

Physiology of the Autonomic Nervous System

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References

The Autonomic Nervous System and the Adrenal Medulla

Chapter 61 (Guyton & Hall)

Objectives

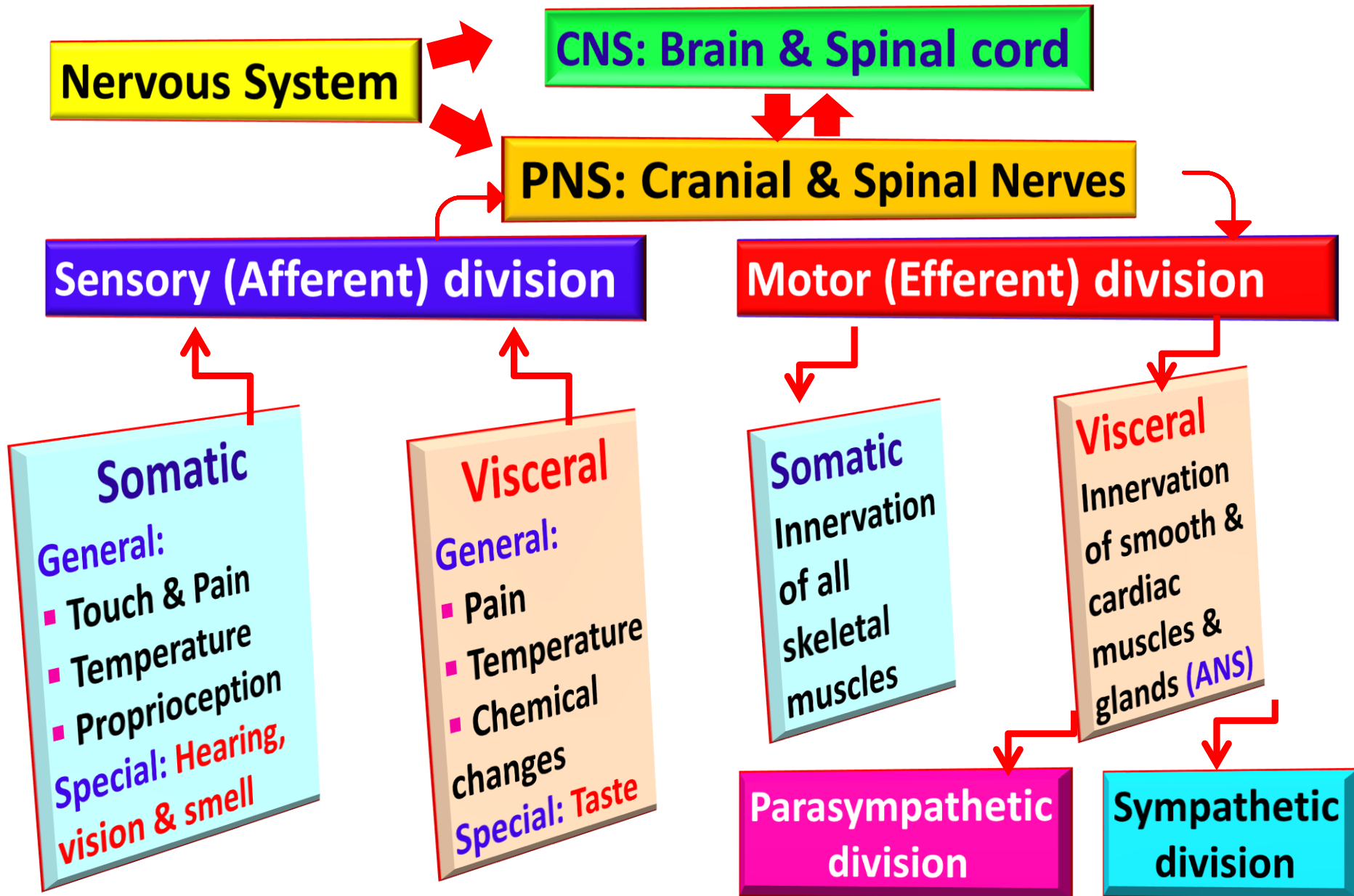
By the end of this session students are expected to:

- Describe the **main** anatomical differences between the sympathetic and parasympathetic divisions of the ANS
- Outline the **main** functions of the ANS and its effects on heart, lungs ...etc
- Name **main** neurotransmitters that are released from pre- and post- ganglionic autonomic fibers
- Discuss receptors of the ANS

Lecture Outline

- Organization of the nervous system
- Comparison between ANS & somatic nervous system
- Sympathetic division of ANS
- Parasympathetic division of ANS
- Neurotransmitters and receptors of ANS
- Some disorders of ANS

Anatomical Divisions of the Nervous System



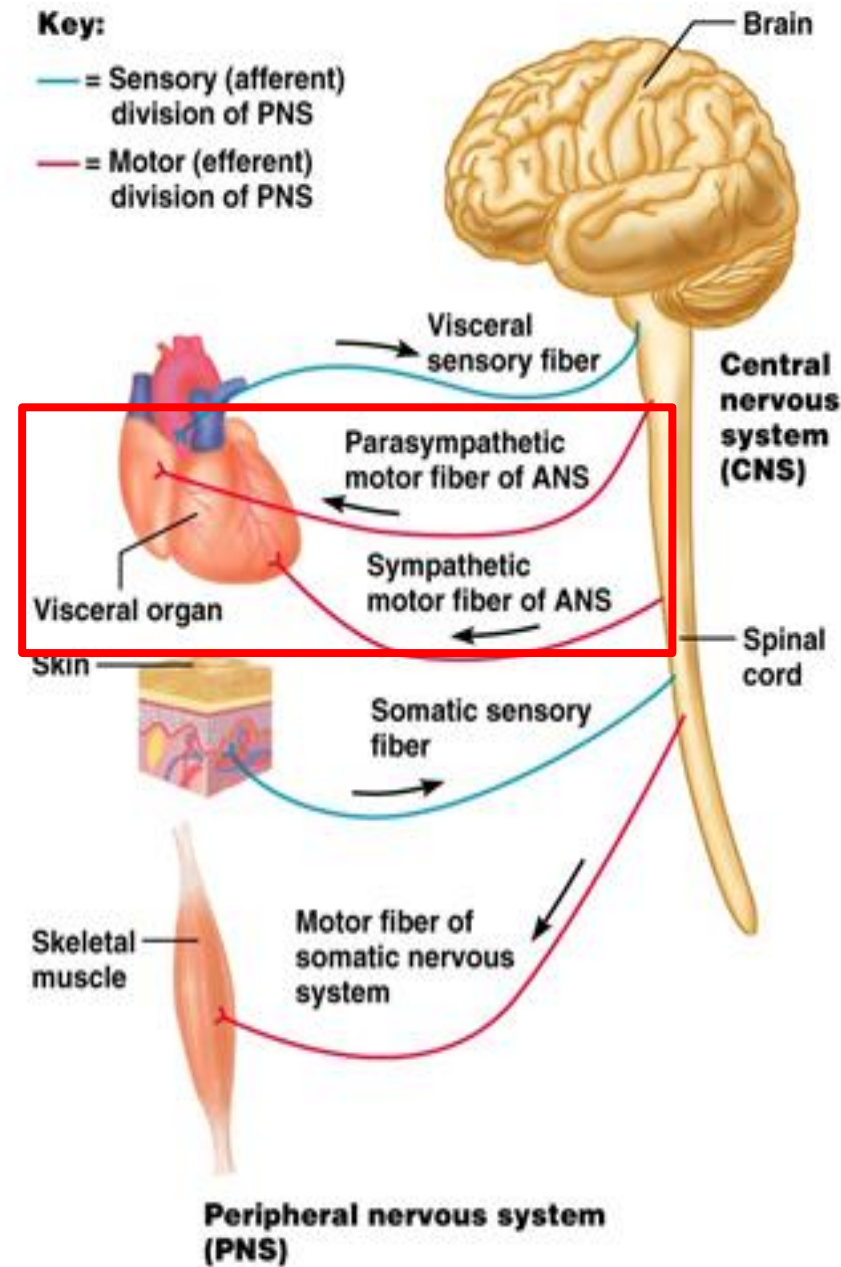
What is Autonomic Nervous System?

