anterior root*
- Preganglionic axons quickly *separate* from spinal nerve anterior ramus to form a small nerve called **white** (**myelinated**) **rami communicantes**; leads to postganglionic cell bodies in *sympathetic chain ganglion*

GROSS AND MICROSCOPIC ANATOMY OF SYMPATHETIC NERVOUS SYSTEM

- Some preganglionic axons pass *through* chain ganglia without forming synapses; may form synapses with **collateral ganglia** located *near target organ*
- Preganglionic axons that synapse with collateral ganglia near *organs of abdominopelvic cavity* are components of **splanchnic nerves**

Gross and Microscopic Anatomy of Sympathetic Nervous System

- Three *synapse locations* are possible between pre- and postganglionic neuron (**Figure 14.5**):
  - Preganglionic axons can synapse with postganglionic cell bodies in *sympathetic chain ganglion* at level of spinal cord *where they exited*
  - Preganglionic axons can *ascend* or *descend* to synapse with postganglionic cell bodies in sympathetic chain ganglia found at a <u>different</u> *spinal cord level* than where they exited
  - Preganglionic axons can pass <u>through</u> chain ganglia and travel to *collateral ganglia* where they synapse

Gross and Microscopic Anatomy of Sympathetic Nervous System

- Postganglionic axons exit ganglia as small **gray** (**unmyelinated**) **rami communicantes**; reunite to travel with *spinal nerves* until they reach their target cells

Sympathetic Neurotransmitters and Receptors

- **Neurotransmitters** bind to specific protein-based **receptors** embedded in plasma membranes of target cells; following slides summarize sympathetic nervous system neurotransmitters and target cell receptors with which they bind

Sympathetic Neurotransmitters and Receptors

- **Sympathetic neurotransmitters** (continued):
  - **Acetylcholine** (**ACh**) – neurotransmitter used in *excitatory* synapses between sympathetic preganglionic axons and postganglionic neurons; postganglionic axons then transmit action potentials to target cell
  - At synapse with their *target cells*, postganglionic axons release one of three neurotransmitters: **ACh**, **epinephrine** (**adrenalin**), or **norepinephrine** (**noradrenalin**; most frequently utilized neurotransmitter released into synapses between postganglionic axons and target cells)

Sympathetic Neurotransmitters and Receptors

- **Classes of sympathetic receptors**: **Adrenergic receptors** bind to *epinephrine* and *norepinephrine*; two major types of adrenergic receptors, alpha and beta, are further classified into subtypes:
  - **Alpha-1 receptors** – in plasma membranes of *smooth muscle cells* of many different organs, including blood vessels in skin, GI tract, and kidneys, arrector pili muscles in dermis, and certain organs of genitourinary tract
  - **Alpha-2 receptors** – in plasma membranes of *preganglionic sympathetic neurons* instead of in peripheral target cells

Sympathetic Neurotransmitters and Receptors

- **Classes of sympathetic receptors: Adrenergic receptor** subtypes (continued):
  - **Beta-1 receptors** – in plasma membranes of *cardiac muscle* cells, certain *kidney* cells, and *adipose* cells
  - **Beta-2 receptors** – in plasma membranes of *smooth muscle cells* lining airways of respiratory tract (bronchioles), and in wall of urinary bladder, *skeletal muscle*

fibers, and cells found in *liver*, *pancreas*, and *salivary glands*
  - **Beta-3 receptors** – primarily in *adipose* cells and *smooth muscle cells* in walls of digestive tract

SYMPATHETIC NEUROTRANSMITTERS AND RECEPTORS

- **Classes of sympathetic receptors: Cholinergic receptors** bind to *acetylcholine*; include two types:
  - **Muscarinic receptors** – on *sweat glands* in skin
  - **Nicotinic receptors** – in membranes of all *postganglionic neurons* within sympathetic ganglia and adrenal medullae

