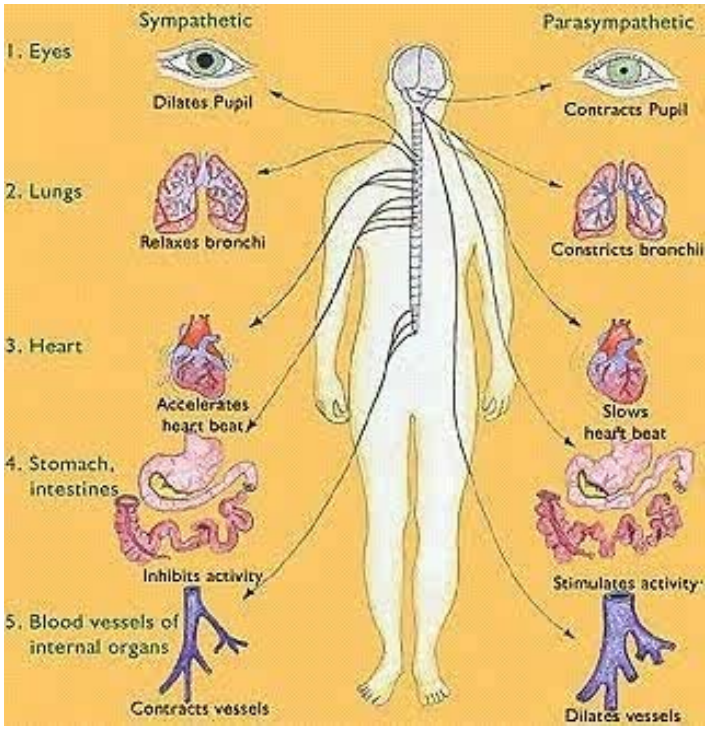
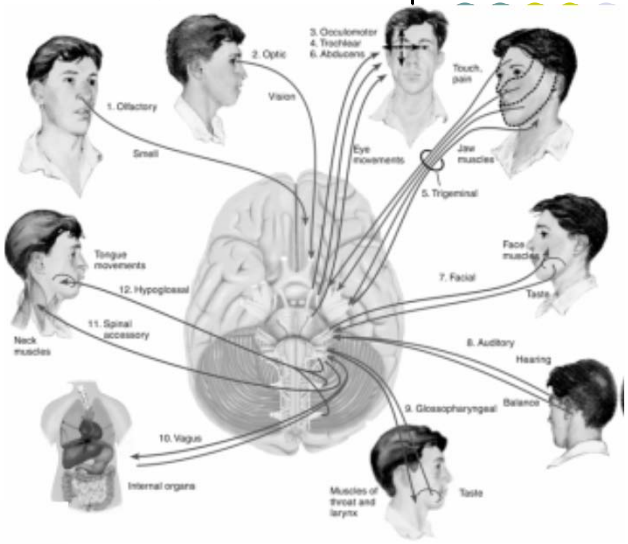
