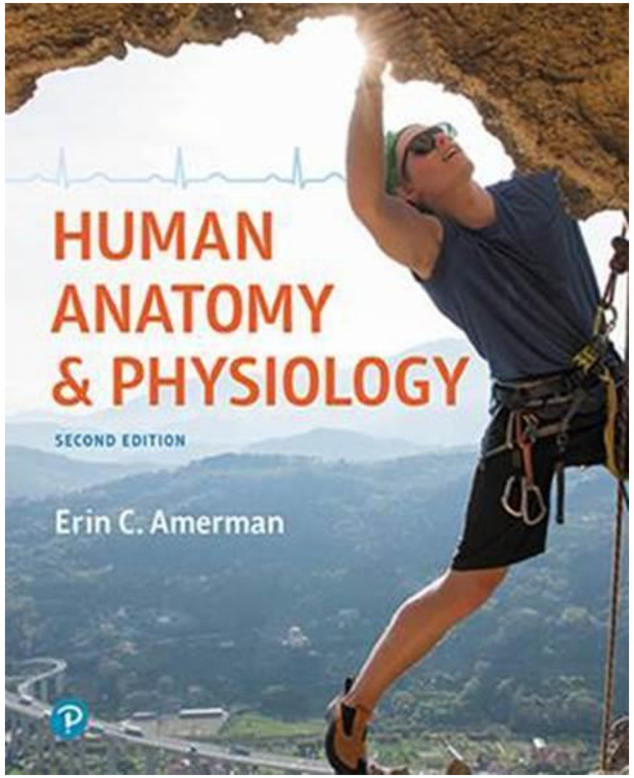
Human Anatomy & Physiology

Second Edition



Chapter 14

The Autonomic Nervous System and Homeostasis

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Pearson

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

Functions of the ANS and Visceral Reflex Arcs

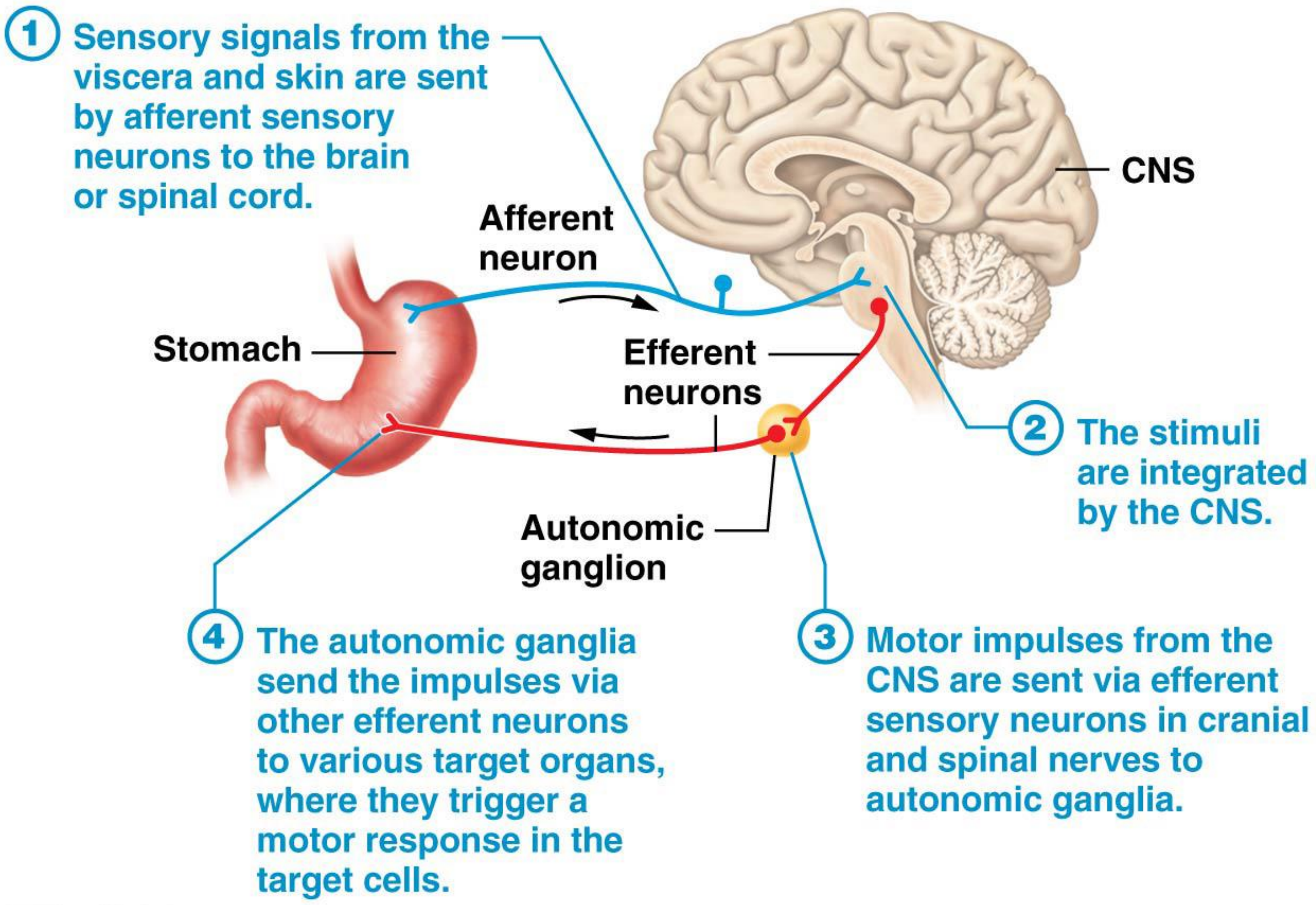
ANS manages vital process through a series of events called **visceral reflex arcs**, in which a *sensory stimulus* leads to a predictable *motor response*; following events summarize these reflexes:

- 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**

Functions of the ANS and Visceral Reflex Arcs



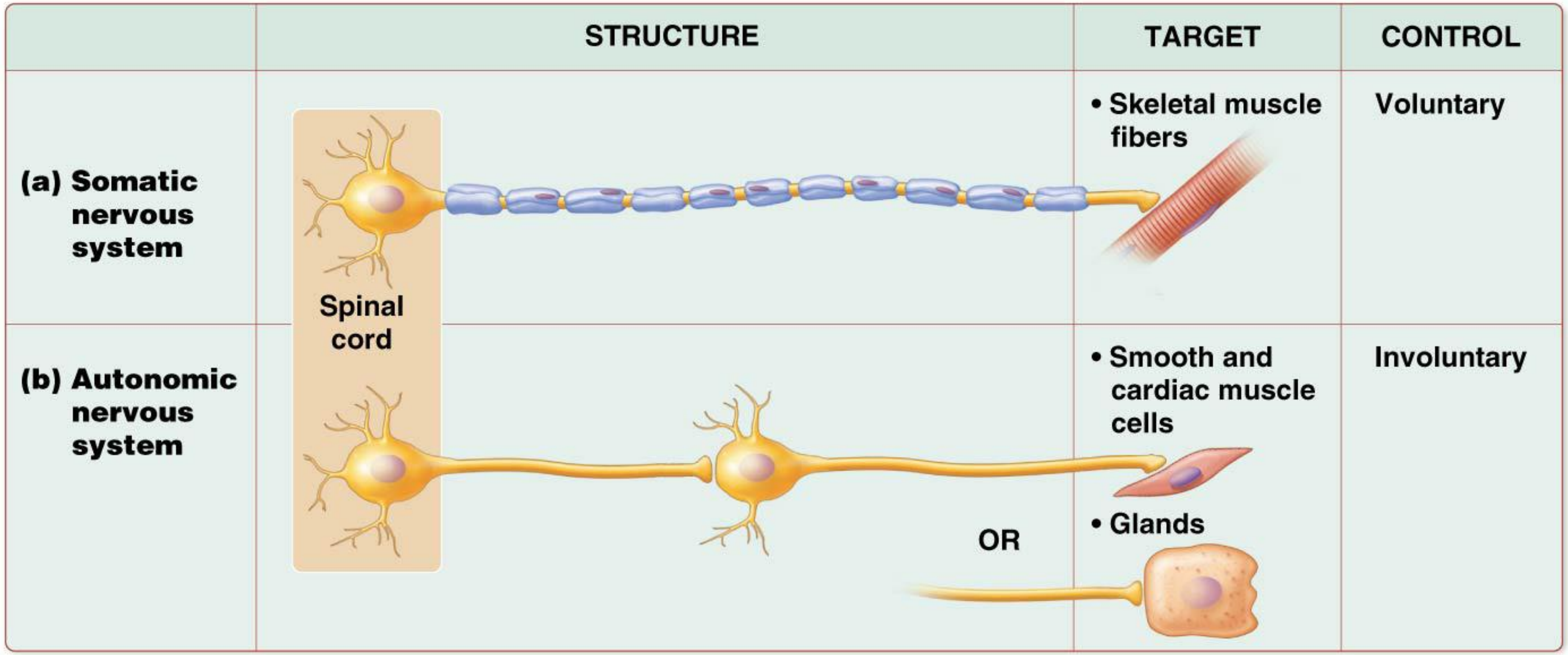
Comparison of Somatic and Autonomic Nervous Systems