SYMPATHETIC NEUROTRANSMITTERS AND RECEPTORS

- **Alpha-2 receptors** differ from other adrenergic receptor subtypes (**Figure 14.6a**):
  - Usually, action potential in a preganglionic neuron leads to ACh release; *stimulates* postganglionic neuron
  - When norepinephrine binds to alpha-2 receptors, axon terminal is *hyperpolarized*; slows or cancels action potential
- Component of a *negative feedback loop* where preganglionic neuron activity is reduced or shut down to prevent excessive sympathetic output; example of **Feedback Loops Core Principle**

SYMPATHETIC NEUROTRANSMITTERS AND RECEPTORS

- **Pharmacology and sympathetic nervous system receptors**: different subtypes of sympathetic nervous system receptors have provided *targets for medication therapy* for many different disease states, including asthma and hypertension

EFFECTS OF SYMPATHETIC NERVOUS SYSTEM ON TARGET CELLS

Effects of SNS on target cells – directed at ensuring *survival* and maintenance of homeostasis during time of *physical* or *emotional stress* (**Figures 14.7**, **14.8**):

- **Effects on cardiac muscle cells**: when norepinephrine binds to *beta-1 receptors* it causes following changes (**Figure 14.7**):
  - Ion channels open on cardiac muscle cells; raises both *rate* and *force* of contraction
  - Amount of *blood delivered to tissues* and *blood pressure* both increase; maintains homeostasis during increased physical activity

EFFECTS OF SYMPATHETIC NERVOUS SYSTEM ON TARGET CELLS

- **Effects on smooth muscle cells**: when norepinephrine binds to specific receptors it mediates following changes (**Figure 14.7**):
  - **Constriction of blood vessels serving digestive**, **urinary**, **and integumentary system** – occurs when norepinephrine binds to *alpha-1 receptors*; decreases *blood flow* to these organs
  - **Dilation of bronchioles** occurs when norepinephrine binds to *beta-2* receptors; increases amount of *air that can be inhaled* with each breath

EFFECTS OF SYMPATHETIC NERVOUS SYSTEM ON TARGET CELLS

- **Effects on smooth muscle cells** (continued):
  - **Dilation of blood vessels serving skeletal and cardiac muscle** – occurs when norepinephrine binds to *beta-2 receptors*; <u>increases</u> *blood flow*; allows for an increase in physical activity
  - **Contraction of urinary and digestive sphincters** – occurs when norepinephrine binds to *beta-2* and *beta-3* receptors respectively; makes *emptying bladder* and *bowel* more <u>difficult</u> during increased physical activity

EFFECTS OF SYMPATHETIC NERVOUS SYSTEM ON TARGET CELLS

- **Effects on smooth muscle cells** (continued):
  - **Relaxation of smooth muscle of digestive tract** – occurs when norepinephrine binds to *beta-2 receptors*; <u>slows</u> *digestion* during increased physical activity
  - **Dilation of pupils** – occurs when norepinephrine binds to *alpha-1* receptors; causes dilator pupillae muscles to contract; causes pupil to allow <u>more</u> *light* into eye
  - **Constriction of blood vessels serving most exocrine glands** – occurs when norepinephrine binds to beta receptors on blood vessels serving various glands (like salivary glands); decreases secretion, <u>except</u> in sweat glands

EFFECTS OF SYMPATHETIC NERVOUS SYSTEM ON TARGET CELLS

- **Effects on cellular metabolism**: during times of sympathetic activation, nearly all cells, especially skeletal muscle, require *higher amounts of ATP*; to meet this higher energy demand norepinephrine has three effects when it binds to:
  - Beta-3 receptors on adipocytes; triggers *breakdown of lipids*; releases *free fatty acids* into bloodstream
  - Beta-2 receptors on liver cells; triggers *release of glucose* from glycogen and *synthesis of glucose* from other resources
  - Binds to beta-2 receptors on cells of pancreas; triggers release of hormone **glucagon**; <u>increases</u> *blood glucose levels*

EFFECTS OF SYMPATHETIC NERVOUS SYSTEM ON TARGET CELLS

- **Effects on secretion from sweat glands**: sympathetic nervous system attempts to *maintain body temperature* homeostasis during periods of increased physical activity
  - Postganglionic sympathetic neurons release ACh onto sweat gland cells in skin
  - ACh binds to muscarinic receptors that <u>increase</u> *sweat gland secretion*
- This is a component of a negative feedback loop that corrects elevated body temperature; example of **Feedback Loops Core Principle**