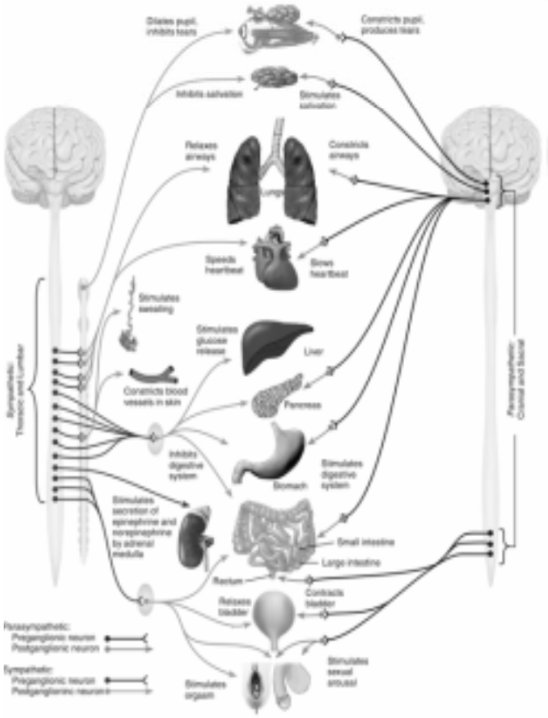
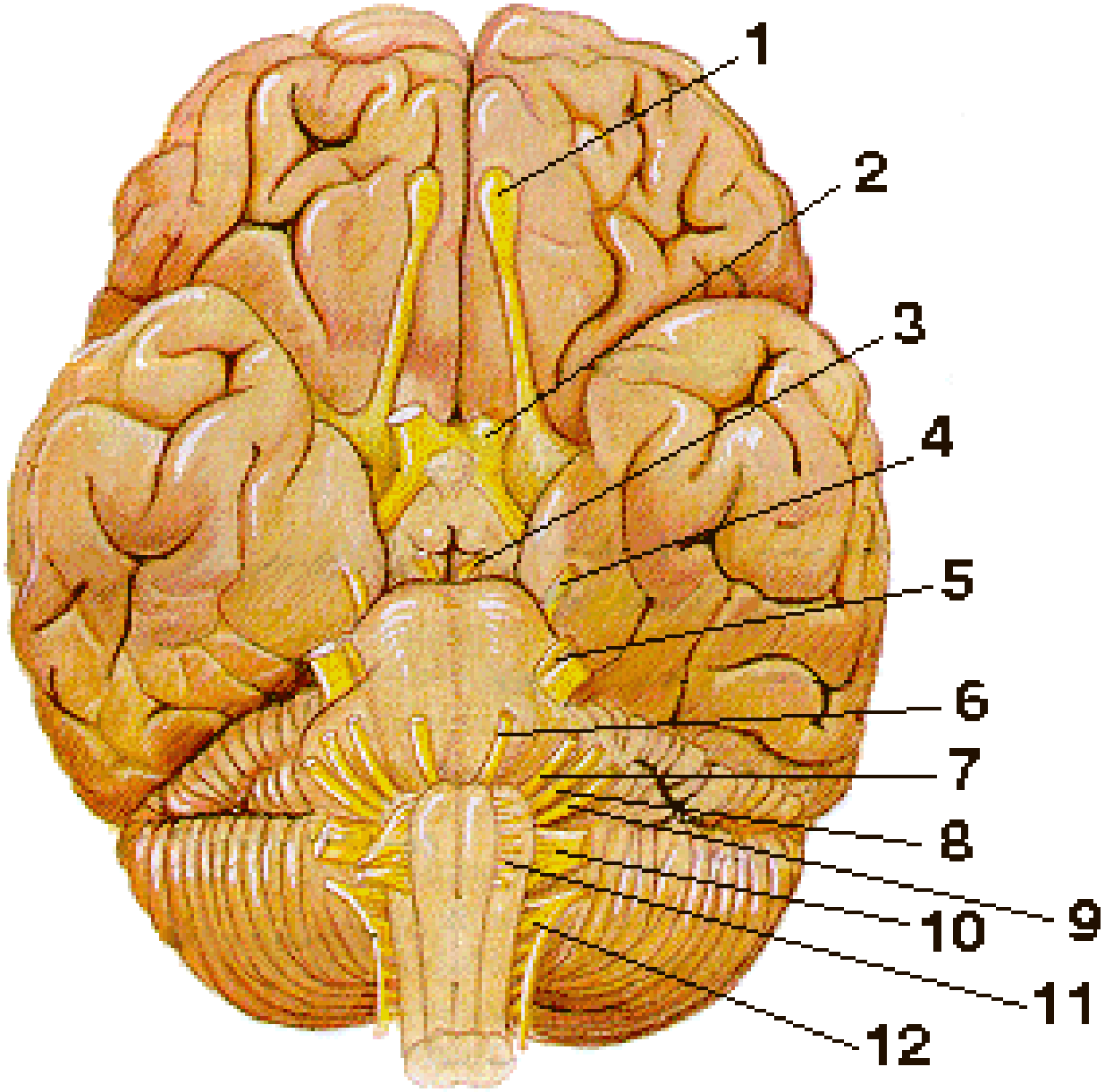
Autonomic Nervous System