- Main *differences* between motor divisions of PNS:
  - Recall that **somatic motor division** consists of somatic motor neurons that innervate skeletal muscle fibers; largely control *voluntary* muscle contractions, initiated consciously, somatic motor neurons directly innervate skeletal muscle fibers, which they stimulate by releasing acetylcholine
  - **Autonomic motor neurons** innervate smooth muscle cells, cardiac muscle cells, and glands; produce *involuntary* actions –See next slide

Comparison of Somatic and Autonomic Nervous Systems

- Main differences (continued):
  - In addition do <u>not</u> *directly* innervate their target cells, instead two neurons are involved:
    - **Preganglionic neuron** – initial efferent neuron; cell body resides in *CNS*; synapses on the cell body of the **Postganglionic neuron** within an *autonomic ganglion* in PNS; axon then triggers a change in the target cell by releasing various neurotransmitters, including ACh and norepinephrine. These may inhibit or stimulate their target cells.

Comparison of Somatic and Autonomic Nervous Systems

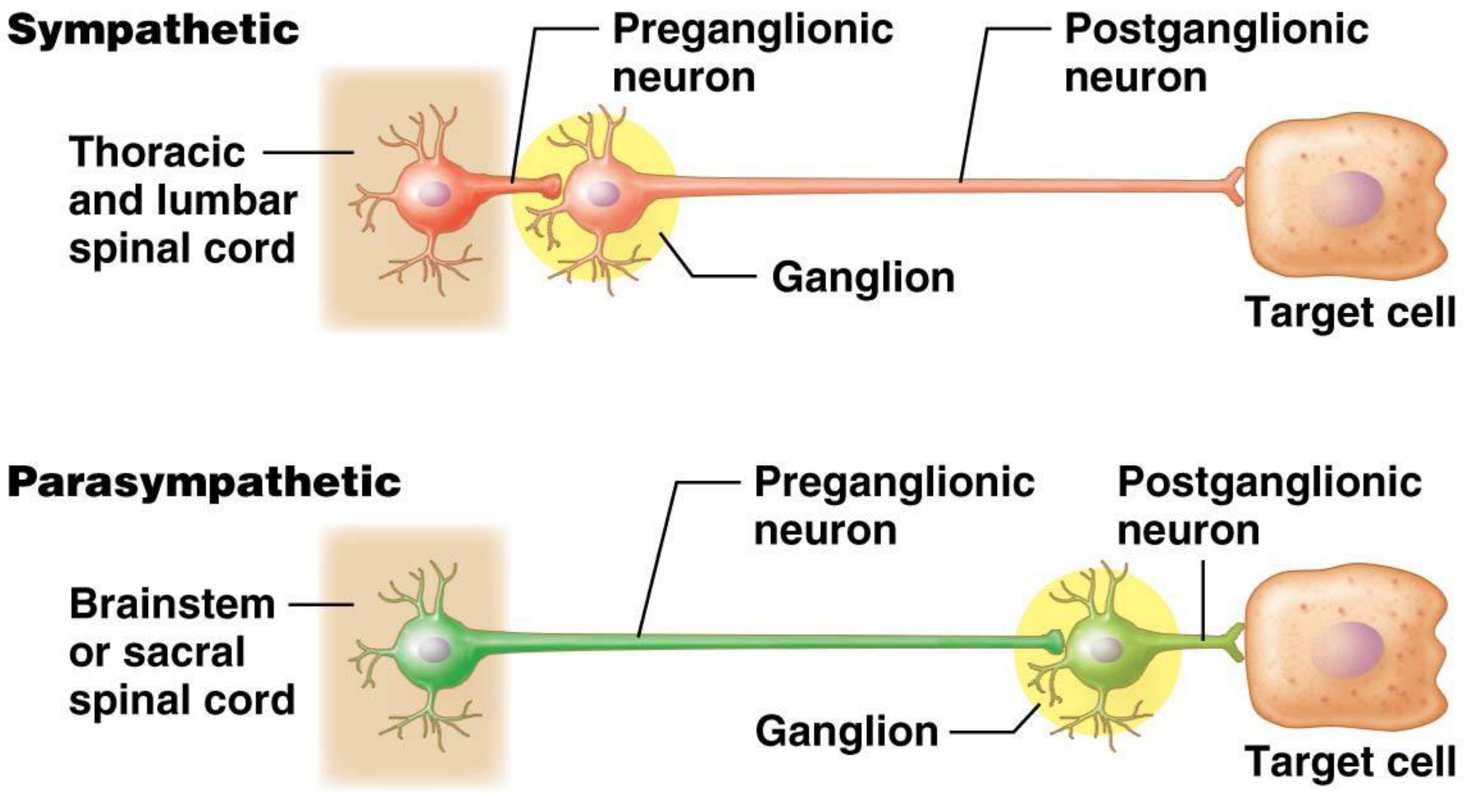


Divisions of the ANS

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

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

Divisions of the ANS



Divisions of the ANS

- **Sympathetic nervous system** exhibits following characteristics:
  - Preganglionic cell bodies originate in *thoracic* and upper *lumbar* spinal cord giving rise to name, **thoracolumbar division** of the ANS
  - These neurons synapse first in **sympathetic ganglia** which are generally located *near spinal cord*, postganglionic neurons innervate their target cells

Divisions of the ANS

- **Sympathetic nervous system** characteristics (continued):
  - "**Fight or flight**" division of ANS; prepares body for *emergency situations*
  - Maintains homeostasis when the body is engaged in any type of physical work and mediates the body's visceral responses to emotion

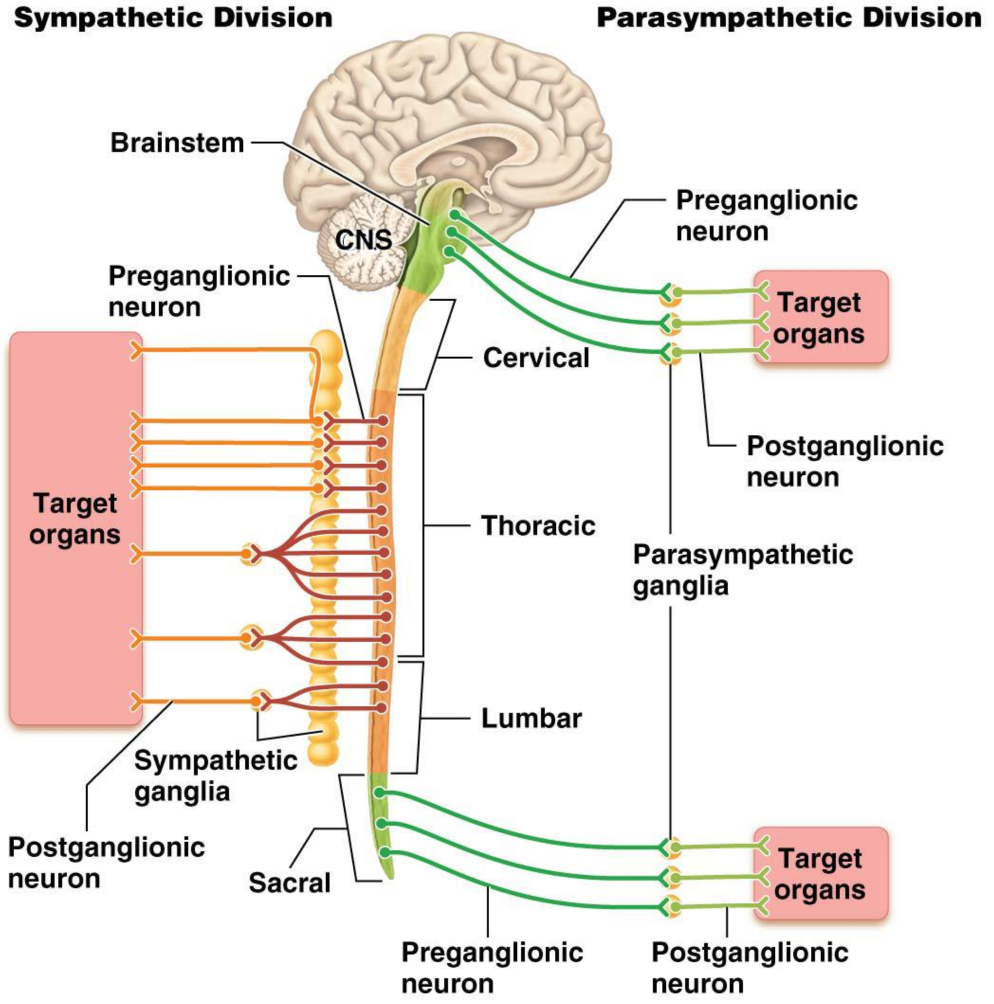
Divisions of the ANS

- **Parasympathetic nervous system** exhibits the following characteristics:
  - Preganglionic cell bodies are located within nuclei of several cranial nerves in *brainstem* and in *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*

