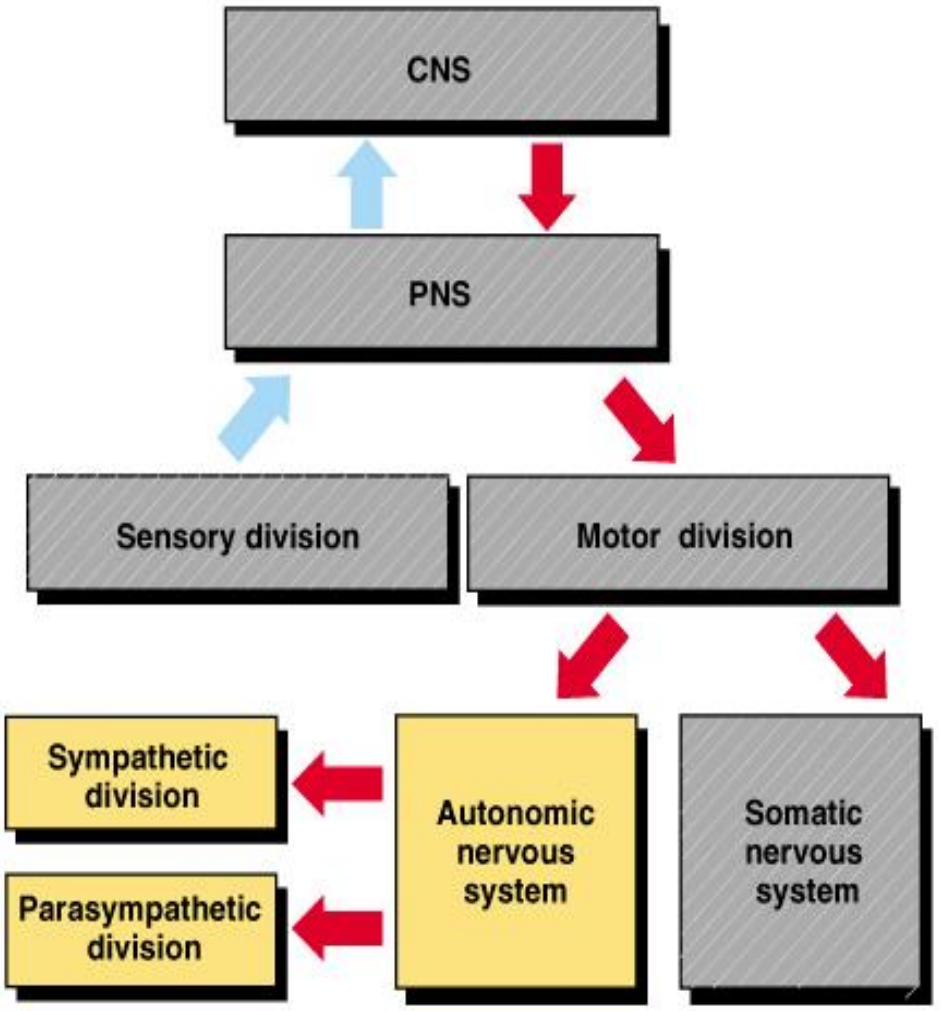
The Autonomic Nervous System

Objectives

- Describe the structure and general functions of the sympathetic nervous system.
- Describe the structure and general functions of the parasympathetic nervous system.
- Distinguish between different types of adrenergic receptors and explain the physiological and clinical significance of these receptors.
- Explain how cholinergic receptors are categorized and describe the effects produced by stimulation of these receptors.

Autonomic Nervous System Overview

- Automatic, involuntary
- Primarily involved in maintaining homeostasis of the internal environment
- Visceral efferent neurons innervate visceral effectors: smooth muscle, cardiac muscle, exocrine glands and endocrine glands



Somatic vs. Autonomic

- Voluntary
- Skeletal muscle
- Single efferent neuron
- Axon terminals release acetylcholine
- Always excitatory
- Controlled by the cerebrum

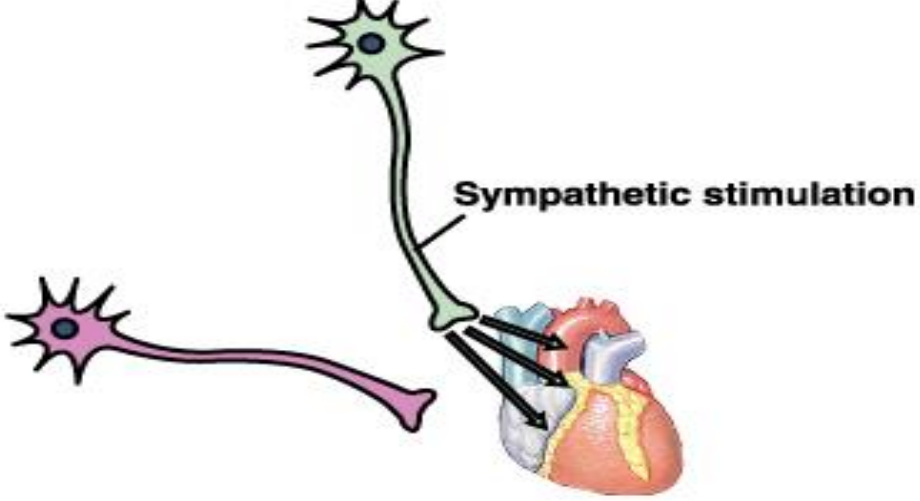
- Involuntary
- Smooth, cardiac muscle; glands
- Multiple efferent neurons
- Axon terminals release acetylcholine or norepinephrine
- Can be excitatory or inhibitory
- Controlled by the homeostatic centers in the brain – pons, hypothalamus, medulla oblongata

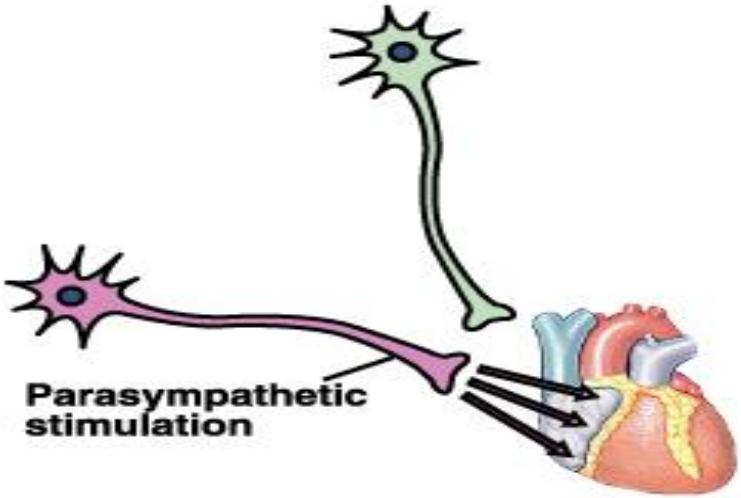
Two Functional Divisions

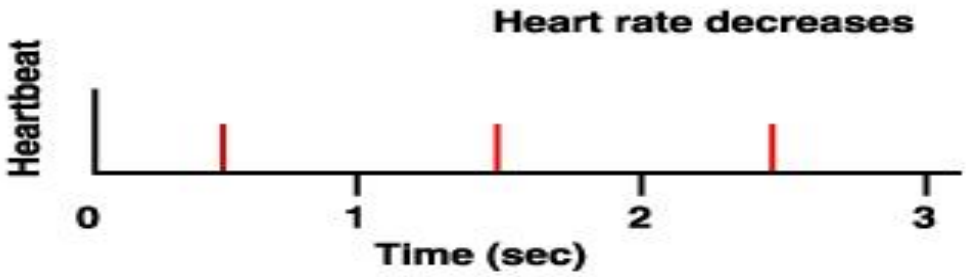
- Parasympathetic and Sympathetic Divisions
- Structurally, each division consists of nerves, nerve plexuses, and autonomic ganglia
- Each motor command is carried in a two-cell circuit
- Most effector organs and tissues receive impulses from both divisions, a dual or parallel innervation
- The two divisions often serve as antagonists to each other in adjusting and maintaining internal homeostasis

Antagonistic Control

* Most internal organs are innervated by both branches of the ANS which exhibit antagonistic control







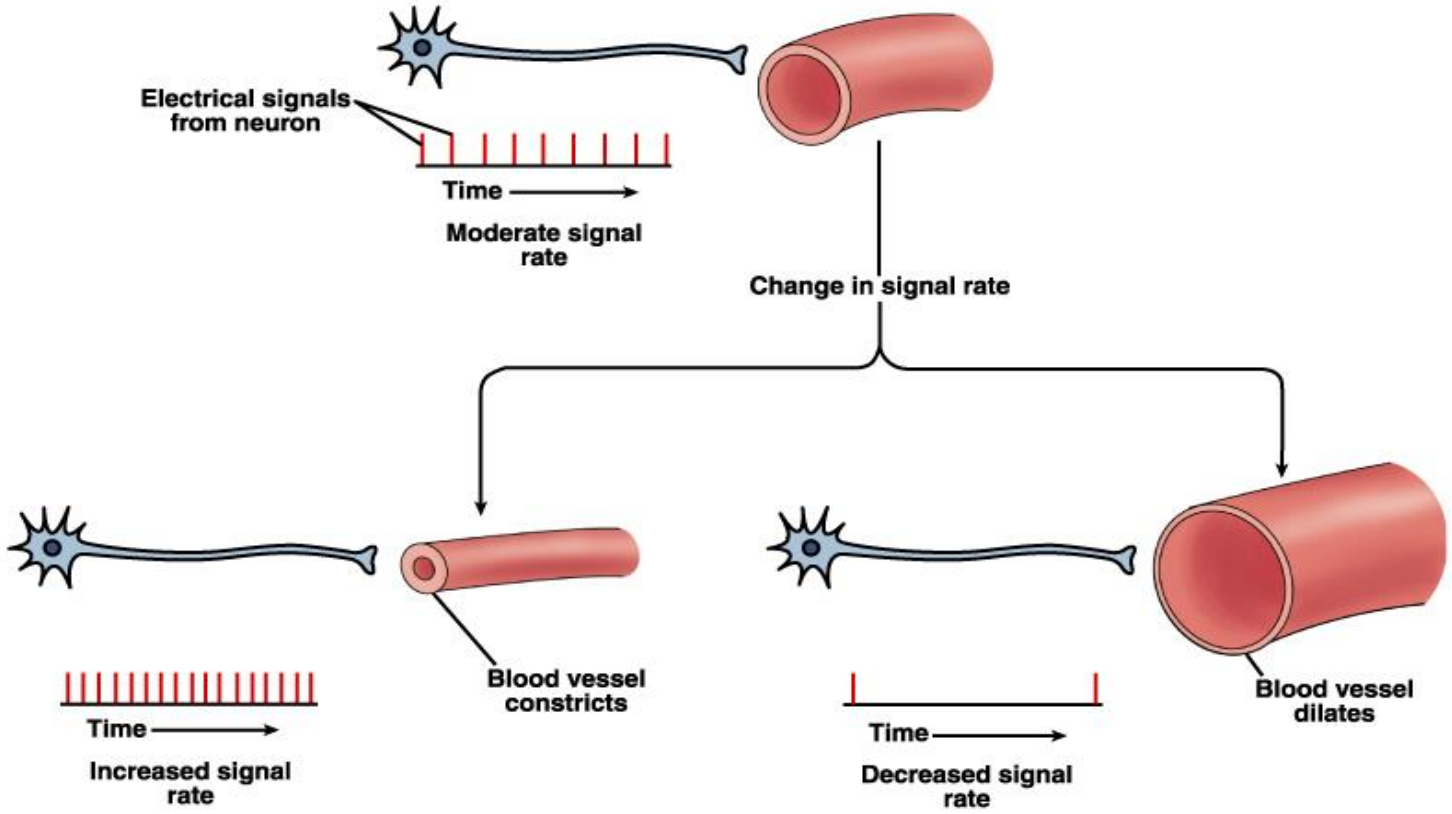
A great example is heart rate. An increase in sympathetic stimulation causes HR to increase whereas an increase in parasympathetic stimulation causes HR to decrease

Exception to the dual innervation rule:

Sweat glands and blood vessel smooth muscle are only innervated by symp and rely strictly on up-down control. Other examples :Adrenal glands, Piloerector muscles of hair

Exception to the antagonism rule:

Symp and parasymp work cooperatively to achieve male sexual function. Parasymp is responsible for erection while symp is responsible to ejaculation. There's similar ANS cooperation in the female sexual response.



Features of ANS

Input (sensing):

- Sensory nerve endings testing the outside (eg via skin, gut wall)
- Sensing within body (eg chemo- and baro-receptors, temperature etc)
- Input from eye etc.

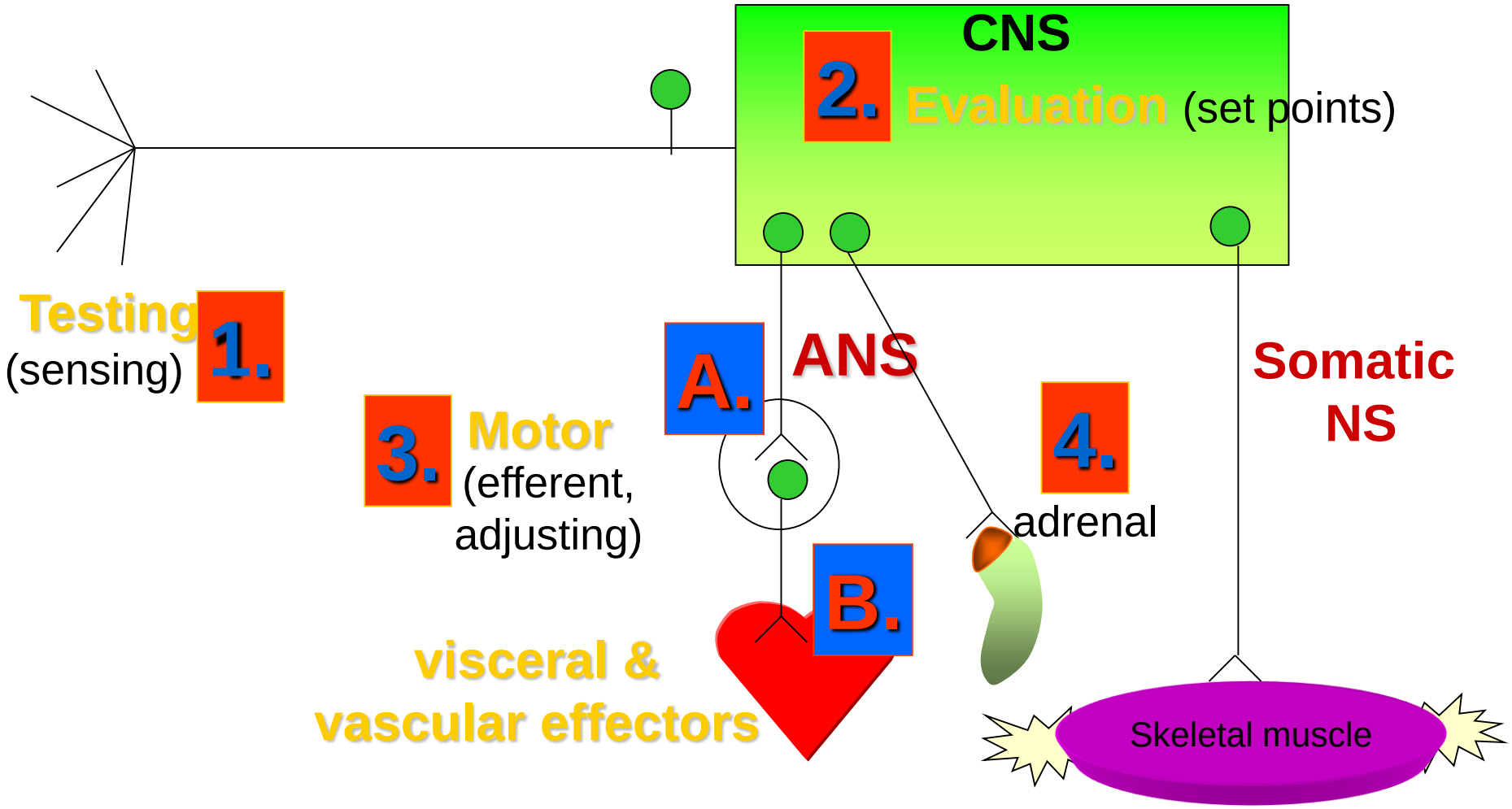
Evaluation (set limits):