EFFECTS OF SYMPATHETIC NERVOUS SYSTEM ON TARGET CELLS

- **Effects on cells of adrenal medulla**: adrenal medulla sits on top of each kidney; in direct contact with preganglionic sympathetic neurons; medulla is composed of *modified sympathetic postganglionic neurons* with following functions (**Figure 14.8**):

Effects of Sympathetic Nervous System on Target Cells

- **Effects on cells of adrenal medulla** (continued):
  - ACh is released from preganglionic neurons; binds to *nicotinic receptors* on adrenal medulla cells
  - ACh stimulates medullary cells to release *norepinephrine* and *epinephrine* into bloodstream; considered **hormones** rather than neurotransmitters
  - Act as *long-distance* chemical messengers; *interface* between endocrine and sympathetic nervous systems

Effects of Sympathetic Nervous System on Target Cells

- **Effects on other cells**: sympathetic nervous system influences many other target cells, all with mission of maintaining homeostasis during increased physical or emotional stress
  - Enhances *mental alertness* by increasing neuron activity in association areas of cerebral cortex
  - Temporarily increases *tension generated* by skeletal muscle cells during a muscle contraction; why people have been known to perform unusual feats of strength under influence of an "adrenaline (epinephrine) rush"

Effects of Sympathetic Nervous System on Target Cells

- **Effects on other cells** (continued):
  - Increases blood's tendency to *clot*, which can be useful if a person is injured during a "fight" or a "flight" situation
  - Postganglionic sympathetic neurons trigger *contraction of arrector pili muscles*, which produces "**goose bumps**"
  - Cause *ejaculation* of semen via effects on smooth muscle cells of male reproductive ducts

Sympathetic NS and Weight Loss Supplements

- Effect of sympathetic nervous system is to increase **metabolic rate**, or increase rate **ATP** is *produced* and *consumed*
- Dietary supplement manufacturers create products intended to result in *weight loss* by capitalizing on this effect; generally sold as *topical creams* that user rubs over "problem areas" with excess adipose tissue
- One chemical found in many of these creams is **Yohimbe**, a plant that contains the active agent **Yohimbine**

Sympathetic NS and Weight Loss Supplements

- Manufacturers claim yohimbine binds to beta-3 receptors on adipocytes and triggers breakdown of lipids; at best, this is misleading; actually blocks alpha-1 receptors in blood vessels and alpha-2 receptors in spinal cord; causes *vasodilation* while also increasing activity of sympathetic neurons which can briefly increase *metabolic rate*
- Can also dangerously elevate heart rate; cause seizures, high blood pressure, and kidney failure; and lead to insomnia and panic attacks

SYMPATHETIC NS AND WEIGHT LOSS SUPPLEMENTS

- Fortunately, yohimbine is not actually *absorbed through epidermis* in any significant amount, so it never reaches blood vessels in dermis and hypodermis; limits amount of harm it can do to your body

MODULE 14.3 THE PARASYMPATHETIC NERVOUS SYSTEM

GROSS AND MICROSCOPIC ANATOMY OF PARASYMPATHETIC NERVOUS SYSTEM

"**Rest and digest**" division of ANS

- Role in body's *maintenance functions*, such as digestion and urine formation
- Known as **craniosacral division** based on association with *cranial nerves* and pelvic nerves from *sacral plexus* (**Figure 14.9**)

GROSS AND MICROSCOPIC ANATOMY OF PARASYMPATHETIC NERVOUS SYSTEM

- **Parasympathetic cranial nerves** – associated with **oculomotor** (CN III), **facial** (CN VII), **glossopharyngeal** (CN IX), and **vagus** (CN X) nerves
  - **Vagus nerves** – main parasympathetic nerves that innervate most *thoracic* and *abdominal viscera*
  - Branches of vagus nerves contribute to *cardiac*, *pulmonary*, and *esophageal plexuses*