ANS is the **Efferent** portion of the peripheral nervous system that controls **involuntary** (subconsciously) visceral functions:

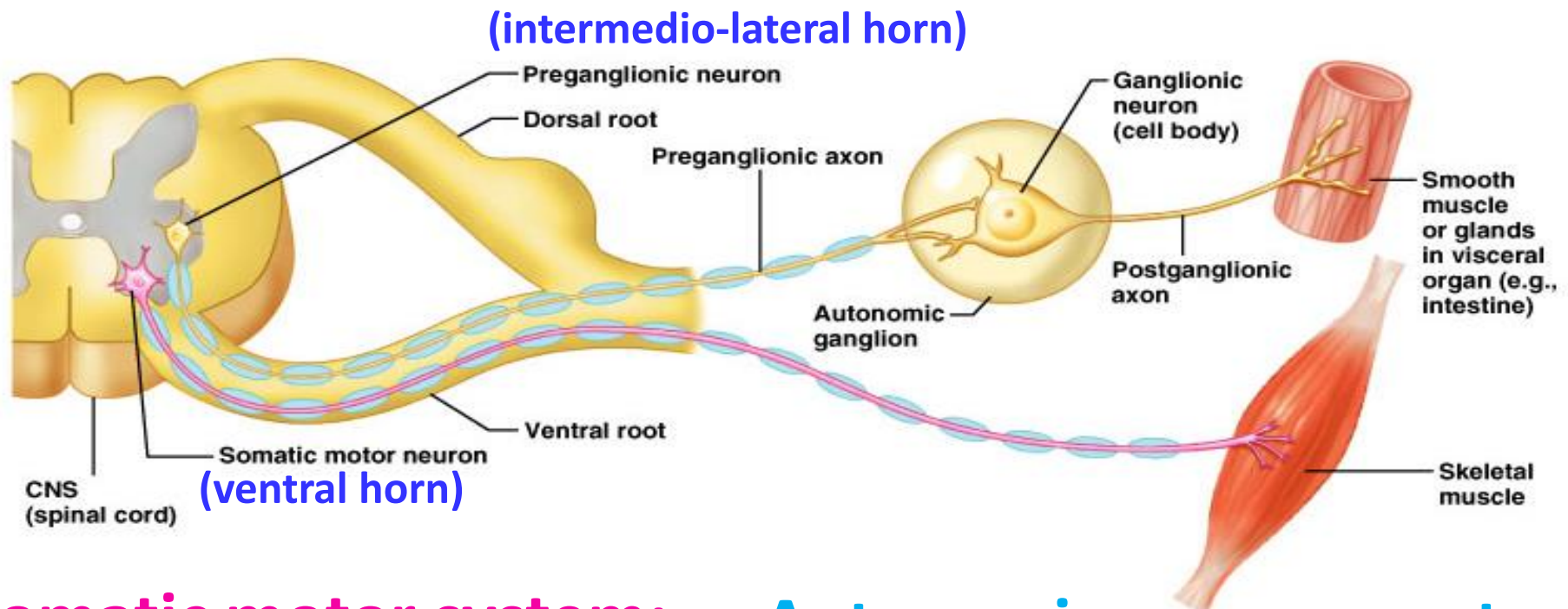
- Blood pressure,
- GI motility and GI secretion,
- Sweating, body temperature,
- **Many other activities**

Divisions of ANS

- **Sympathetic**
- **Parasympathetic**



Comparison Between Autonomic and Somatic Motor Systems



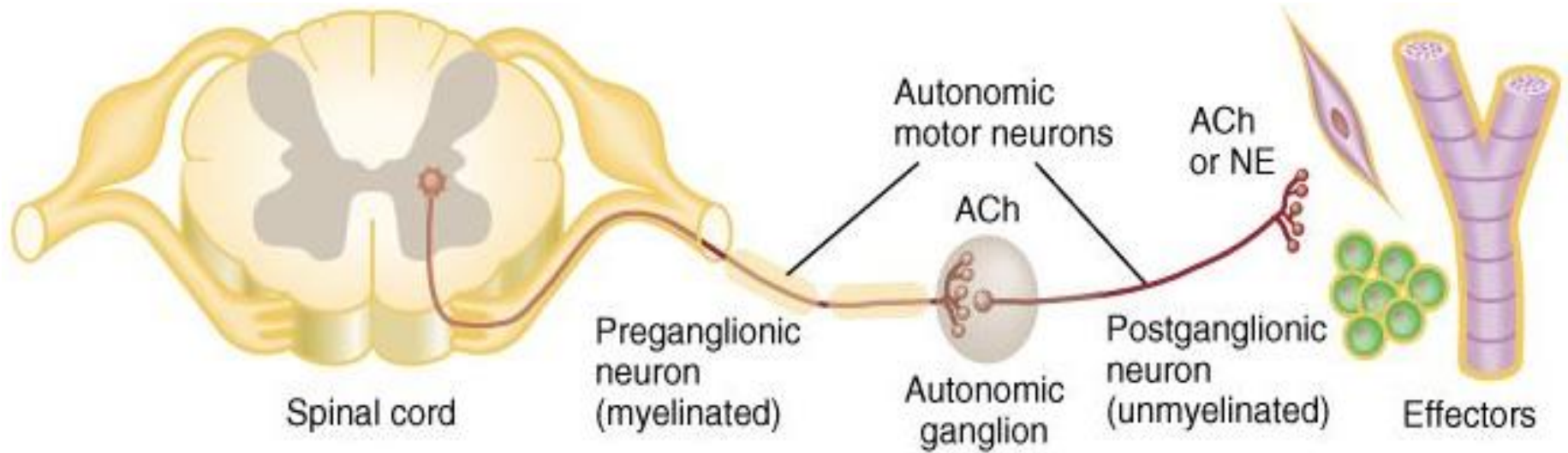
Somatic motor system:

- One motor neuron extends from CNS to skeletal muscle
- Axons are thickly myelinated, conduct impulses rapidly

Autonomic nervous system:

- Chain of two motor neurons
 - Preganglionic neuron
 - Postganglionic neuron
- Conduction is slower due to thinly or unmyelinated axons

Basic Anatomy of the ANS



Preganglionic neuron

- Cell body in brain or spinal cord
- Axon is **myelinated** (**A β -type**) that extends to autonomic ganglion

Postganglionic neuron

- Cell body is outside in CNS in an autonomic ganglion
- Axon is **unmyelinated** (**C-type**) that terminates on an effector cell

A single preganglionic neuron synapses with 8-9 postganglionic neurons

I. Sympathetic Division of the ANS

The 2 divisions originate from different regions of the CNS

A. Sympathetic division

originates from thoracic & lumbar levels of spinal cord.

