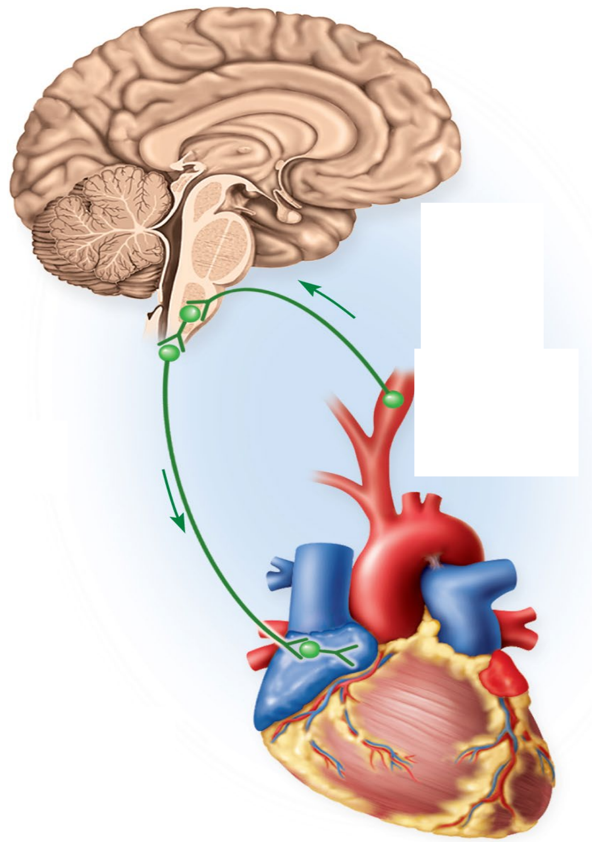
Chapter 15.1

Structure and Function of the Autonomic Nervous System



General Properties of ANS

Autonomic nervous system is a motor nervous system that controls glands, cardiac muscle, and smooth muscle

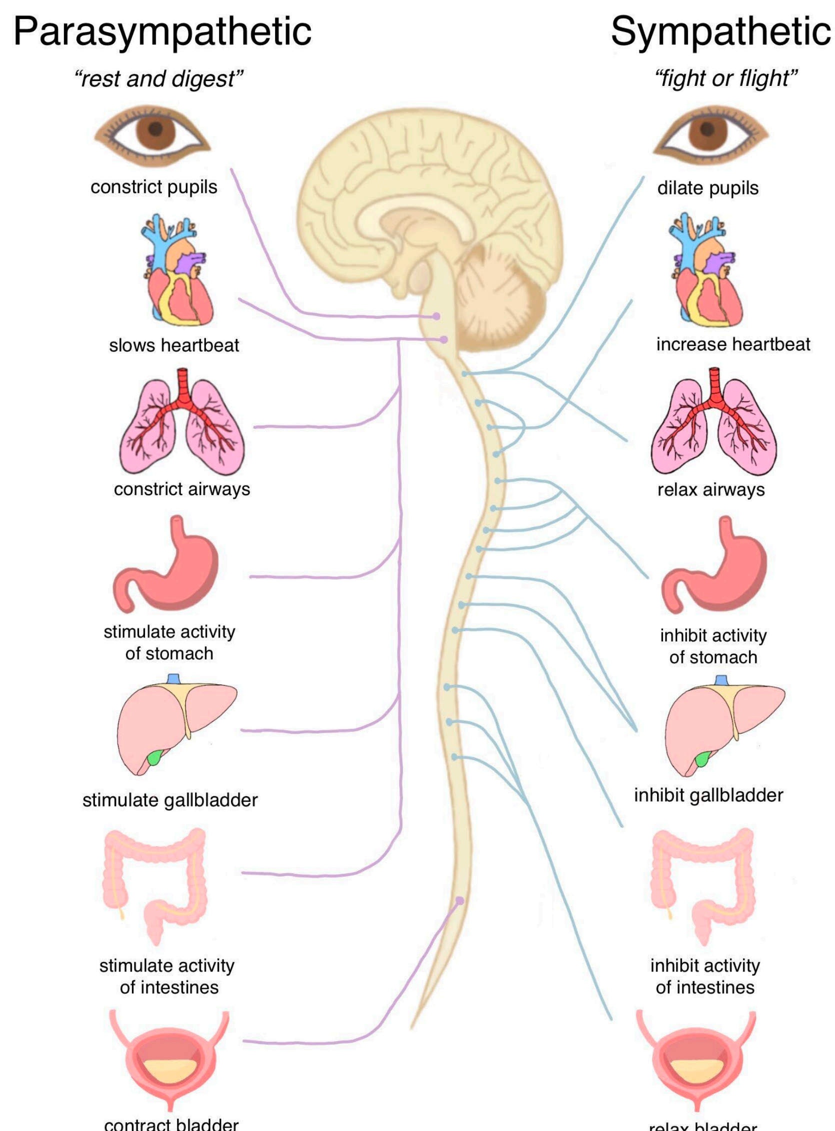
Also called the visceral motor system because ANS regulates the glands and smooth muscles in organs

ANS has two divisions

- Parasympathetic division
- Sympathetic division

Not responsible for the organ's function

But increases or decreases the rate of the organ's function (e.g. increase or slow the heart rate)



Divisions of ANS

★ ★

Two divisions: sympathetic vs parasympathetic

Common for organs to be innervated by both divisions

Called dual innervation // dual innervation may have cooperative or antagonistic effects

Sympathetic division /// general outcome = prepares body for physical activity // exercise, trauma, arousal, competition, anger, or fear // increases heart rate, BP, airflow, blood glucose levels, while reducing blood flow to the skin and digestive tract

Parasympathetic division /// general outcome = calms many body functions // rest and restoration division // reducing energy expenditure and assists in bodily maintenance /// active during digestion and waste elimination

General Properties of ANS

ANS control the smooth muscle and glands of the body's organs

Body organs are called viscera.

ANS primary targets are the viscera of the thoracic and abdominal cavities

ANS also target some structures in the body's cutaneous membrane

- cutaneous blood vessels (i.e. thermoregulation)
- sweat glands
- piloerector muscles

General Properties of ANS

This is the nervous system that operates in comparative secrecy (it is not voluntary)

ANS regulates homeostasis in response to a change in the “internal environment”

Walter Cannon studied the ANS // coined the expressions *homeostasis* and the fright, *fight or flight response*

<u>Homeostasis can not be maintained without the ANS or without the endocrine system</u>

The hypothalamus regulates both the endocrine and ANS // the hypothalamus is the “boss of homeostasis”

<u>An imbalance in homeostasis causes a disease state or death</u>

General Properties of ANS

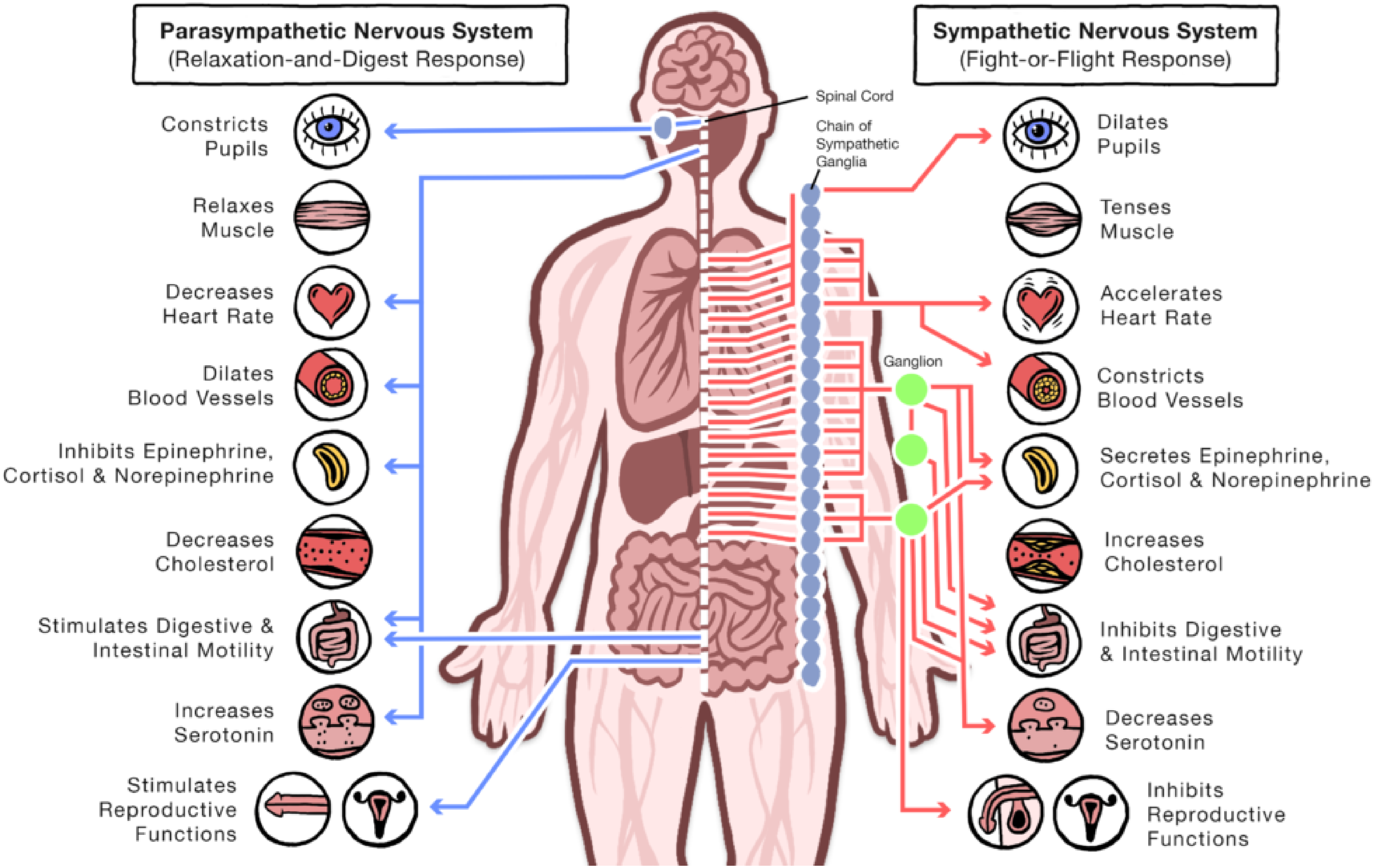
ANS is used to adjust the organ’s rate of function and not the function of the orgen

ANS goal is the match organ's performance to the need of the organism

Example 1) The heart has an internal pacemaker but the ANS is used to increase or decrease heart rate in response to exercise or resting state

Example 2) Denervation hypersensitivity // exaggerated response of cardiac muscle and   smooth muscle if ANS fibers are severed

AUTONOMIC NERVOUS SYSTEM



Components of the Visceral Reflex Arc

stimulus – a change in the internal environment

receptors – nerve endings that detect stretch, tissue damage, blood chemicals, body temperature, and other internal stimuli

afferent neurons – send stimulus to CNS / sensory / unipolar neuron

inter-neurons – only in the CNS

efferent neurons – carry motor signals away from the CNS to target tissue (either parasympathetic or sympathetic motor fibers)

the effectors – adjust homeostasis by regulating cardiac muscle, or smooth muscle and glands of the viscera

ANS only modifies the organ's function // the organs functions (i.e. the effectors) is not dependent on the ANS

Visceral Reflex In Response to High BP

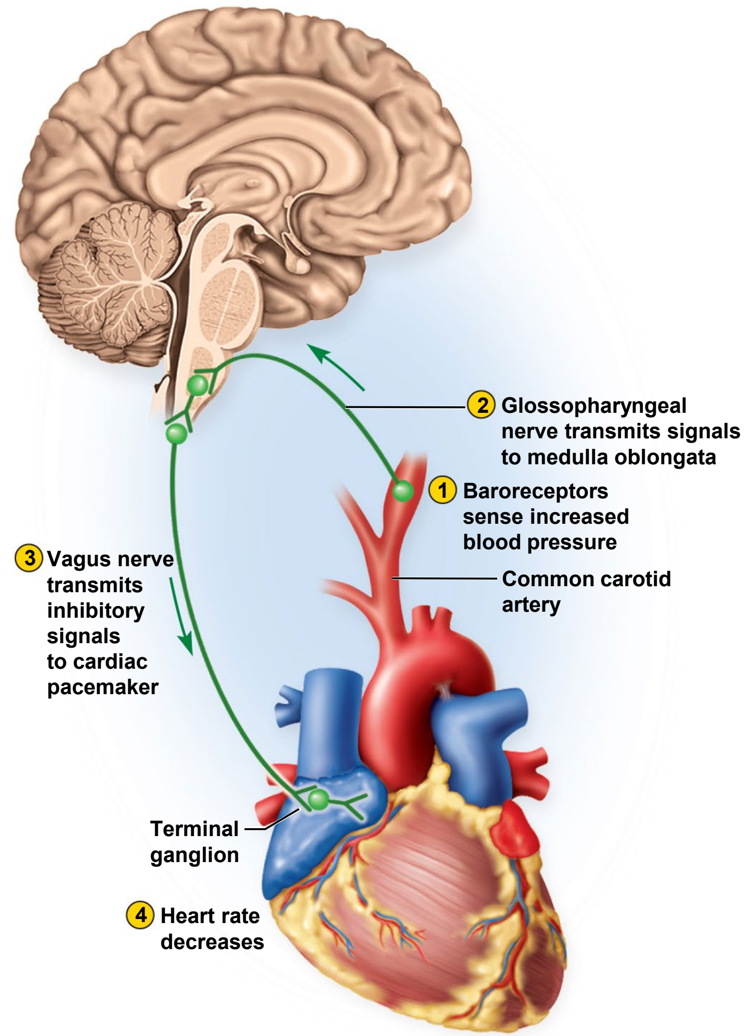
(1) high blood pressure detected by arterial stretch receptors

(2) afferent neuron carries signal to CNS & interneurons process signals

(3) efferent neurons carry signals to the heart

(4) heart slows reducing blood pressure

This is an example of a homeostatic negative feedback loop



Interoception vs Exteroception

Exteroception is the awareness of external stimuli—sights, sounds, smells, tastes and tangible objects. (This externally-directed focus is where we allocate most of our attention.) Proprioception is the awareness of where our body is in space.