- Centres in brain (eg respiratory, cardiac centres etc)
- Reflexes
- Exchange of information

Output (motor):

- Sympathetic
- Parasympathetic
- Enteric Nervous system

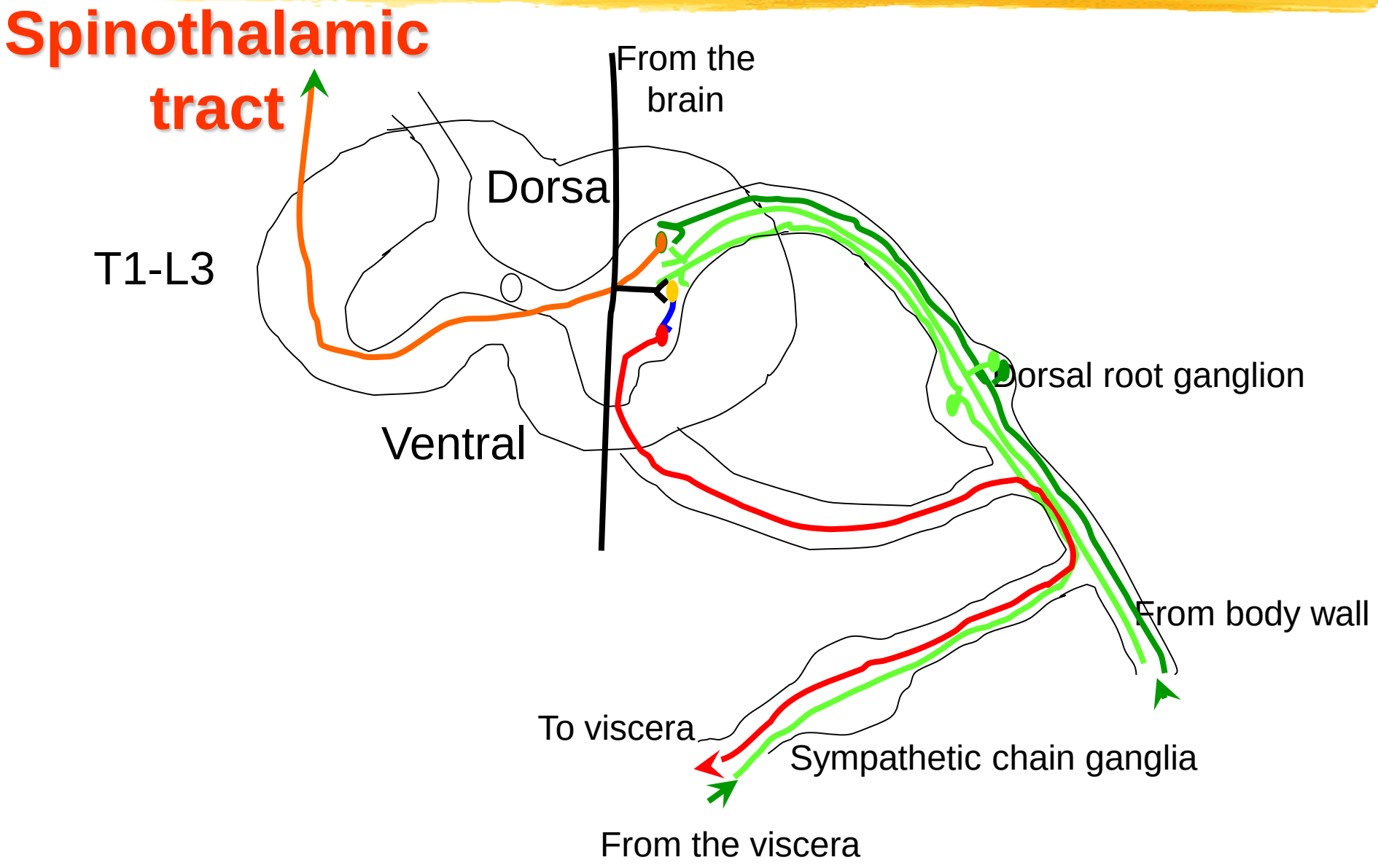
General outline



1.

Sensory neurons

Sensory nerves in ANS



Characteristics

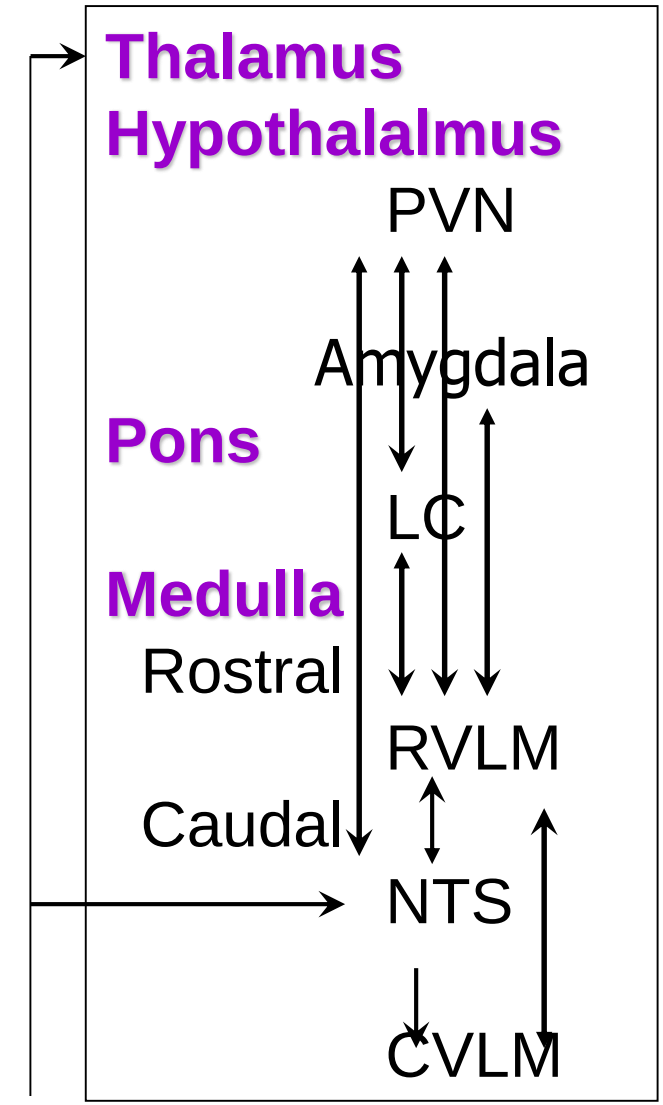
- Sensory endings in skin, viscera etc
- Cell body in dorsal root ganglia (DRG)
- Thin, myelinated Aδ and unmyelinated C fibres
- Run in same nerve trunk containing efferent nerves
- Terminal in dorsal horn of spinal cord
- Glutamate is the fast excitatory neurotransmitter in spinal cord
- CGRP(Calcitonin gene related protein) and substance P in cord (slow and prolonged) and periphery

2.

ANS in the brain

Autonomic integration and signal processing in the brain

- Many brain centres determine outflow in ANS
- Key locations include



In the brain: summary

- NTS - nucleus tractus solitarius. Receives information. Main input station of sensory nerves that are of special relevance to the ANS.
- PVN - paraventricular nucleus. Part of hypothalamus.
- LC - locus ceruleus. Distributes information. Major site of noradrenaline in brain.
- RVLM - rostral ventrolateral medulla. Collects information. Receives input from many centres involved in homeostatic control.
- CVLM - caudal ventrolateral medulla. Major output control. Sends info down into the spinal cord and up to other areas of the brain.

Higher centres involved in ANS

1. Cortex (thought of, sight of etc).
2. Limbic (satiety, aggression, flight and other survival behaviours)
3. Thalamus (receives and distributes information)

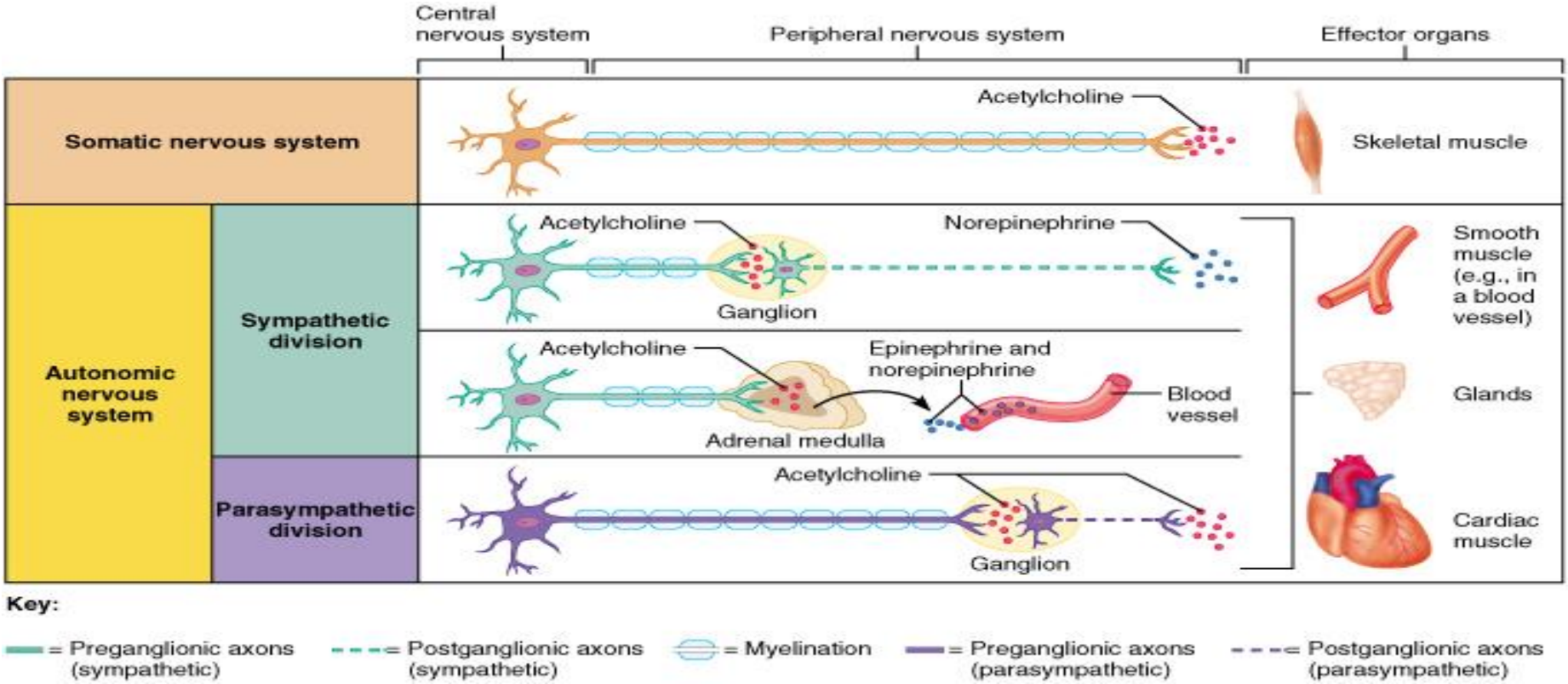
3.

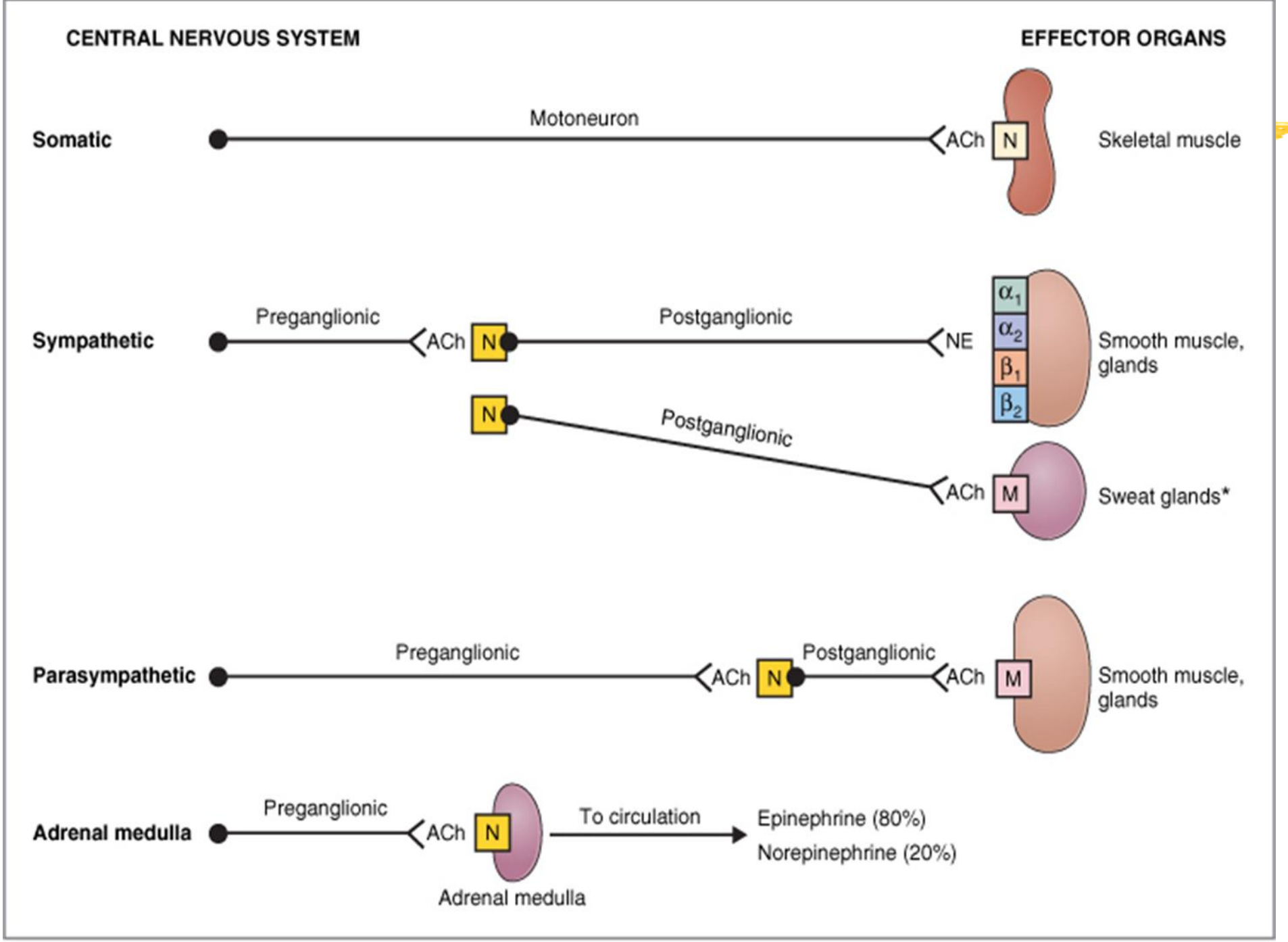
Output

1. General arrangement
2. In the spinal cord

Two Types of Autonomic Neurons

- preganglionic neurons
  - cell bodies in the CNS (brain or spinal cord)
  - transmit Action Potentials from the CNS
- postganglionic neurons
  - cell bodies in autonomic ganglia in the periphery
  - transmit APs to effectors