Divisions of the ANS

- **Parasympathetic nervous system** characteristics (continued):
  - **Sacral nerves** innervate structures within *pelvic cavity*
  - As in the sympathetic division, the preganglionic neurons synapse first in the parasympathetic ganglia, and the postganglionic neurons then innervate the target organs.
  - Ganglia of the parasympathetic neurons are typically located near or within the target organs
  - "**Rest and digest**" division; role in *digestion* and in maintaining body's homeostasis at *rest*

Divisions of the ANS



Divisions of the ANS

- **Balance between parasympathetic and sympathetic nervous systems**: actions of parasympathetic nervous system directly *antagonize* those of sympathetic nervous system; together, maintain a delicate *balance* to ensure that homeostasis is maintained at all times

Study Boost: Remembering the Difference between Pre- and Postganglionic Neurons

Remember:

- Ganglion – cluster of neuronal cell bodies
- Prefixes *pre*- and *post*- mean “before” and “after,” respectively
- So, *pre*ganglionic neuron is neuron that comes *before* ganglion; *post*ganglionic neuron is one whose cell body is located <u>within</u> ganglion, and whose axon comes *after* ganglion

Study Boost: Remembering the Difference between Pre- and Postganglionic Neurons

- If you still find yourself getting confused with terminology, try to associate different words with “pre-” and “post-” that are easy to remember
- For example, something as simple as “first neuron” and “second neuron” may remind you of positions of pre- and postganglionic neurons in pathway

Module 14.2 The Sympathetic Nervous System

Gross and Microscopic Anatomy of Sympathetic Nervous System

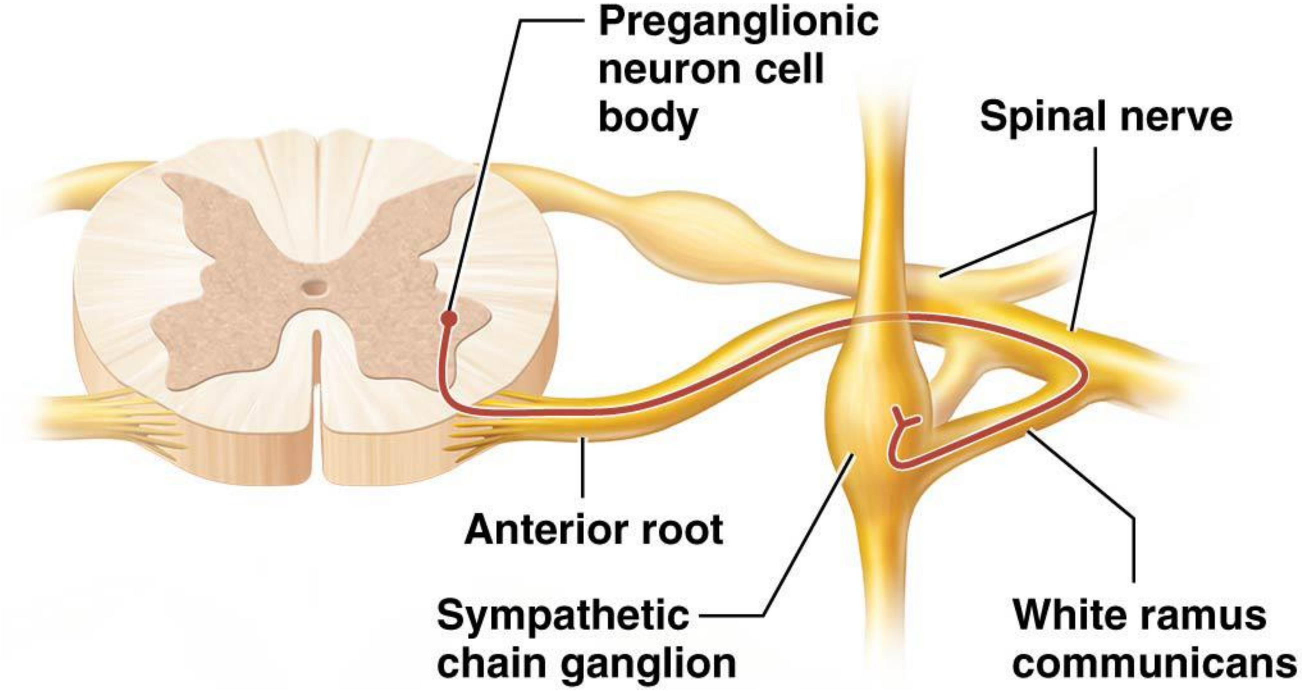
"Fight or flight system" – anatomical features are summarized as follows:

- Most of the cell bodies of postganglionic neurons are found in a series along the vertebral column, chain like appearance, has given them the name **sympathetic chain ganglia**;
- Sympathetic chain ganglia extend beyond thoracic and lumbar spinal cord, from the **superior cervical ganglion** down to the inferior sacral ganglion

Gross and Microscopic Anatomy of Sympathetic Nervous System

- **Preganglionic neurons** originate in lateral horns of *thoracic* and *lumbar* spinal cord; axons of preganglionic neurons exit the spinal cord with the axons of the lower motor neurons via the anterior root. They then travel with the spinal nerve and the anterior ramus for a short distance before branching off to form small nerves called **white rami communicantes**. See next slide.

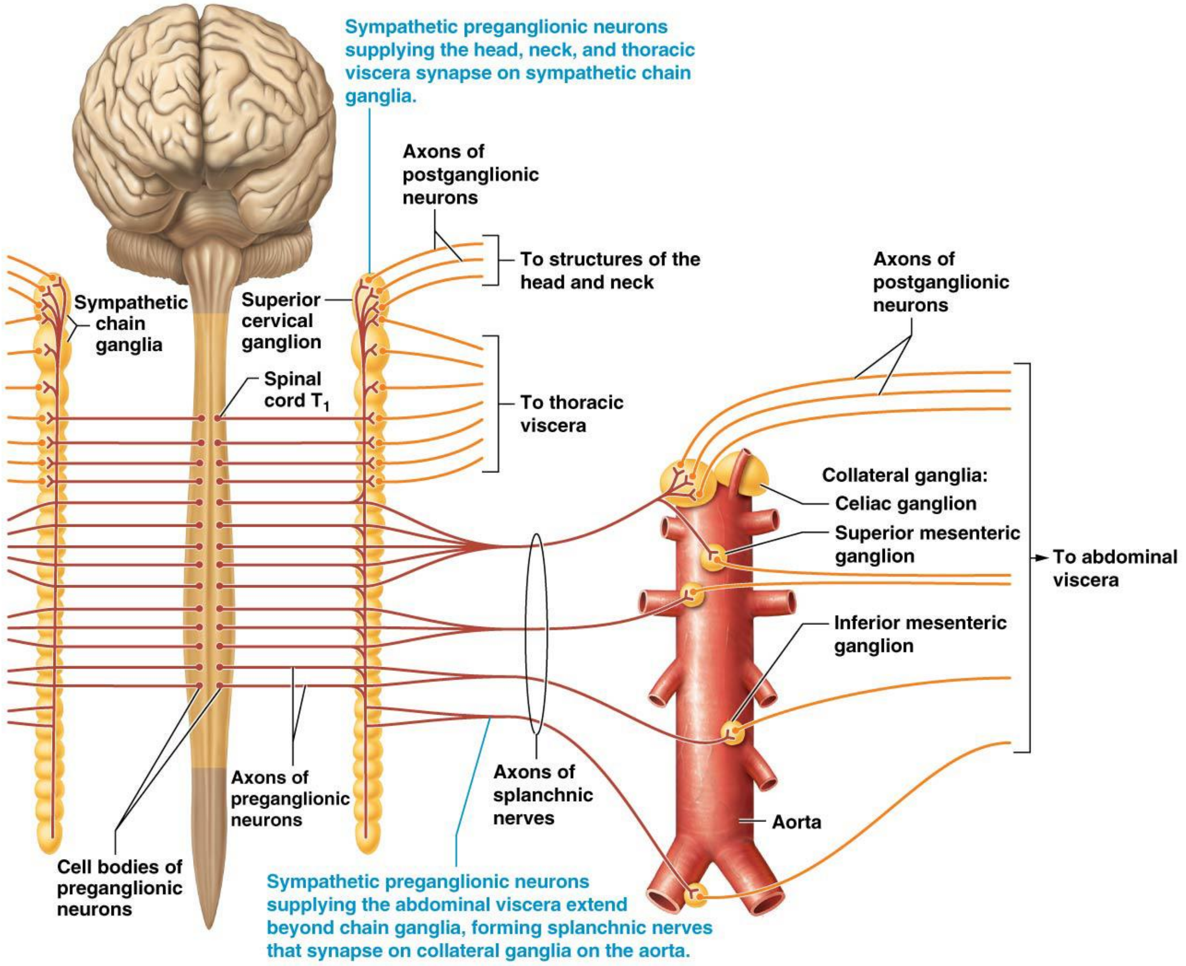
Gross and Microscopic Anatomy of Sympathetic Nervous System