Interoception is the awareness of stimulus from inside our bodies. // the ability to be aware of internal sensations in the body, including heart rate, respiration, hunger, fullness, temperature, and pain, as well as emotion sensations.

The two divisions of the ANS are responsible for homeostasis and we are made aware of what ANS accomplishes through our interoception.

The insula is the area of the brain where we become aware of interoception.

Integration centers use parasympathetic and sympathetic efferent fibers to send motor signals to the organs, but ANS also send ANS action potentials to the insula

What is ANS tone?

ANS is never "turned off"

In most cases both division are sending signals to same organ

One division will dominate over the other division

The dominate division is said to "set the "ANS tone"

Parasympathetic tone = Example: Holds resting heart rate at 70 to 80 beats per minute // however, heart rate is 100 beats per minute without any ANS influence

Sympathetic tone = Example: Keep most blood vessels partially constricted /// this maintains peripheral resistance and blood pressure

One Division May Have Opposite Effect on Different Organs

An ANS division may have opposite effects on different organs.

sympathetic division excites the hearts but inhibits digestive system and urinary bladder activity

parasympathetic division inhibits the heart rate but excites the digestive and urinary bladder activity

How is this possible?

Same neurotransmitter but different receptors!

ANS Motor Neural Pathway

ANS neural pathway uses **two neurons** to move AP between the spinal cord and the target organ

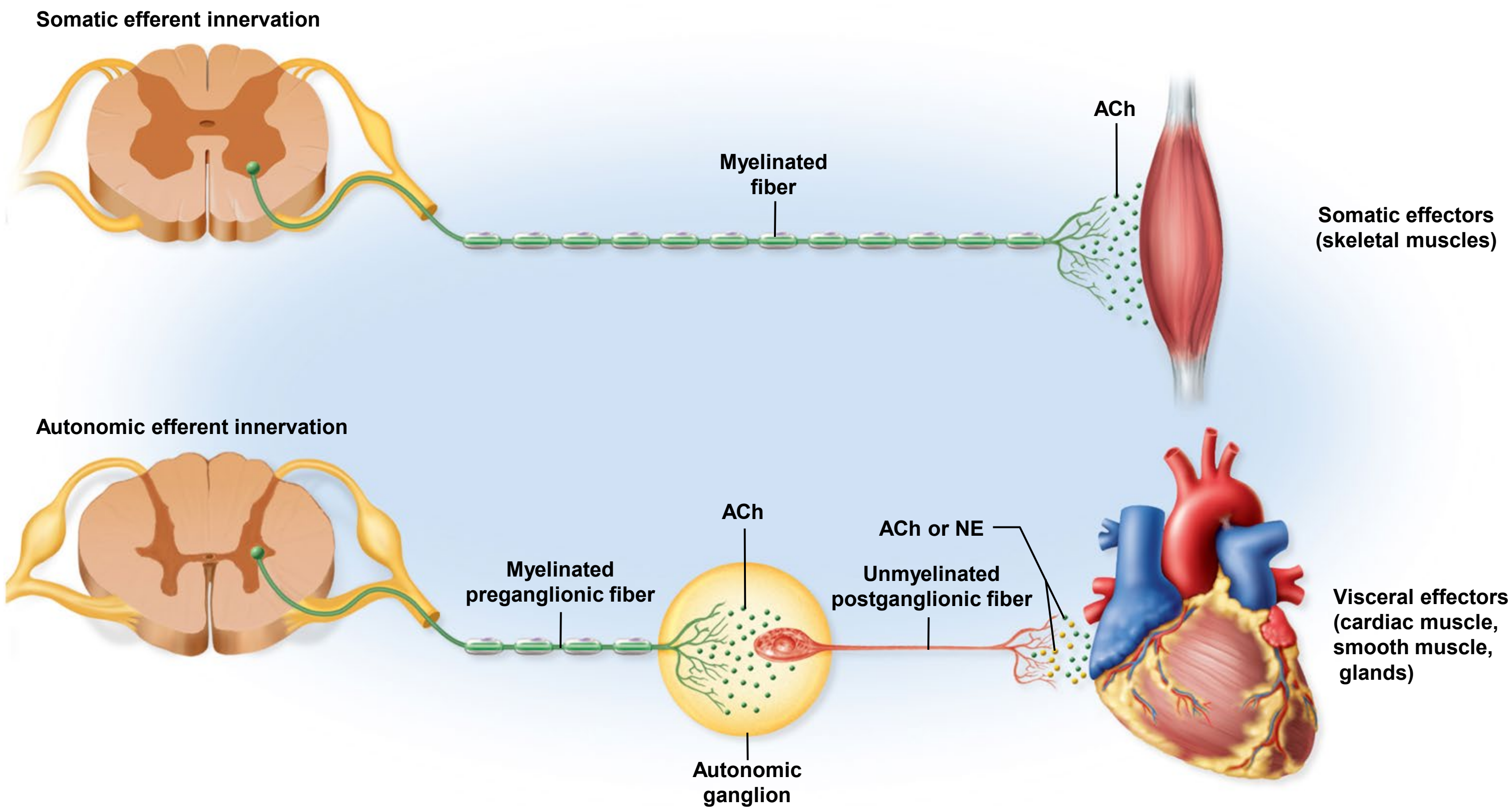
This pathway must cross a synapse /// it occurs at the autonomic ganglia and acetylcholine is the neurotransmitter

> **Pre-ganglionic neuron** – the first neuron has a soma in the brainstem or spinal cord (myelinated fiber)

> **Post-ganglionic neuron -** soma form the ganglion and its axon extends the rest of the way to the target cell (unmyelinated fiber)

Note: *a ganglion is a collection of soma in the PNS (i.e. nuclei are a collection of soma in the CNS)*

What is the Difference Between Somatic and Autonomic Nervous System Pathways?



Somatic nervous system – lower motor neuron is a single nerve to target tissue

ANS – lower motor neuron uses two neurons to target tissue

ANS Neural Pathways

Different parts of the ANS are in the central nervous system and peripheral nervous systems

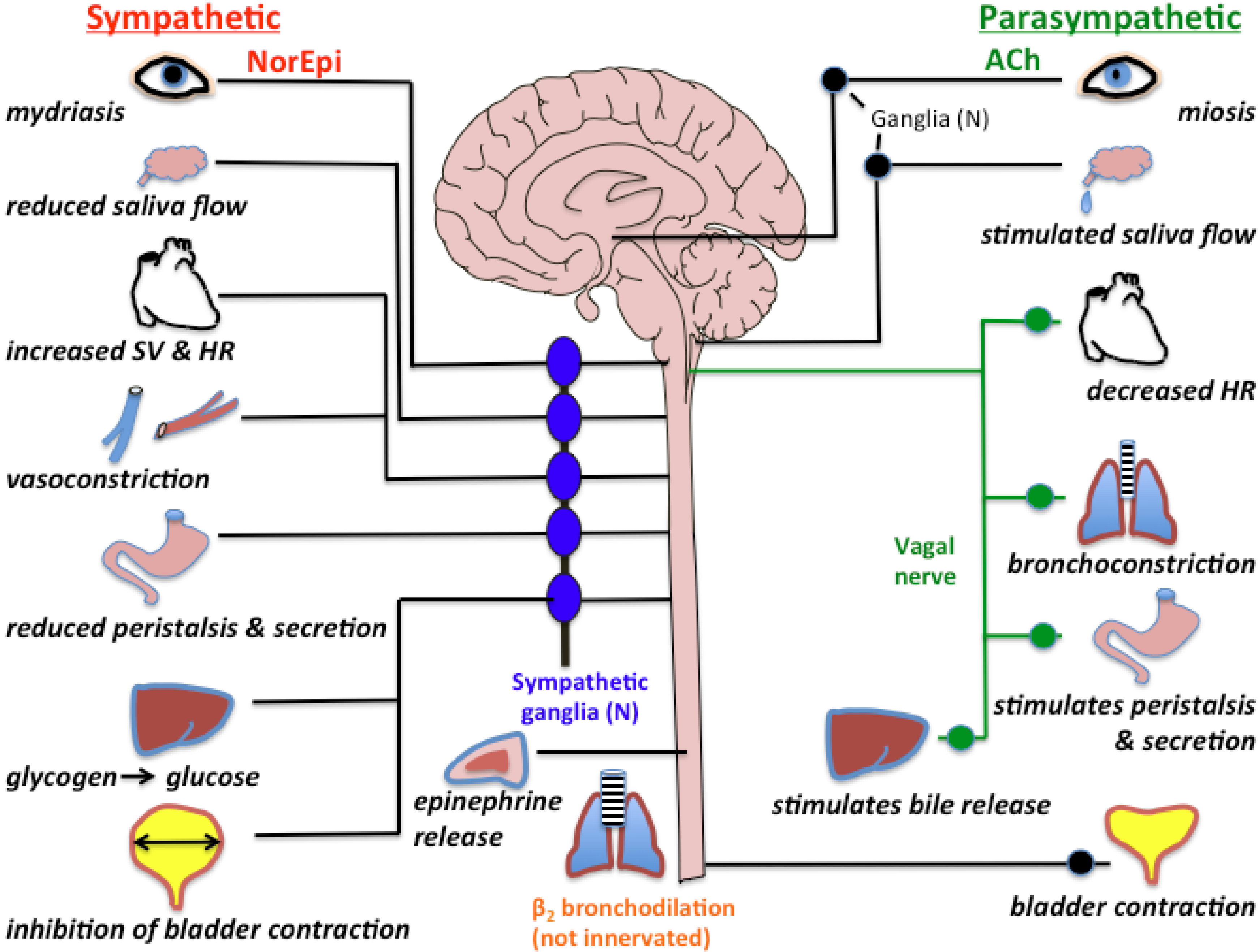
The controlling nuclei (integrating centers) for both divisions of the ANS are in the brain stem regions and controlled by the hypothalamus

A neuron from the brain stem's integrating centers will carry the action potential to either the parasympathetic or sympathetic nervous system's motor pathways.

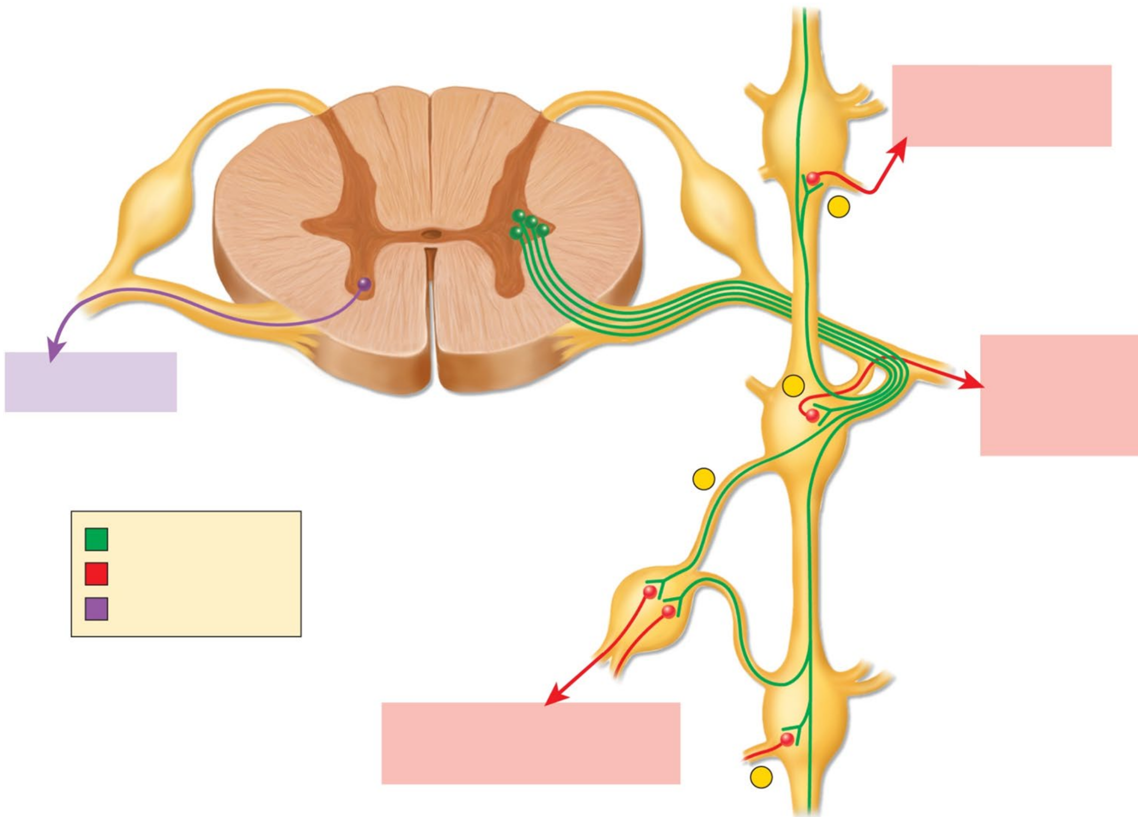
Sympathetic NS motor pathway's originate in the thoracolumbar regions of the spinal cord's lateral horn = the preganglionic neuron

Parasympathetic NS motor pathways originate in the crainiolumbar regions of the spinal cord