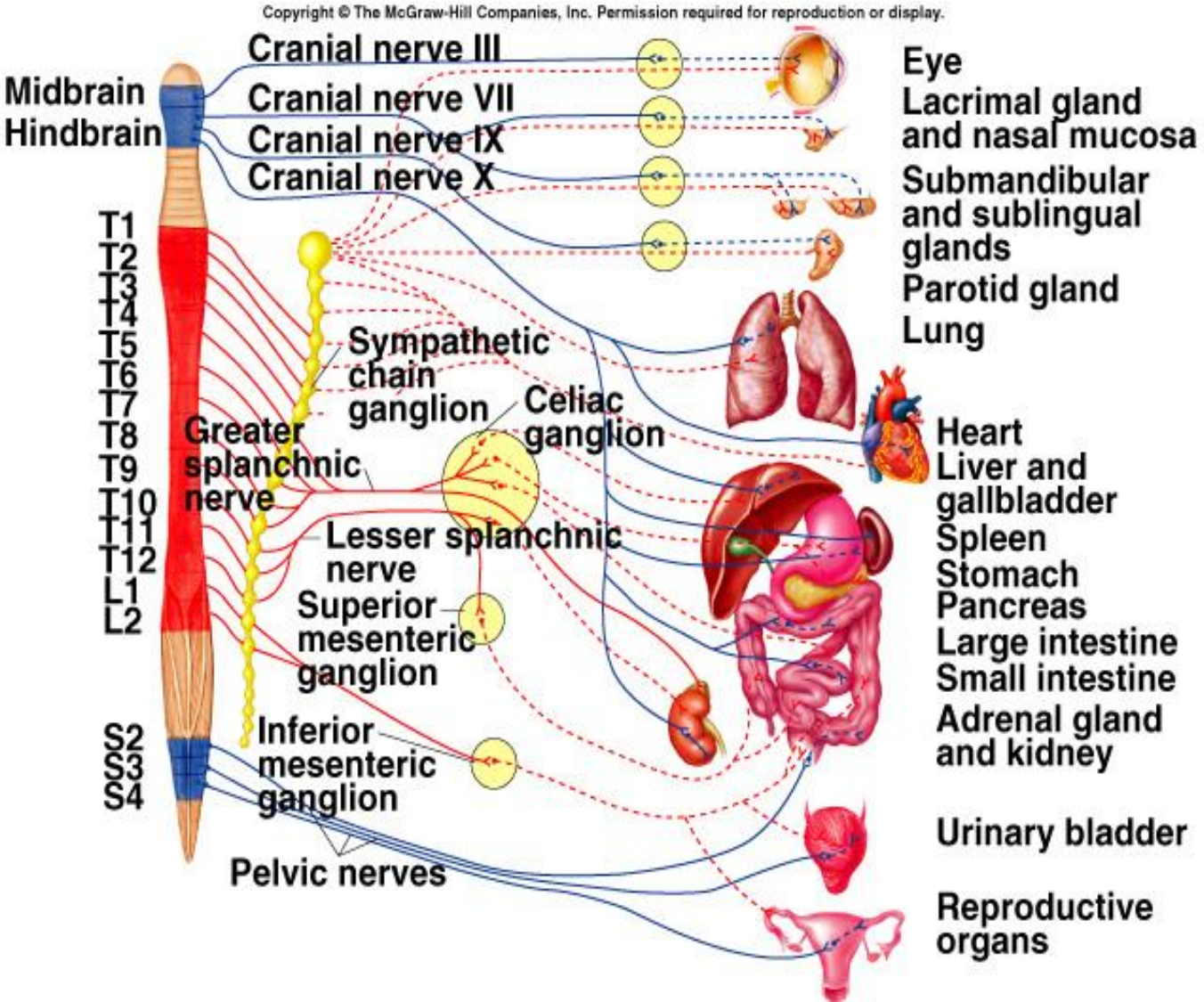


Two Cell Motor Pathways in the ANS

- the first is the preganglionic neuron, whose cell body is located in the brain or spinal cord
  - in the sympathetic division, the cell body is located in the lateral gray horns (thoraco-lumbar)
  - in the parasympathetic division, the cell body is located in various nuclei of brain stem or in the lateral gray horns (cranio-sacral)
- the second is the postganglionic neuron, whose cell body is in an autonomic ganglion
  - the postganglionic fiber sends impulses to a target organ
  - the effects at the target organ are due to type of neurotransmitter and specific cell surface receptors on the effector cells

Divisions of the ANS

- Sympathetic nervous system and para-sympathetic nervous system:
  - Both have preganglionic neurons that originate in CNS.
  - Both have postganglionic neurons that originate outside of the CNS in ganglia.



ANS Anatomy

Division	Origin of Fibers	Length of Fibers	Location of Ganglia
Sympathetic	Thoracolumbar region of the spinal cord	Short preganglionic and long postganglionic	Close to spinal cord
Parasympathetic	Brain and sacral spinal cord (craniosacral)	Long preganglionic and short postganglionic	In visceral effector organs

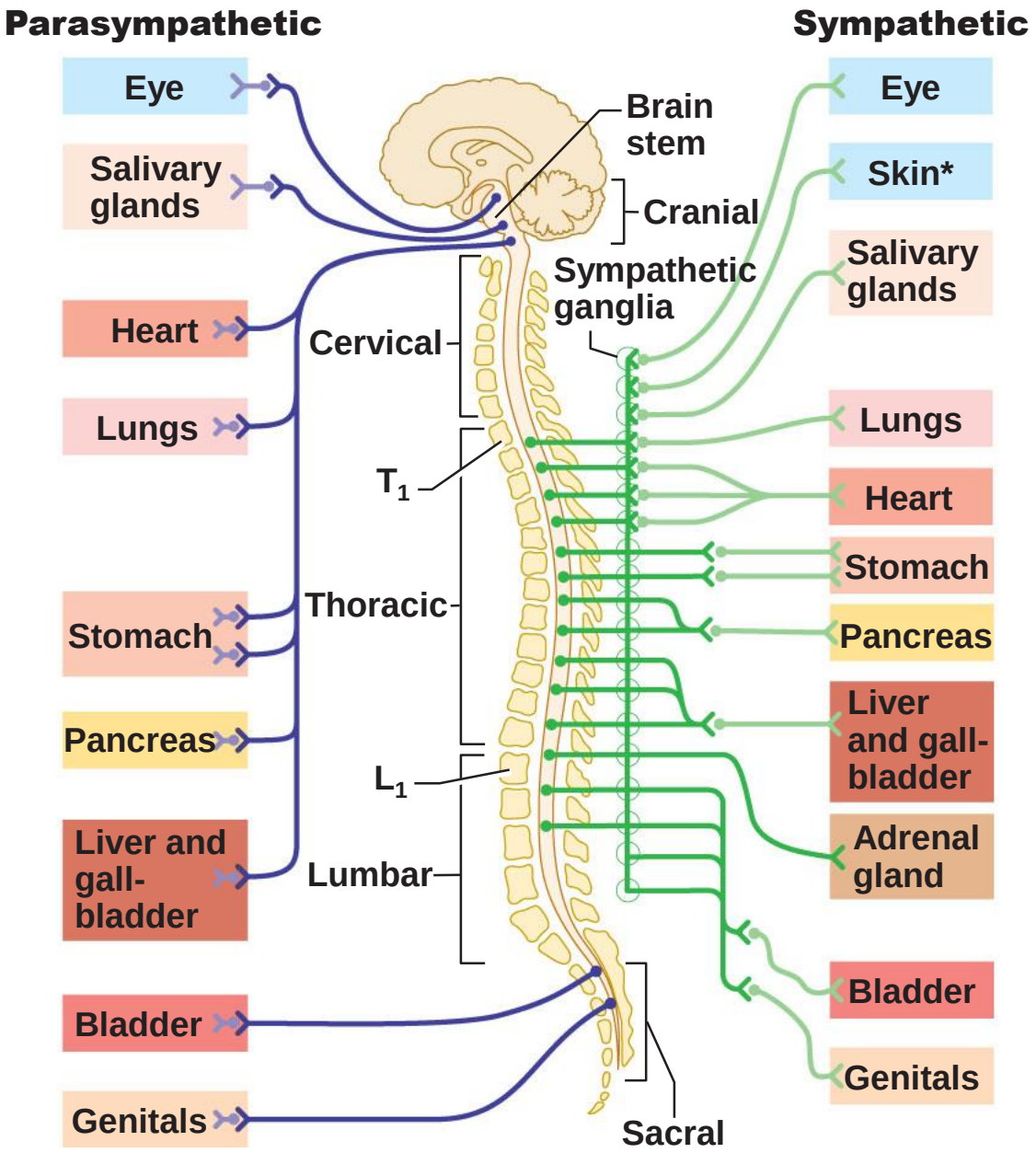

Parasympathetic
Sympathetic
Eye
Salivary glands
Heart
Lungs
Stomach
Pancreas
Liver and gall-bladder
Bladder
Genitals
Brain stem
Cranial
Sympathetic ganglia
Cervical
T_1
Thoracic
L_1
Lumbar
Sacral
Eye
Skin*
Salivary glands
Lungs
Heart
Stomach
Pancreas
Liver and gall-bladder
Adrenal gland
Bladder
Genitals

Figure 14.3

Sympathetic (Thoracolumbar) Division

- Preganglionic neurons are in spinal cord segments $T_1 - L_2$
- Sympathetic neurons produce the lateral horns of the spinal cord
- Preganglionic fibers pass through the white rami communicantes and enter sympathetic trunk (paravertebral) ganglia

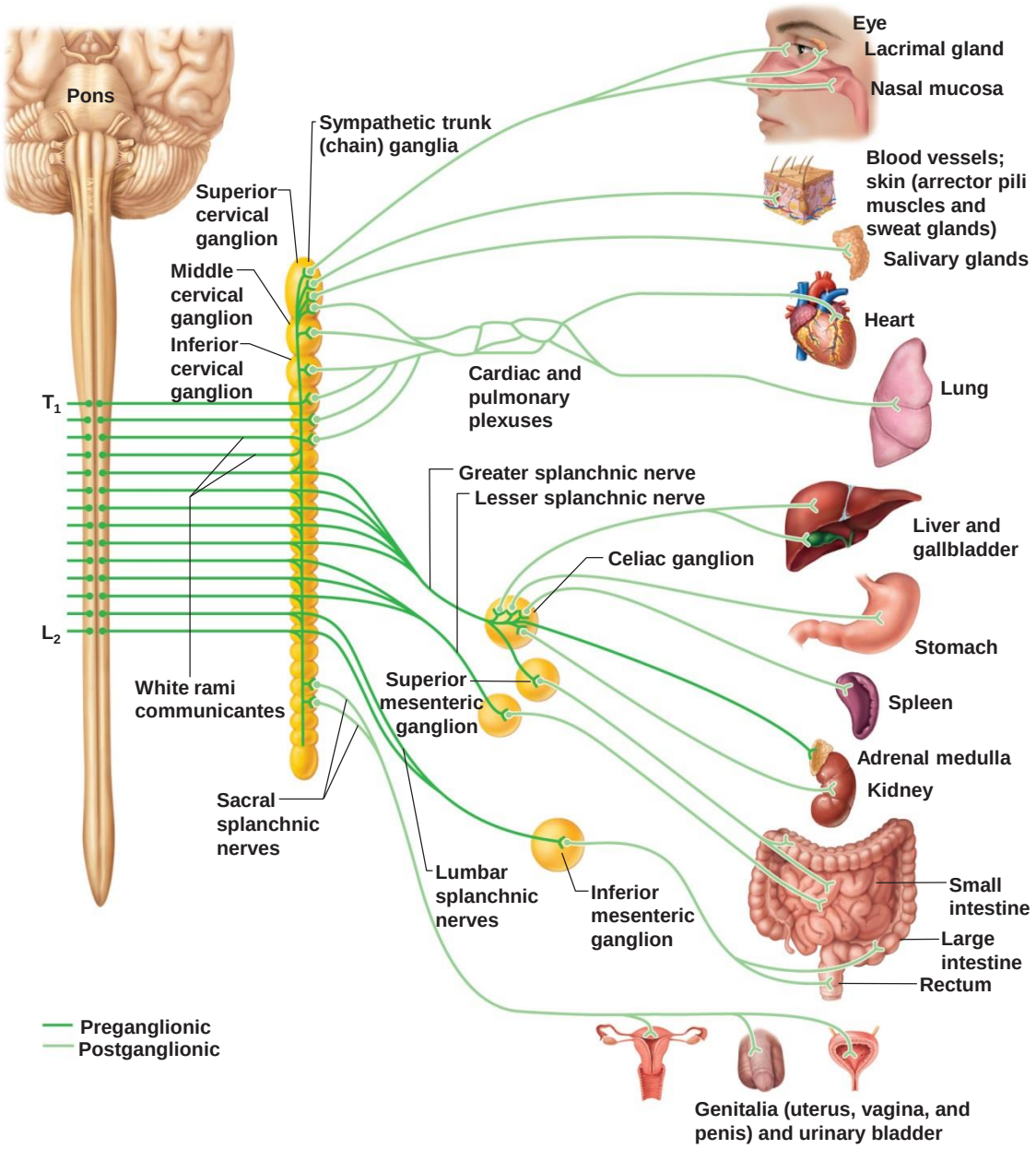
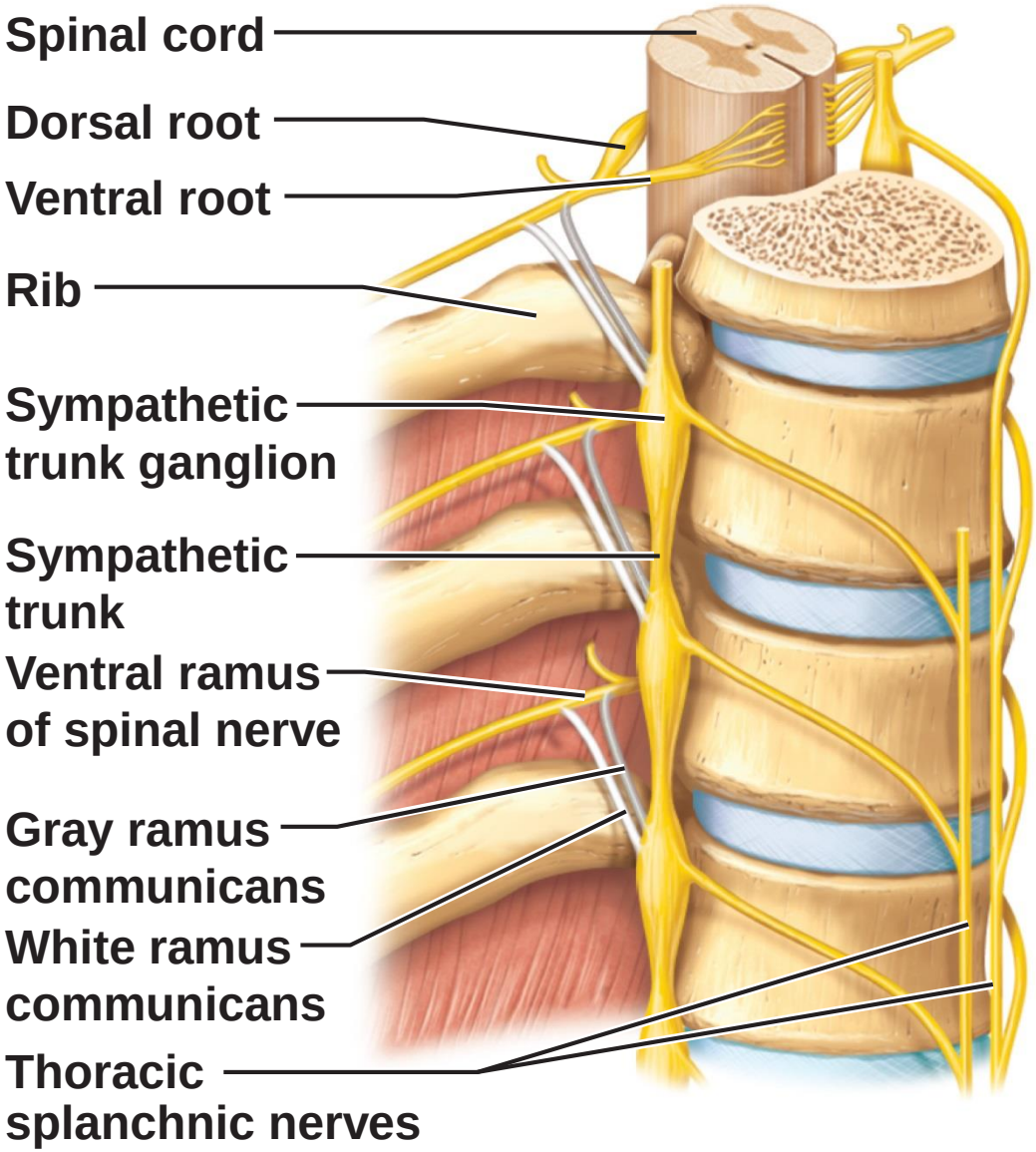