Gross and Microscopic Anatomy of Sympathetic Nervous System

- The axons in the white rami communicantes then enter the sympathetic chain ganglia that house the cell bodies of the postganglionic sympathetic neurons.
- Some preganglionic neurons pass *through* sympathetic chain ganglia <u>without</u> synapsing; instead may synapse on cell bodies in different chain ganglia, or on **collateral ganglia** which are 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



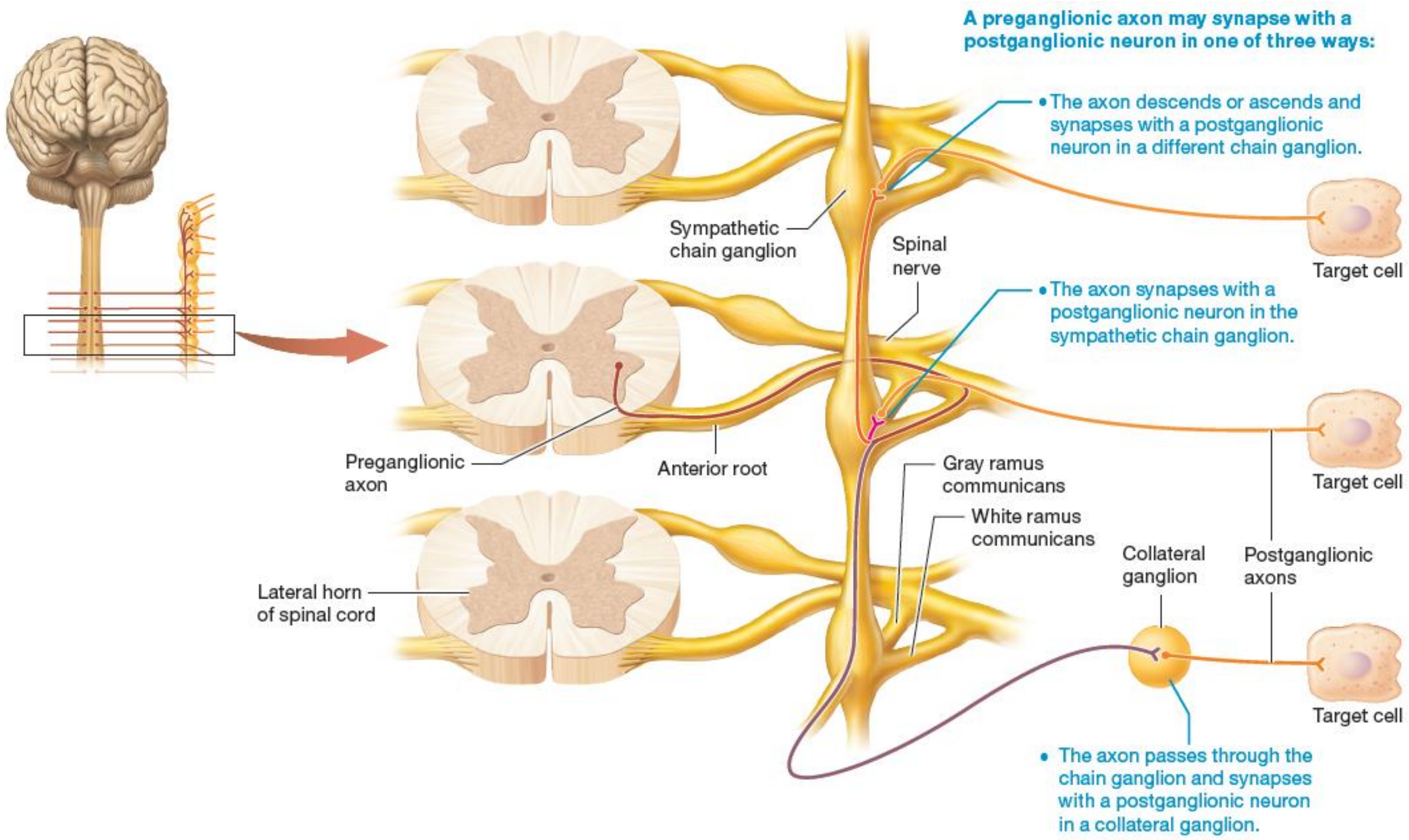
Gross and Microscopic Anatomy of Sympathetic Nervous System

- **Preganglionic neuron may synapse with a postganglionic neuron in one of three ways**:
  - Preganglionic axon synapses with postganglionic neuron in the *sympathetic chain ganglion*
  - Preganglionic axon can *ascend* or *descend* and synapse with postganglionic neuron in a different chain ganglion
  - Preganglionic axon can pass through chain ganglion and synapses with a postganglionic neuron in a *collateral ganglion*

Gross and Microscopic Anatomy of Sympathetic Nervous System

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

Gross and Microscopic Anatomy of Sympathetic Nervous System (8 of 8)



Sympathetic Neurotransmitters and Receptors

- **Remember that neurons communicate with other neurons and target cells through the release of chemicals called neurotransmitters.** A neurotransmitter interacts with a target cell by binding to a specific protein-based receptor in plasma membrane of the target cell.

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 synapses with their *target cells*, postganglionic axons release one of three neurotransmitters: **ACh**, **epinephrine** (**adrenalin**), or **norepinephrine** (**noradrenalin**-approximately 80% of postganglionic sympathetic neurons release norepinephrine.)

Sympathetic Neurotransmitters and Receptors

- **Classes of sympathetic receptors**: **Adrenergic receptors** bind *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, uterus (during pregnancy) on arrector pili muscles in dermis, and certain organs of genitourinary system
  - **Alpha-2 receptors** – most in membrane of *preganglionic sympathetic neurons* instead of in peripheral target cells, also found in the plasma membranes of certain sympathetic target cells including cells in pancreas and adipose tissue.

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* tissue
  - **Beta-2 receptors** – in plasma membranes of *smooth muscle cells* lining airway passages in the lungs (**bronchioles**), and in smooth muscle cells of urinary bladder, *skeletal muscle* fibers, smooth muscle cells of blood vessels serving skeletal muscles, and cells of *liver*, *pancreas*, and *salivary glands*
  - **Beta-3 receptors** – primarily on cells of *adipose* tissue and *smooth muscle cells* in wall 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 medulla