The Autonomic Nervous System



Sympathetic Nervous System



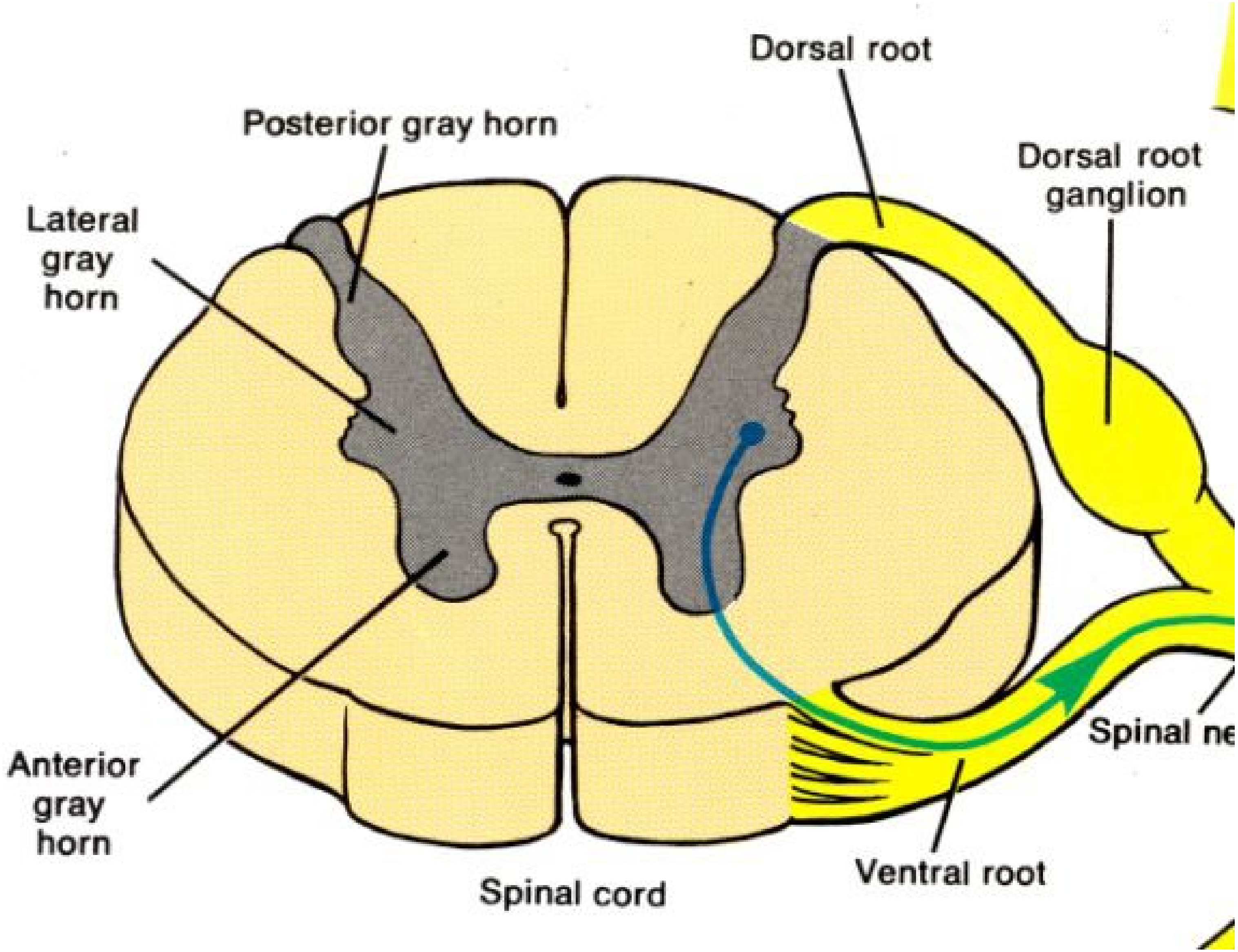
The Sympathetic Nervous System

Called the thoracolumbar division because it arises from the thoracic and lumbar regions of the spinal cord

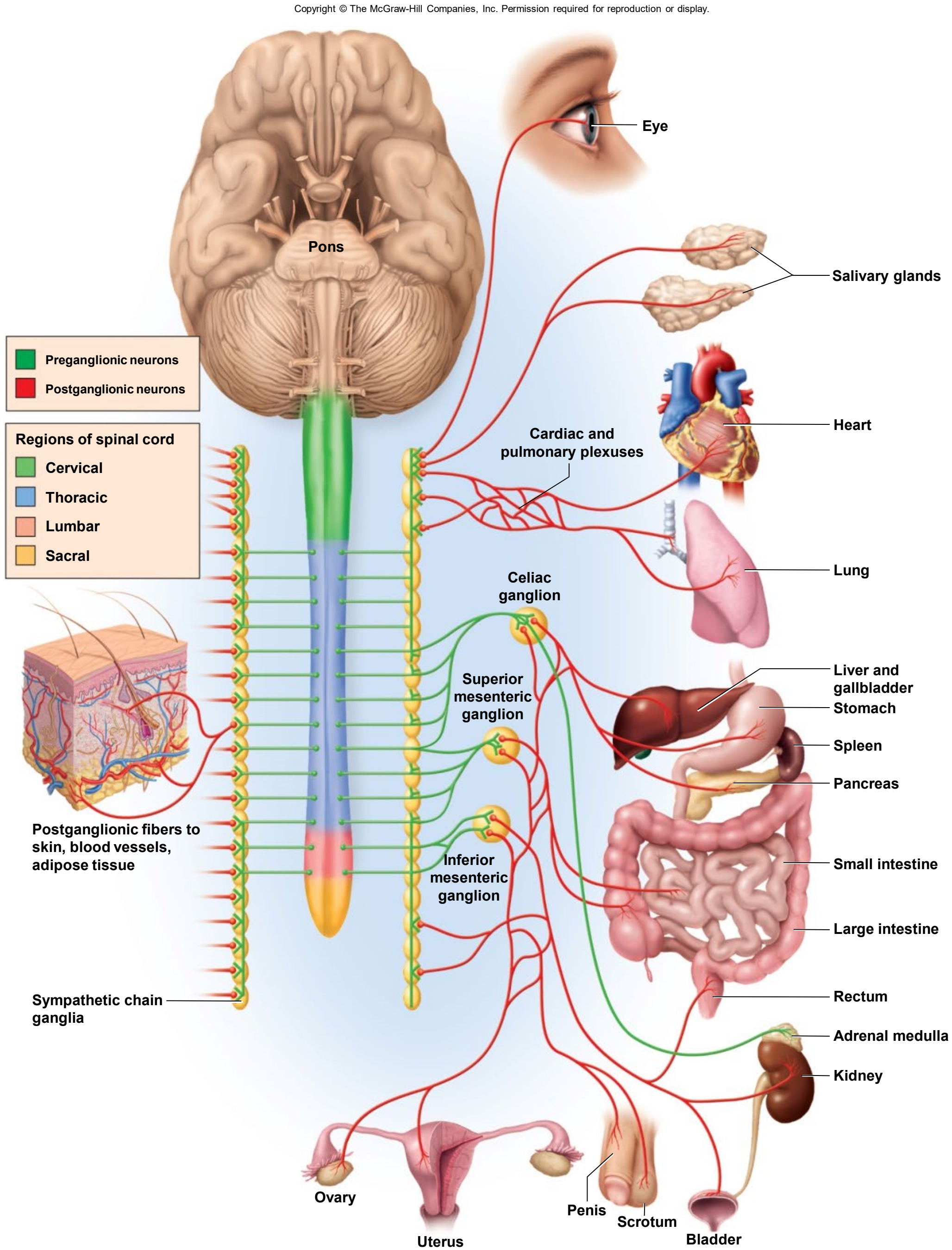
Preganglionic somas of the SNS are in lateral horns within the thoracic and lumbar regions of the vertebral column

Sympathetic Chain Ganglia (Paravertebral ganglia) parallel to vertebral column adjacent to thoracic and lumbar regions

SNS characterized by having short preganglionic and long postganglionic fibers // more divergent!


Dorsal root
Posterior gray horn
Dorsal root
ganglion
Lateral
gray
horn
Anterior
gray
horn
Spinal ne
Ventral root
Spinal cord

SNS Efferent Pathways



Sympathetic Nervous System

SNS fibers exit spinal cord through spinal nerves T1 to L2

Transit to nearby sympathetic chain of ganglia (also called the para-vertebral ganglia)

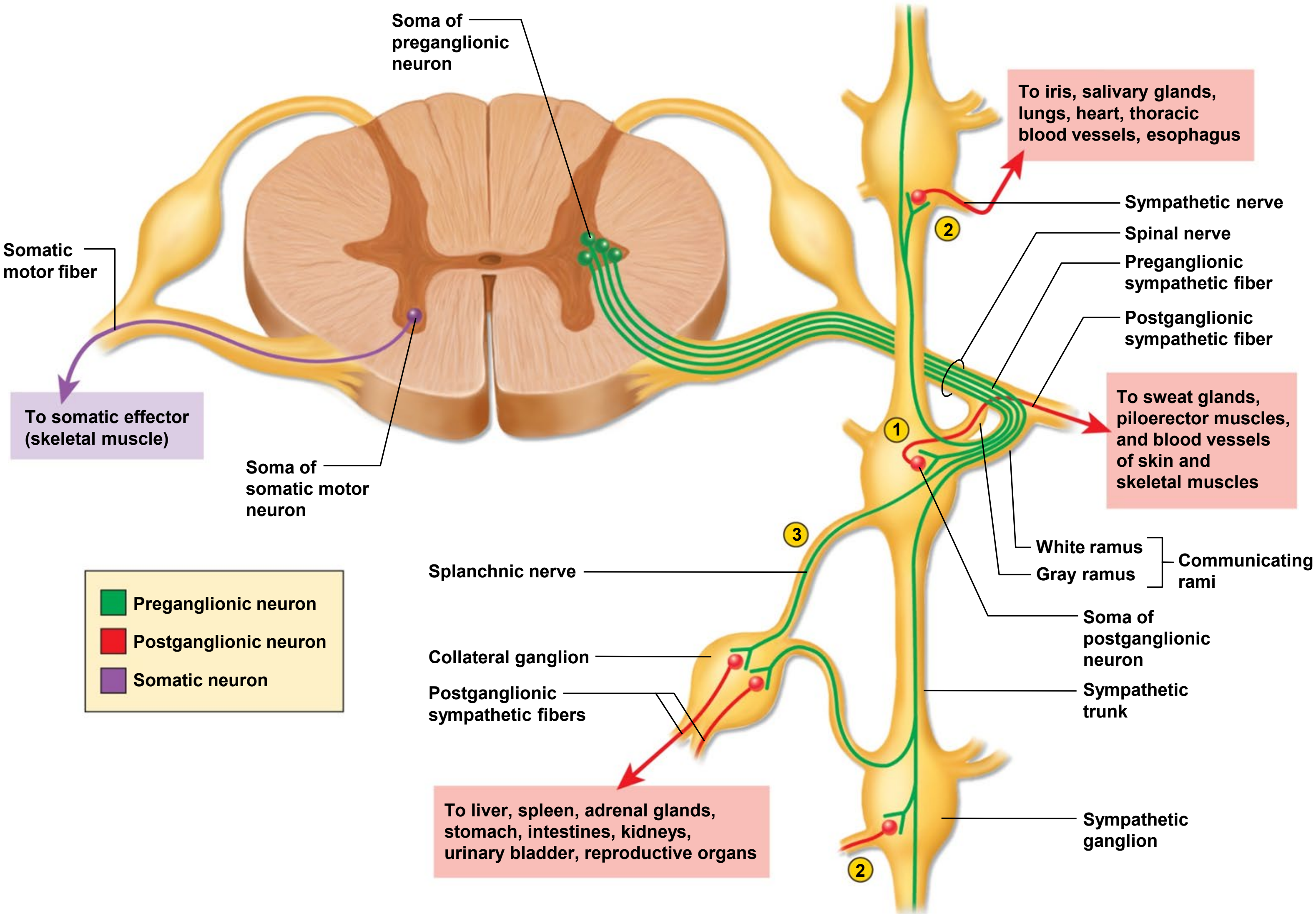
Series of longitudinal ganglia adjacent to both sides of the vertebral column from cervical to coccygeal levels

Usually 3 cervical, 11 thoracic, 4 lumbar, 4 sacral, and 1 coccygeal ganglion

Sympathetic nerve fibers are distributed to every level of the body

Sympathetic fibers move along multiple pathways

Sympathetic Nervous System's Preganglionic Pathways



Sympathetic Nervous System

Each paravertebral ganglion is connected to a spinal nerve by two branches – communicating rami

Preganglionic fibers are small myelinated fibers that travel form spinal nerve to the ganglion by way of the white communicating ramus (myelinated)

Postganglionic fibers leave the ganglion by way of the gray communicating ramus (unmyelinated) /// forms a bridge back to the spinal nerve

The postganglionic fibers extend the rest of the way to the target organ

Sympathetic Nervous System

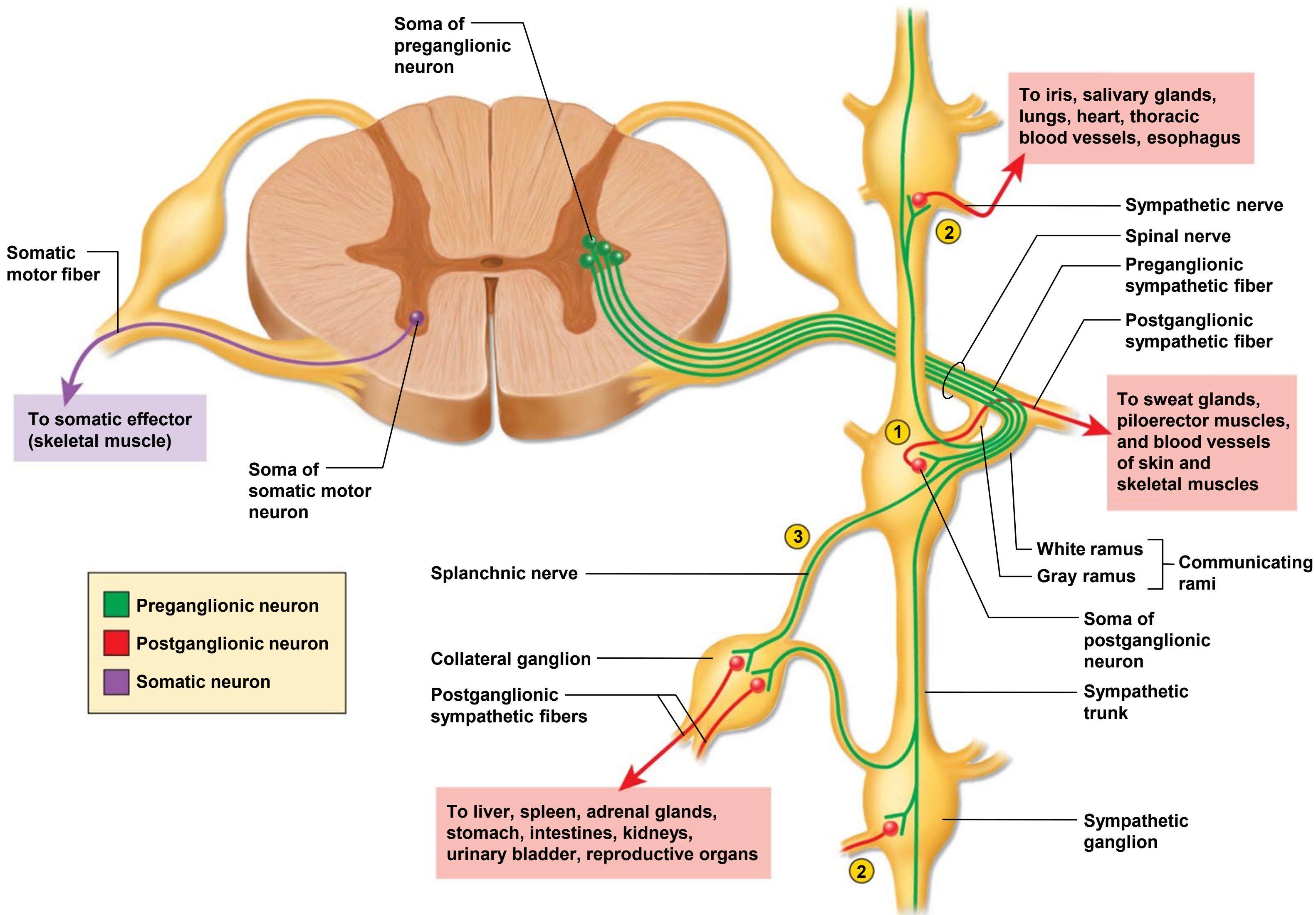
After entering the sympathetic chain /// the postganglionic fibers may follow one of three possible courses

