

14

The Autonomic Nervous System and Homeostasis

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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 together to maintain *homeostasis*
- Oversees most *vital functions* including heart rate, blood pressure, and digestive and urinary processes autonomously without *conscious control*

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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 other efferent neurons to various target organs where they trigger a motor response
- Visceral reflex arcs provide another example of **Cell-Cell Communication Core Principle**

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MODULE 14.1 OVERVIEW OF THE AUTONOMIC NERVOUS SYSTEM

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

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FUNCTIONS OF THE ANS AND VISCERAL REFLEX ARCS

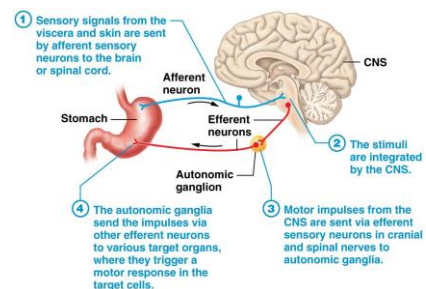


Figure 14.1 Visceral reflex arcs.

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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

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COMPARISON OF SOMATIC AND AUTONOMIC NERVOUS SYSTEMS



	STRUCTURE	TARGET	CONTROL
(a) Somatic nervous system		• Skeletal muscle fibers	Voluntary
(b) Autonomic nervous system		• Smooth and cardiac muscle cells OR • Glands	Involuntary

Figure 14.2 Comparison of the somatic and autonomic nervous systems.

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COMPARISON OF SOMATIC AND AUTONOMIC NERVOUS SYSTEMS

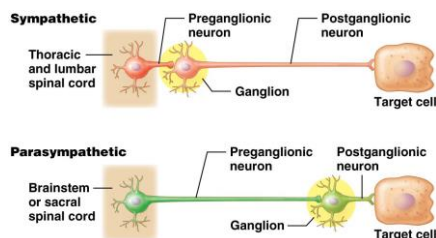
- Main differences (continued):
 - ANS motor neurons do not *directly* innervate their target like somatic motor neurons; require a two-neuron circuit (Figure 14.2b):
 - **Preganglionic neuron** – initial efferent neuron; cell body resides within *CNS*; all axons release *acetylcholine*
 - **Postganglionic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



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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*

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DIVISIONS OF THE ANS

- **Parasympathetic nervous system** exhibits the 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 most abdominal viscera*

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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*

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DIVISIONS OF THE ANS

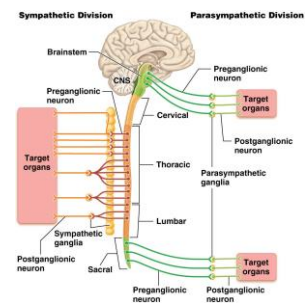


Figure 14.3 Overview of the structure of ANS divisions.

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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

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MODULE 14.2 THE SYMPATHETIC NERVOUS SYSTEM

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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**

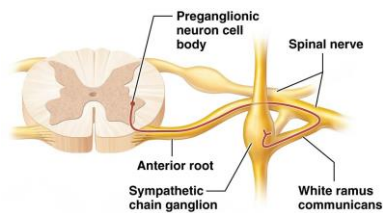
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GROSS AND MICROSCOPIC ANATOMY OF SYMPATHETIC NERVOUS SYSTEM

- **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



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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

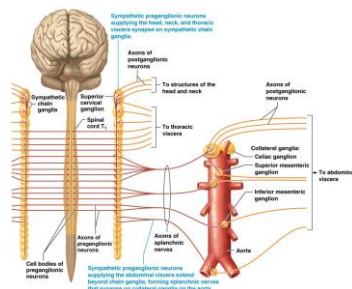


Figure 14.4 Organization of the sympathetic nervous system.

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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 different spinal cord level than where they exited
 - Preganglionic axons can pass through 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

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GROSS AND MICROSCOPIC ANATOMY OF SYMPATHETIC NERVOUS SYSTEM

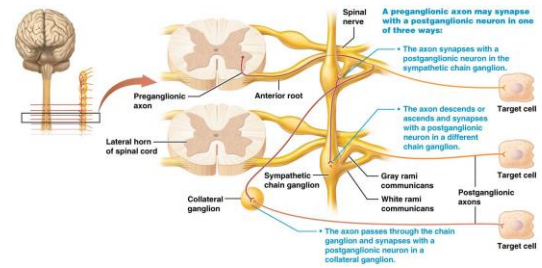


Figure 14.5 Three possible pathways of sympathetic preganglionic and postganglionic neurons.