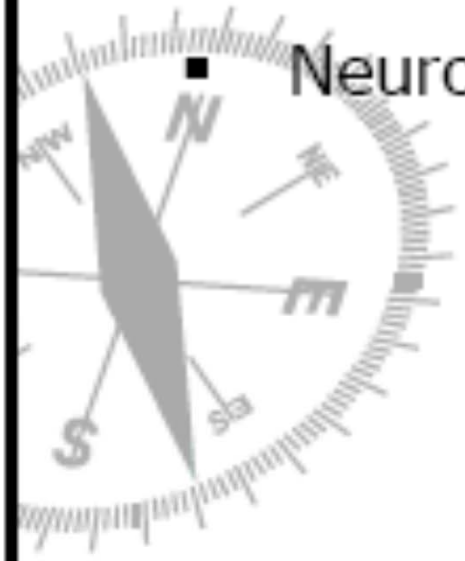


12 Cranial Nerves

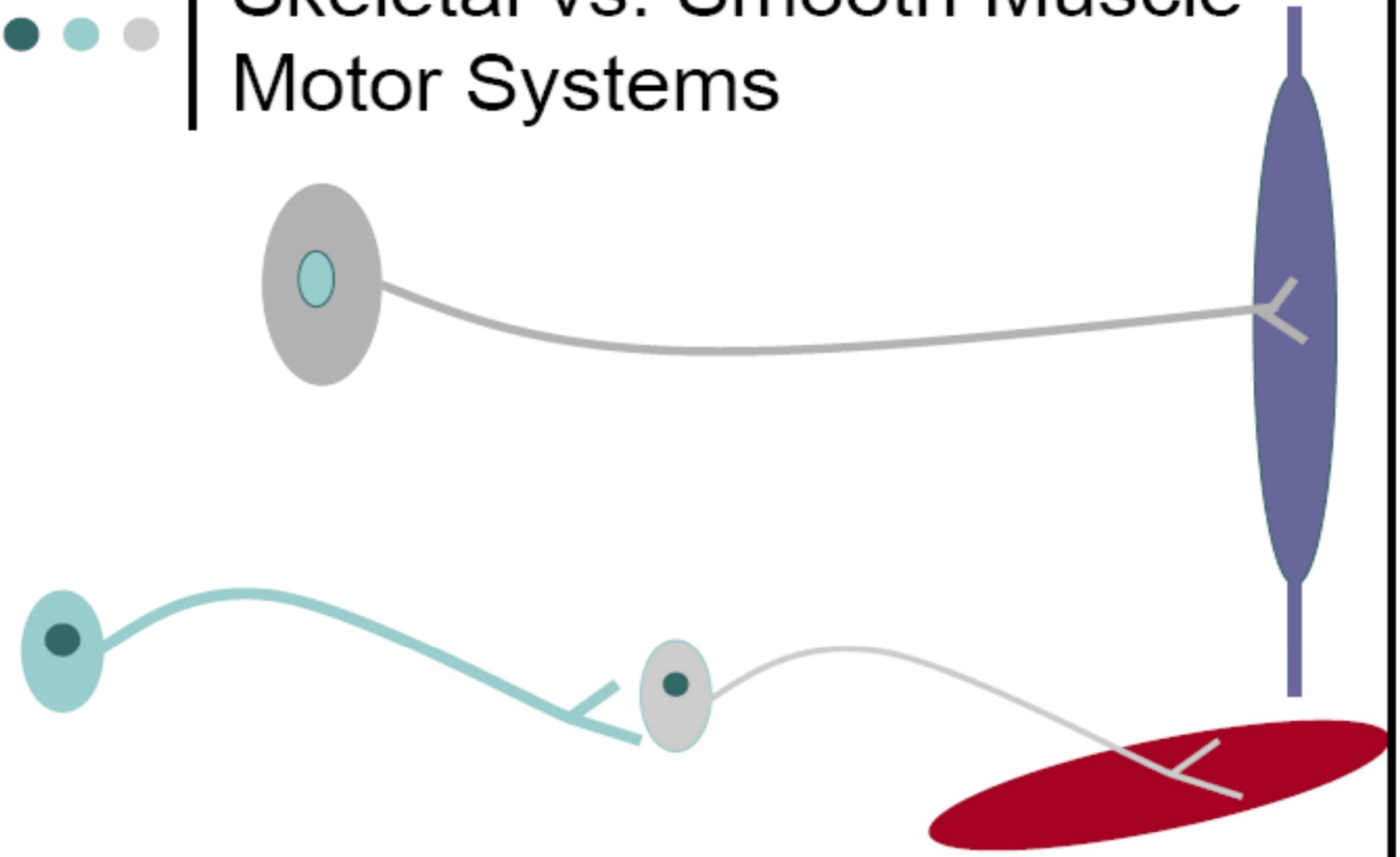


ANS Versus SNS

- The ANS differs from the SNS in the following areas:
  - Effectors
  - Efferent pathways
  - Neurotransmitter effects