Pharmacology and sympathetic nervous system Receptors

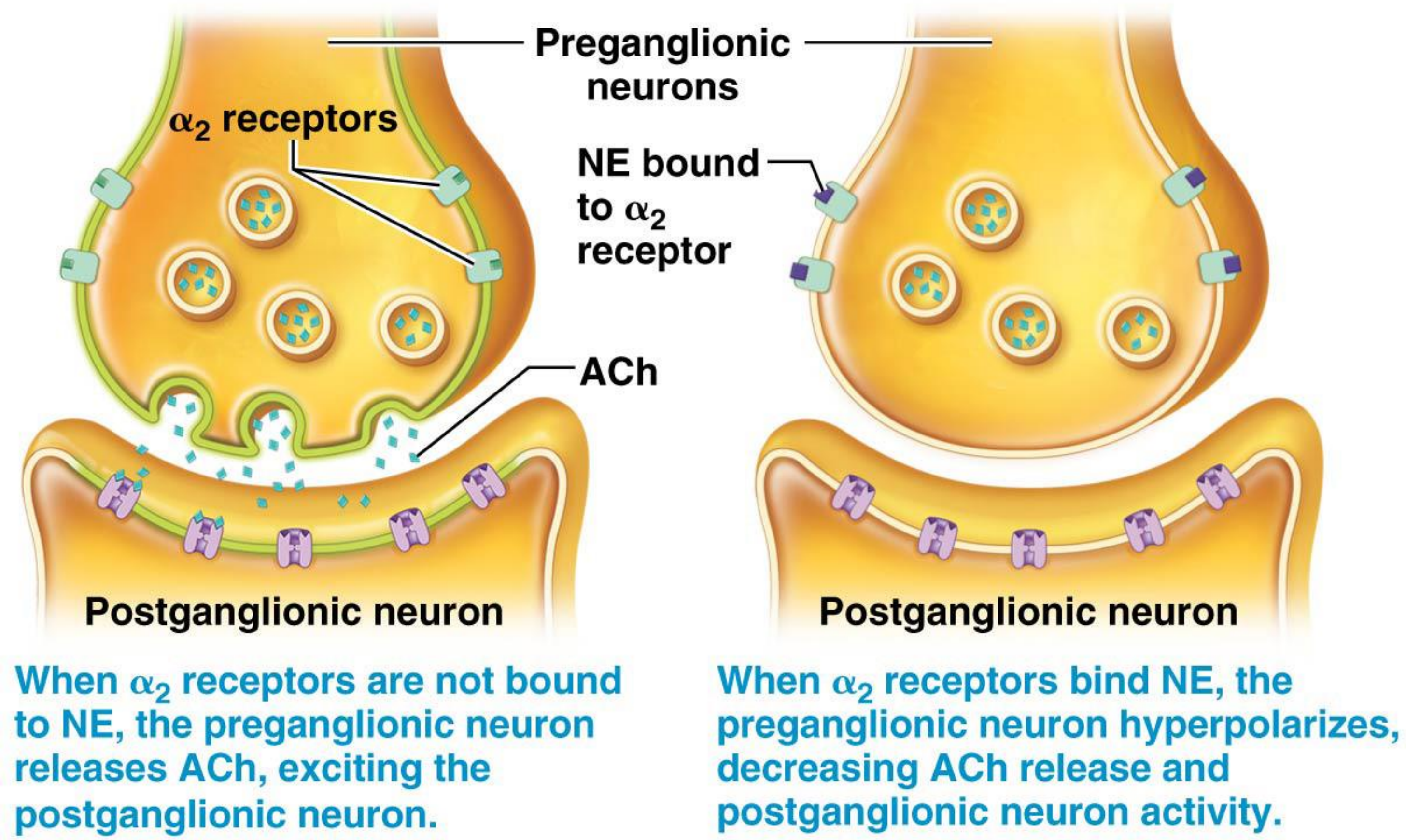
- The existence of different subtypes of sympathetic nervous system receptors has allowed researchers to design drugs that are fairly specific for one type of receptor, this helps minimize potential side effects

- **Antagonists-** block the receptor
- **Agonists-** bind the receptor

Sympathetic Neurotransmitters and Receptors

- **Alpha-2 receptors** differ from other adrenergic receptor subtypes:
  - Normally, an action potential in a preganglionic neuron leads to ACh release, which *stimulates* postganglionic neuron
  - However, when norepinephrine binds to alpha-2 receptors, axon terminal is *hyperpolarized*; slows or cancels action potential, as a result the preganglionic neuron stops stimulating the postganglionic neuron, which dampens or even shuts off the sympathetic response.
- **Part of a *negative feedback loop* that prevents excessive sympathetic activity**

Sympathetic Neurotransmitters and Receptors



(a) α_2 receptor with no NE

(b) α_2 receptor bound to NE

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*:

- **Effects on cardiac muscle cells**: when norepinephrine binds to *beta-1 receptors* it causes following changes:
  - Ion channels open; raises both *rate* and *force* of contraction
  - Increases *blood delivered to tissues* and *blood pressure*; 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:
  - **Constriction of blood vessels serving digestive**, **urinary**, **and integumentary system** – occurs when norepinephrine binds to *alpha-1 receptors on smooth muscle cells of blood vessels serving organs of digestive, urinary, and integumentary systems.*
  - **Dilation of bronchioles** occurs when norepinephrine binds to *beta-2* receptors; <u>increases</u> 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*
  - **Contraction of urinary and digestive sphincters** – The binding of norepinepherine to the smooth muscle cells of the sphincters of the urinary and digestive systems causes them to contract, makes emptying bowel and bladder more difficult.

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-3 receptors*; causes relaxation of the remainder of the smooth muscle in the digestive tract, <u>slows</u> *digestive processes*
  - **Dilation of pupils** – occurs when norepinephrine binds to *alpha-1* receptors; causes dilator pupillae muscles to contract; dilates pupil and allows <u>more</u> *light* into eye
  - **Constriction of blood vessels serving most exocrine glands** – sympathetic nervous system nearly universally decreases secretion from exocrine glands (except sweat glands) via norepinephrine binding to beta-2 receptors.

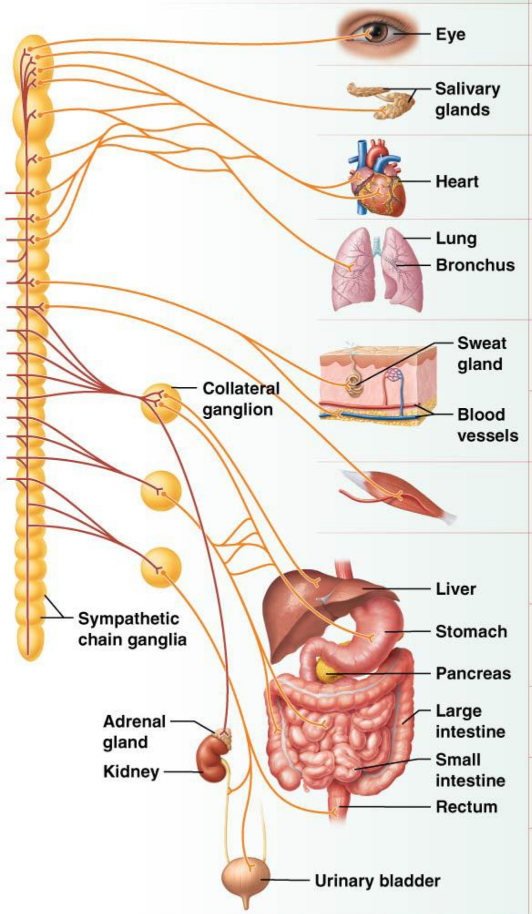
Effects of Sympathetic Nervous System on Target Cells

- **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*

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 controls body temperature; example of **Feedback Loops Core Principle**

Effects of Sympathetic Nervous System on Target Cells



TARGET	NT	RECEPTOR	MAIN EFFECTS
Smooth muscle cells around pupil	NE	α_1	Dilation of pupil
Cells of salivary glands	NE	β_1 and β_2	Increase in secretion in certain cells
Cardiac muscle cells	NE	β_1	Increase in heart rate and force of contraction
Smooth muscle cells of bronchus	NE	β_2	Dilation of bronchioles (bronchodilation)
Cells of sweat glands	ACh	Muscarinic	Increase in secretion
Smooth muscle cells of blood vessels to skin	NE	α_1	Constriction of blood vessels (vasoconstriction)
Smooth muscle cells of blood vessels to skeletal muscles	NE	β_2	Dilation of blood vessels (vasodilation)
Smooth muscle cells of blood vessels to digestive and urinary organs	NE	α_1	Vasoconstriction
Smooth muscle cells of digestive and urinary tracts and sphincters	NE	α_1 (sphincters) β_3 (digestive) β_2 (urinary)	Relaxation of digestive and urinary tracts, contraction of sphincters
Cells of digestive glands	NE	β_2	Decrease in secretion
Cells of pancreas and liver	NE	β_2	Increase in release of glucose
Cells of adrenal medulla	ACh	Nicotinic	Release of epinephrine and norepinephrine

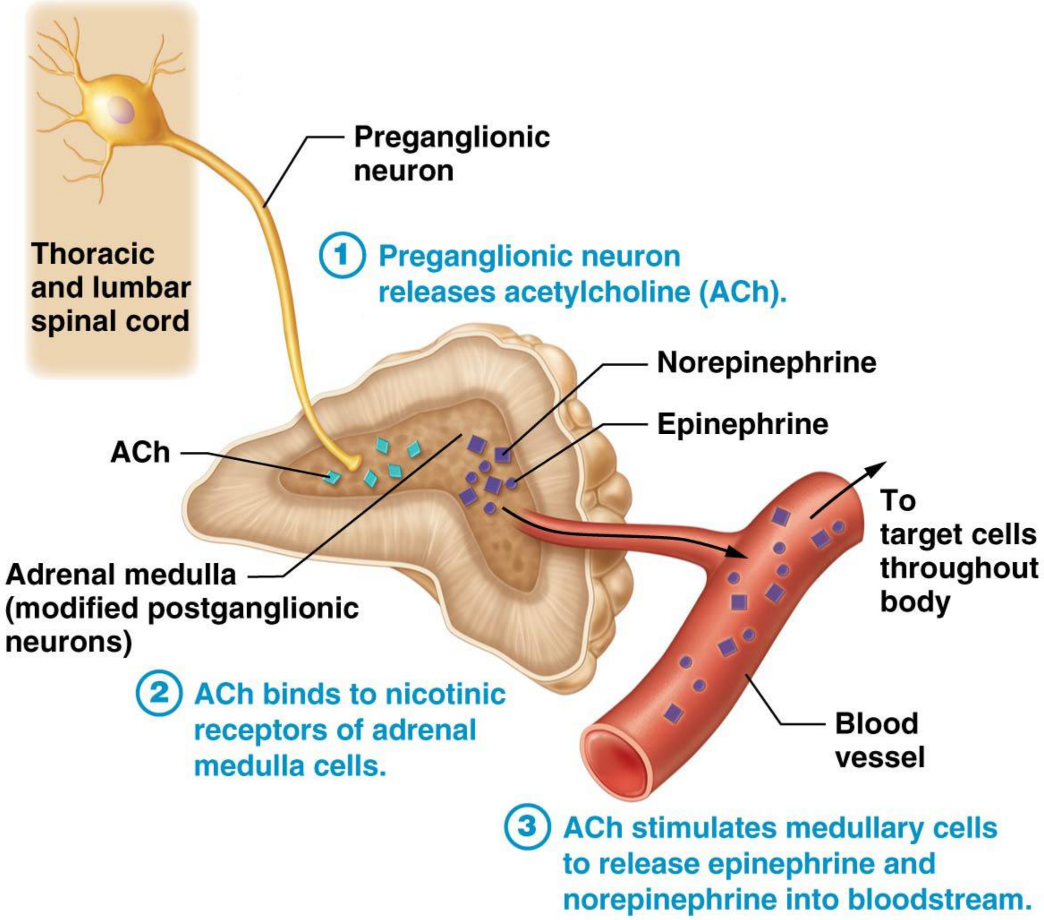
Effects of Sympathetic Nervous System on Target Cells