Pons
Sympathetic trunk (chain) ganglia
Superior cervical ganglion
Middle cervical ganglion
Inferior cervical ganglion
T1
L2
White rami communicantes
Sacral splanchnic nerves
Cardiac and pulmonary plexuses
Greater splanchnic nerve
Lesser splanchnic nerve
Celiac ganglion
Superior mesenteric ganglion
Lumbar splanchnic nerves
Inferior mesenteric ganglion
Eye
Lacrimal gland
Nasal mucosa
Blood vessels; skin (arrector pili muscles and sweat glands)
Salivary glands
Heart
Lung
Liver and gallbladder
Stomach
Spleen
Adrenal medulla
Kidney
Small intestine
Large intestine
Rectum
Genitalia (uterus, vagina, and penis) and urinary bladder
Preganglionic
Postganglionic

Figure 14.6

Sympathetic Trunks and Pathways

- There are 23 paravertebral ganglia in the sympathetic trunk (chain)
  - 3 cervical
  - 11 thoracic
  - 4 lumbar
  - 4 sacral
  - 1 coccygeal

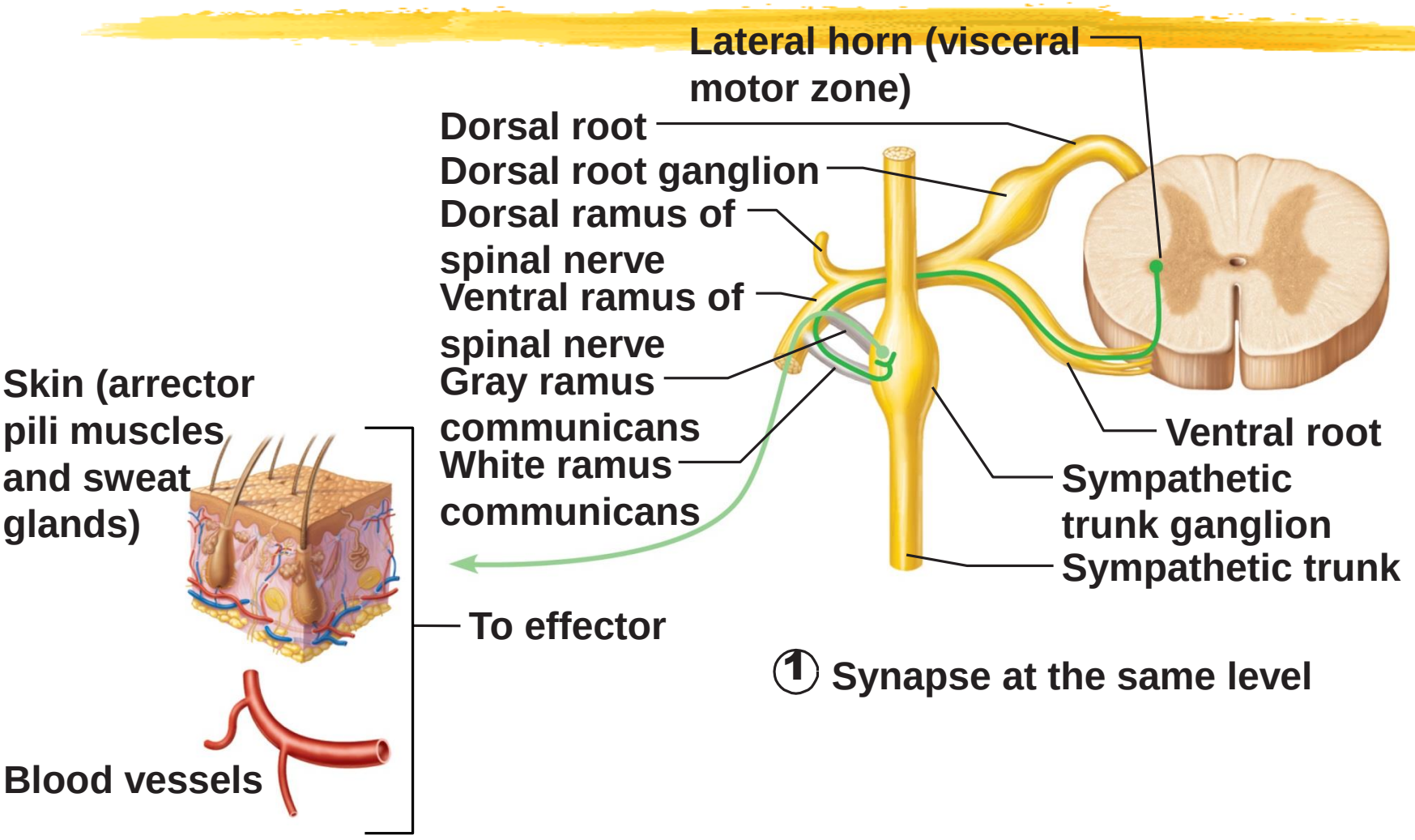


(a) Location of the sympathetic trunk

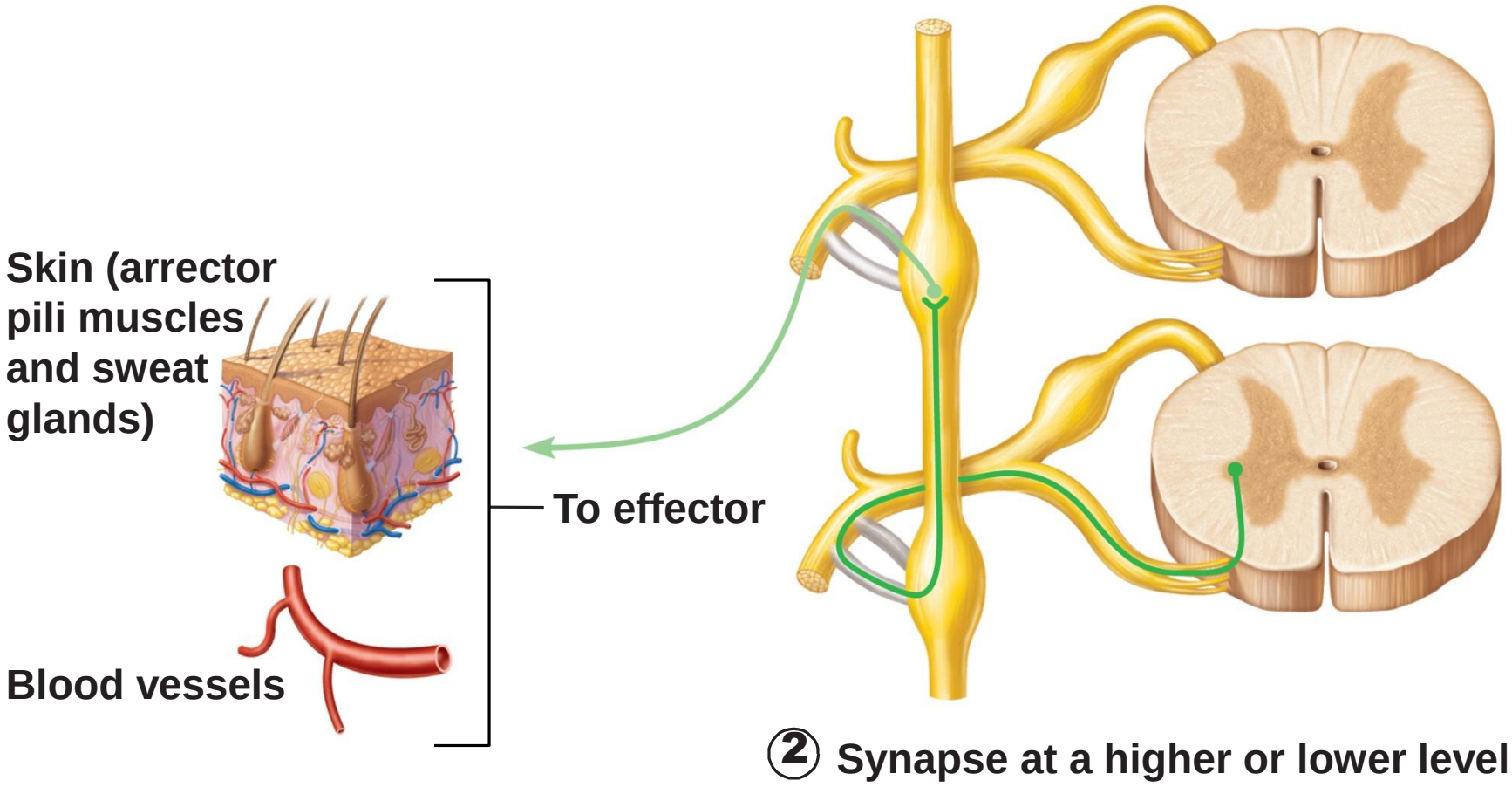
Figure 14.5a

Sympathetic Trunks and Pathways

- Upon entering a sympathetic trunk ganglion a preganglionic fiber may do one of the following:
  1. Synapse with a ganglionic neuron within the same ganglion
  2. Ascend or descend the sympathetic trunk to synapse in another trunk ganglion
  3. Pass through the trunk ganglion and emerge without synapsing



(b) Three pathways of sympathetic innervation



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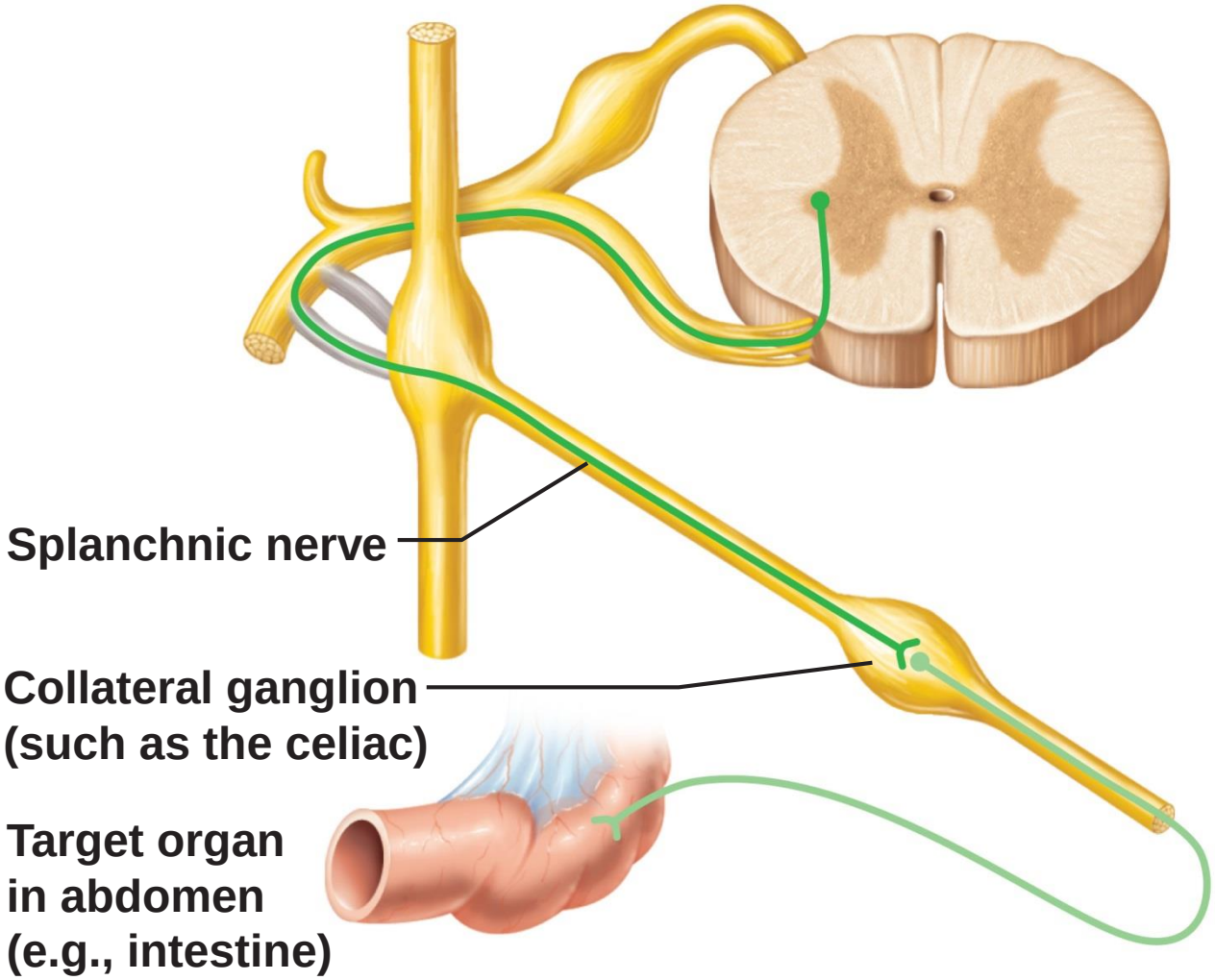


(b) Three pathways of sympathetic innervation

Pathways with Synapses in Chain Ganglia

- Postganglionic axons enter the ventral rami via the gray rami communicantes
- These fibers innervate
  - Sweat glands
  - Arrector pili muscles
  - Vascular smooth muscle

Pathways to the Head

- Fibers emerge from T_1 – T_4 and synapse in the superior cervical ganglion
- These fibers
  - Innervate skin and blood vessels of the head
  - Stimulate dilator muscles of the iris
  - Inhibit nasal and salivary glands

Pathways to the Thorax

- Preganglionic fibers emerge from $T_1 - T_6$ and synapse in the cervical trunk ganglia
- Postganglionic fibers emerge from the middle and inferior cervical ganglia and enter nerves $C_4 - C_8$
- These fibers innervate:
  - Heart via the cardiac plexus
  - Thyroid gland and the skin
  - Lungs and esophagus

Pathways with Synapses in Collateral Ganglia

- Most fibers from $T_5 – L_2$ synapse in collateral ganglia
- They form thoracic, lumbar, and sacral splanchnic nerves
- Their ganglia include the celiac and the superior and inferior mesenteric

Pathways to the Abdomen

- Preganglionic fibers from $T_5 – L_2$ travel through the thoracic splanchnic nerves
- Synapses occur in the celiac and superior mesenteric ganglia
- Postganglionic fibers serve the stomach, intestines, liver, spleen, and kidneys

Pathways to the Pelvis

- Preganglionic fibers from $T_{10} – L_2$ travel via the lumbar and sacral splanchnic nerves
- Synapses occur in the inferior mesenteric and hypogastric ganglia
- Postganglionic fibers serve the distal half of the large intestine, the urinary bladder, and the reproductive organs

Pathways with Synapses in the Adrenal Medulla

- Some preganglionic fibers pass directly to the adrenal medulla without synapsing
- Upon stimulation, medullary cells secrete norepinephrine and epinephrine into the blood