GROSS AND MICROSCOPIC ANATOMY OF PARASYMPATHETIC NERVOUS SYSTEM

- **Parasympathetic cranial nerves** (continued):
  - Preganglionic axons in *oculomotor* (*CN III*) *nerve* synapse with **ciliary ganglia**
  - **Submandibular** and **pterygopalatine ganglia** house cell bodies of sensory neurons and synapse with *facial* (*CN VII*) *nerve*
  - *Glossopharyngeal* (*CN IX*) *nerve* preganglionic axons synapse with **otic ganglia**

GROSS AND MICROSCOPIC ANATOMY OF PARASYMPATHETIC NERVOUS SYSTEM

- **Parasympathetic sacral nerves** make up pelvic nerve component of this division; innervates last segment of *large intestine*, *urinary bladder*, and *reproductive organs*
  - Sacral nerve branches form **pelvic splanchnic nerves**; form plexuses in *pelvic floor*
  - Some preganglionic neurons synapse with terminal ganglia in associated plexuses; most synapse in terminal ganglia *within walls of target organs*

PARASYMPATHETIC NEUROTRANSMITTERS AND RECEPTORS

- Both pre- and postganglionic parasympathetic neurons release ACh at their synapses; effect is generally *excitatory*; two cholinergic receptors are components of this ANS division:
  - **Nicotinic receptors** – located in membranes of all *postganglionic neurons*
  - **Muscarinic receptors** – located in membranes of *all parasympathetic target cells*

EFFECTS OF PARASYMPATHETIC NERVOUS SYSTEM ON TARGET CELLS

- Following effects can be seen under influence of this system when body is at *rest* (**Figure 14.10**):
- **Effects on cardiac muscle cells**
  - Parasympathetic activity decreases *heart rate* and *blood pressure*
  - Preganglionic parasympathetic neurons travel to heart with *vagus nerve* (*CN X*)

EFFECTS OF PARASYMPATHETIC NERVOUS SYSTEM ON TARGET CELLS

- **Effects on smooth muscle cells**: postganglionic neurons innervate *smooth muscle cells* in many organs with following effects:
  - **Constriction of pupil** involves CN III, ciliary ganglion, and sphincter pupillae muscle; reduces *amount of light* allowed into eye
  - **Accommodation of lens for near vision** involves CN III and contraction of ciliary muscle; changes lens to a more *rounded shaped*

EFFECTS OF PARASYMPATHETIC NERVOUS SYSTEM ON TARGET CELLS

- **Effects on smooth muscle cells** (continued):
  - **Constriction of bronchioles** (**bronchoconstriction**) – involves CN X; reduces *air flow* through bronchioles
  - **Contraction of smooth muscle lining digestive tract** – involves CN X; produces rhythmic contractions called **peristalsis**; *propels food* through digestive tract
  - **Relaxation of digestive and urinary sphincters** – involves CN X and sacral nerves; promotes *urination* and *defecation*

EFFECTS OF PARASYMPATHETIC NERVOUS SYSTEM ON TARGET CELLS

- **Effects on smooth muscle cells** (continued):
  - **Engorgement of penis or clitoris** – occurs when stimulated by sacral nerves in male or female respectively
  - Although parasympathetic division only innervates specific blood vessels, many blood vessels dilate when system is activated, due to a reduction in *sympathetic activity*

EFFECTS OF PARASYMPATHETIC NERVOUS SYSTEM ON TARGET CELLS

- **Effects on glandular epithelial cells**: parasympathetic division has little effect on sweat glands but does *increase secretion* from other glands:
  - CN VII stimulation stimulates *tear* production from lacrimal glands and *mucus* production from glands in nasal mucosa
  - CN VII and IX stimulation leads to increased production of *saliva* from salivary glands

- CN X stimulates secretion of *enzymes* and other products from digestive tract cells

Effects of Parasympathetic Nervous System on Target Cells

- **Effects on other cells**: parasympathetic division has no direct effect on cells that mediate metabolic rate, mental alertness, force generated by skeletal muscle contractions, blood clotting, adipocytes, or most endocrine secretions
  - Each of above bodily functions *returns to a* “*resting*” *state* during periods of parasympathetic activity; allows for replenishment of glucose storage and other fuels
  - *Fuel replenishment* is critical for allowing sympathetic nervous system to function properly when needed