- **Effects on cells of adrenal medulla**: adrenal medulla is the internal part of the adrenal glands, which sit on top of each kidney
- Contacted directly by preganglionic sympathetic neurons; adrenal medulla is composed of *modified sympathetic postganglionic neurons (In other words, each adrenal medulla is functionally a ganglion)*

Effects of Sympathetic Nervous System on Target Cells

- **Adrenal medulla** (continued):
  - When preganglionic neuron releases ACh it binds to the nicotinic receptors of adrenal medulla cells.
  - ACh then stimulates medullary cells to release additional *norepinephrine* and *epinephrine* into bloodstream; considered **hormones** rather than neurotransmitters
  - Act as *long-distance* chemical messengers; *interface* between sympathetic nervous and endocrine systems

Effects of Sympathetic Nervous System on Target Cells



Effects of Sympathetic Nervous System on Target Cells

- **Effects on other cells**: sympathetic nervous system influences many of the body's other processes via its effects on 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
  - Can 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 Neurotransmitters and Receptors

- **Pharmacology and sympathetic nervous system receptors**: sympathetic nervous system receptors have provided *targets for medication therapy* for many different disease states, including asthma and hypertension
- Existence of different subtypes of sympathetic nervous system receptors has allowed researchers to design drugs that are fairly specific for one type of receptor and so certain organs; helps minimize potential side effects

Sympathetic Neurotransmitters and Receptors

- Most drugs targeting sympathetic nervous system work in one of two ways:
  - *Antagonists* – block receptor and *prevent* norepinephrine from binding to it
  - *Agonists* – bind receptor and *mimic* effects of norepinephrine

Sympathetic Neurotransmitters and Receptors

- Common drugs that bind to sympathetic receptors include:
  - *Alpha-1 blockers* (*antagonists*) – bind to alpha-1 receptors, particularly on smooth muscle cells lining blood vessels
    - Block action of norepinephrine; prevent blood vessels from constricting; lowers blood pressure; useful in treating hypertension
    - Certain alpha-1 blockers also cause relaxation of smooth muscle in prostate gland; used to treat benign prostatic hyperplasia

Sympathetic Neurotransmitters and Receptors

- Common drugs that bind to sympathetic receptors (continued):
  - *Alpha-2 agonists* – bind to presynaptic alpha-2 receptors and activate them
    - Decreases output of both preganglionic and postganglionic sympathetic neurons
    - May be used in treatment of hypertension and other conditions such as opiate withdrawal

Sympathetic Neurotransmitters and Receptors

- Common drugs that bind to sympathetic receptors (continued):
  - *Beta blockers* **–** antagonists that bind to beta-1 receptors on heart and decrease its rate and force of contraction; widely used in treatment of hypertension and other diseases of cardiovascular system
  - *Beta-2 agonists* **–** bind to beta-2 receptors on smooth muscle of bronchioles; cause bronchodilation; commonly used to treat asthma

Sympathetic NS and Weight Loss Supplements

- One 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 **Yohimbine**, which is the active ingredient derived from a plant called **Yohimbe**.

Sympathetic NS and Weight Loss Supplements

- Manufacturers claim yohimbine binds to beta-3 receptors on adipocytes and triggers breakdown of lipids; this is, at best, a misleading statement; Yohimbine actually <u>blocks</u> alpha-1 receptors in blood vessels and alpha-2 receptors in spinal cord; causes *vasodilation* while also increasing activity of sympathetic neurons, the higher sympathetic activity can, briefly, increase the metabolic rate.
- However, 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 <u>not</u> 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

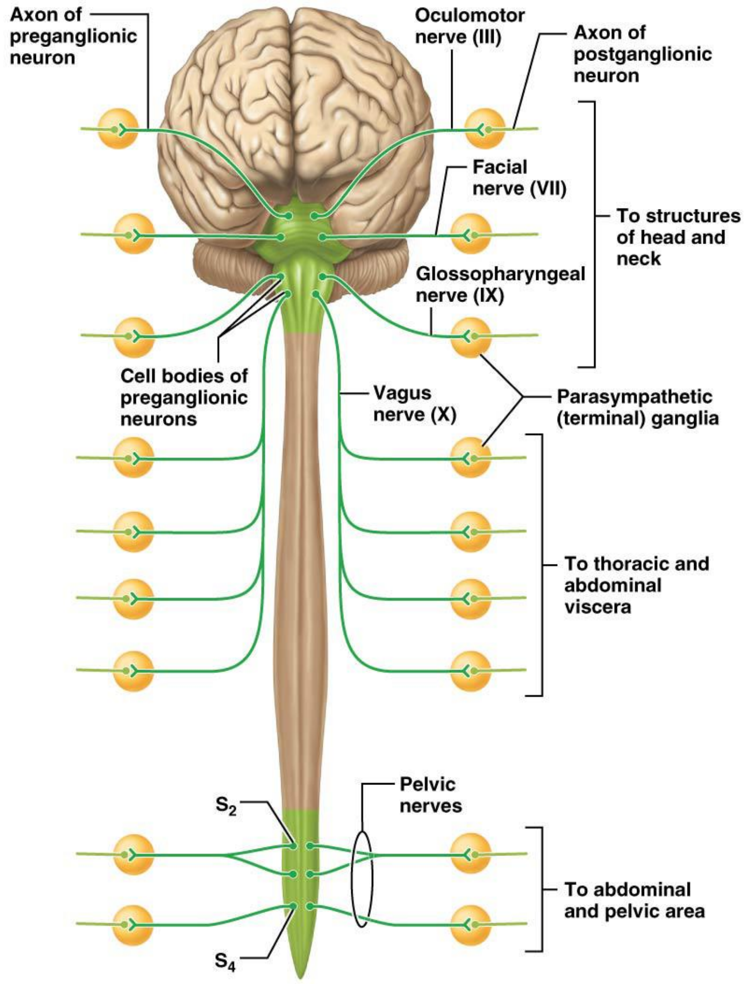
Module 14.3
The Parasympathetic Nervous System

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, that are typically carried out during times of rest
- Like the sympathetic nervous system, this system is rarely completely silent, although, it is in general considered subordinate to the sympathetic nervous system.