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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

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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)

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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

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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

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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

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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**

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SYMPATHETIC NEUROTRANSMITTERS AND RECEPTORS

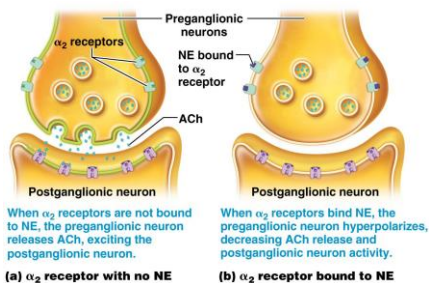


Figure 14.6 The effect of alpha-2 receptors on preganglionic neurons.

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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

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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

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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*; increases 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 difficult during increased physical activity

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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*; slows 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 more 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, except in sweat glands

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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**; increases blood glucose levels

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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 increase sweat gland secretion
- This is a component of a negative feedback loop that corrects elevated body temperature; example of **Feedback Loops Core Principle**

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EFFECTS OF SYMPATHETIC NERVOUS SYSTEM ON TARGET CELLS

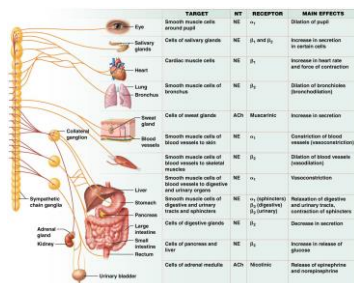


Figure 14.7 The main effects of the sympathetic nervous system on target cells.

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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**):

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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

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EFFECTS OF SYMPATHETIC NERVOUS SYSTEM ON TARGET CELLS

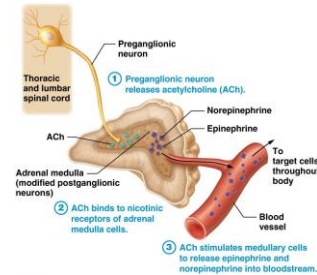


Figure 14.8 Sympathetic nervous system stimulation of the adrenal medulla.

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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”

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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

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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**

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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*

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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

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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**)

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GROSS AND MICROSCOPIC ANATOMY OF PARASYMPATHETIC NERVOUS SYSTEM

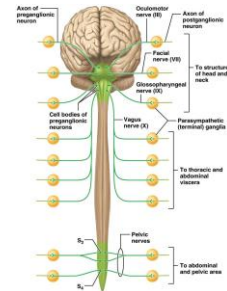


Figure 14.9 Organization of the parasympathetic nervous system.

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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*

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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**

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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*

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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*

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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)*

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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

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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*

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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*

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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

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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

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EFFECTS OF PARASYMPATHETIC NERVOUS SYSTEM ON TARGET CELLS

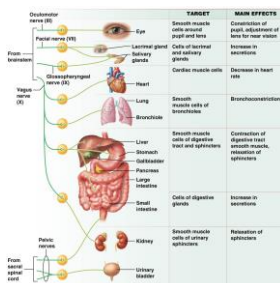


Figure 14.10 The main effects of parasympathetic nervous system on target cells.

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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*

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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

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MODULE 14.4 HOMEOSTASIS PART II: PNS MAINTENANCE OF HOMEOSTASIS

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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

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INTERACTIONS OF AUTONOMIC DIVISIONS

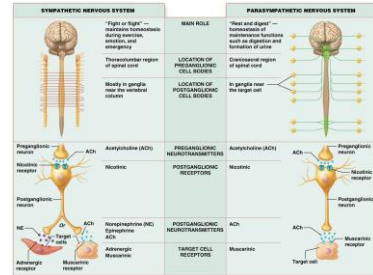


Figure 14.11 Comparison of sympathetic and parasympathetic nervous system structures and effects.

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AUTONOMIC TONE

- Autonomic tone** refers to fact that neither division is ever 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*

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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

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SUMMARY OF NERVOUS SYSTEM CONTROL OF HOMEOSTASIS

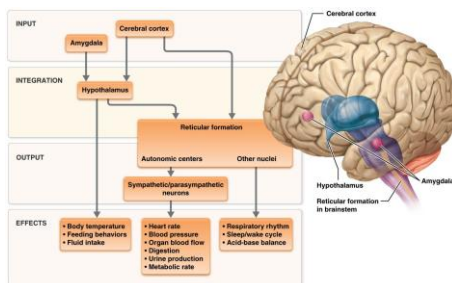


Figure 14.12 Summary of nervous system control of homeostasis.

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POSTURAL ORTHOSTATIC TACHYCARDIA SYNDROME

- Postural orthostatic tachycardia syndrome (POTS)** – characterized by an abnormally large increase 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 drop 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

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POSTURAL ORTHOSTATIC TACHYCARDIA SYNDROME

- Fundamental cause of POTS has yet to be determined, but symptoms appear to be secondary to excessive sympathetic activity or *sensitivity of sympathetic receptors* to epinephrine and norepinephrine
- Normally, when a person stands up, sympathetic nervous system temporarily increases 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

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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 block sympathetic receptors
- Most patients will see some improvement in condition gradually, although some will struggle with it for remainder of their lives

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