#1 = some synapse on ganglia at entry level with a postganglionic neuron

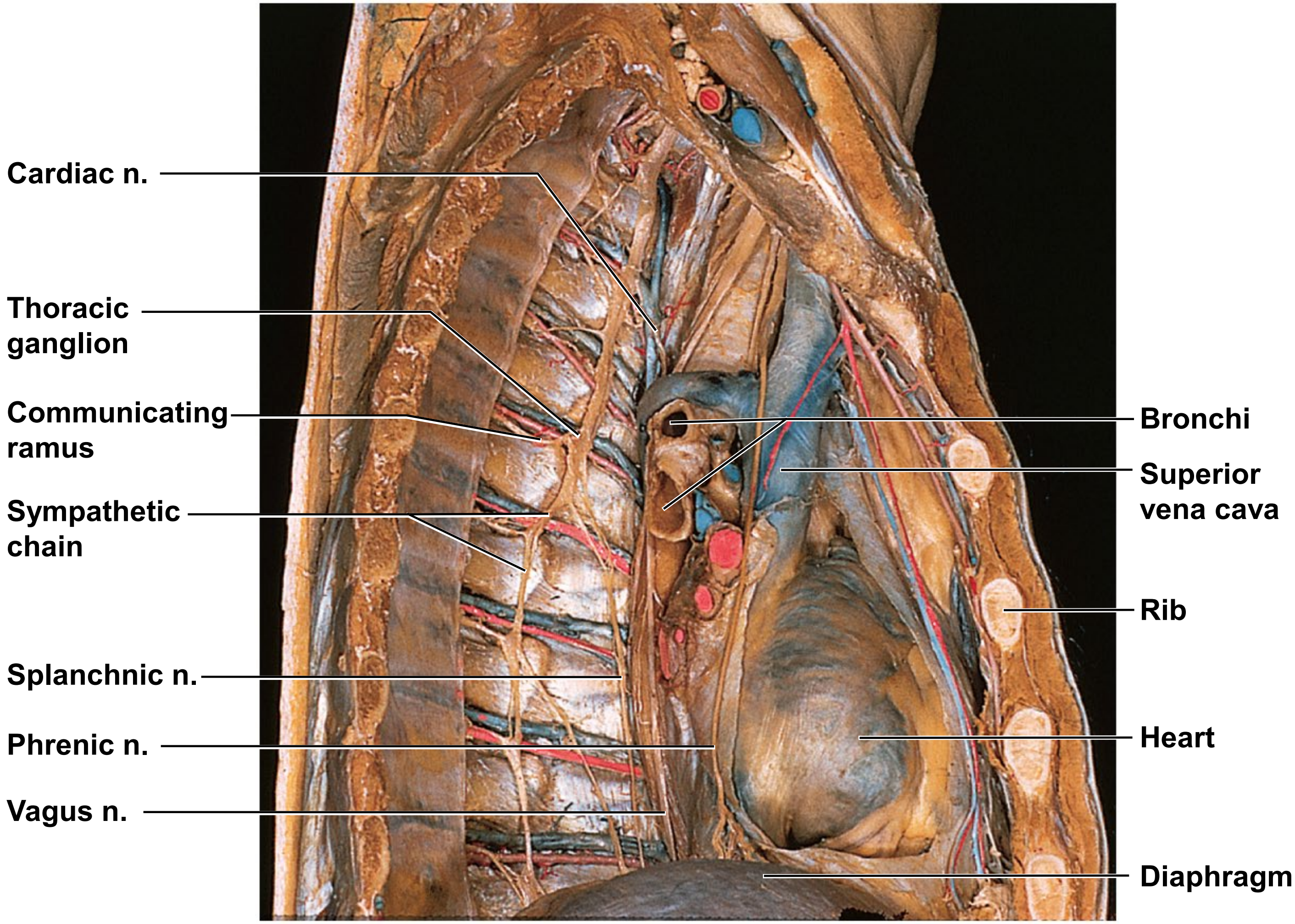
#2 = some travel up or down the chain and synapse in ganglia at other levels of the spinal cord

#3 - Some pass through the sympathetic chain ganglia without a synapse and <u>continue as *splanchnic nerves*</u>

Sympathetic Nervous System's Preganglionic Pathways



Sympathetic Chain Ganglia



Sympathetic Nervous System

Sympathetic nerve fibers leave the paravertebral ganglia and travel to their target tissue following one of there pathways // in the spinal nerve, in a sympathetic nerve, or as a splanchnic nerve

The spinal nerve route

- **Some postganglionic fibers exit a ganglion by way of the gray ramus**
- **Returns to the spinal nerve and travels the rest of the way to the target organ**
- **Pathway for most sweat glands, piloerector muscles, and blood vessels of the skin and skeletal muscles**

Sympathetic Nervous System

Sympathetic nerve route

other nerves leave by way of a sympathetic nerve that extend to the heart, lungs, esophagus and thoracic blood vessels

these nerves form carotid plexus around each carotid artery of the neck

issue fibers from there to the effectors in the head /// sweat & salivary glands, nasal glands, piloerector muscles, blood vessels, dilators of iris

some fibers of superior and middle cervical ganglia form cardiac nerves to the heart

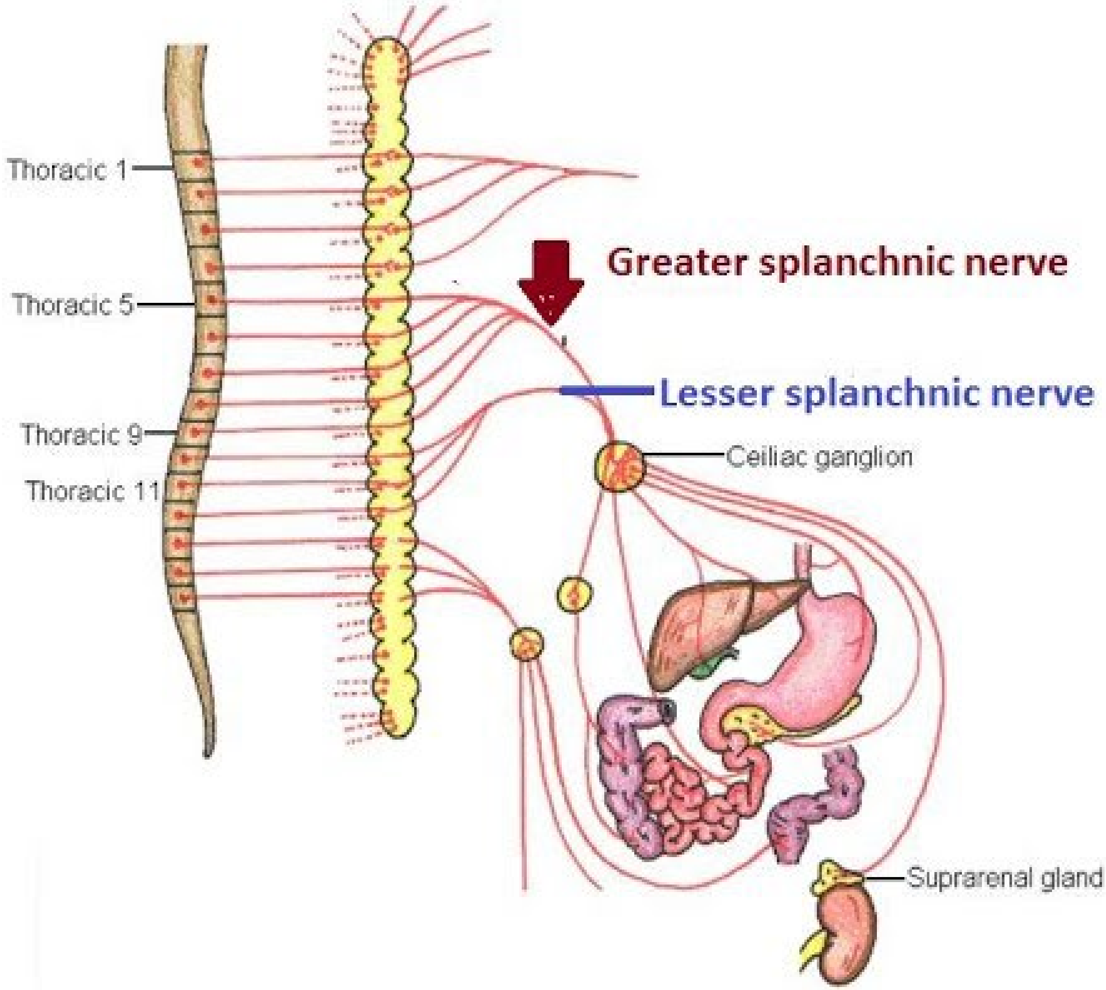
Sympathetic Nervous System

Splanchnic nerve route

Fibers that arise from spinal nerves T5 to T12 pass through the sympathetic ganglia without a synapse

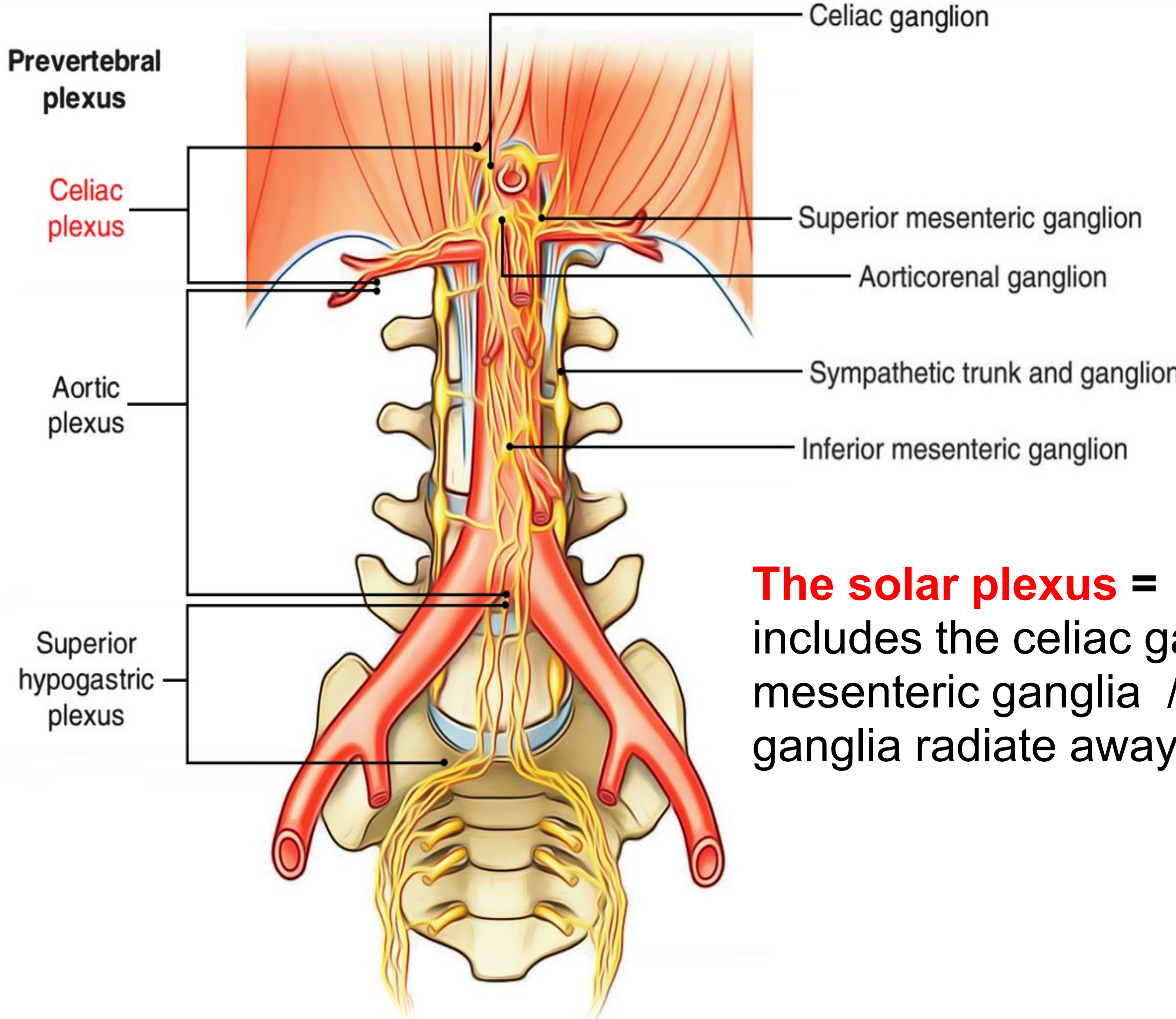
Continue as the splanchnic nerves

Splanchnic nerve go to different *collateral ganglia* where these preganglionic fibers then synapse