Gross and Microscopic Anatomy of Parasympathetic Nervous System



Gross and Microscopic Anatomy of Parasympathetic Nervous System

- **Cranial nerves involved in parasympathetic nervous system– oculomotor** (CN III), **facial** (CN VII), **glossopharyngeal** (CN IX), and **vagus** (CN X) nerves
  - **The main parasympathetic nerves are the two vagus nerves (CN X)**, which innervate most thoracic and abdominal viscera and together provide about 90% of the parasympathetic innervation to the body.
  - Branches of vagus nerve contribute to *cardiac*, *pulmonary*, and *esophageal plexuses*

Gross and Microscopic Anatomy of Parasympathetic Nervous System

- **Parasympathetic cranial nerves** supply most of the viscera of the thoracic and abdominopelvic cavities.
- The remaining organs, including the last segment of the large intestine, the urinary bladder, and reproductive organs, are supplied by **parasympathetic sacral nerves.**
- Branches from sacral spinal cord form the **pelvic splanchnic nerves**; form plexuses in *pelvic floor*
  - Some preganglionic neurons synapse in terminal ganglia; <u>most</u> 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 types of cholinergic receptors:
  - **Nicotinic receptors** – located in membranes of all *postganglionic parasympathetic neurons*
  - **Muscarinic receptors** – located in membranes of *all parasympathetic target cells*

Effects of Parasympathetic Nervous System on Target Cells

- Effects of the parasympathetic nervous system on its target cells are easily understood if you keep in mind its most basic function, to maintain homeostasis when the body is at rest:
- **Effects on cardiac muscle cells**
  - Parasympathetic activity decreases *heart rate* and *blood pressure*
  - Preganglionic parasympathetic neurons travel to heart via *vagus nerve* (*CN X*) and stimulate postganglionic neurons to reduce the rate of the heart's contraction, which lowers blood pressure

Effects of Parasympathetic Nervous System on Target Cells

- **Effects on smooth muscle cells**: postganglionic parasympathetic neurons innervate the smooth muscle cells in many different organs, and trigger the following effects:
  - **Constriction of pupil** involves CN III, ciliary ganglion, and sphincter pupillae muscle; <u>reduces</u> *amount of light* allowed into eye
  - **Accommodation of lens for near vision** involves CN III and contraction of ciliary muscle; changes lens to a <u>more</u> *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**; help *propel 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** – involves sacral division
  - Although parasympathetic division only innervates specific blood vessels, many blood vessels dilate when parasympathetic nervous system is active, **however, this dilation is due to a decrease in *sympathetic activity* and removal of epinephrine from bloodstream**

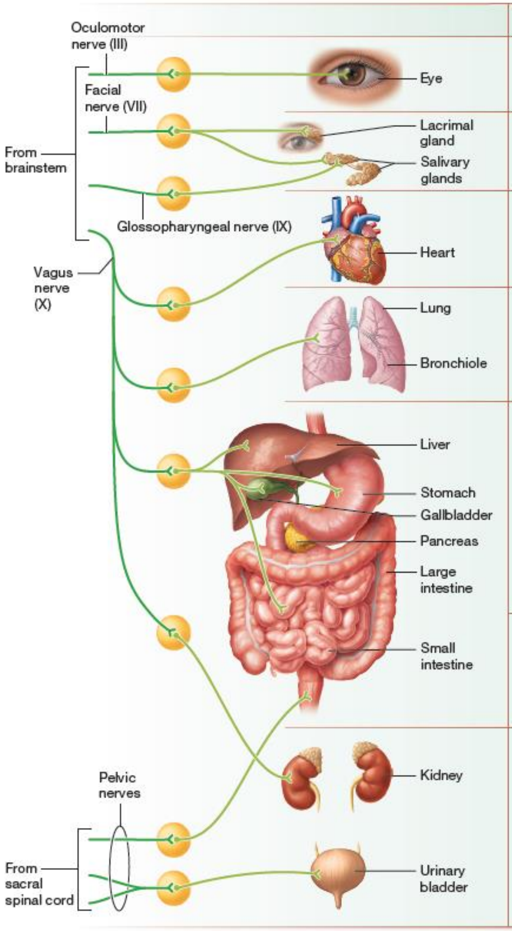
Effects of Parasympathetic Nervous System on Target Cells

- **Effects on glandular epithelial cells**: parasympathetic division has little to no effect on sweat glands but does trigger copious secretion from <u>other</u> glands:
  - CN VII stimulates *tear* production from lacrimal glands and *mucus* production from glands in nasal mucosa
  - CN VII and IX stimulate secretion of *saliva* from salivary glands
  - CN X stimulate 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 <u>direct</u> effect on cells that mediate metabolic rate, mental alertness, force generated by skeletal muscle contractions, blood clotting, adipocytes, or most endocrine secretions
  - Instead, each of these factors *returns to a* normal "*resting*" *state* during times of parasympathetic activity; simply because the sympathetic system is no longer dominant
  - *The return to resting state is important time for body to store glucose and other fuels in preparation for the next round of sympathetic nervous system activity.*

Effects of Parasympathetic Nervous System on Target Cells



TARGET	MAIN EFFECTS
Smooth muscle cells around pupil and lens	Constriction of pupil, adjustment of lens for near vision
Cells of lacrimal and salivary glands	Increase in secretions
Cardiac muscle cells	Decrease in heart rate
Smooth muscle cells of bronchioles	Bronchoconstriction
Smooth muscle cells of digestive tract and sphincters	Contraction of digestive tract smooth muscle, relaxation of sphincters
Cells of digestive glands	Increase in secretions
Smooth muscle cells of urinary sphincters	Relaxation of sphincters

Side Effects of Anticholinergic Drugs

- Many drugs <u>block</u> either *ACh release* or *ACh receptors* as an unintended side effect; such drugs are prescribed for many different conditions such as allergies, respiratory diseases, and gastrointestinal conditions; some 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

- (continued):
  - **Dry mouth** – one of the most common anticholinergic effects is a *dry mouth*, caused by a decrease in parasympathetic nervous system's ability to stimulate secretion of saliva

Concept Boost: Understanding Effects of Sympathetic and Parasympathetic Nervous Systems

- **Sympathetic nervous system promotes survival in emergency situations;** mnemonic:
  - Walking through woods; swarm of bees starts chasing you; *sympathetic* nervous system is *sympathetic* to situation, and initiates changes in body that will make it easier to escape bees
  - Use logic to figure out what physiological changes would help you escape swarm of bees (next slide)

Concept Boost: Concept Boost: Understanding Effects of Sympathetic and Parasympathetic Nervous Systems

- Obviously muscles will be more active because you will be running; blood flow to muscles will <u>increase</u> (*vasodilation*); blood flow to other organs that aren't currently needed, (digestive organs, urinary organs, and skin) will <u>decrease</u> (*vasoconstriction*)
- You will need more oxygen to fuel demands of skeletal muscles; bronchioles will dilate to allow <u>more</u> air to be *exchanged* with each breath

Concept Boost: Concept Boost: Understanding Effects of Sympathetic and Parasympathetic Nervous Systems

- Your heart will have to beat faster and harder to keep up with increased demands of skeletal muscles; will increase blood pressure
- Because you are running through woods, your eyes will want to collect as much light as possible to see better; pupils will dilate

Concept Boost: Understanding Effects of Sympathetic and Parasympathetic Nervous Systems

- Parasympathetic nervous system restores resting conditions <u>after</u> burst of sympathetic activity; mnemonic:
  - You have escaped swarm of bees, but not without receiving few stings
  - Your *para*sympathetic nervous system will help you *repair*, rest, and recover from your escape
  - Simple logic (next slide)

Concept Boost: Understanding Effects of Sympathetic and Parasympathetic Nervous Systems

- To repair tissues, you need to take in nutrients; requires digestive activities, so all digestive processes increase; when we take in food, we also take in liquids; results in formation of urine; urinary processes also increase
- Your muscles are no longer actively moving, so blood flow to muscles decreases (*vasoconstriction*); digestive and urinary organs are actively working; blood flow increases (*vasodilation*); note **–** due only to decreased sympathetic activity

Concept Boost: Understanding Effects of Sympathetic and Parasympathetic Nervous Systems

- You no longer need additional oxygen; bronchioles will constrict back to normal and heart rate will slow (decreasing blood pressure)
- Since you aren’t running through woods, your eyes don’t need to collect as much light or see as far away; pupils constrict and lenses adjust for near vision

Concept Boost: Understanding Effects of Sympathetic and Parasympathetic Nervous Systems

- other effects that also make sense if you think about them in these settings (fleeing to escape swarm of bees or recovering from escape)
- As is often true, *understanding* concepts rather than simply memorizing proves much more useful in end