Side Effects of Anticholinergic Drugs

- Many drugs block either *ACh release* or *ACh receptors* as an unintended side effect; prescribed for many different conditions such as allergies, respiratory diseases, and gastrointestinal conditions; some of more common unwanted effects are:
  - **Urinary retention** – block relaxing effect that parasympathetic nervous system has on urinary sphincters, and makes *passing urine more difficult*
  - **Constipation** – block parasympathetic nervous system’s effect on smooth muscle of digestive tract; causes digested food to move more slowly through tract and can lead to *constipation*

Side Effects of Anticholinergic Drugs

- Many drugs block either *ACh release* or *ACh receptors* as an unintended side effect; prescribed for many different conditions such as allergies, respiratory diseases, and gastrointestinal conditions; some of more common unwanted effects are (continued):
  - **Dry mouth** – one of most common effects is a *dry mouth*, caused by a decrease in parasympathetic nervous system’s ability to stimulate secretion of saliva

Module 14.4 Homeostasis Part II: PNS Maintenance of Homeostasis

Interactions of Autonomic Divisions

- Sympathetic and parasympathetic divisions work *together* to keep many of body’s functions within their normal homeostatic ranges (**Figure 14.11**)
  - Both divisions innervate many of same organs where their actions *antagonize* one another, a condition called **dual innervation**
  - Dual innervation allows sympathetic division to become dominant and trigger effects that maintain homeostasis during *physically demanding periods*
  - Parasympathetic division regulates same organs, preserving homeostasis between periods of increased physical activity

AUTONOMIC TONE

- **Autonomic tone** refers to fact that neither division is <u>ever</u> completely *shut down*; constant amount of activity from each division
  - **Sympathetic tone** dominates in *blood vessels*; keeps them *partially constricted*
  - **Parasympathetic tone** dominates in *heart*; keeps heart rate at an average of *72 beats per minute*

SUMMARY OF NERVOUS SYSTEM CONTROL OF HOMEOSTASIS

- Maintenance of homeostasis is one of body's most essential functions; ANS plays a critical role (**Figure 14.12**)
  - Homeostasis is controlled centrally by *hypothalamus* and *brainstem reticular formation*; actions carried out by the two divisions of ANS
  - **Autonomic centers** – regions found in reticular formation that contact *hypothalamus*; contain neurons that control activity of preganglionic sympathetic and parasympathetic neurons

POSTURAL ORTHOSTATIC TACHYCARDIA SYNDROME

- **Postural orthostatic tachycardia syndrome** (**POTS**) – characterized by an abnormally large <u>increase</u> in *heart rate* (known as **tachycardia**) when an individual moves from lying or sitting down to *standing up*; inappropriate rise of heart rate is accompanied by vasodilation of most blood vessels; causes *blood pressure* to <u>drop</u> due to gravity
- **Symptoms** (from low blood pressure) include dizziness and lightheadedness, fatigue, and thirst; low blood pressure also reduces blood flow to organs, leading to shortness of breath, chest pain, cold extremities, and muscle weakness

POSTURAL ORTHOSTATIC TACHYCARDIA SYNDROME

- Fundamental cause of POTS has yet to be determined, but symptoms appear to be secondary to <u>excessive</u> *sympathetic activity* or *sensitivity of sympathetic receptors* to epinephrine and norepinephrine
- Normally, when a person stands up, sympathetic nervous system temporarily <u>increases</u> blood pressure to ensure that blood flow remains constant against force of gravity; sympathetic response then tapers off, and parasympathetic tone resumes control of heart rate

POSTURAL ORTHOSTATIC TACHYCARDIA SYNDROME

- In POTS, response to sympathetic stimulation is *exaggerated*, leading to characteristic symptoms
- **Treatment** for POTS generally consists of dietary modifications such as increasing water and salt intake; an exercise regimen; and medications to <u>block</u> sympathetic receptors
- Most patients will see some improvement in condition gradually, although some will struggle with it for remainder of their lives