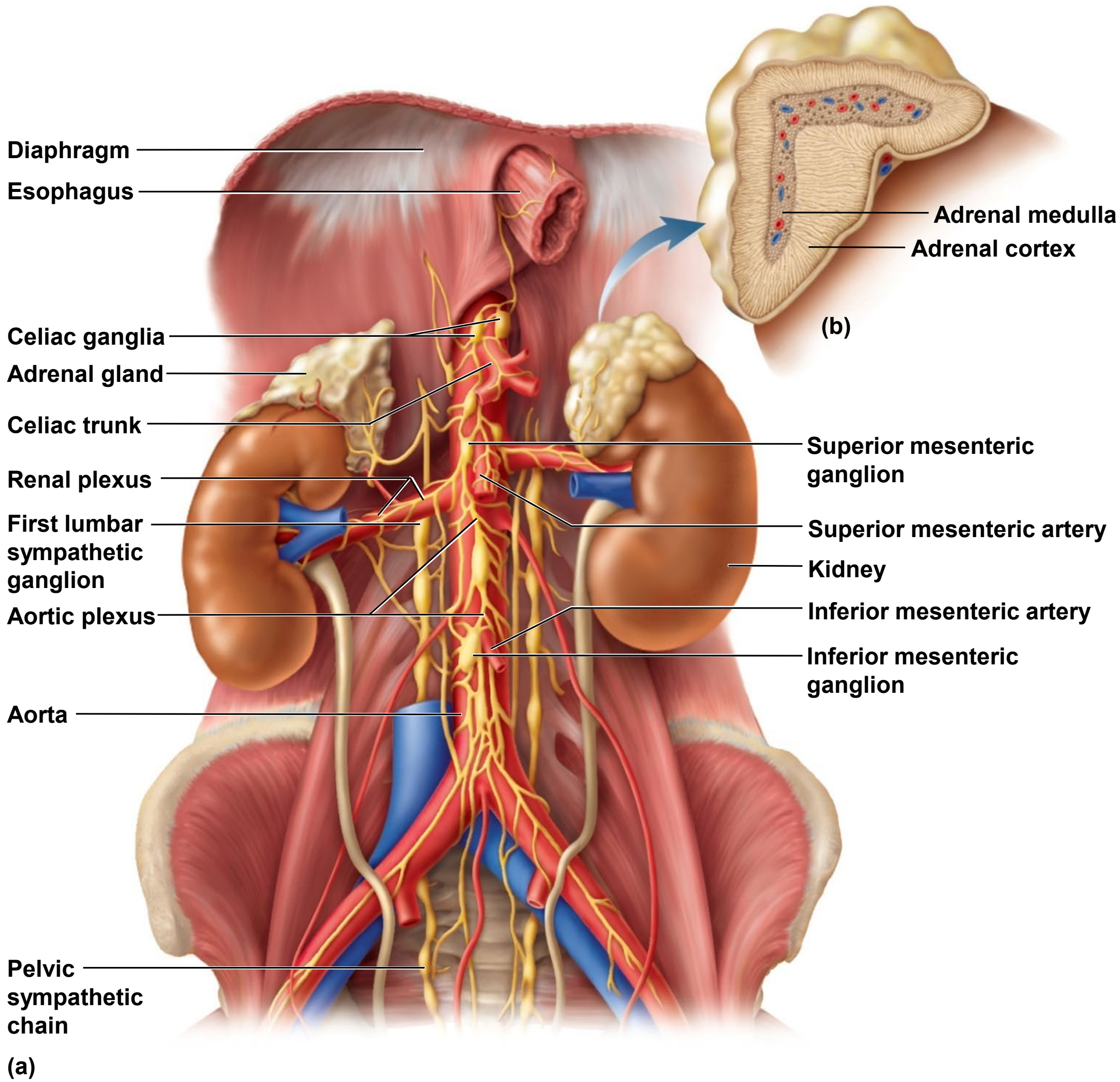
Thoracic 1
Thoracic 5
Thoracic 9
Thoracic 11
Greater splanchnic nerve
Lesser splanchnic nerve
Ceiliac ganglion
Suprarenal gland

Plexus of Sympathetic Nervous System ★

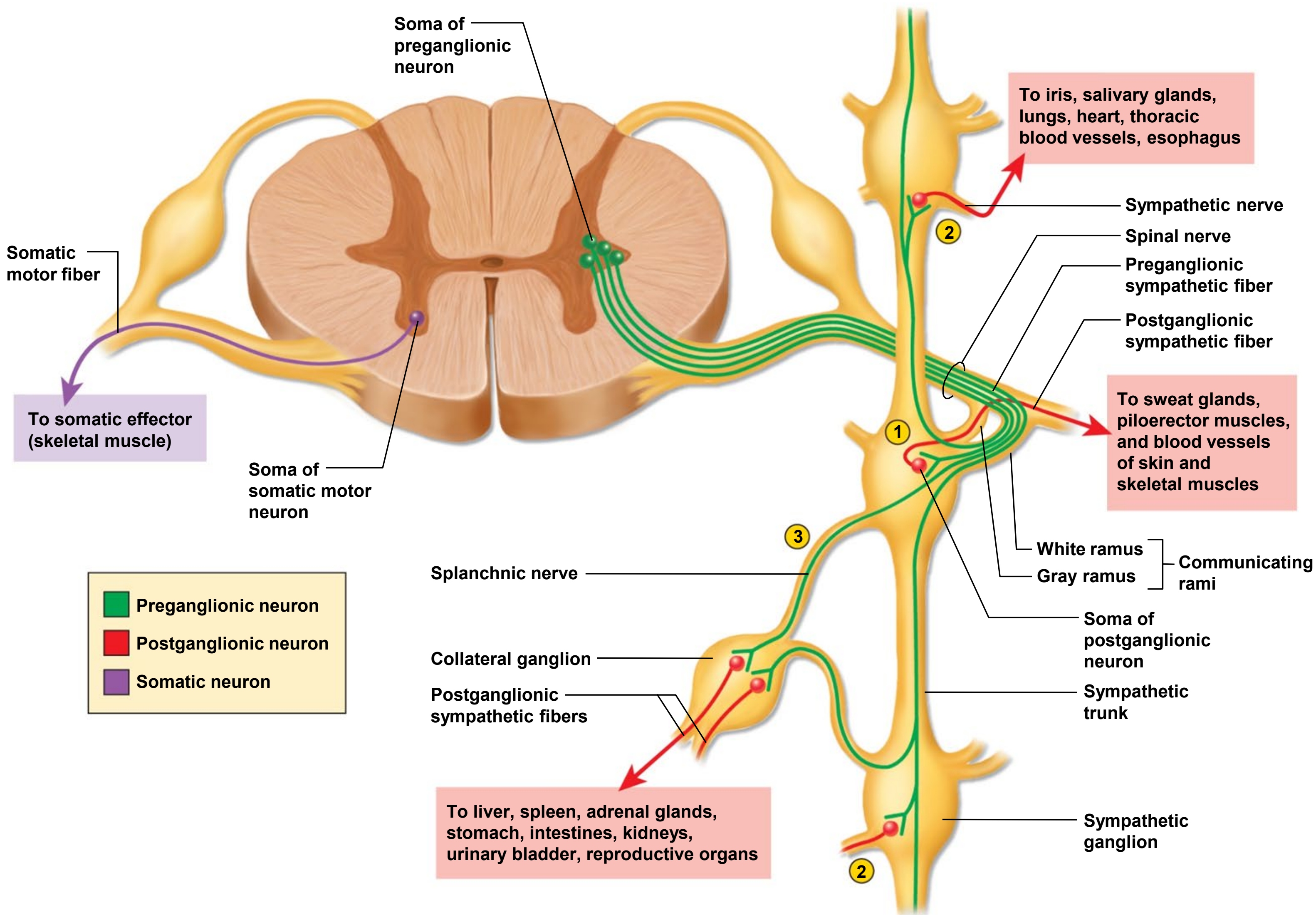


The solar plexus = group of ganglia that includes the celiac ganglia and superior mesenteric ganglia // nerves from these ganglia radiate away like rays of the sun

Ganglia and Abdominal Aortic Plexus



Sympathetic Nervous System's Preganglionic Pathways



Plexus of Sympathetic Nervous System

Collateral ganglia contribute to a network called the abdominal aortic plexus

The abdominal aortic plexus wraps around abdominal aorta

Form three major collateral ganglia in this plexus (lab objectives)

- celiac
- superior mesenteric
- Inferior mesenteric

These nerves of use similar named as the arteries to their target organs

Summary of Sympathetic Innervation

Effector tissue in body walls of viscera are innervated by sympathetic fibers that travel in spinal nerves

Effectors in head and thoracic cavity are innervated by sympathetic fibers in sympathetic nerves

Effectors in abdominal cavity are innervated by sympathetic fibers in splanchnic nerves

What is Neuronal Divergence?

Neuronal divergence is a characteristic of the sympathetic nervous system

The nerve signal pathway spreads out to reach a large number of target tissues.

Each preganglionic cell branches and synapses on 10 to 20 postganglionic cells

One preganglionic neuron can <u>excite multiple postganglionic fibers leading to different target organs</u>

The net outcome is to have relatively widespread effects over many different target organs.

Summary of Sympathetic Innervation

Effector tissue in <u>body walls of the viscera</u> are innervated by sympathetic fibers that travel in <u>spinal nerves</u>

Effectors in <u>head and thoracic cavity</u> are innervated by sympathetic fibers in <u>sympathetic nerves</u>

Effectors in <u>abdominal cavity</u> are innervated by sympathetic fibers in <u>splanchnic nerves</u>

Why is the Adrenal Gland called a SNS Ganglia?

The adrenal glands are a pair of glands located on the superior pole of each kidney

Adrenal gland is divided into two separate regions with different functions

Adrenal cortex (outer layer) // secretes steroid hormones (i.e. glucocorticoids, mineralcorticoids, estrogens, androgens)

Adrenal medulla (inner core) // this is *essentially a sympathetic ganglion* --- *secretes epinephrine and norepinephrine into the blood*

Adrenal Glands

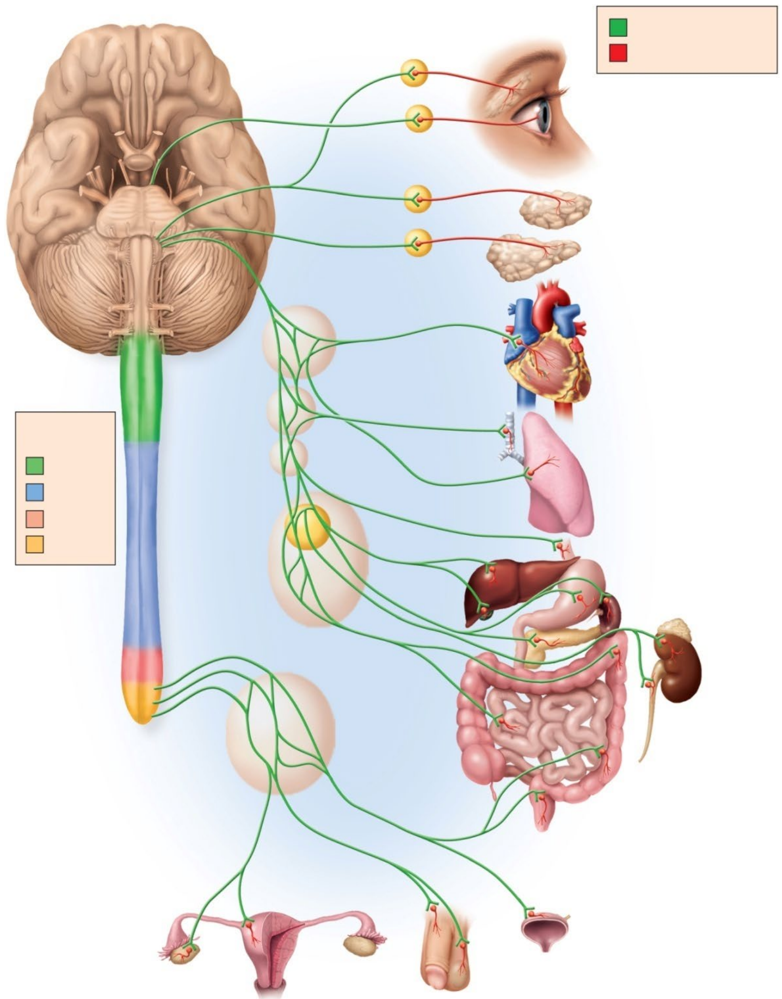
Adrenal medulla (inner core) /// Consists of modified postganglionic neurons without dendrites or axons

Stimulated by preganglionic sympathetic neurons that terminate on these cells

Adrenal medulla secretes a mixture of hormones into bloodstream /// catecholamines // 85% epinephrine (adrenaline) // 15% norepinephrine (noradrenaline) // norepinephrine also function as neurotransmitters // some dopamine

Sympathoadrenal system = the closely related functions of the adrenal medulla and sympathetic nervous system

The Parasympathetic Nervous System



Parasympathetic Division

Parasympathetic division is “rest and restoration division”