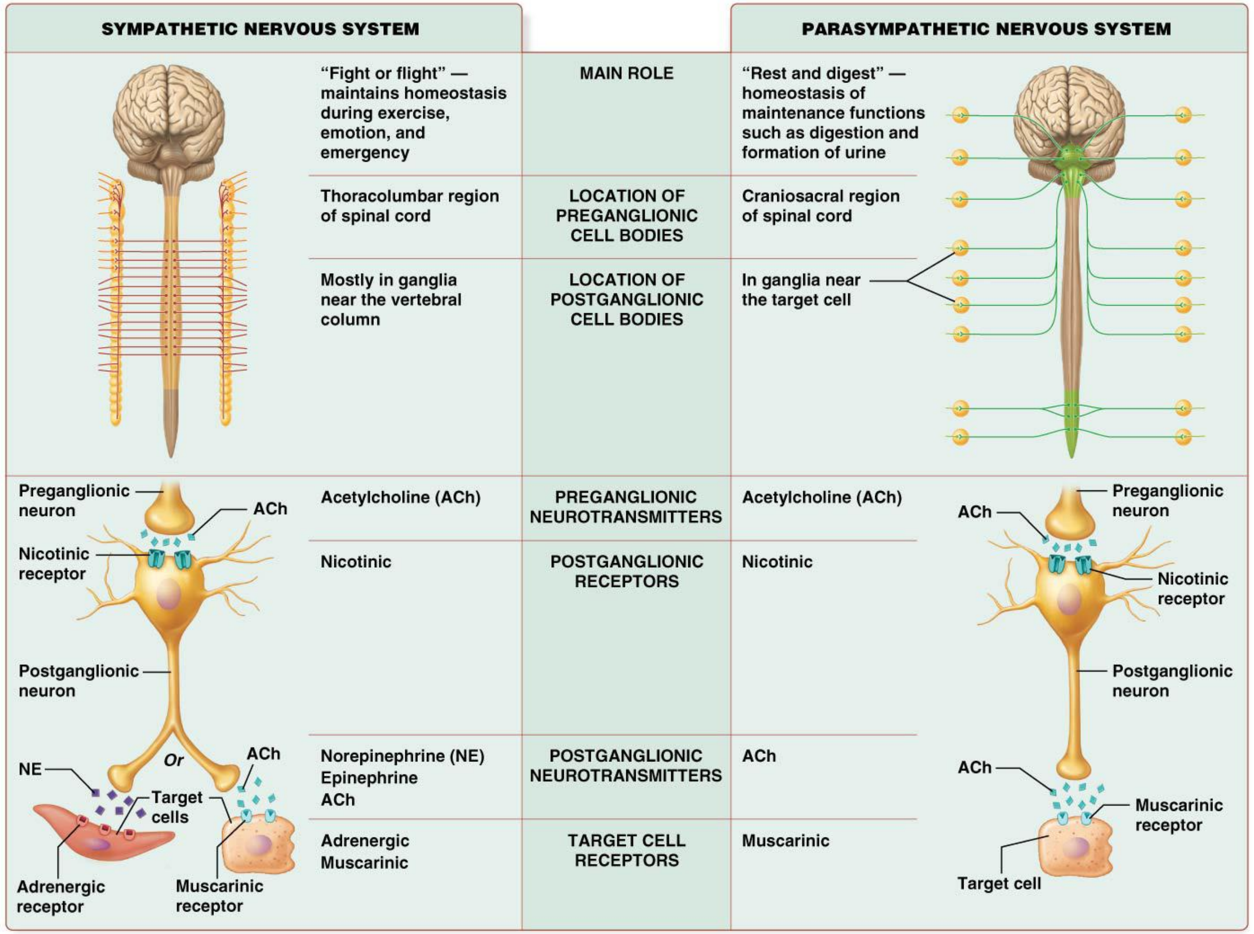
Module 14.4 Homeostasis Part II: PNS Maintenance of Homeostasis

Interactions of Autonomic Divisions

- Sympathetic and parasympathetic divisions work *together* to keep many of body's functions within their normal homeostatic ranges
  - The sympathetic and parasympathetic nervous systems generally work **antagonistically**, each having the opposite effect on a particular body function or organ.
  - Together, the two maintain a balance that ensures the body's needs are met at all times. They can accomplish this because most organs are innervated by neurons from BOTH systems, referred to as **dual innervation**

- Dual innervation allows sympathetic division to become dominant and trigger effects that maintain homeostasis during *exercise or emergency*
- Parasympathetic division regulates same organs, preserving homeostasis <u>between</u> periods of increased physical activity

Interactions of Autonomic Divisions



SYMPATHETIC NERVOUS SYSTEM		PARASYMPATHETIC NERVOUS SYSTEM
"Fight or flight" — maintains homeostasis during exercise, emotion, and emergency	MAIN ROLE	"Rest and digest" — homeostasis of maintenance functions such as digestion and formation of urine
Thoracolumbar region of spinal cord	LOCATION OF PREGANGLIONIC CELL BODIES	Craniosacral region of spinal cord
Mostly in ganglia near the vertebral column	LOCATION OF POSTGANGLIONIC CELL BODIES	In ganglia near the target cell
Acetylcholine (ACh)	PREGANGLIONIC NEUROTRANSMITTERS	Acetylcholine (ACh)
Nicotinic	POSTGANGLIONIC RECEPTORS	Nicotinic
Norepinephrine (NE) Epinephrine ACh	POSTGANGLIONIC NEUROTRANSMITTERS	ACh
Adrenergic Muscarinic	TARGET CELL RECEPTORS	Muscarinic

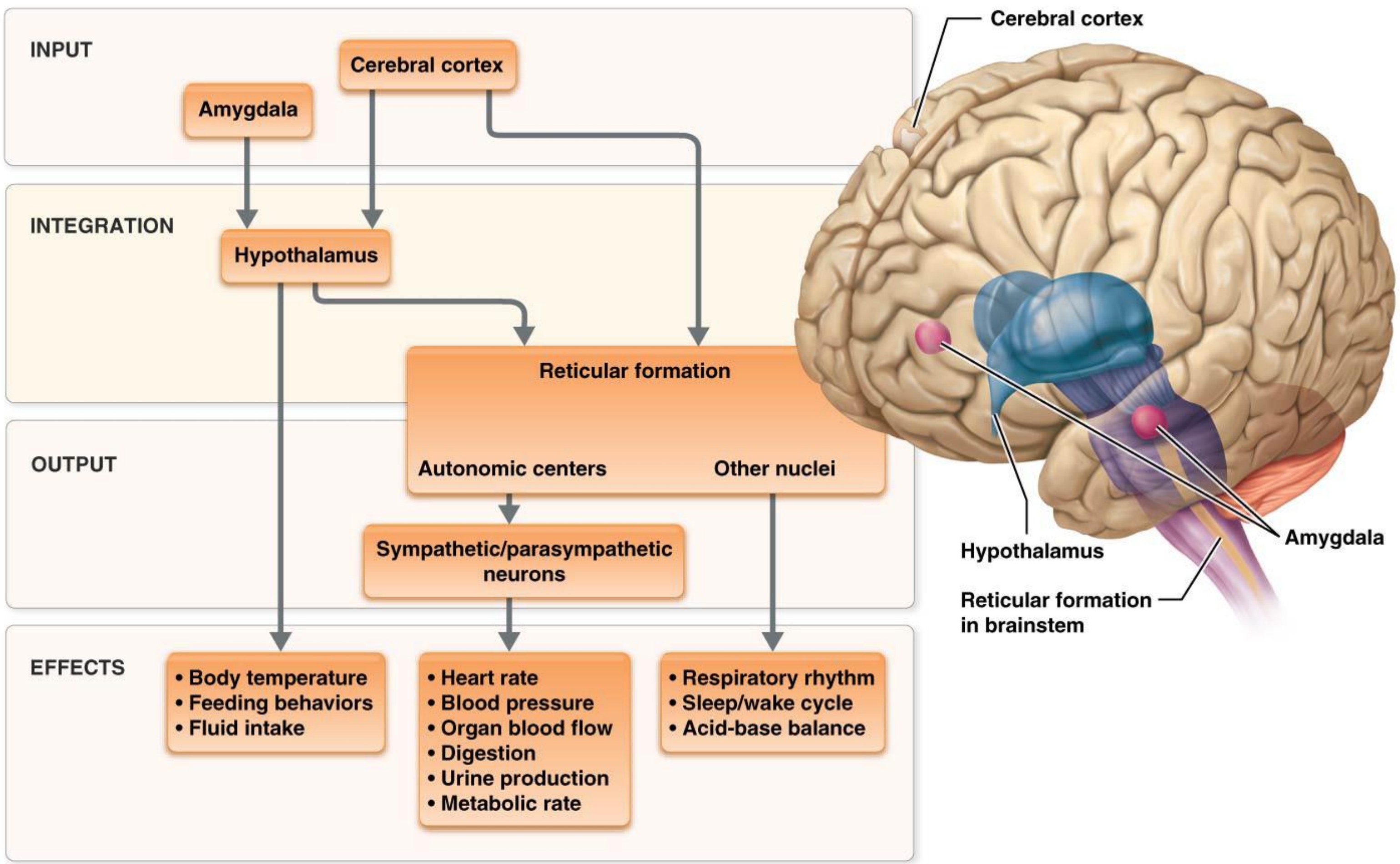
Autonomic Tone

- Neither the sympathetic nor parasympathetic nervous system is ever completely silent, as both are active to some degree most of the time.
- This constant amount of activity from each system is known as **autonomic tone,** can be divided into sympathetic and parasympathetic tone.
  - **Sympathetic nervous system is normally dominant in blood vessels and keeps them partially constricted at all times** (important for maintaining blood pressure at rest).
  - **Parasympathetic nervous system is normally dominant in the heart and keeps the 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
  - Homeostasis is largely controlled centrally by *hypothalamus* and *brainstem reticular formation*; many of the actions of these structures are mediated via the sympathetic and parasympathetic nervous systems
  - Many signals sent from the hypothalamus are directed toward areas of the reticular formation called **autonomic centers** – these centers contain neurons that control the activity of preganglionic sympathetic and parasympathetic neurons.

Summary of Nervous System Control of Homeostasis



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** (generally result 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 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

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