(called **thoraco-lumbar, T1- L2**)

- Two (bilateral) sympathetic trunk (chain) ganglia (**paravertebral ganglia**)
- **Prevertebral ganglia** (e.g. celiac)
- Short preganglionic fibers to ST
- Long postganglionic fibers, terminating at effectors.

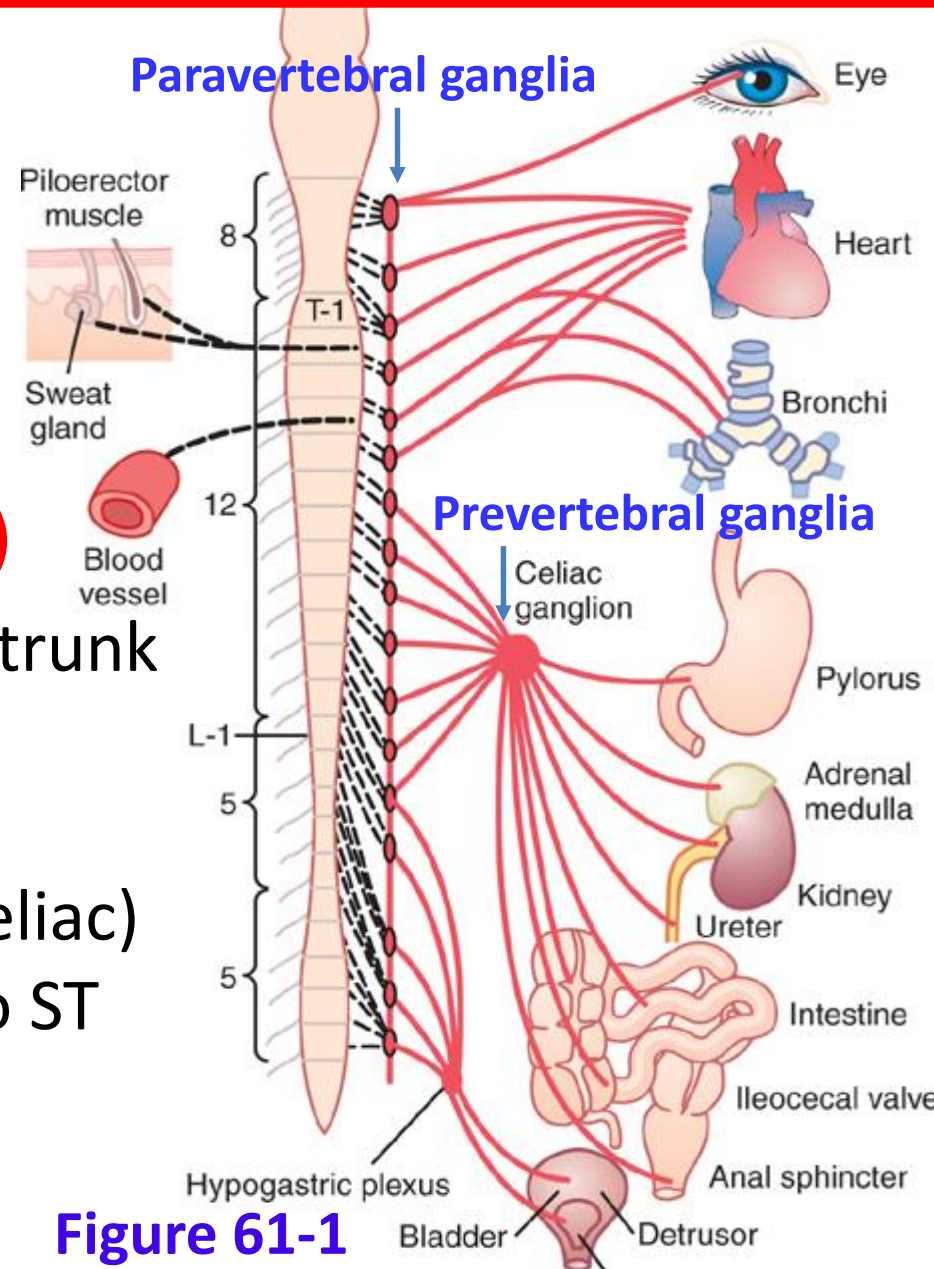


Figure 61-1

Course of Preganglionic Fibers

1. Synapse in chain ganglion at same level or different level (up or down)

2. Synapse in a peripheral (prevertebral) ganglion

3. Synapse in adrenal gland (next slide)

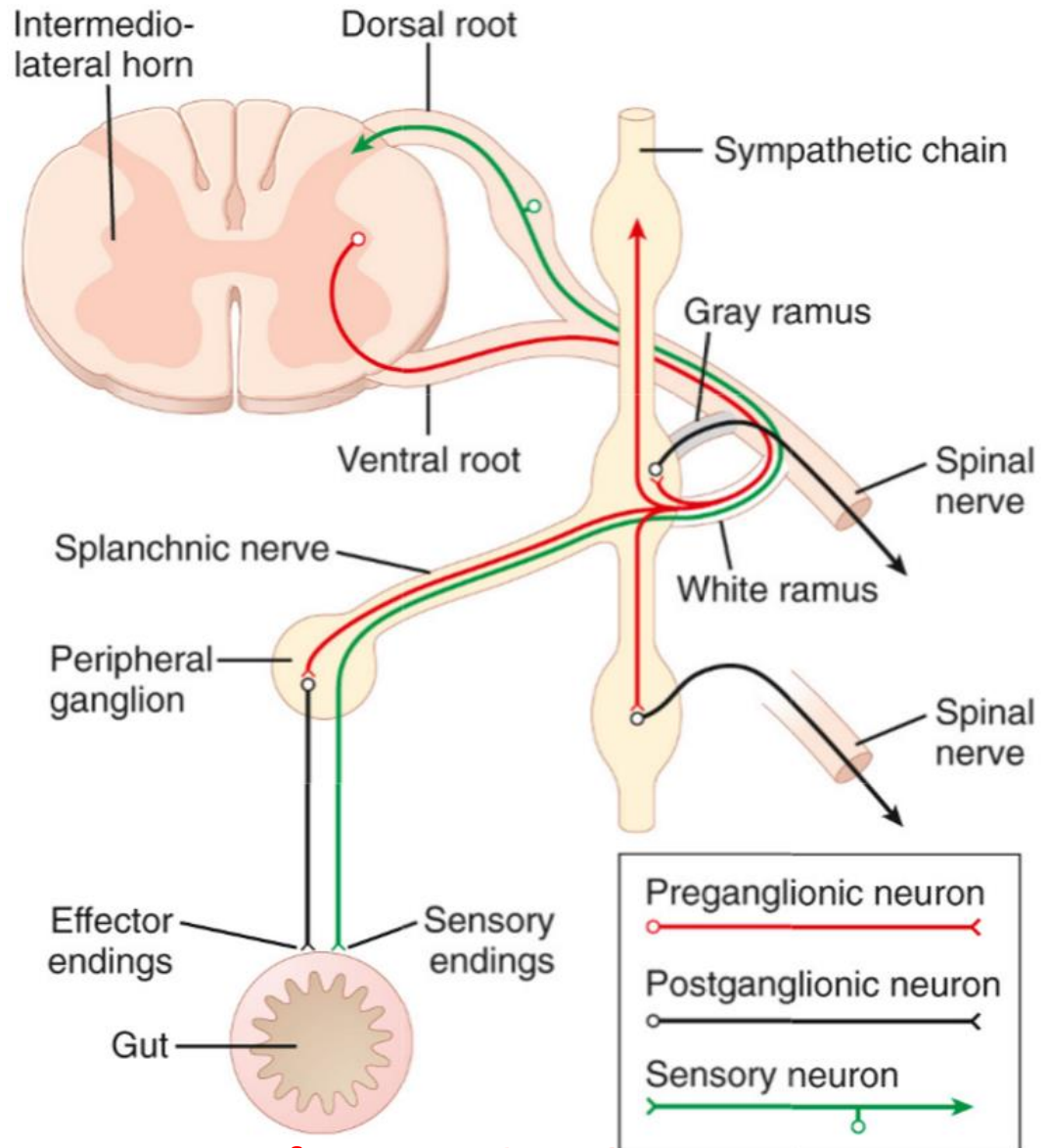


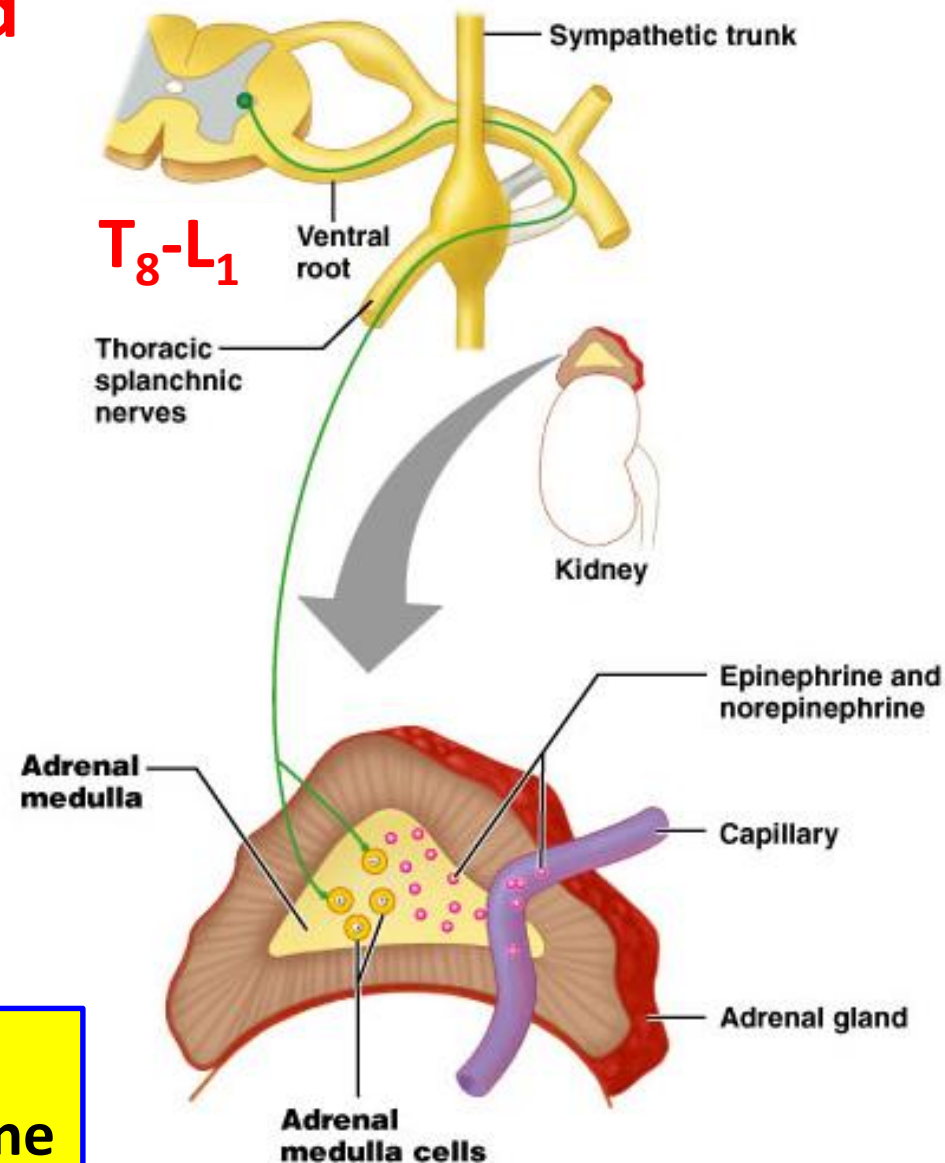
Figure 61-2

Sympathetic Pathways

Synapse in adrenal gland

- Adrenal gland (on top of each kidney) is a major organ of ANS