Also called the **craniosacral division**

The origin is from the brainstem and the sacral region of the spinal cord

Parasympathetic nerve fibers travel in cranial and sacral nerves

Long preganglionic neurons and short postganglionic neurons

Less divergent than the SNS

Parasympathetic Division

Pathways of long preganglionic fibers

–fibers in cranial nerves III, VII, IX and X

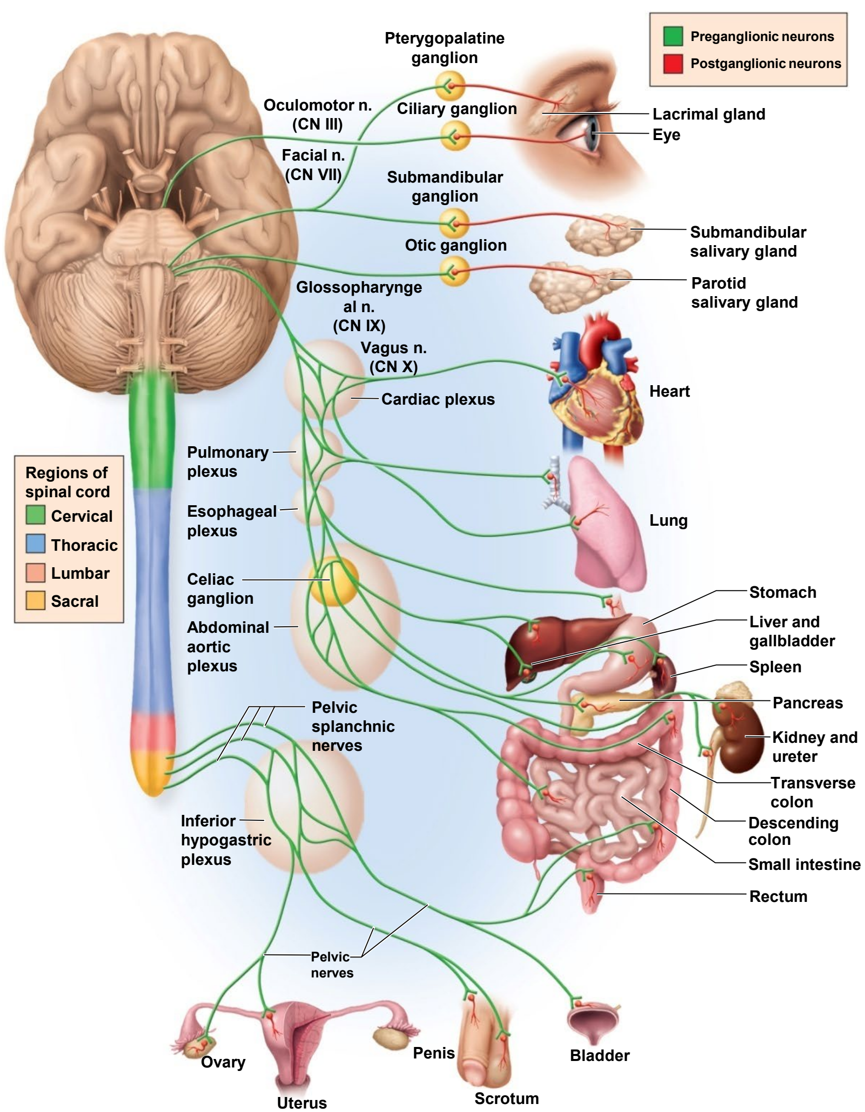
–fibers arising from sacral spinal cord // in pelvic splanchnic nerves and inferior hypogastric plexus

Ganglia near or on target organ /// long preganglionic, short postganglionic fibers

Less neuronal divergence than sympathetic division

One preganglionic fiber reaches the target organ and then stimulates fewer than 5 postganglionic cells

Parasympathetic Cranial Nerves



Oculomotor nerve (III)

–narrows pupil and focuses lens

Facial nerve (VII)

–tear, nasal and salivary glands

Glossopharyngeal nerve (IX)

–parotid salivary gland

Vagus nerve (X)

–viscera as far as proximal half of colon

–cardiac, pulmonary, and esophageal plexus

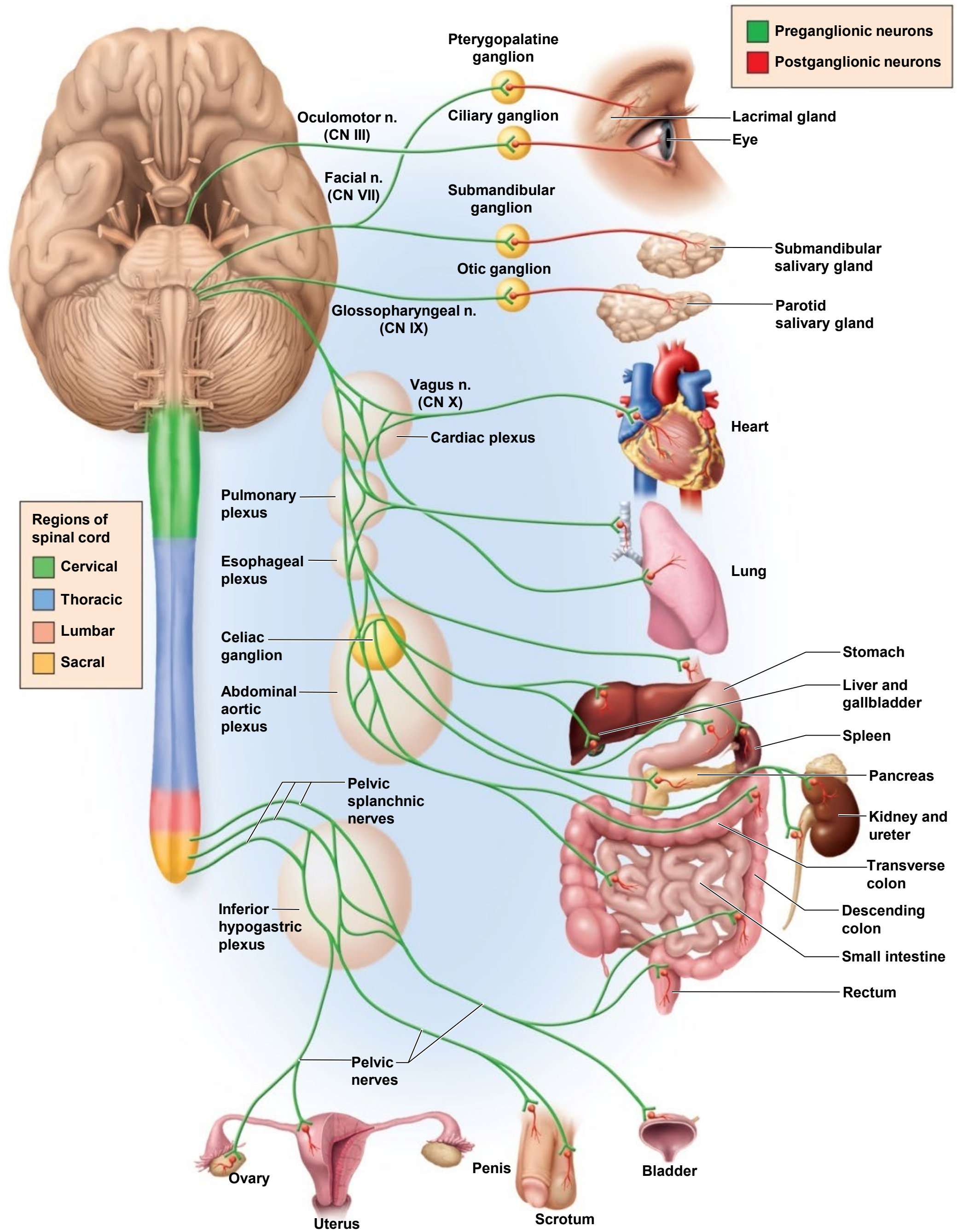
Efferent Pathways

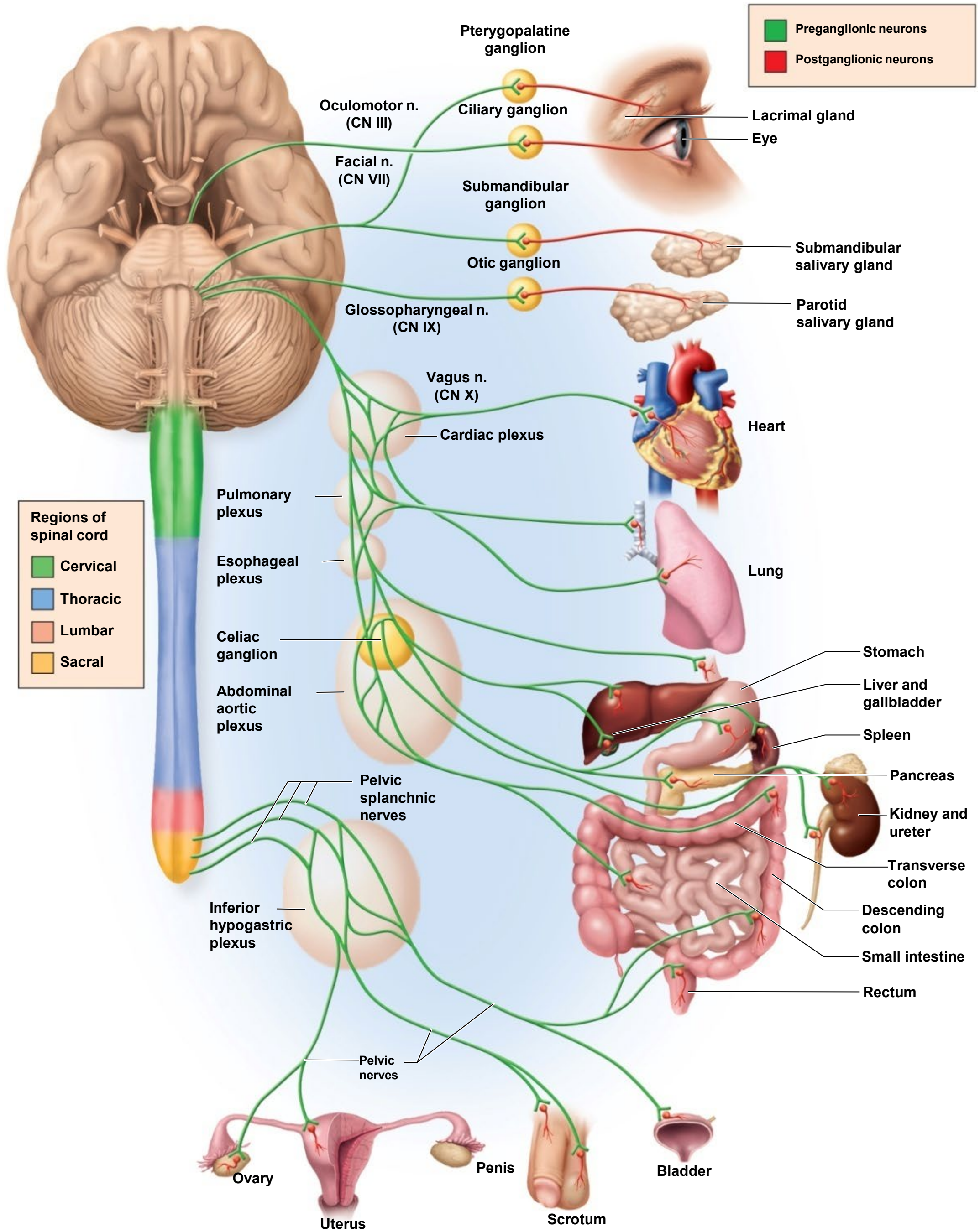
Remaining parasympathetic fibers arise from levels S2 to S4 of the spinal cord

Form pelvic splanchnic nerves that then lead to the inferior hypogastric plexus

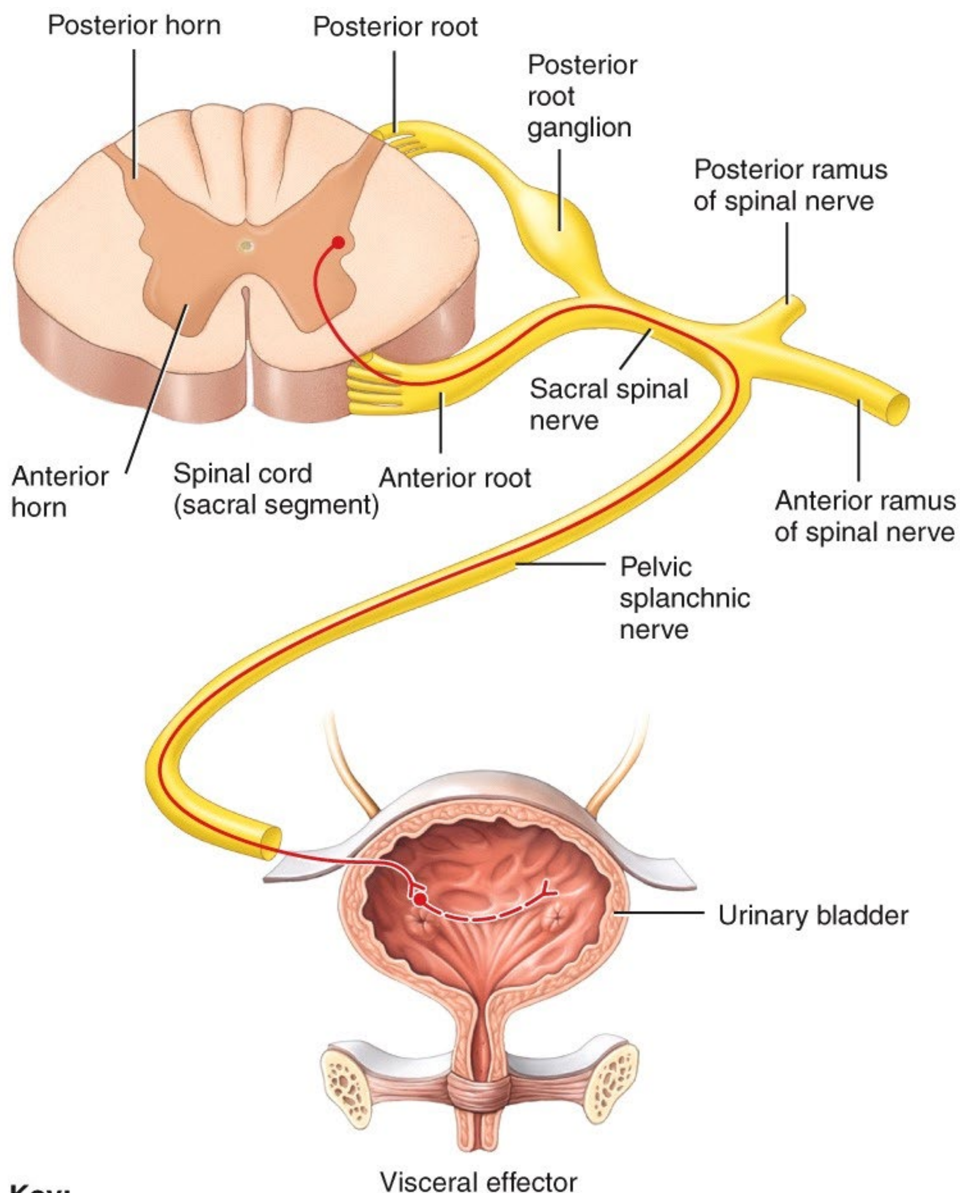
Most form pelvic nerves to their terminal ganglion on the target organs

Distal half of colon, rectum, urinary bladder, and reproductive organs





Preganglionic neurons
Postganglionic neurons
Pterygopalatine ganglion
Oculomotor n. (CN III)
Ciliary ganglion
Facial n. (CN VII)
Lacrimal gland
Eye
Submandibular ganglion
Submandibular salivary gland
Otic ganglion
Glossopharyngeal n. (CN IX)
Parotid salivary gland
Vagus n. (CN X)
Cardiac plexus
Heart
Pulmonary plexus
Esophageal plexus
Lung
Regions of spinal cord
Cervical
Thoracic
Lumbar
Sacral
Celiac ganglion
Abdominal aortic plexus
Stomach
Liver and gallbladder
Spleen
Pancreas
Pelvic splanchnic nerves
Kidney and ureter
Transverse colon
Descending colon
Inferior hypogastric plexus
Small intestine
Rectum
Pelvic nerves
Ovary
Uterus
Penis
Scrotum
Bladder



Key:
- Parasympathetic preganglionic neuron
- Parasympathetic postganglionic neuron

Neurotransmitters and Receptors of the ANS

It is possible for one division of the ANS to create opposite outcomes in different target organs // stimulate one organ but inhibit the other organ. // How is possible?