Visceral Reflexes

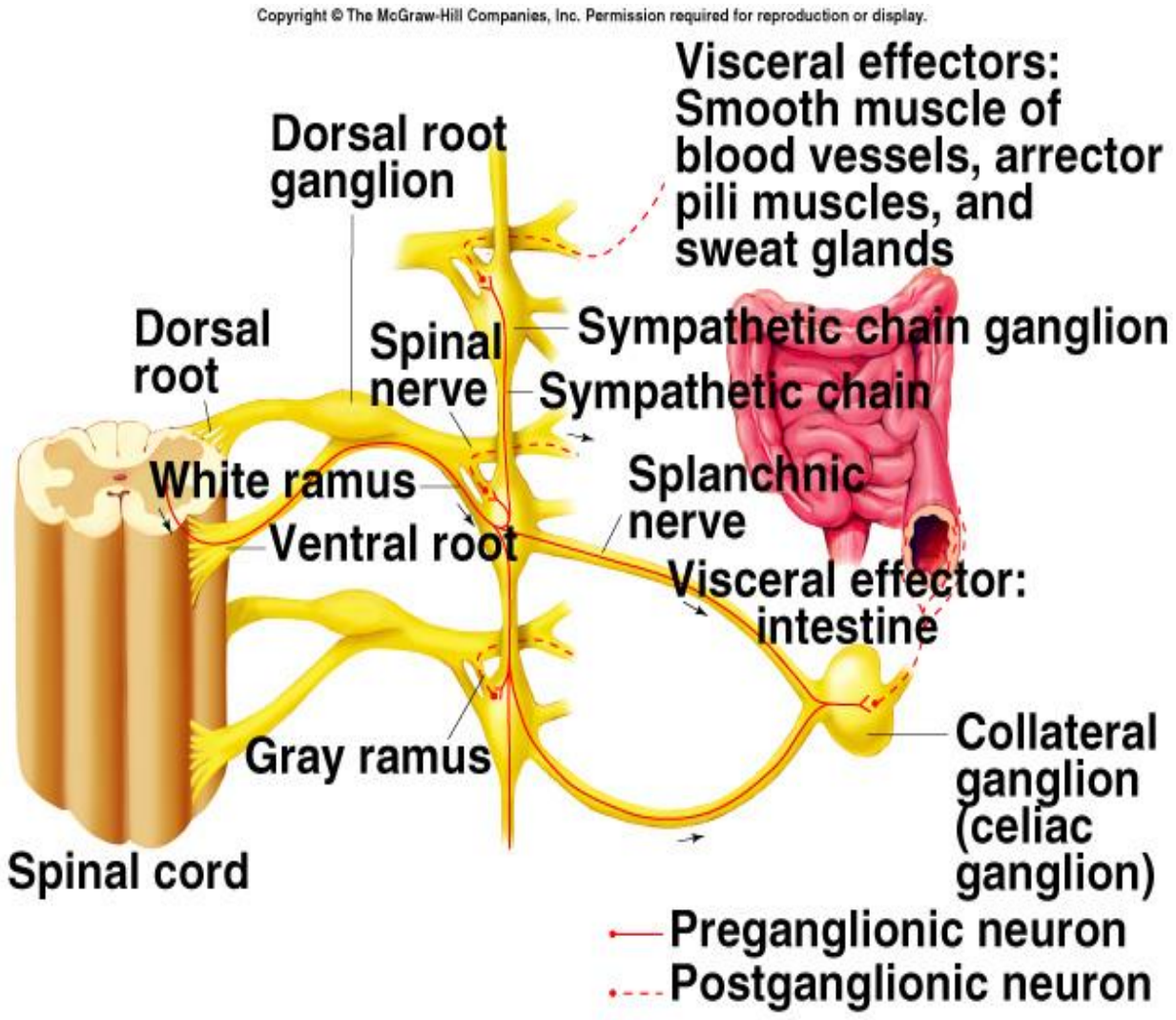
- Visceral reflex arcs have the same components as somatic reflexes
- Main difference: visceral reflex arc has two neurons in the motor pathway
- Visceral pain afferents travel along the same pathways as somatic pain fibers, contributing to the phenomenon of referred pain

Sympathetic Division

- Myelinated preganglionic fibers exit spinal cord in ventral roots from T1 to L2 levels.
- Most sympathetic nerve fibers separate from somatic motor fibers and synapse with postganglionic neurons within paravertebral ganglia.
  - Ganglia within each row are interconnected, forming a chain of ganglia that parallels spinal cord to synapse with postganglionic neurons.
- Divergence:
  - Preganglionic fibers branch to synapse with # of postganglionic neurons.
- Convergence:
  - Postganglionic neuron receives synaptic input from large # of preganglionic fibers.

Sympathetic Division (continued)

- Mass activation:
  - Divergence and convergence cause the SNS to be activated as a unit.
- Axons of postganglionic neurons are unmyelinated to the effector organ.



Adrenal Glands

- Adrenal medulla secretes epinephrine (Epi) and norepinephrine (NE) when stimulated by the sympathetic nervous system.
- Modified sympathetic ganglion:
  - Its cells are derived form the same embryonic tissue that forms postganglionic sympathetic neurons.
- Sympathoadrenal system:
  - Stimulated by mass activation of the sympathetic nervous system.
  - Innervated by preganglionic sympathetic fibers.

Parasympathetic (Craniosacral) Division Outflow

	Cranial Nerve	Ganglia (Terminal Ganglia)	Effector Organ(s)
Cranial Outflow	Oculomotor (III)	Ciliary	Eye
	Facial (VII)	Pterygopalatine Submandibular	Salivary, nasal, and lacrimal glands
	Glossopharyngeal (IX)	Otic	Parotid salivary glands
	Vagus (X)	Within the walls of target organs	Heart, lungs, and most visceral organs
Sacral Outflow	S_2-S_4	Within the walls of target organs	Large intestine, urinary bladder, ureters, and reproductive organs

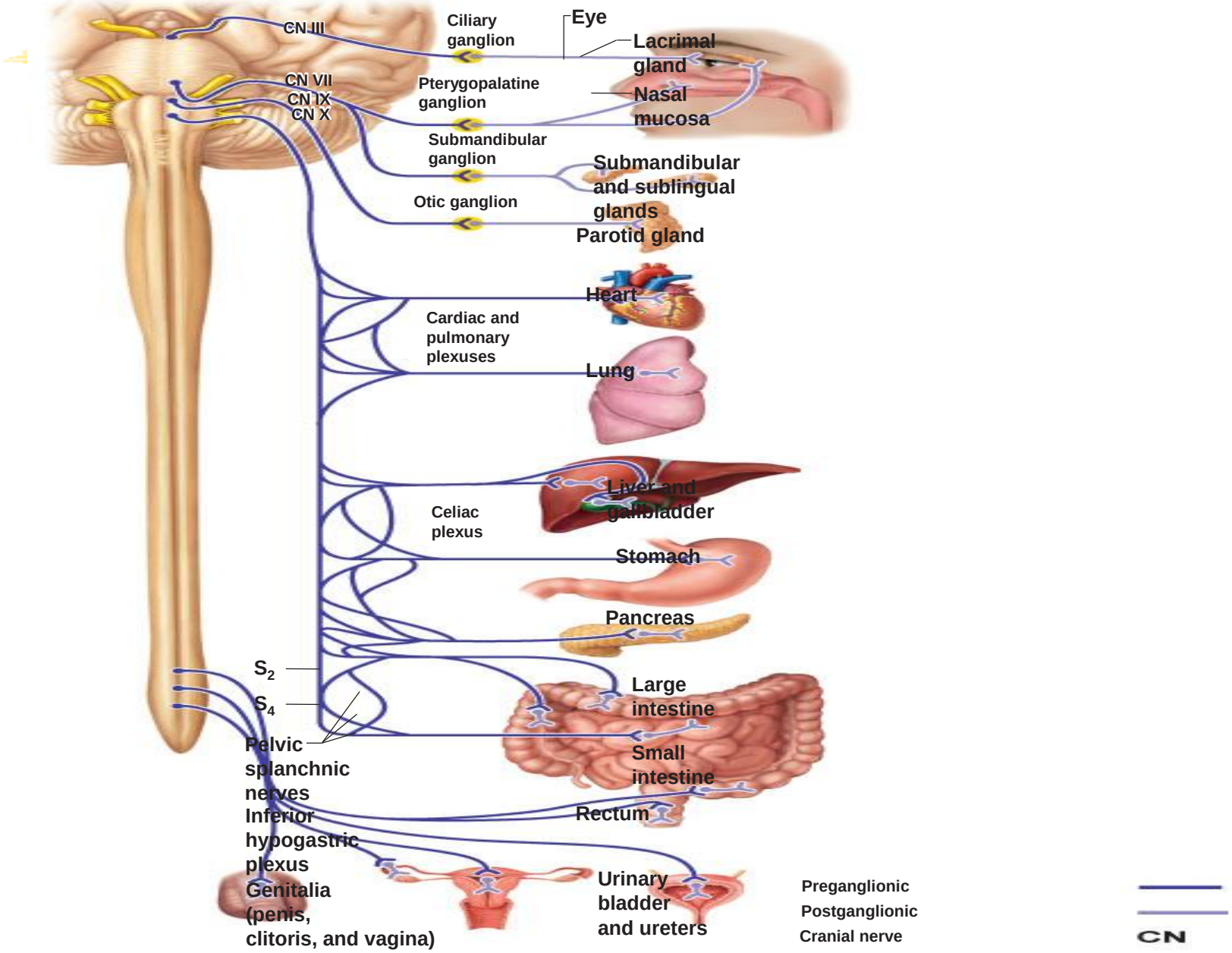
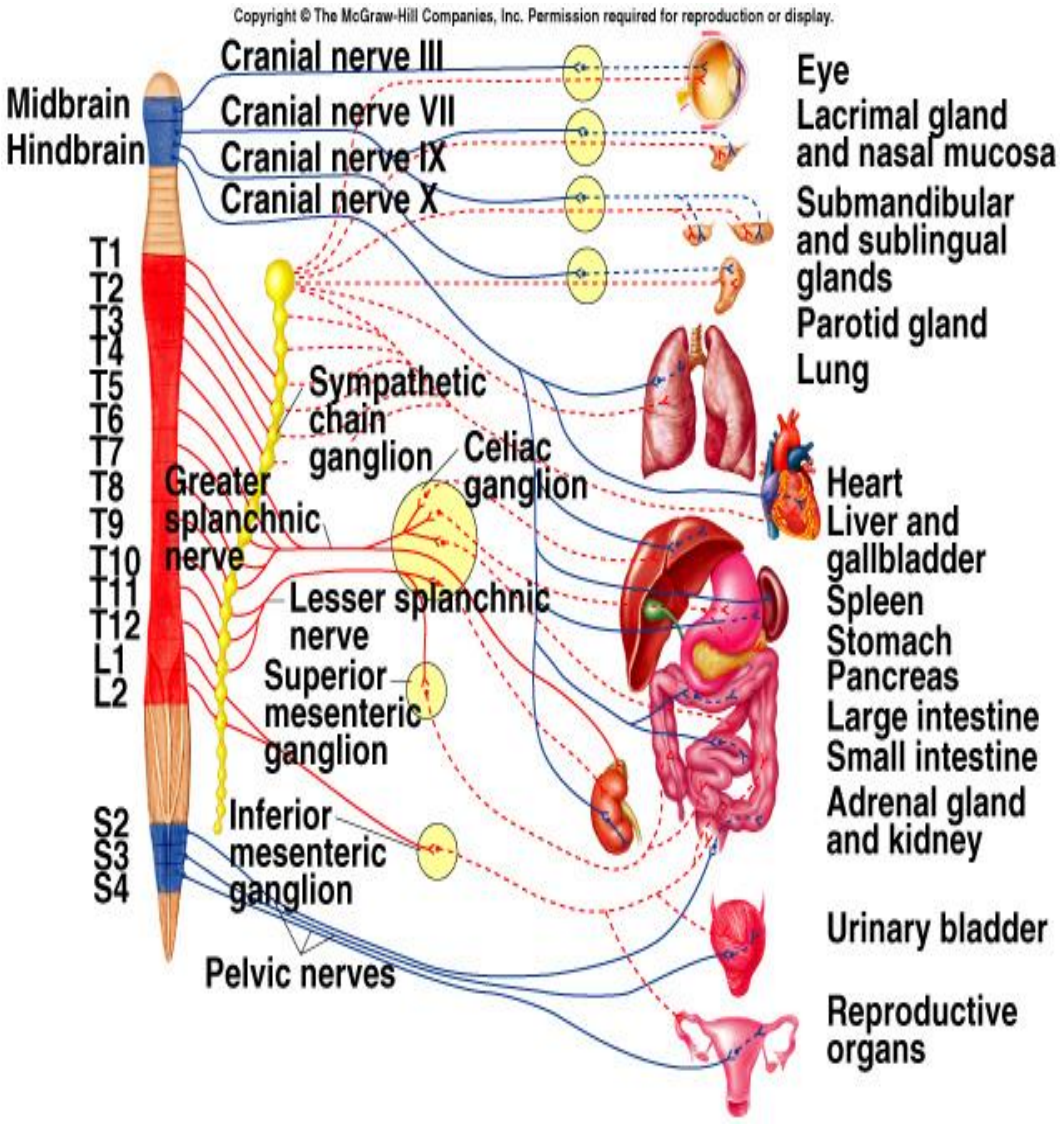

CN III
Ciliary ganglion
Eye
Lacrimal gland
CN VII
CN IX
CN X
Pterygopalatine ganglion
Nasal mucosa
Submandibular ganglion
Submandibular and sublingual glands
Otic ganglion
Parotid gland
Heart
Cardiac and pulmonary plexuses
Lung
Liver and gallbladder
Celiac plexus
Stomach
Pancreas
S_2
S_4
Large intestine
Pelvic splanchnic nerves
Small intestine
Rectum
Inferior hypogastric plexus
Genitalia (penis, clitoris, and vagina)
Urinary bladder and ureters
Preganglionic
Postganglionic
Cranial nerve
CN

Figure 14.4

Parasympathetic Division

- Preganglionic fibers originate in midbrain, medulla, pons; and in the 2-4 sacral levels of the spinal column.
- Preganglionic fibers synapse in terminal ganglia located next to or within organs innervated.
- Most parasympathetic fibers do not travel within spinal nerves.
  - Do not innervate blood vessels, sweat glands, and arrector pili muscles.



Parasympathetic Division (continued)

- 4 of the 12 pairs of cranial nerves (III, VII, X, IX) contain preganglionic parasympathetic fibers.
- III, VII, IX synapse in ganglia located in the head.
- X synapses in terminal ganglia located in widespread regions of the body.
- Vagus (X):
  - Innervates heart, lungs esophagus, stomach, pancreas, liver, small intestine and upper half of the large intestine.
- Preganglionic fibers from the sacral level innervate the lower half of large intestine, the rectum, urinary and reproductive systems.