- Release **adrenaline** (80%) & **noradrenaline** (20%) in emergencies (adrenaline “rush”)

Epinephrine= Adrenaline
Norepinephrine= Noradrenaline



Key Characteristics of ANS

✚ The striking characteristics of ANS is the **rapidity** and **intensity** with which it can change visceral functions

- Heart rate can be doubled within **3-5 sec.**
- Blood pressure can be doubled or decreased low enough to cause fainting within **10-15 sec.**
- Sweating can begin within **seconds**
- The urinary bladder may empty involuntarily, also within **seconds**

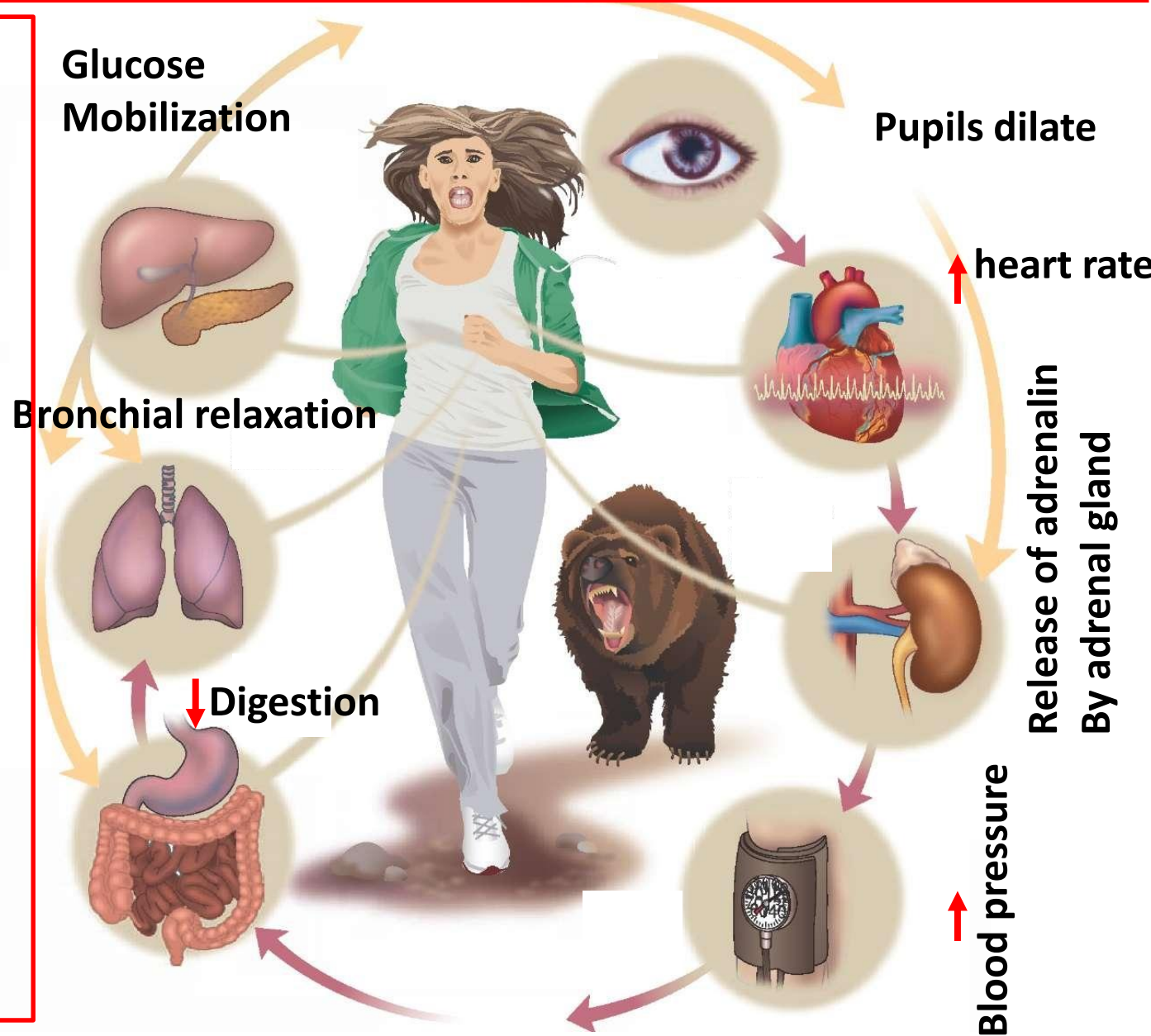
Sympathetic ANS Dominates During Fight-or-Flight Response