Example: The SNS will increase activity in the heart but at the same time the SNS will inhibit or slow down activity in the GI tract?

This is possible because target tissues have different types of receptors for the same neurotransmitter

It is the receptor that determines the outcome and not necessarily the neurotransmitter!

Example - Histamine will cause systemic blood vessels to dilate and respiratory bronchioles to constrict

Where is Acetylcholine (Ach) Used in the ANS?

ACh secreted by all preganglionic neurons by both divisions of the ANS (ionotropic receptor / sodium channels / fast / always stimulatory!)

Ach is secreted by postganglionic parasympathetic neurons

Postganglionic parasympathetic neurons may use either an ionotropic receptor or metabotropic receptor (second messenger type receptor).

Any fiber that secretes Ach is called a cholinergic fibers

Any receptor that binds Ach is called a cholinergic receptor

Two Acetylcholine (Ach) Receptors
Nicotinic VS Muscarinic

- **Acetylcholine's Nicotinic receptors**

  ionotropic receptor // always sodium ion channel /// ligand mode of action // fast

  always stimulates

  receptor at all ANS ganglia /// these are on <u>postganglionic neuron's soma</u>

  nicotinic receptors also at <u>medulla of the adrenal gland and at neuromuscular junctions</u>

Acetylcholine’s Muscarinic receptors

Possible receptor on target organs associated with neurotransmitter secreted by post ganglionic cholinergic fibers

this uses the metabotropic receptor (i.e. second messenger) mode of action / not an ion channel (note: metabotropic – always require two or more transmembrane proteins)

- cardiac muscle
- smooth muscle
- glands

<u>Note: affect can be either excitatory or inhibitory due to sub-classes of muscarinic receptors</u>

Adrenergic Fibers & Receptors

Most sympathetic postganglionic neurons release
norepinephrine (adrenergic neurotransmitter)

These are called adrenergic fibers // secrete NE

Receptors called adrenergic receptors // alpha or beta with subtypes // general rule alpha stimulates and beta inhibit but there are exceptions to this rule

Note: there are some post ganglionic sympathetic fibers that secrete acetlycholine // these fibers use muscarinic receptors! // found in cutaneous membrane structures = piloerector muscles, sweat glands, blood vessels

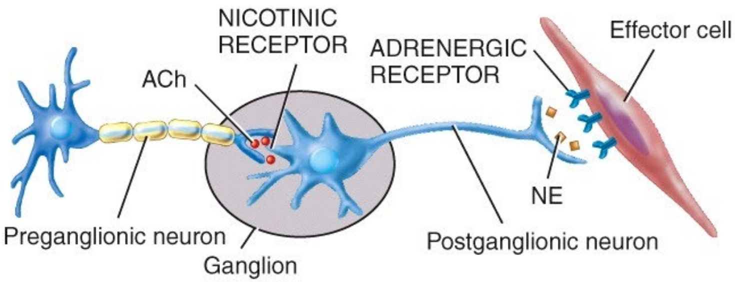
Two Type of Adrenergic Receptors

Two types of NE receptors (cAMP as a second messenger)

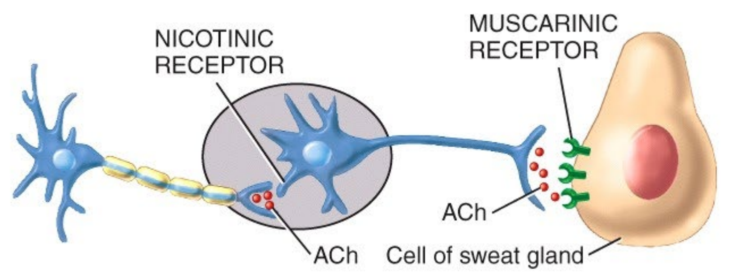
alpha-adrenergic receptors /// <u>usually excitatory</u> // 2 subclasses use different second messengers (α_1 & α_2)

beta-adrenergic receptors /// <u>usually inhibitory</u> // 2 subclasses with different effect

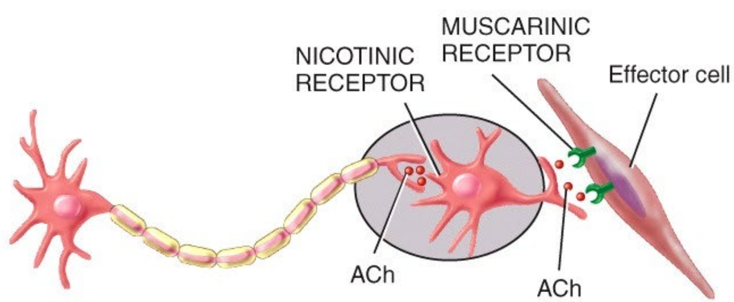
Neurotransmitters and Receptors



(a) Sympathetic division–innervation to most effector tissues



(b) Sympathetic division–innervation to most sweat glands



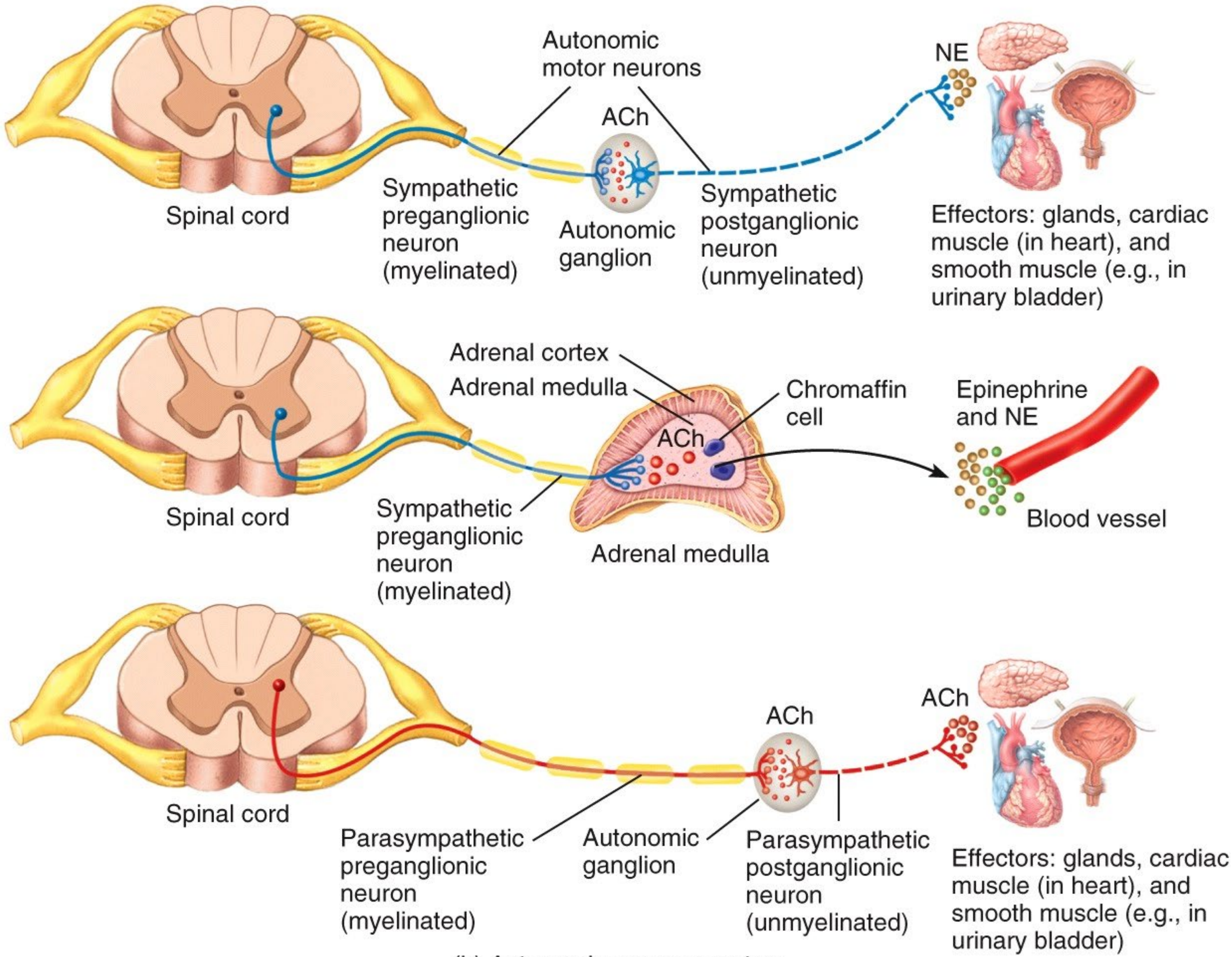
(c) Parasympathetic division

Muscarinic receptors are metabotropic (i.e. second messenger) – outcome variable

NE has two classes of adrenergic receptors (e.g. alpha & beta) // outcome dependent on receptor type // each with sub-classes

Nicotinic receptors (ionotropic) are sodium ion channels that are always stimulatory (i.e. depolarize membrane - stimulate)

Merocrine sweat gland (thermoregulation) // sympathetic cholenergic w metabotropic receptors



(b) Autonomic nervous system

TABLE 15.5 Effects of the Sympathetic and Parasympathetic Nervous Systems

Target	Sympathetic Effect and Receptor Type	Parasympathetic Effect (All Muscarinic)
Eye		
Iris	Pupillary dilation (α)	Pupillary constriction
Ciliary muscle and lens	Relaxation for far vision (β)	Contraction for near vision
Lacrimal (tear) gland	None	Secretion
Integumentary system		
Merocrine sweat glands (cooling)	Secretion (muscarinic)	No effect
Apocrine sweat glands (scent)	Secretion (α)	No effect
Piloerector muscles	Hair erection (α)	No effect
Adipose tissue	Decreased fat breakdown (α) Increased fat breakdown (α, β)	No effect
Adrenal medulla	Hormone secretion (nicotinic)	No effect
Circulatory system		
Heart rate and force	Increased (β)	Decreased
Deep coronary arteries	Vasodilation (β) Vasoconstriction (α)	Slight vasodilation
Blood vessels of most viscera	Vasoconstriction (α)	Vasodilation
Blood vessels of skeletal muscles	Vasodilation (β)	No effect
Blood vessels of skin	Vasoconstriction (α)	Vasodilation, blushing
Platelets (blood clotting)	Increased clotting (α)	No effect
Respiratory system		
Bronchi and bronchioles	Bronchodilation (β)	Bronchoconstriction
Mucous glands	Decreased secretion (α) Increased secretion (β)	No effect
Urinary system		
Kidneys	Reduced urine output (α)	No effect
Bladder wall	No effect	Contraction
Internal urinary sphincter	Contraction, urine retention (α)	Relaxation, urine release
Digestive system		
Salivary glands	Thick mucous secretion (α)	Thin serous secretion
Gastrointestinal motility	Decreased (α, β)	Increased
Gastrointestinal secretion	Decreased (α)	Increased
Liver	Glycogen breakdown (α, β)	Glycogen synthesis
Pancreatic enzyme secretion	Decreased (α)	Increased
Pancreatic insulin secretion	Decreased (α) Increased (β)	No effect
Reproductive system		
Penile or clitoral erection	No effect	Stimulation
Glandular secretion	No effect	Stimulation
Orgasm, smooth muscle roles	Stimulation (α)	No effect
Uterus	Relaxation (β) Labor contractions (α)	No effect

Overview of ANS Function

Autonomic effects on gland"s secretion is the result of their effect on blood vessels

Vasodilation – increased blood flow results in an increased secretion

Vasoconstriction – decreased blood flow results in a decreased secretion

Overview of ANS Function

Sympathetic effects tend to last longer than parasympathetic effects

ACh released by parasympathetic fibers is broken down quickly by enzymes in the synaptic cleft

NE released by sympathetic nerve fibers is either reabsorbed by nerve or...