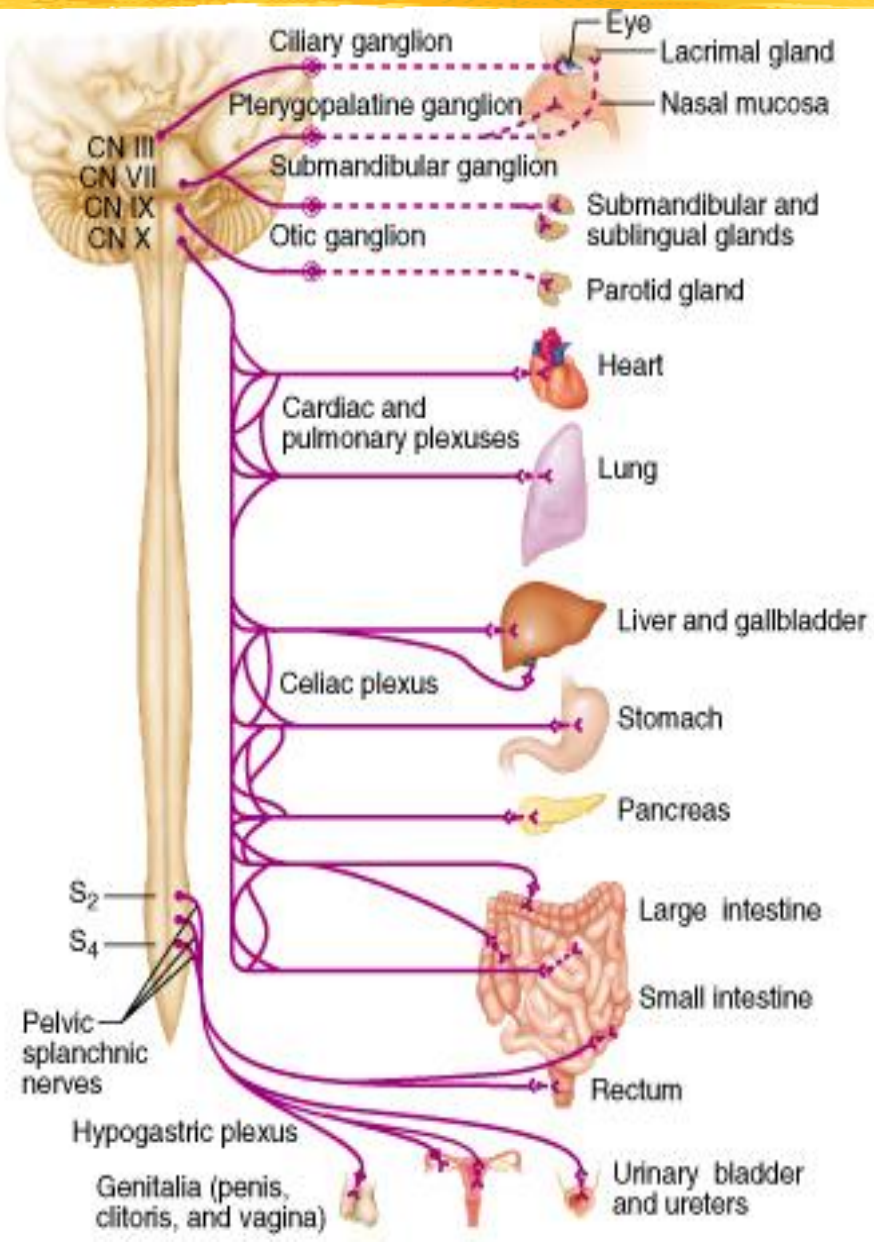
4. Autonomic ganglia

In general:

- Myelin lost as preganglionic axon enters ganglion
- Parasympathetic
  - preganglionic axons long
  - ganglia usually on the wall of the target organ (thus near impossible to surgically denervate)
  - thus postganglionic axons short
- Sympathetic
  - preganglionic axons shorter
  - ganglia close to spinal cord (sympathetic chain ganglia, especially for cardiovascular targets) or about half-way to target organ (eg mesenteric, hypogastric ganglia)
  - can surgically denervate (separate postganglionic cell body from terminals)

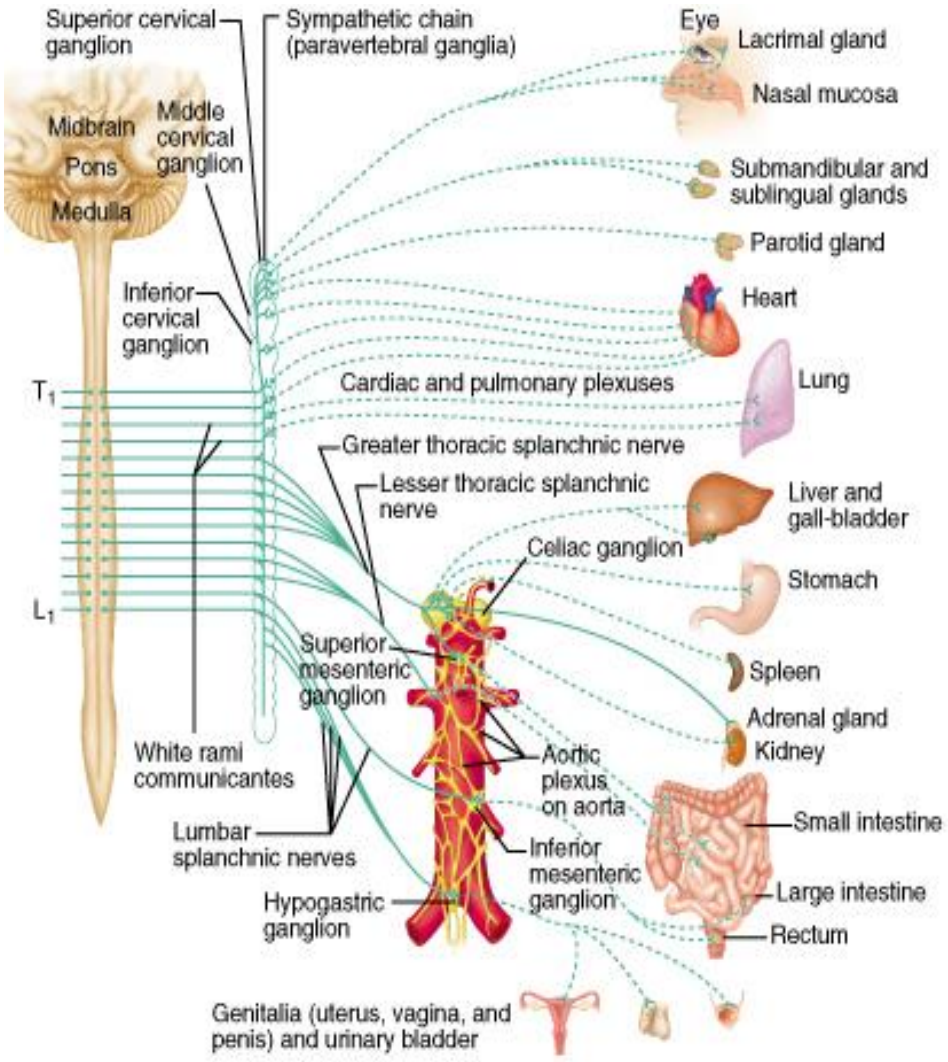
Parasympathetic Ganglia

- parasympathetic terminal ganglia = intramural ganglia
  - ganglia are located very close to or in the wall of the visceral organs
  - each preganglionic neuron synapses with a only few postganglionic neurons
- parasympathetic preganglionic fibers are long
- parasympathetic postganglionic fibers are short



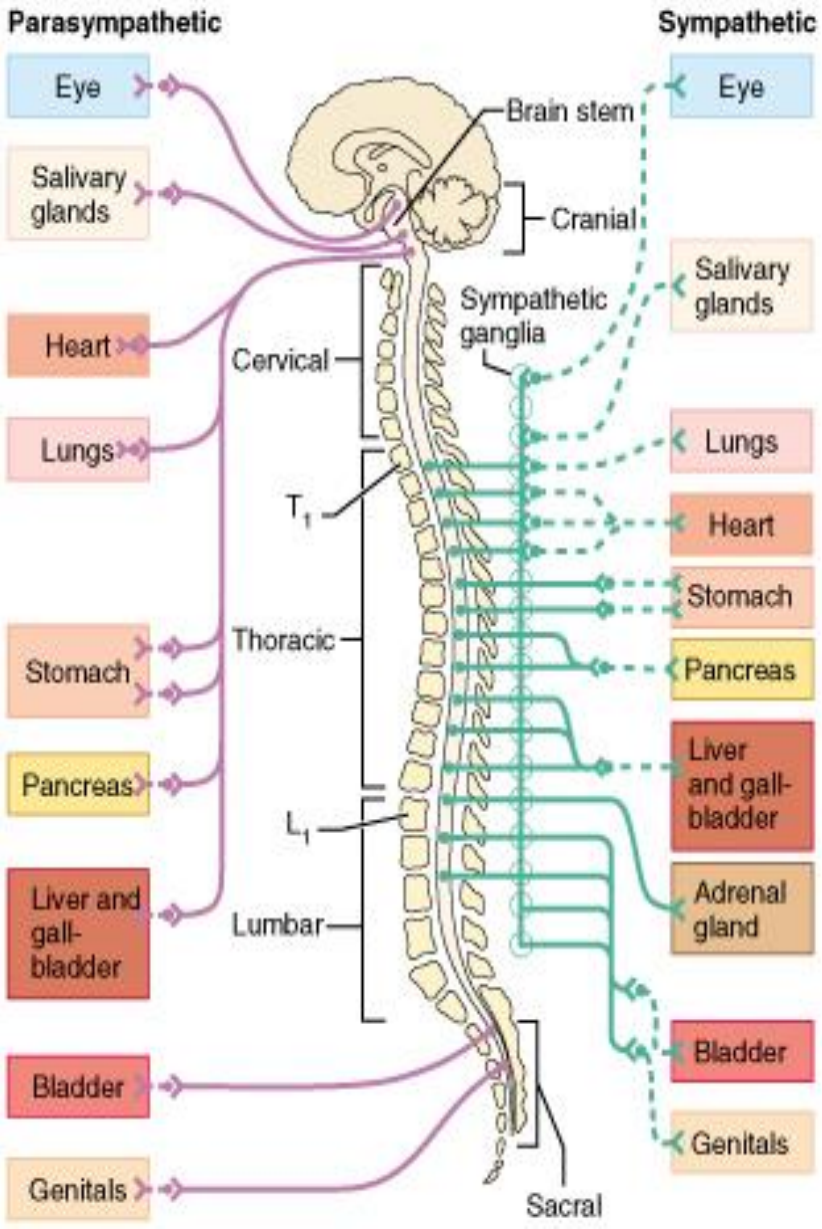
Sympathetic Ganglia

- sympathetic trunk = vertebral chain ganglia = paravertebral ganglia
  - a vertical row on either side of the vertebral column
  - these ganglia are interconnected
  - thoracic and lumbar origin
  - each preganglionic neuron synapses with many postganglionic neurons
- other sympathetic ganglia are located in the walls of major abdominal arteries
- sympathetic preganglionic fibers are short
- postganglionic fibers are long



ANS Dual Innervation

- The Sympathetic and Parasympathetic Divisions of the ANS innervate many of the same organs
- Different effects are due to specific different neurotransmitters and receptor types of effectors



ANS Neurotransmitters & Receptors

- Neurotransmitters
  - Preganglionic - Acetylcholine
  - Postgangionic
    - Parasympathetic - acetylcholine
    - Sympathetic – norepinephrine & in a few locations acetylcholine
- Receptors
  - Parasympathetic
    - nicotinic - excitatory
    - muscarinic - excitatory or inhibitory
  - Sympathetic
    - alpha - excitatory
    - beta - excitatory or inhibitory

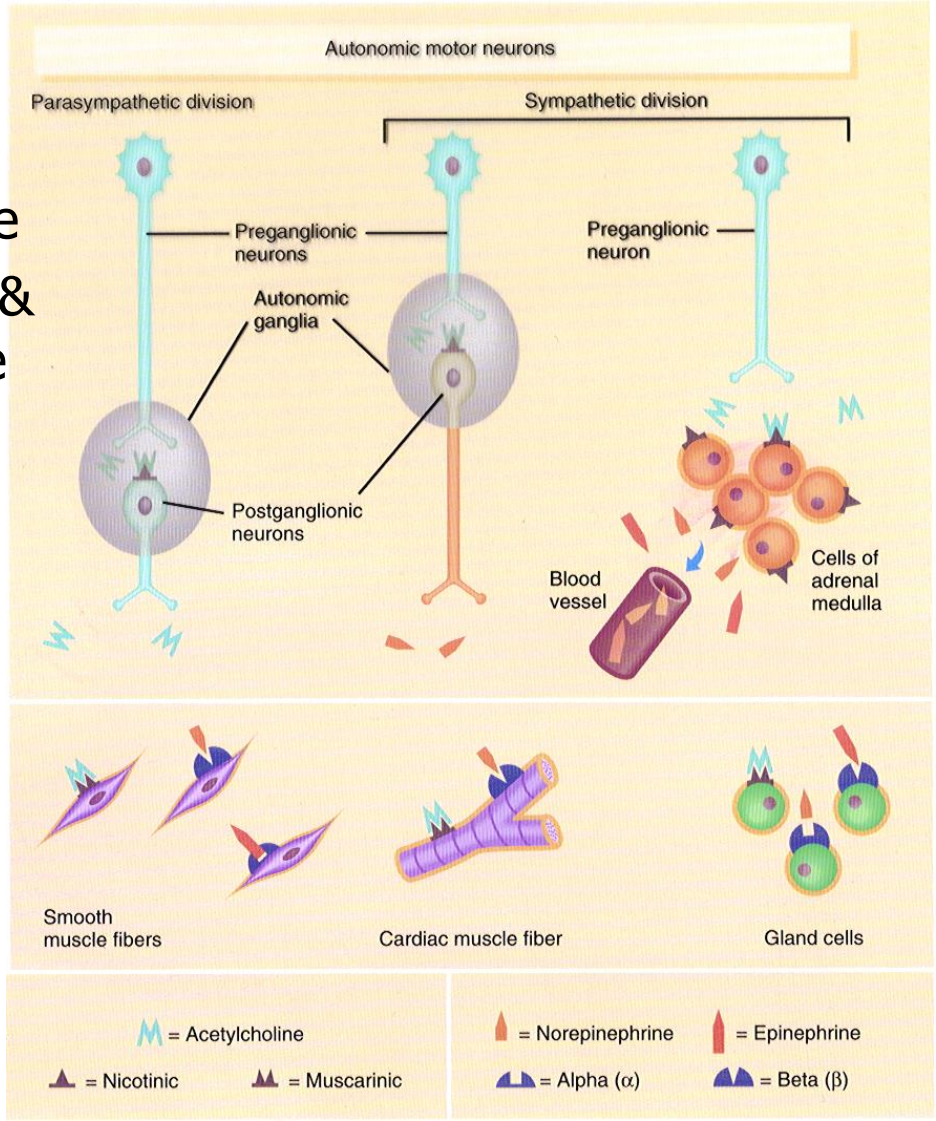


TABLE 14.2 Cholinergic and Adrenergic Receptors

NEUROTRANSMITTER	RECEPTOR TYPE	MAJOR LOCATIONS*	EFFECT OF BINDING
Acetylcholine	**Cholinergic**		
	Nicotinic	All ganglionic neurons; adrenal medullary cells (also neuromuscular junctions of skeletal muscle)	Excitation
	Muscarinic	All parasympathetic target organs	Excitation in most cases; inhibition of cardiac muscle
		Limited sympathetic targets:	
		▪ Eccrine sweat glands	Activation
		▪ Blood vessels in skeletal muscles	Vasodilation (may not occur in humans)

TABLE 14.2 Cholinergic and Adrenergic Receptors

NEUROTRANSMITTER	RECEPTOR TYPE	MAJOR LOCATIONS*	EFFECT OF BINDING
Norepinephrine (and epinephrine released by adrenal medulla)	**Adrenergic**		
	β_1	Heart predominantly, but also kidneys and adipose tissue	Increases heart rate and strength; stimulates renin release by kidneys
	β_2	Lungs and most other sympathetic target organs; abundant on blood vessels serving the heart, liver and skeletal muscle	Effects mostly inhibitory; dilates blood vessels and bronchioles; relaxes smooth muscle walls of digestive and urinary visceral organs; relaxes uterus
	β_3	Adipose tissue	Stimulates lipolysis by fat cells
	α_1	Most importantly blood vessels serving the skin, mucosae, abdominal viscera, kidneys, and salivary glands; also, virtually all sympathetic target organs except heart	Constricts blood vessels and visceral organ sphincters; dilates pupils of the eyes
	α_2	Membrane of adrenergic axon terminals; pancreas; blood platelets	Inhibits NE release from adrenergic terminals; inhibits insulin secretion by pancreas; promotes blood clotting

* Note that all of these receptor subtypes are also found in the CNS.