- **Fight-or-Flight** (or **Freeze**) response is an **automatic survival mechanism** that prepares the body for emergency
- When faced with a life threatening danger many changes in body functions occur:
- **Sympathetic functions** that **mobilize energy** are initiated rapidly:
 - Conversion of glycogen into glucose
 - Increased heart rate
- All **parasympathetic functions** not needed for the struggle are **inhibited**:
 - Digestion
 - Sexual function



Fight-or-Flight Response

- **Threat:** an attack (**bear**), harmful event
- Signal processing in the brain
- Amygdala and hypothalamus
- Activation of sympathetic NS
- **Super man strength and speed**



II-Parasympathetic Division of ANS

✚ **B. Parasympathetic division** originates from cranial (III, VII, IX and X) & sacral levels of CNS (called the **cranio-sacral**)

- Long preganglionic fibers
- Short postganglionic fibers
- There are **terminal ganglia** on or near effectors.

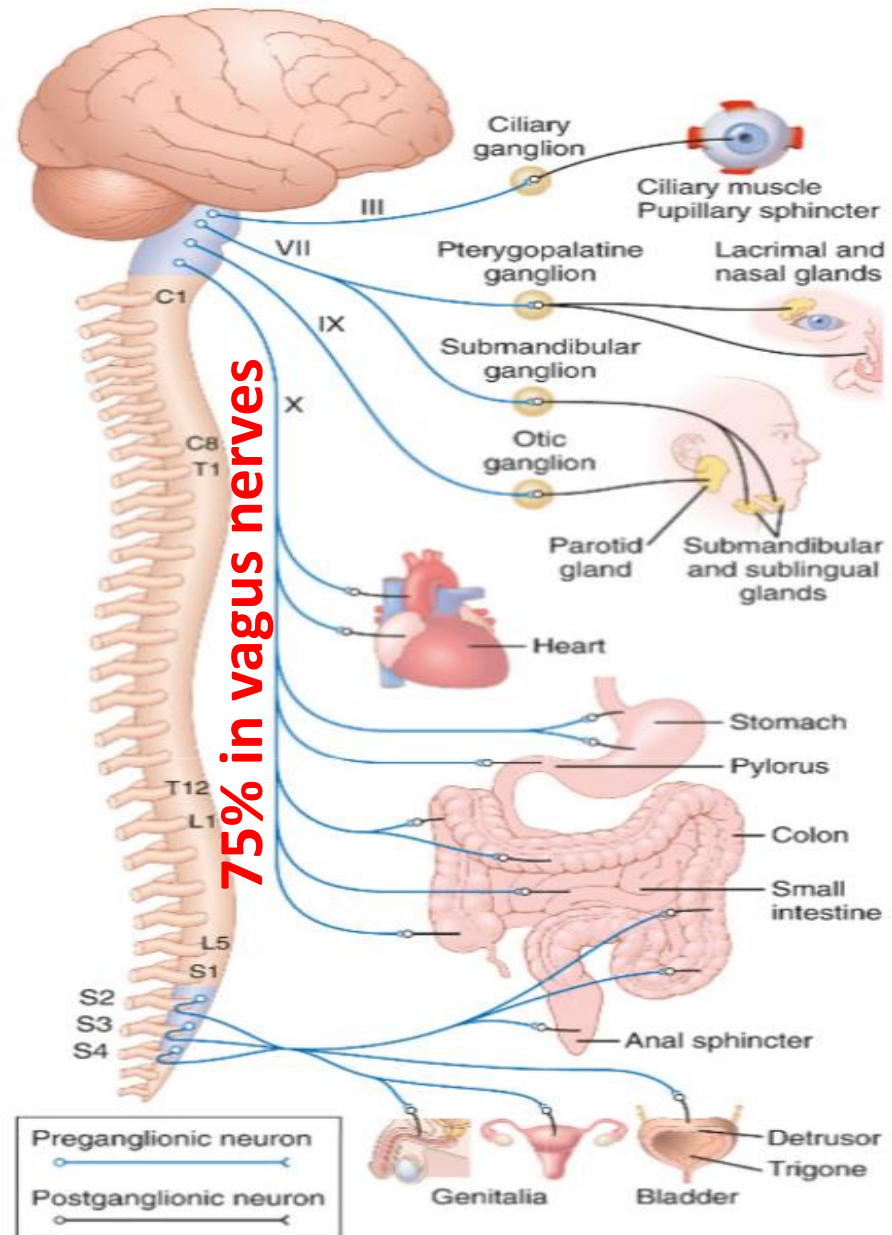


Figure 61-3

Parasympathetic ANS Dominates During Relaxed Situations

- Responsible for stimulation of “**Rest & Digest**” or “**Feed & Breed**” activities
- Elicits responses that are **usually (but not always!) opposite** to those caused by sympathetic division.
- Conservation of body energy

Rest & Digest

Dual innervation allows the precise control over the activity of a visceral organ.



Exceptions to General Rule of Dual Innervation

- **Most** innervated blood vessels (arterioles and veins) receive only **sympathetic** nerve fibers (**except in clitoris/penis: erection**).
- **Most** sweat glands are innervated only by **sympathetic nerves** (**except in hand palms**).
- Both ANS subdivisions **stimulate** the activity of some **glands**.