Skeletal vs. Smooth Muscle Motor Systems

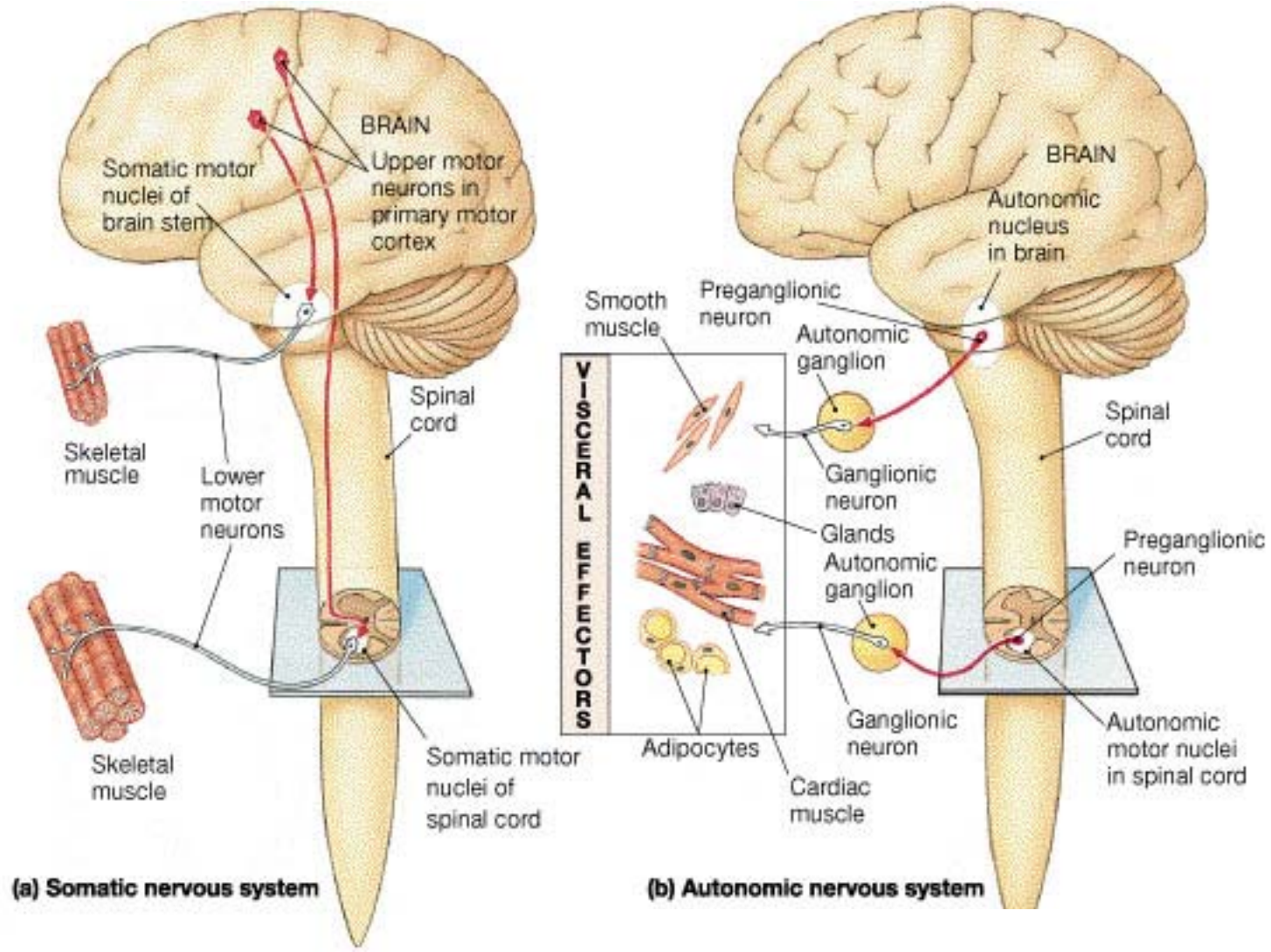


Somatic vs. Autonomic