Adrenergic Receptors

- Two types
  - Alpha (α) (subtypes α1, α2)
  - Beta (β) (subtypes β1, β2 , β3)
- Effects of NE depend on which subclass of receptor predominates on the target organ

Adrenergic Receptors

- Two types
  - Alpha (α) (subtypes α1, α2)
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- Effects of NE depend on which subclass of receptor predominates on the target organ

ANS Neurotransmitter Performance

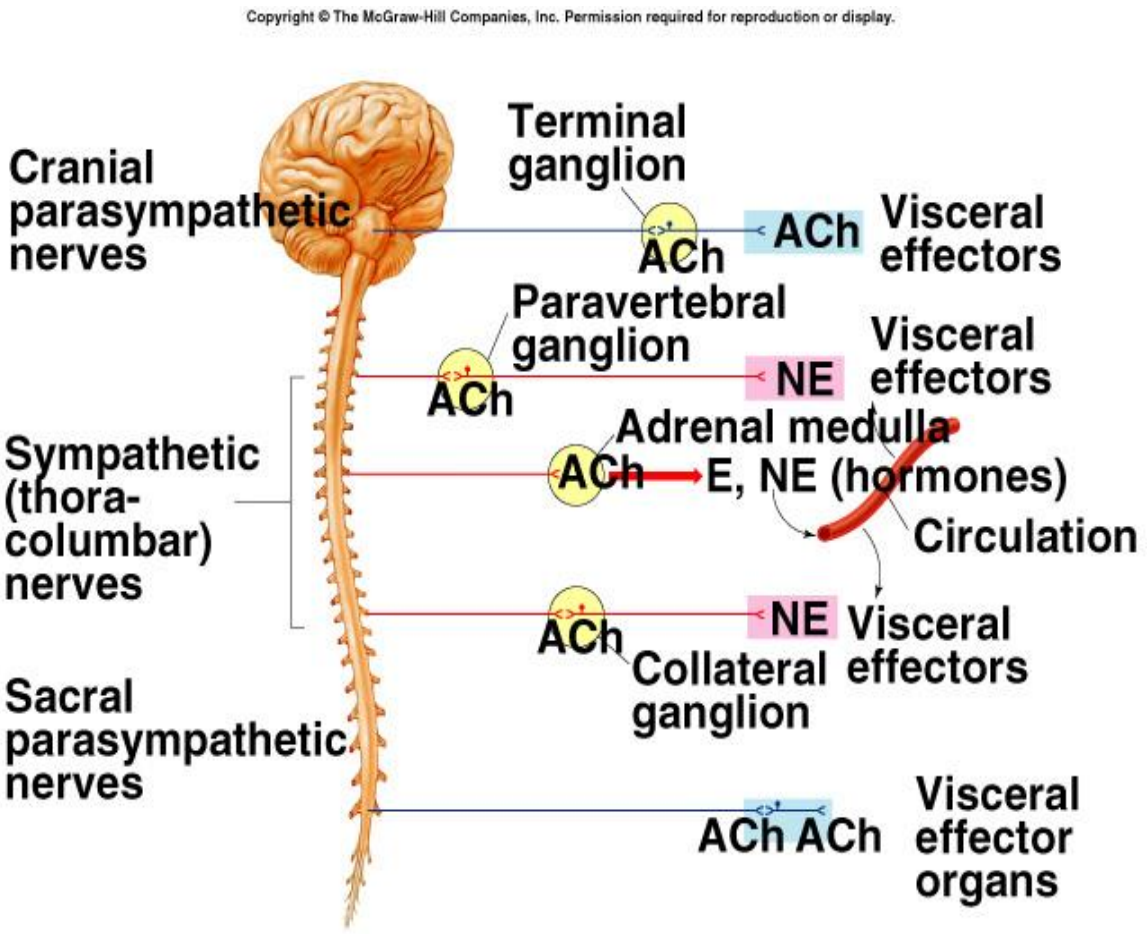
- Cholinergic fibers/neurons tend to cause relatively short-lived effects due to the rapid hydrolysis of acetylcholine by cholinesterase in the synapse
- Adrenergic fibers/neurons tend to cause relatively longer-lived effects due to the slower degradation of norepinephrine by catechol-o-methyltransferase (COMT) and monoamine oxidase (MAO) in the synapse or in body fluids
- Adrenergic receptors also respond to the closely-related hormone, epinephrine = adrenalin, secreted by the adrenal medulla

Drugs Related to ANS Neurotransmitters

- Drugs which mimic the action of ACh and NE at their receptors are termed cholinergic and adrenergic agonists respectively
- Drugs which block or inhibit the action of ACh and NE at their receptors are termed cholinergic and adrenergic antagonists respectively
- Drugs which enhance the action of ACh and NE at their synapses by delaying enzymatic degradation are termed anticholinesterases monoamine oxidase inhibitors (MAO-inhibitors)

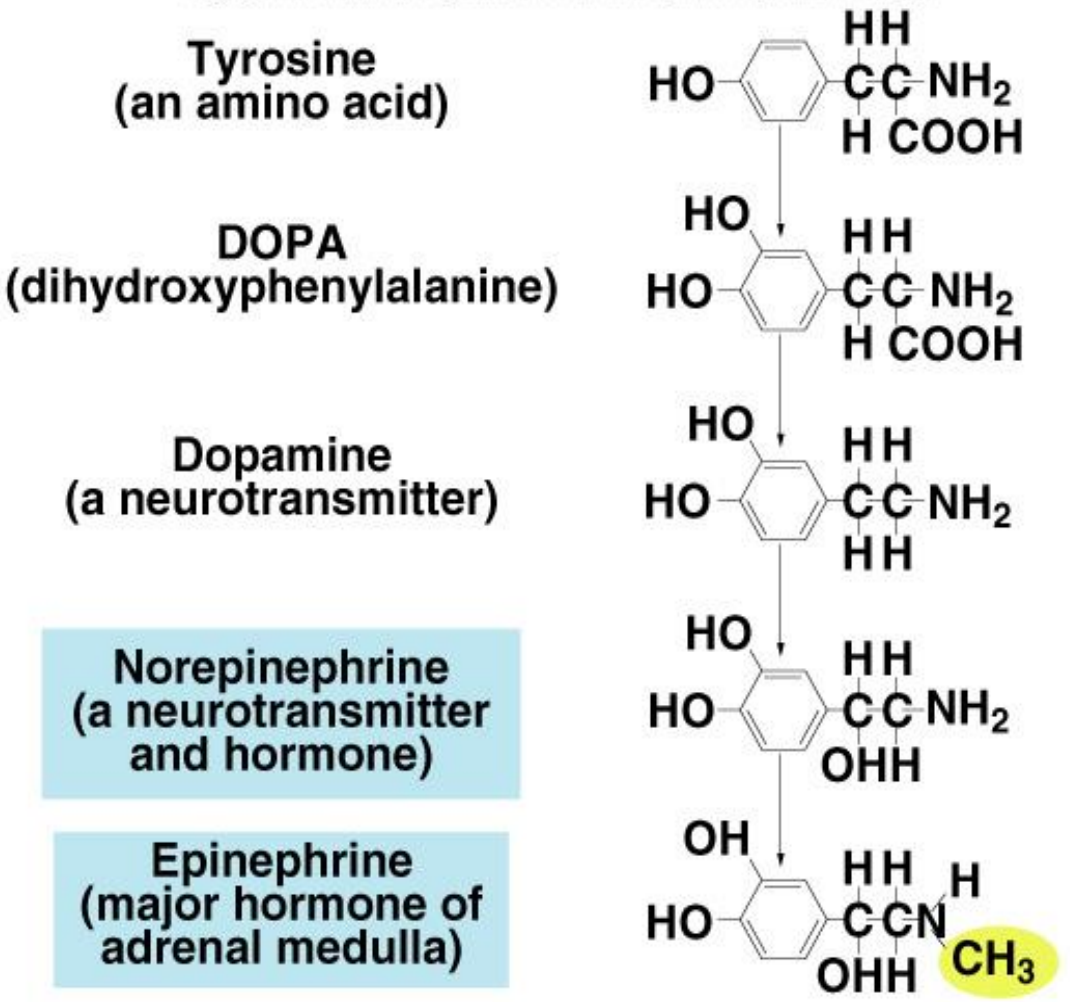
Adrenergic and Cholinergic Synaptic Transmission

- ACh is NT for all preganglionic fibers of both sympathetic and parasympathetic nervous systems.
- Transmission at these synapses is termed cholinergic:
  - ACh is NT released by most postganglionic parasympathetic fibers at synapse with effector.
- Axons of postganglionic sympathetic neurons have numerous varicosities along the axon that contain NT.



Adrenergic and Cholinergic Synaptic Transmission (continued)

- Transmission at these synapses is called adrenergic:
  - NT released by most postganglionic sympathetic nerve fibers is NE.
  - Epi, released by the adrenal medulla is synthesized from the same precursor as NE.
- Collectively called catecholamines.



Acetylcholine

- Synthesis
  - in cytoplasm of varicosity (has the enzymes)
- Stored
  - transported into and stored in vesicles
- Removal
  - acetylcholinesterase (ACh-ase) in junction
  - choline recycled
  - very efficient
  - virtually no ACh escapes ACh-ase
  - no ACh in circulation

Cholinoceptors in target tissues

- Muscarinic receptors
  - smooth and cardiac muscle, most glands
  - at least 5 types, M_1-M_5
  - blocked by atropine
  - may cause depolarization (via eg cation channels)
  - activate second messengers
- Prejunctional muscarinic receptors
  - in postganglionic membrane (varicosity)
  - reduce transmitter released upon second and subsequent stimulus

Responses to Cholinergic Stimulation

- All somatic motor neurons, all preganglionic and most postganglionic parasympathetic neurons are cholinergic.
  - Release ACh as NT.
  - Somatic motor neurons and all preganglionic autonomic neurons are excitatory.
  - Postganglionic axons, may be excitatory or inhibitory.
- Muscarinic receptors:
  - Ach binds to receptor.
  - Requires the mediation of G-proteins.
  - $\beta\gamma$-complex affects opening or closing a channel, or activating enzymes.

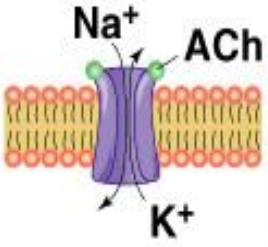
Responses to Cholinergic Stimulation (continued)

- Nicotinic receptors (ligand-gated):
  - ACh binds to 2 nicotinic receptor binding sites.
  - Causes ion channel to open within the receptor protein.
    - Opens a Na^+ channel.
- Always excitatory.

Responses to Cholinergic Stimulation (continued)

Nicotinic ACh receptors

Postsynaptic membrane of
- All autonomic ganglia
- All neuromuscular junctions
- Some CNS pathways



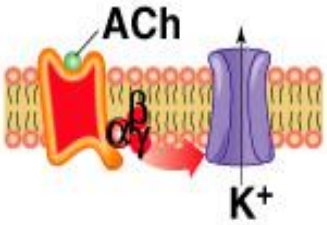
Ligand-gated channels (ion channels are part of receptor)

Depolarization

Excitation

Muscarinic ACh receptors

- Produces parasympathetic nerve effects in the heart, smooth muscles, and glands
- G-protein-coupled receptors (receptors influence ion channels by means of G-proteins)

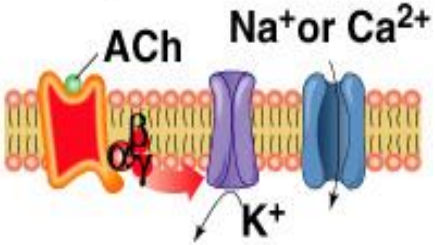


Hyperpolarization

(K^+ channels opened)

Inhibition

Produces slower heart rate



Depolarization

(K^+ channels closed)

Excitation

Causes smooth muscles of the digestive tract to contract

Blockers to Cholinergic receptors

- Tubocurarine blocks Nicotinic Ach receptors

- Atropine blocks Muscarinic Ach receptors

Noradrenaline

- Synthesis
  - in vesicles (they contain the enzymes)
- Stored
  - in vesicles
- Removal
  - broken down in junction and in surrounding cells
    - catechol-O-methyl transferase (COMT)
    - monoamine oxidase (MAO)
  - uptake
    - into prejunctional neuron (uptake 1) (the principle mechanism)
    - into target tissues (uptake 2) (may also occur)
  - diffusion
  - NA measurable in circulation

Uptake of noradrenaline

- Important physiological mechanism of terminating actions of NA
- Uptake I (neuronal)
  - into varicosity
  - pumped up (energy required)
  - targeted by drugs
  - broken down or repackaged
- Uptake II (extraneuronal)
  - also pumped (different pump)
  - blocked by steroids
  - broken down
- Residual
  - NA present in the circulation

Therapeutic targeting of removal mechanisms

- Uptake I blocked by cocaine and tricyclic antidepressants
- Uptake II suppressed by corticosteroids
- MAO inhibited by hydralazine and amphetamine derivatives and are used to treat depression
- COMT blocked by flavinoids

Responses to Adrenergic Stimulation

- Beta adrenergic receptors:
  - Produce their effects by stimulating production of cAMP.
  - NE binds to receptor.
  - G-protein dissociates into α subunit or $\beta\gamma-$ complex.
  - Depending upon tissue, either α subunit or $\beta\gamma$–complex produces the effects.
    - Alpha subunit activates adenylate cyclase, producing cAMP.
      - cAMP activates protein kinase, opening ion channels.

Responses to Adrenergic Stimulation (continued)

- Alpha$_1$ adrenergic receptors:
  - Produce their effects by the production of Ca^{2+}.
  - Epi binds to receptor.
  - Ca^{2+} binds to calmodulin.
  - Calmodulin activates protein kinase, modifying enzyme action.
- Alpha$_2$ adrenergic receptors:
  - Located on presynaptic terminal.
    - Decreases release of NE.
      - Negative feedback control.
  - Located on postsynaptic membrane.
    - When activated, produces vasoconstriction.

Responses to Adrenergic Stimulation (continued)

- Has both excitatory and inhibitory effects.
- Responses due to different membrane receptor proteins.
  - α_1 : constricts visceral smooth muscles.
  - α_2 : contraction of smooth muscle.
  - β_1 : increases HR and force of contraction.
  - β_2 : relaxation of smooth muscles (E.g.: Skeletal muscular BV, GIT, bronchioles).
  - β_3: adipose tissue, function unknown.

Therapeutic targeting of neurotransmitter action

- α_1-AR blockers (phenoxybenxamine, prazosin) to treat hypertension and vasospasm
- NA release is modulated by α_2-AR and these receptors can be stimulated (clonidine) or blocked (phentolamine, yohimbine). Used to treat hypertension
- β_2-AR agonists (salbutamol) relax smooth muscle and are used to treat asthma and delay uterine contractions in preterm labour
- α_1-AR agonists (phenylephrine) used in hypotension
- β-AR blockers (propranolol) used for angina and hypertension

Other Autonomic NTs

- Certain nonadrenergic, noncholinergic postganglionic autonomic axons produce their effects through other NTs.
  - ATP.
  - VIP.
  - NO.

Sympathetic Effects

- Fight or flight response.
- Release of norepinephrine (NT) from postganglionic fibers and epinephrine (NT) from adrenal medulla.
- Mass activation prepares for intense activity.
  - Heart rate (HR) increases.
  - Bronchioles dilate.
  - Blood [glucose] increases.

Parasympathetic Effects

- Normally not activated as a whole.
  - Stimulation of separate parasympathetic nerves.
- Release ACh as NT.
- Relaxing effects:
  - Decreases HR.
  - Dilates visceral blood vessels.
  - Increases digestive activity.

Autonomic Nervous System Actions

- Parasympathetic
  - S(alivation) L(acrimation) U(rination) D(efecation)
  - metabolic "business as usual"
  - rest and digest - basic survival functions
- Sympathetic
  - fight or flight = "survival"
  - any increase in skeletal muscular activity

    for these activities - increase heart rate, blood flow, breathing

    decrease non-survival activities - food digestion, etc.