Summary of Main Functions of ANS

PARASYMPATHETIC NERVES

"Rest and digest"

SYMPATHETIC NERVES

"Fight or flight"

Constrict pupils

Stimulate saliva

Slow heartbeat

Constrict airways

Stimulate activity of stomach

Inhibit release of glucose; stimulate gallbladder

Stimulate activity of intestines

Contract bladder

Promote erection of genitals

Dilate pupils

Inhibit salivation

Increase heartbeat

Relax airways

Inhibit activity of stomach

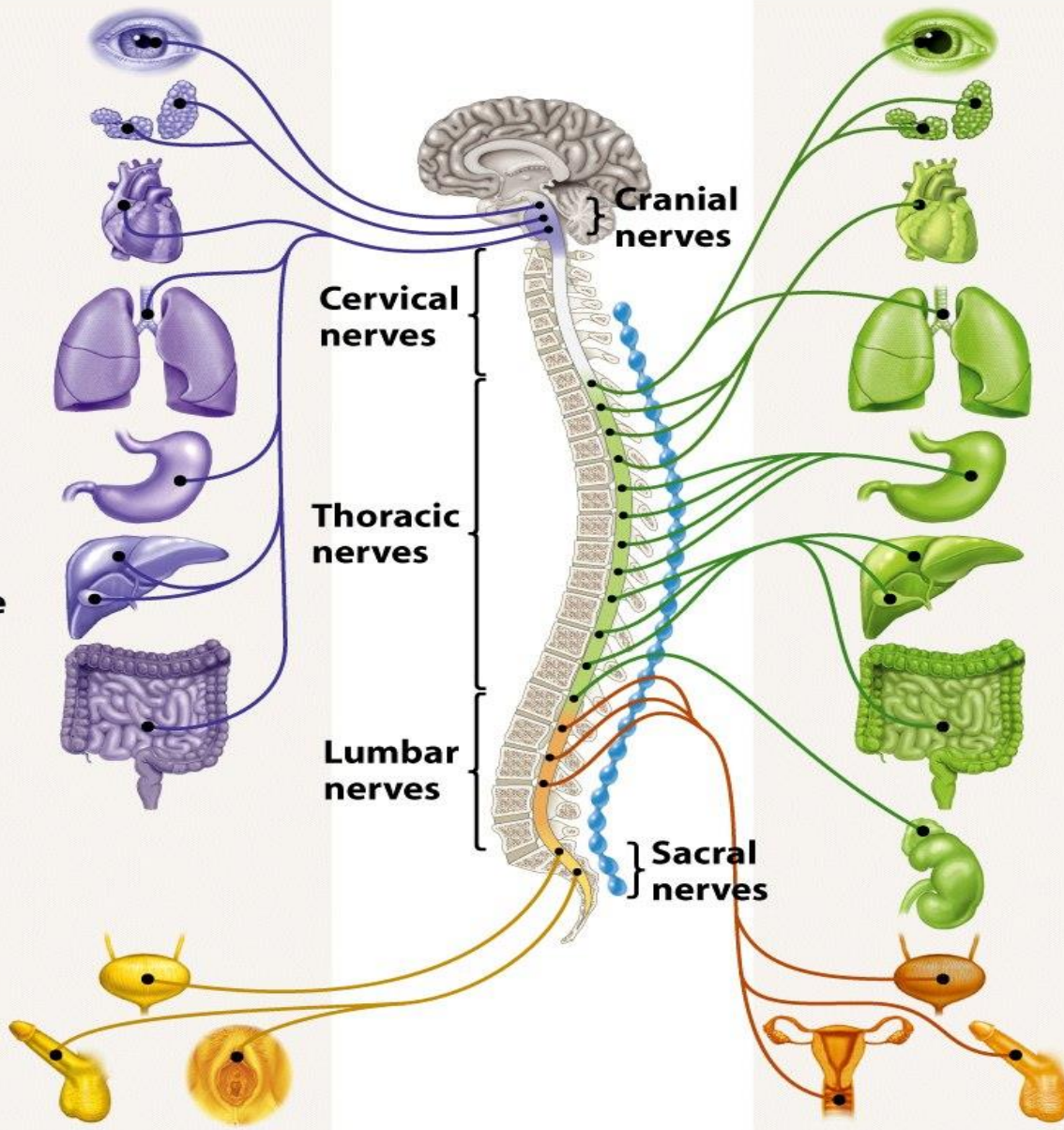
Stimulate release of glucose; inhibit gallbladder