> NE will diffuse into adjacent tissues and blood without catabolic enzymes // breakdown slowly
>
> While NE circulate in blood the neurotransmitter "hit" other adrenergic receptors throughout body. This pro-long SNS stimulation
>
> Catecholamines also released from adrenal medulla and then circulate in the blood

Overview of ANS Function

Many substances are released as neuromodulators that **modulate ACh and NE function**

Sympathetic fibers also secrete enkephalin, substance P, neuropeptide Y, somatostatin, neurotensin, or gonadotropin-releasing hormone

Parasympathetic fibers stimulate endothelial cells to release the gas, nitric oxide – causes vasodilation by inhibiting smooth muscle tone

Note: Nitric oxide is crucial in a penile erection /// Viagra increase nitric oxide

Dual Innervation

Most viscera receive nerve fibers from both parasympathetic and sympathetic divisions

- –antagonistic effect – oppose each other
- –cooperative effects – two divisions act on different effectors to produce a unified overall effect

The two divisions do not "influence" the same organ equally // one division dominates over the other division

One division will set the tone for the organ (e.g. the parasympathetic sets the tone for the heart)

Dual Innervation to Same Organ

Cooperative effects - <u>when the two divisions act on same organ to produce a “similar effect”</u>

<u>ANS innervation of salivary glands</u>

- PNS increase salivary serous cell secretion
- SNS increase salivary mucous cell secretion

Dual Innervation to Same Organ

Antagonistic effects (oppose each other)

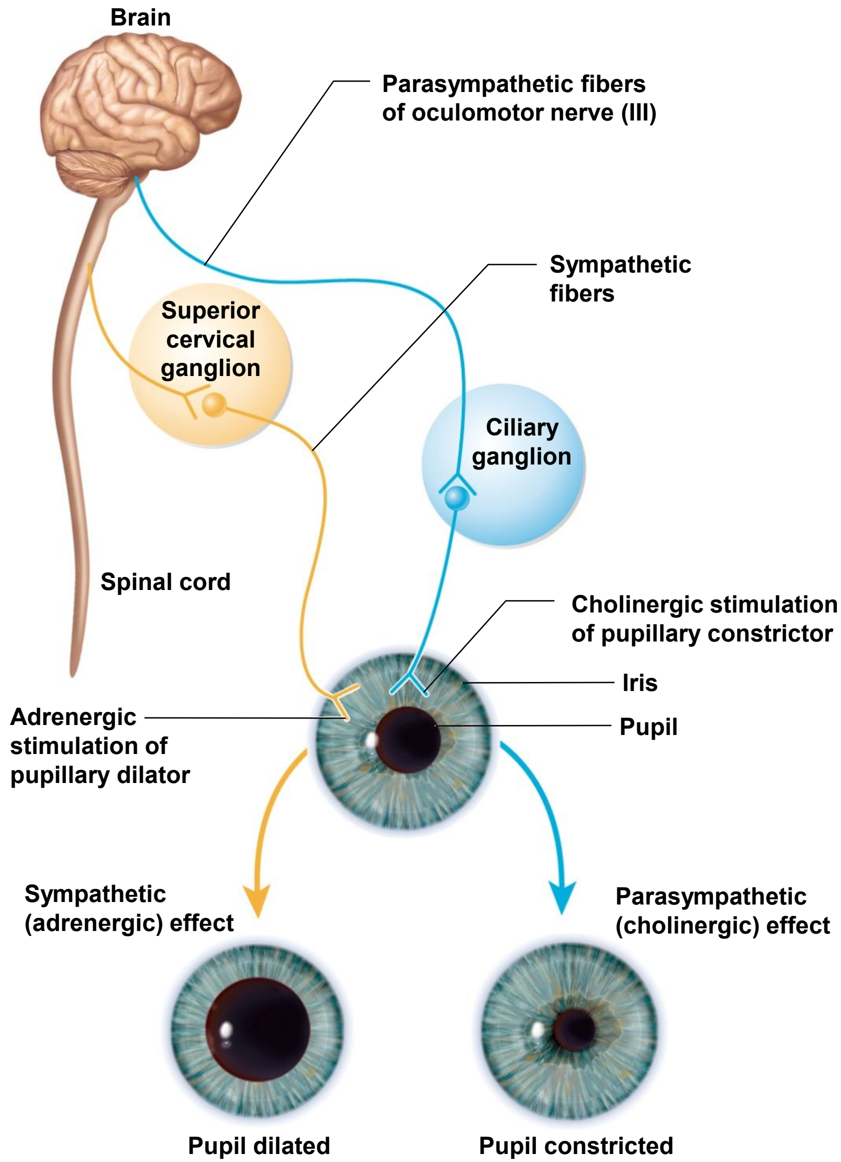
<u>1st option // exerted through dual innervation of same group of cells</u>

- heart rate decreases (parasympathetic)
- heart rate increases (sympathetic)

<u>2nd option // exerted because each division innervates different group of cells</u>

- pupillary dilator muscle (sympathetic) dilates pupil
- constrictor pupillae (parasympathetic) constricts pupil

Dual Innervation of the Iris



Dilate iris with radial fasicles.

Constrict iris with sphincter fasicles.

Regulation With Single Division Innervation

Some effectors receive **only sympathetic fibers**

–adrenal medulla

–arrector pili muscles

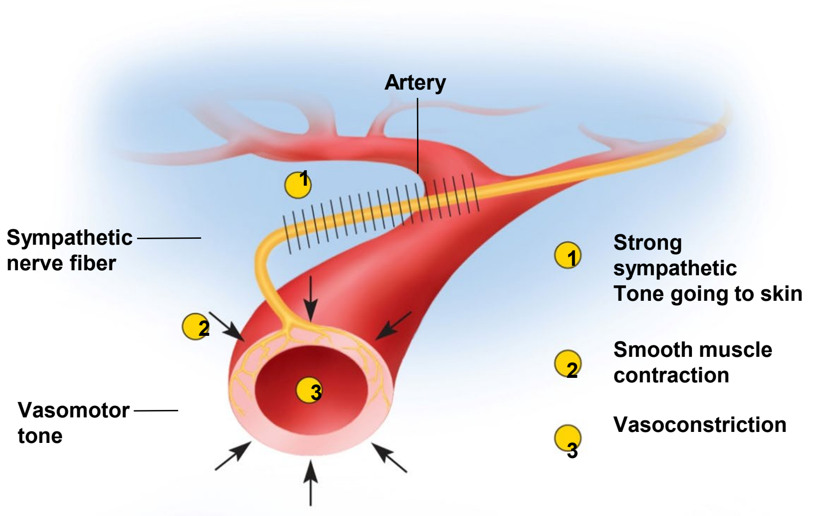
–sweat glands

–many blood vessels throughout body

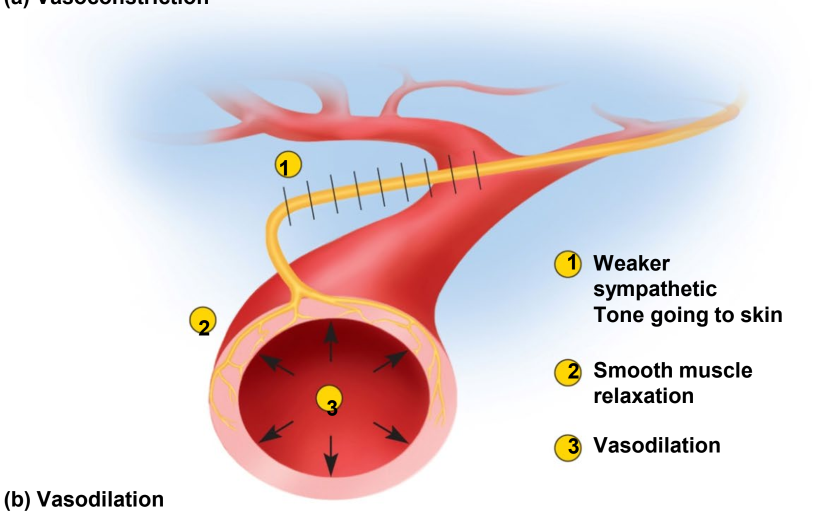
How is blood flow, blood pressure, and routes of blood flow regulated by only sympathetic nerve fibers?

- (see next slide)

Regulation Without Dual Innervation



(a) Vasoconstriction



(b) Vasodilation

How can we control blood pressure and distribution of blood flow using only sympathetic innervation?

This is possible because we first establish sympathetic vasomotor tone - a baseline firing frequency of sympathetic fibers....

This keeps vessels in state of partial constriction

If increase in firing frequency – causes more vasoconstriction

If decrease in firing frequency – causes less vasoconstriction (which has same effect as vasodilation)

Note: this illustration shows blood vessels in skin with muscarinic receptors / at the same time different blood vessels in skeletal muscles will dilate due to NE binding to adrenergic receptors

Control of Autonomic Function (1 of 2)

ANS influenced by different levels of the CNS

Cerebral cortex has an influence // prefrontal cortex hardwired to amygdala (limbic system)

Amygdala all about vigilance, anxiety, fear, , aggression

Powerful emotions influence the ANS because of the connections between our limbic system (emotional brain) to the hypothalamus

Hypothalamus - visceral motor control center // exerts influence by connections to pituitary (hormones) or nerve tracks to nuclei in medulla oblongata (ANS)

Medulla oblongata nuclei regulate primitive functions – e.g. hunger, thirst, sex

Control of Autonomic Function (2 of 2)

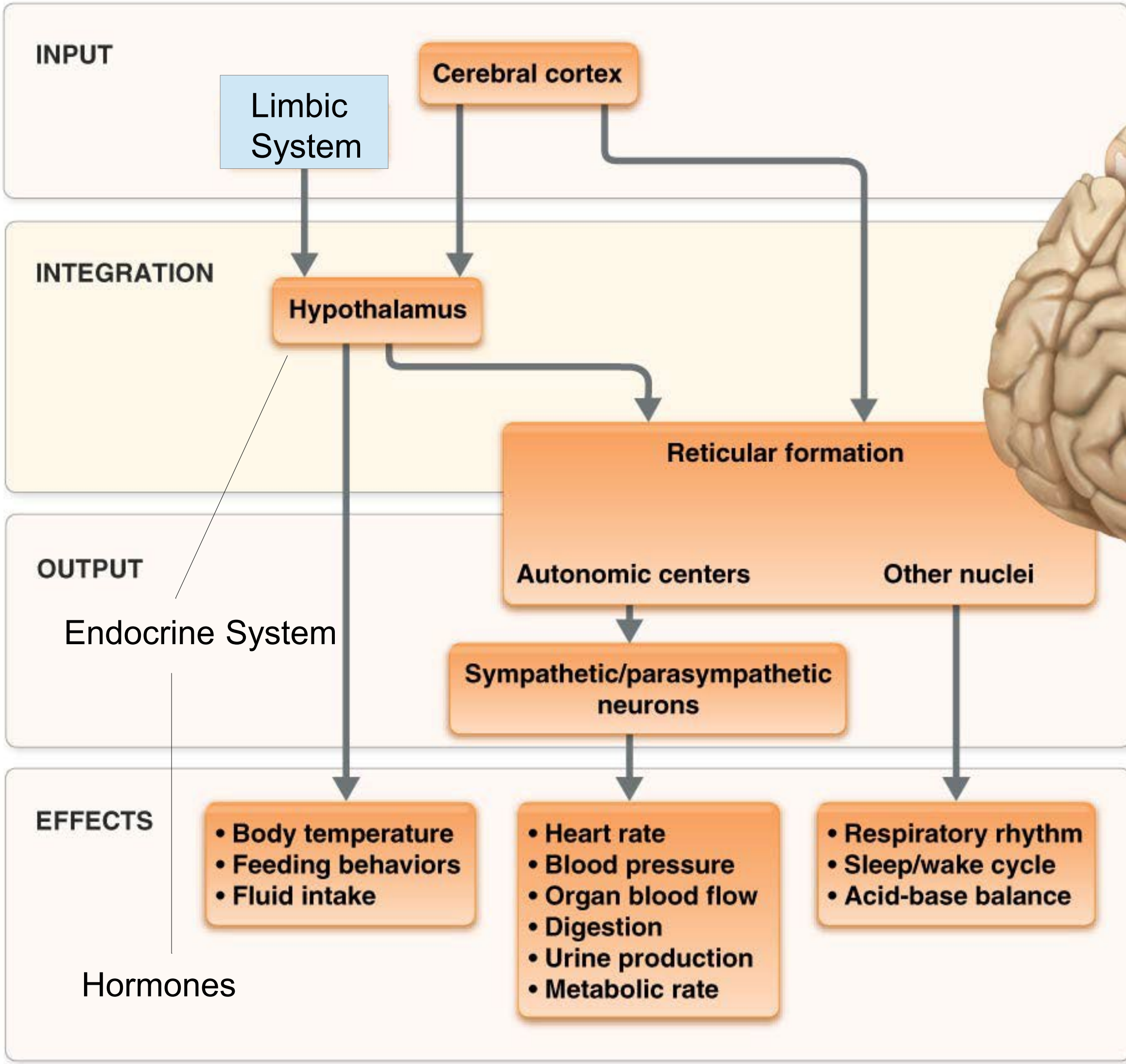
Midbrain, **pons**, and **medulla oblongata**

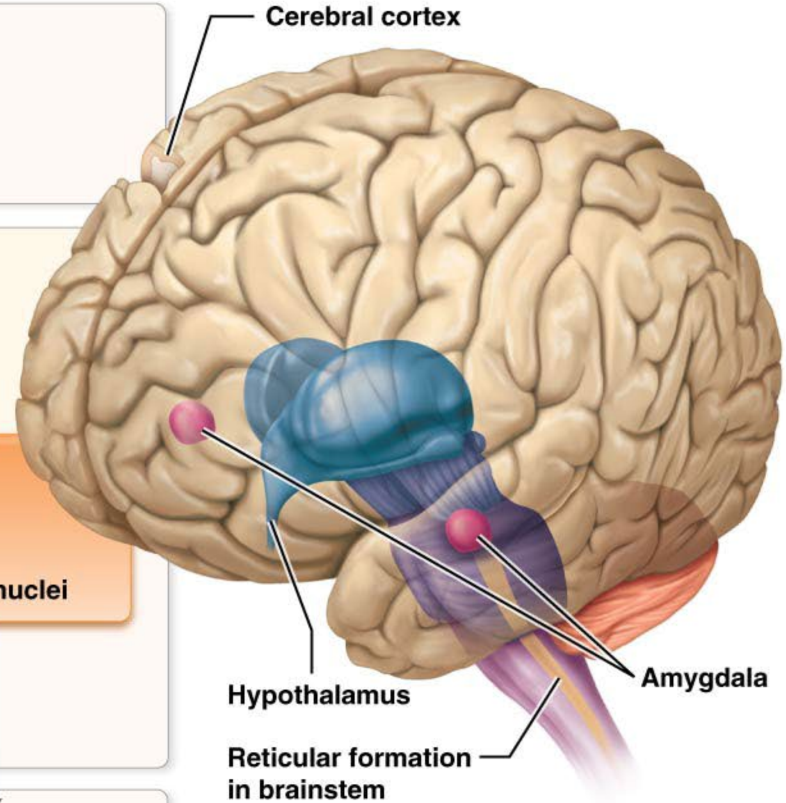
Many nuclei for cardiac and vasomotor control, salivation, swallowing, sweating, bladder control, and pupillary changes

Spinal cord reflexes

- defecation and micturition reflexes are integrated in spinal cord
- we control these functions because of our <u>control over skeletal muscle sphincters…</u>
- if the spinal cord is damaged, the smooth muscle of bowel and bladder is controlled by autonomic reflexes built into the spinal cord

Summary of nervous system control of homeostasis.





Note:
The hypothalamus is the "boss" of the ANS and endocrine system.