TABLE 15.5 Effects of the Sympathetic and Parasympathetic Nervous Systems

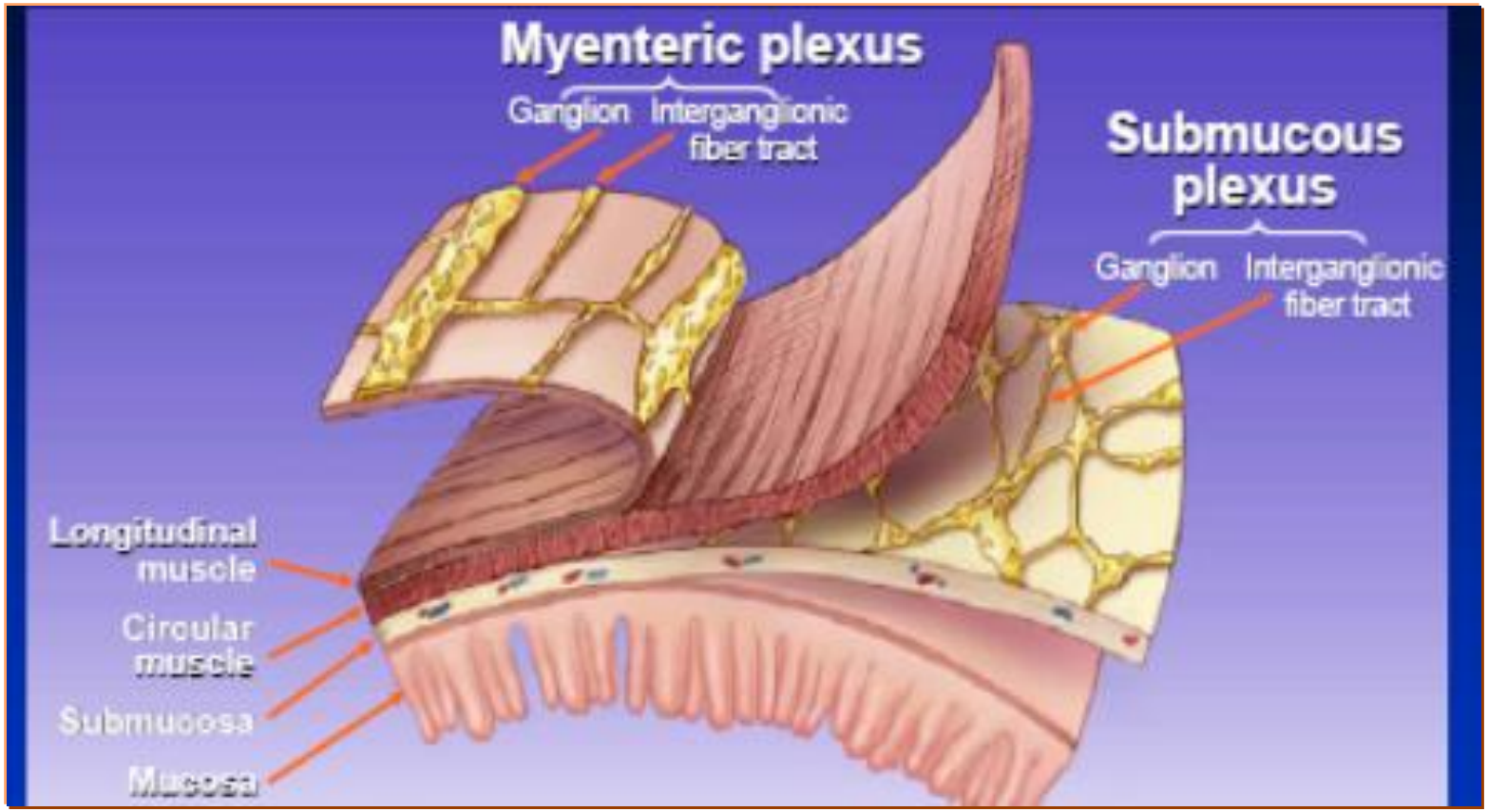
Target	Sympathetic Effect and Receptor Type	Parasympathetic Effect (all muscarinic)
Eye		
Iris	Pupillary dilation (α_1)	Pupillary constriction
Ciliary muscle and lens	Relaxation for far vision (β_2)	Contraction for near vision
Lacrimal (tear) gland	None	Secretion
Integumentary System		
Merocrine sweat glands (cooling)	Secretion (muscarinic)	No effect
Apocrine sweat glands (scent)	Secretion (α_1)	No effect
Piloerector muscles	Hair erection (α_1)	No effect
Adipose Tissue	Decreased fat breakdown (α_2) Increased fat breakdown (α_1, β_1)	No effect
Adrenal Medulla	Hormone secretion (nicotinic)	No effect
Circulatory System		
Heart rate and force	Increased (β_1, β_2)	Decreased
Deep coronary arteries	Vasodilation (β_2) Vasoconstriction (α_1, α_2)	Slight vasodilation
Blood vessels of most viscera	Vasoconstriction (α_1)	Vasodilation
Blood vessels of skeletal muscles	Vasodilation (β_2)	No effect
Blood vessels of skin	Vasoconstriction (α_1, α_2)	Vasodilation, blushing
Platelets (blood clotting)	Increased clotting (α_2)	No effect
Respiratory System		
Bronchi and bronchioles	Bronchodilation (β_2)	Bronchoconstriction
Mucous glands	Decreased secretion (α_1) Increased secretion (β_2)	No effect

TABLE 15.5 Effects of the Sympathetic and Parasympathetic Nervous Systems (*cont.*)

Target	Sympathetic Effect and Receptor Type	Parasympathetic Effect (all muscarinic)
Urinary System		
Kidneys	Reduced urine output (α_1, α_2)	No effect
Bladder wall	No effect	Contraction
Internal urethral sphincter	Contraction, urine retention (α_1)	Relaxation, urine release
Digestive System		
Salivary glands	Thick mucous secretion (α_1)	Thin serous secretion
Gastrointestinal motility	Decreased (α_1, α_2, β_1, β_2)	Increased
Gastrointestinal secretion	Decreased (α_2)	Increased
Liver	Glycogen breakdown (α_1, β_2)	Glycogen synthesis
Pancreatic enzyme secretion	Decreased (α_1)	Increased
Pancreatic insulin secretion	Decreased (α_2)	No effect
	Increased (β_2)	
Reproductive System		
Penile or clitoral erection	No effect	Stimulation
Glandular secretion	No effect	Stimulation
Orgasm, smooth muscle roles	Stimulation (α_1)	No effect
Uterus	Relaxation (β_2)	No effect
	Labor contractions (α_1)	

Enteric Nervous system

- Neuronal network in the walls of GI tract
- It is a third division of the autonomic nervous system, which functions as a brain in the gut



Characteristics of ENS

- Enteric Neurons:
  - Excitatory
  - Inhibitory

- Neurotransmitters

  Ach, SP (Substance P), VIP (Vasoactive intestinal peptide), CGRP (Calcitonin gene related peptide), GRP (Gastrin releasing peptide)…etc

Classification of Autonomic Dysfunction

Localized disorders: Affect an organ or region of the body but they may be part of generalized disease, such as gustatory sweating in diabetes mellitus

Generalized disorders: often affect systems, such as those involved in blood pressure control and thermoregulation. They can be primary when the cause is often unclear, or secondary when associated with a specific disease or its complications

Clinical features

Clinical features of autonomic disease cover a wide spectrum and result from Underactivity or Overactivity.

- Sympathetic adrenergic failure causes orthostatic (postural) hypotension and ejaculatory failure in the male;
- Sympathetic cholinergic failure causes anhidrosis;
- Parasympathetic failure causes dilated pupils, fixed heart rate, sluggish urinary bladder, atonic large bowel and, in the male, erectile failure

Horner syndrome

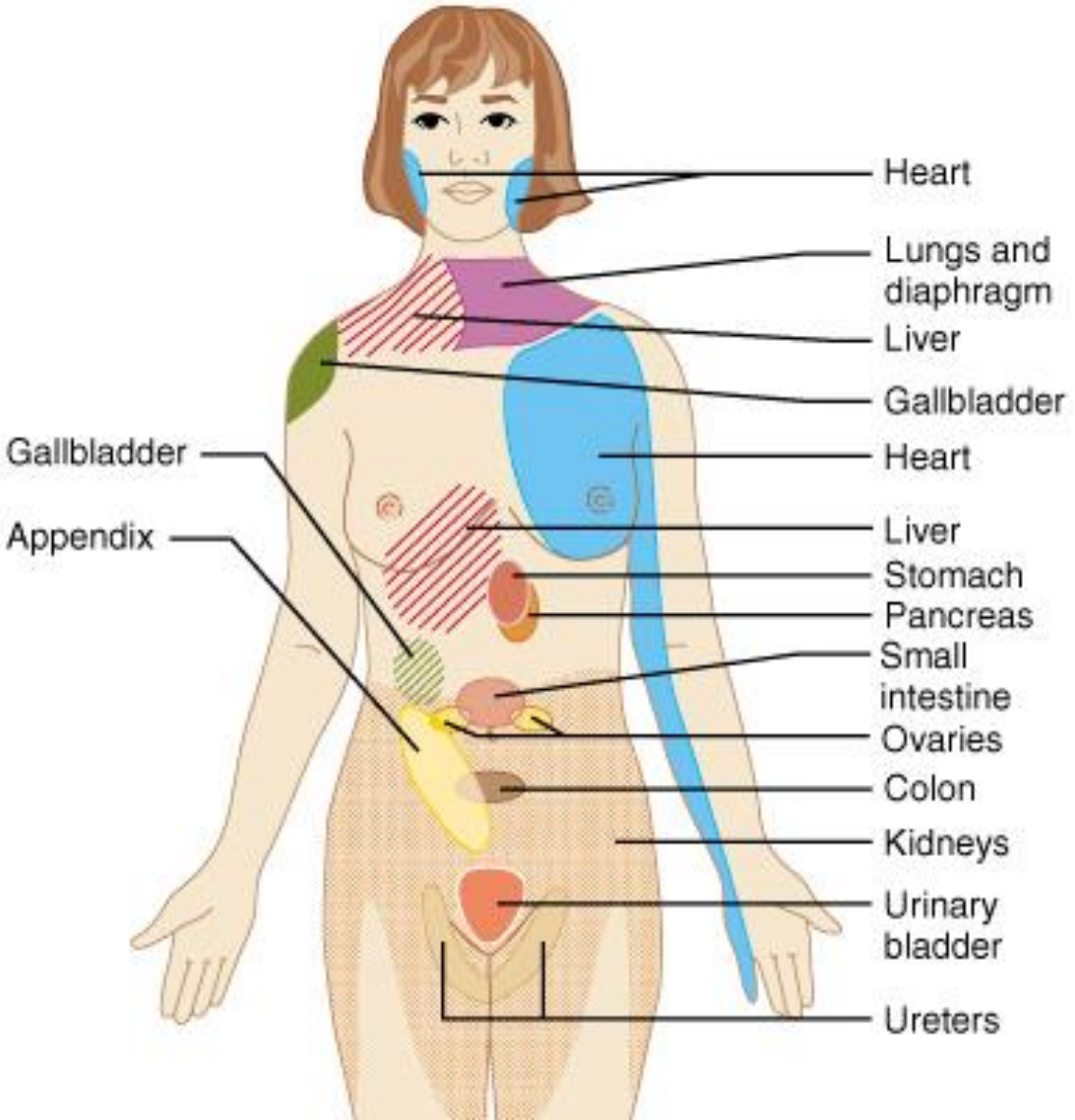
- Horner's syndrome or oculosympathetic paresis results from an interruption of the sympathetic nerve supply to the eye
- It is characterized by the classic triad of miosis (ie, constricted pupil), partial ptosis, and loss of hemifacial sweating (ie, anhidrosis).

ANS Testing

- Resting heart rate, blood pressure & pulse (arterial) waveform
- Valsalva Maneuver
- Deep breathing
- Response to postural change (sitting to standing)
- Heart Rate Variability (HRV) which monitors the R-R intervals, beat by beat blood pressure and pulse wave form throughout all segments of the test.

Referred Pain

- Visceral afferents run in the same nerves with somatic afferents
- Pain in the viscera is transferred or interpreted as if it came from somatic areas
- Heart attack
  - afferents in T_1 - T_5
  - pain in the chest, arm, neck or face



Sympathetic vs. Parasympathetic

Structural Differences:

Point of CNS Origin	T1 → L2 (thoracolumbar)	Brainstem, S2 → S4 (craniosacral)
Site of Peripheral Ganglia	Paravertebral – in sympathetic chain	On or near target tissue
Length of preganglionic fiber	Short	Long
Length of postganglionic fiber	Long	Short

Sympathetic vs. Parasympathetic *Receptor/NT Differences:*

	Symp .	Parasymp.
NT at Target Synapse	Norepinephrine (adrenergic neurons)	Acetylcholine (cholinergic neurons)
Type of NT Receptors at Target Synapse	Alpha and Beta (α and β)	Muscarinic
NT at Ganglion	Acetylcholine	Acetylcholine
Receptor at Ganglion	Nicotinic	Nicotinic

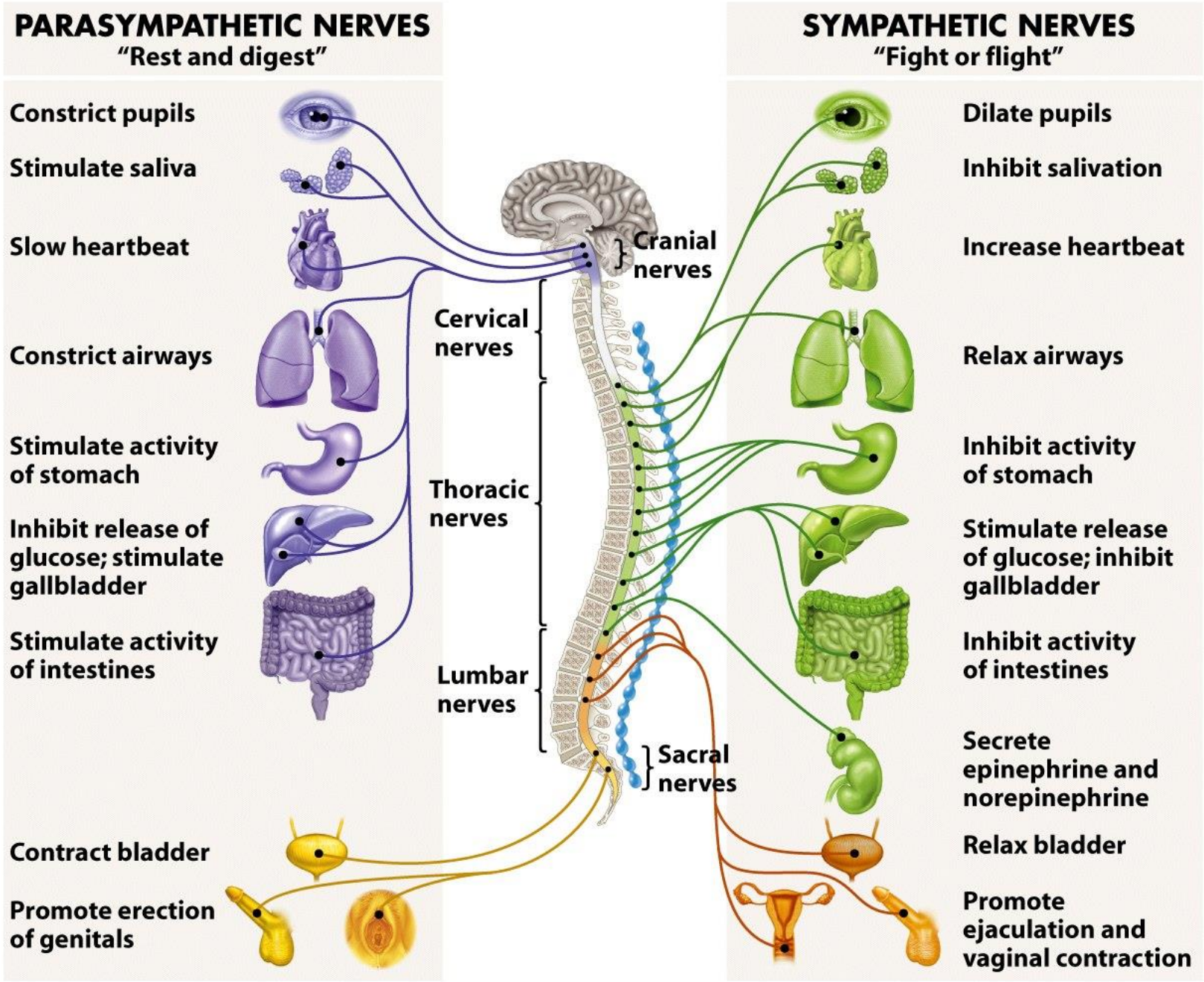


Figure 45-20 Biological Science, 2/e