Inhibit activity of intestines

Secrete epinephrine and norepinephrine

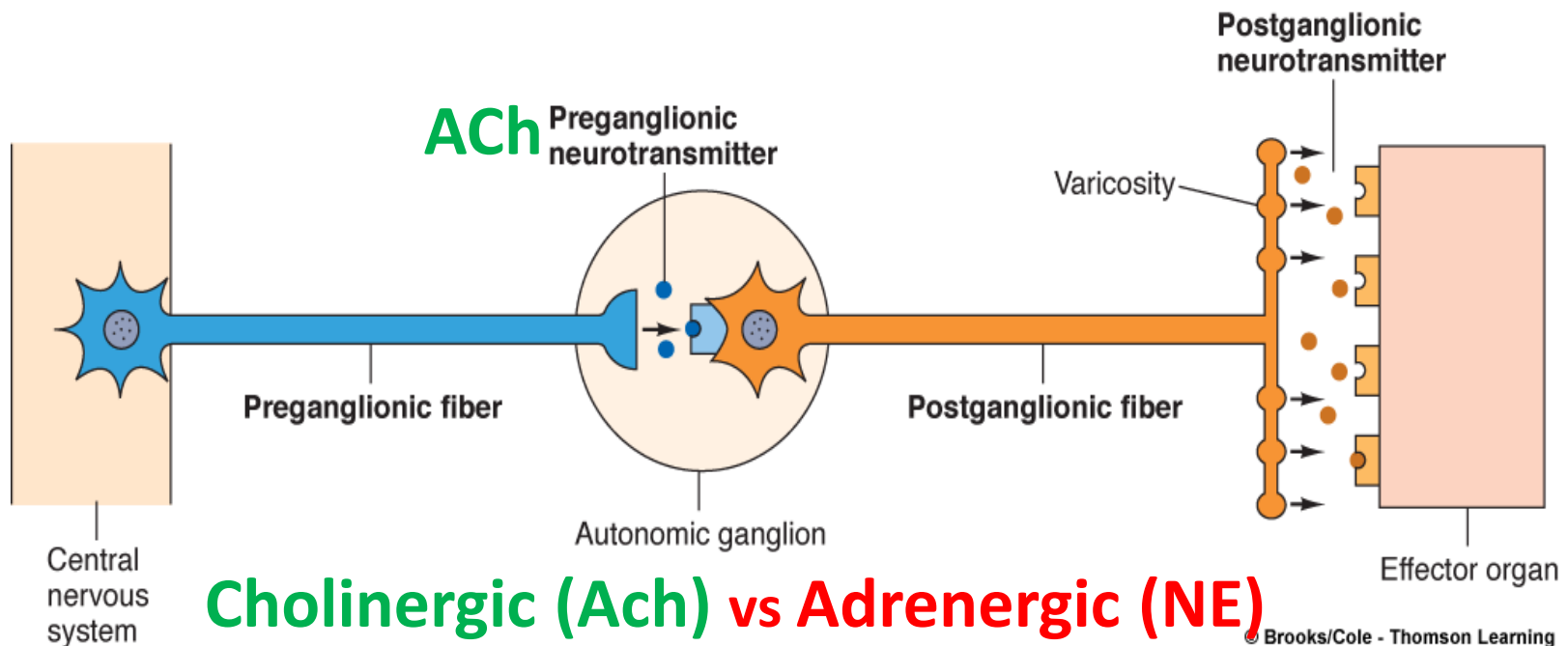
Relax bladder

Promote ejaculation and vaginal contraction



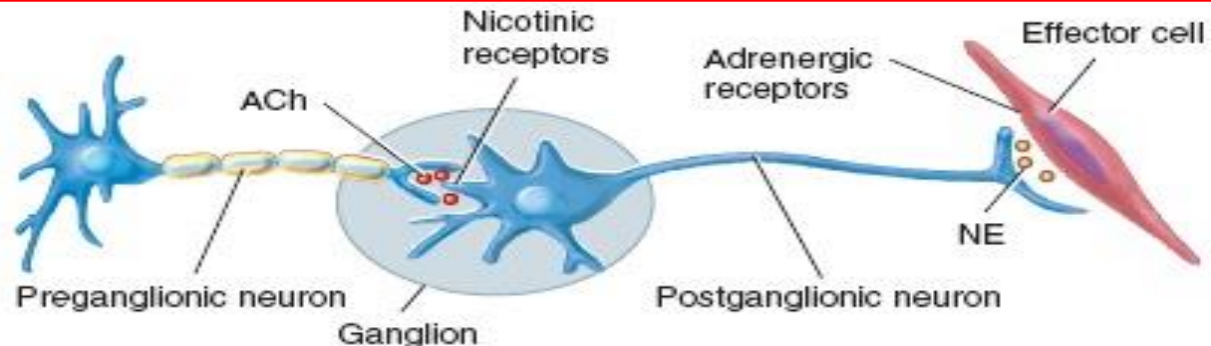
Neurotransmitters & Receptors of the ANS

- **All** preganglionic fibers of ANS release and **all** parasympathetic postganglionic fiber release **acetylcholine (ACh) (cholinergic)**.
- **MOST** sympathetic postganglionic fibers release **norepinephrine (adrenergic)**, except at sweat glands and some blood vessels in skeletal muscles where they release **Ach**.

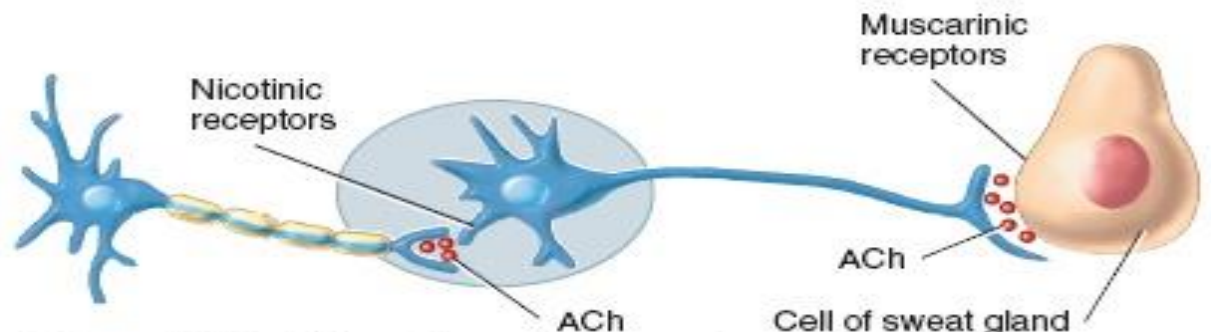


Cholinergic & Adrenergic Receptors

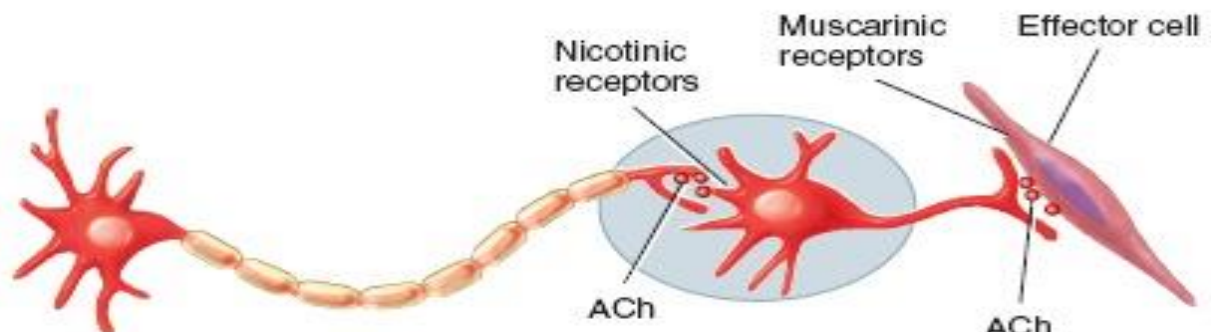
- All cholinergic receptors on the postganglionic neurons of **sympathetic** and **parasympathetic** systems, and on the adrenal gland are **nicotinic**
- All cholinergic receptors on effector cells are **muscarinic**



(a) Sympathetic division—innervation to most effector tissues



(b) Sympathetic division—innervation to most sweat glands



(c) Parasympathetic division

1. Cholinergic Receptors

They are named after the drugs that bind to them:

- A. Muscarinic** (G-protein coupled) Receptors (bind muscarine)
- B. Nicotinic** (ligand-gated) Receptors (bind nicotine)

Muscarinic Receptors



M1
M2
M3
M4
M5

Muscarine (Mushroom)

Nicotinic Receptors



Nicotine (Tobacco)

Blocker: Aatropine blocks M receptors and is used to inhibit salivary and bronchial secretion before surgery.

2. Adrenergic Receptors

- ✦ Adrenergic receptors bind to norepinephrine and epinephrine
 - **α 1-receptors:** their activation usually produces **excitation** (most target tissues)
 - **α 2-receptors:** their activation usually produce **inhibition** (digestive organs)
 - **β 1-receptors:** They cause an **excitatory response** (mainly in heart).
 - **β 2-receptors:** their activation in general causes **inhibition** (blood vessels and airways).
 - **β 3-receptors:** ???

Functions of Adrenergic Receptors

Alpha (α -) Receptor	Beta (β -) Receptor
Vasoconstriction	Vasodilation (β_2)
Iris dilation	Cardioacceleration (β_1)
Intestinal sphincter contraction	Increased myocardial strength (β_1)
Bladder sphincter contraction	Bronchodilation (β_2)
Pilomotor contraction	Glycogenolysis (β_2)

Table 61-1 (modified)

More details in Pharmacology lecture

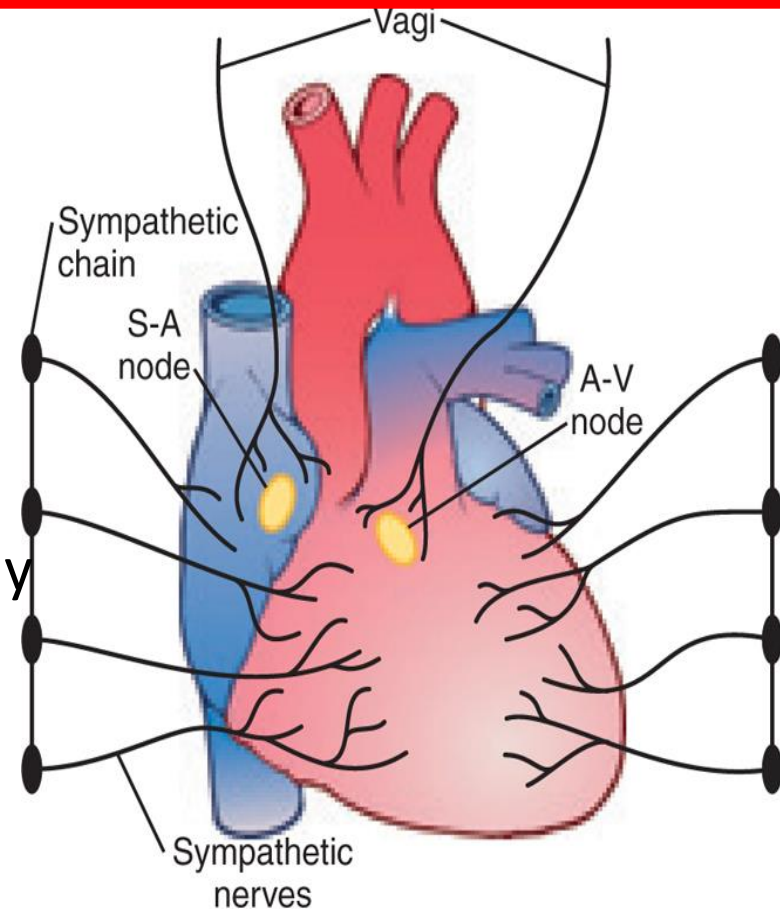
Effects of ANS on the Heart

Effects of sympathetic S:

- Increase the **heart rate** and **force** of contraction
- Activation of β_1 -receptors by NE
- Increase permeability of **Na⁺** and **Ca²⁺** channels causing depolarization and increased contractile strength respectively

Effects of parasympathetic S:

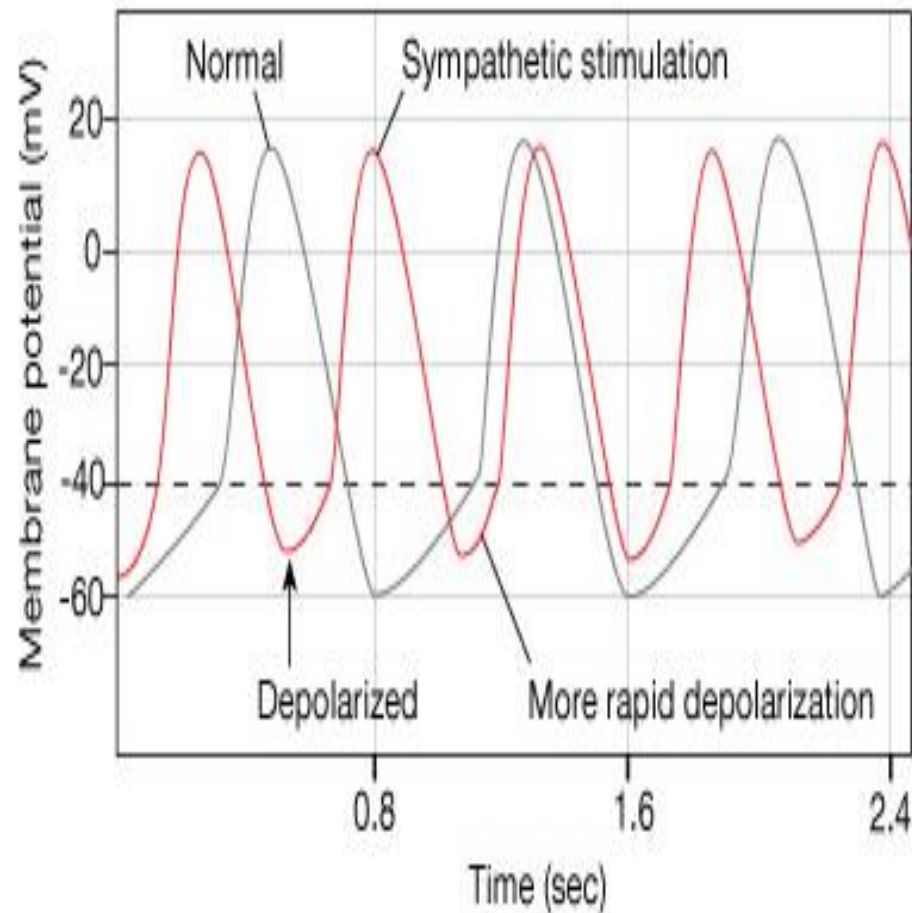
- Decrease heart rate (vagus nerve) but has not effect on contraction
- Release of Ach which increases permeability of **K⁺** channels (hyperpolarization) via activation of Muscarinic receptors .



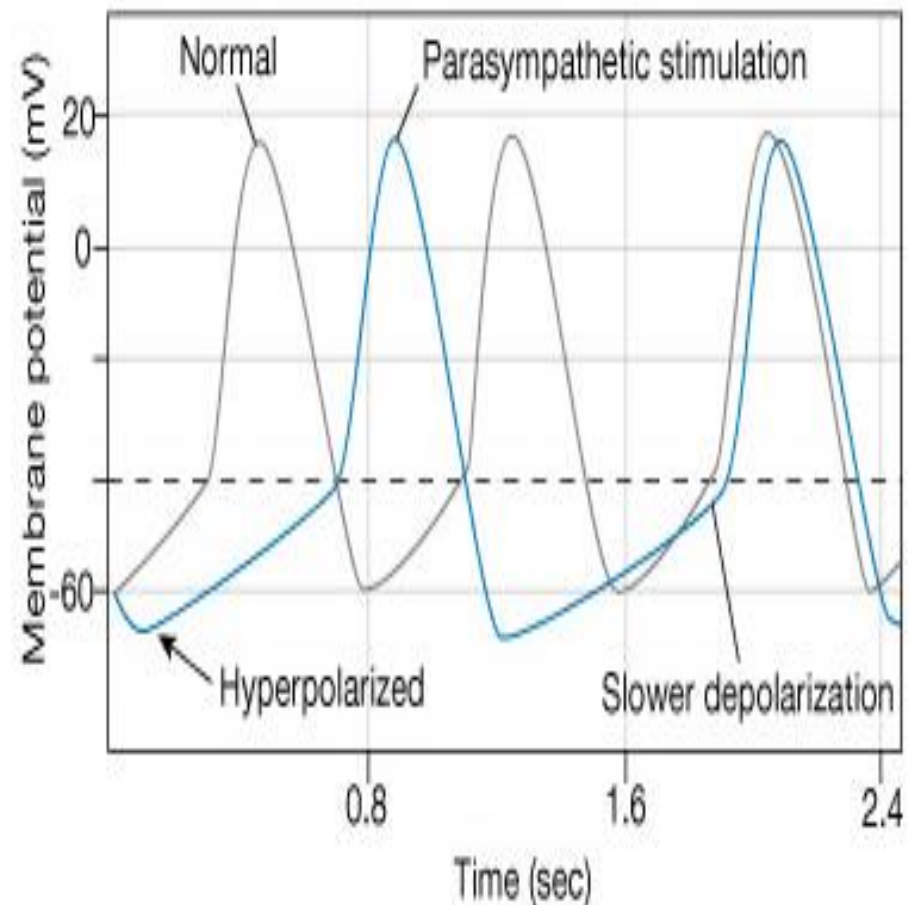
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Modulation of Heart Rate by ANS

(a) Sympathetic stimulation and epinephrine depolarize the autorhythmic cell and speed up the depolarization rate, increasing the heart rate.



(b) Parasympathetic stimulation hyperpolarizes the membrane potential of the autorhythmic cell and slows depolarization, slowing down the heart rate.



Disorders of the ANS

Raynaud's disease:

- Characterized by constriction of blood vessels
- It is an exaggeration of vasomotor responses to cold or emotional stress
- During an attack, the fingers and toes can change colours from white to blue to red.



Disorders of the ANS

Hypertension – high blood pressure

- Can result from overactive sympathetic vasoconstriction



The background of the image is a soft-focus field of bright pink flowers, likely gerberas, with some green stems visible. The flowers are scattered across the frame, creating a delicate and vibrant backdrop for the central text.

Thank
You