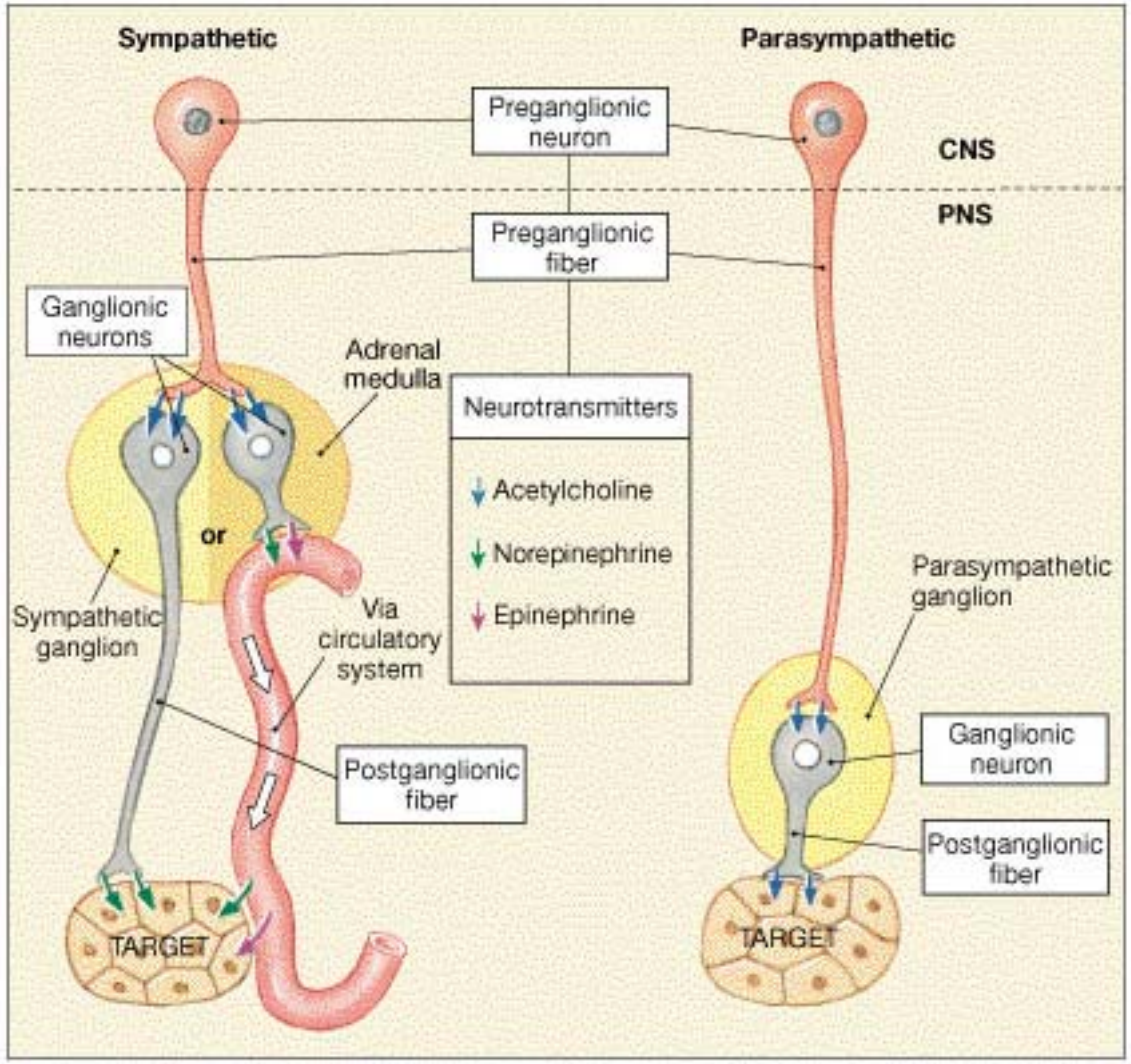
- Voluntary
- Skeletal muscle
- Single efferent neuron
- Axon terminals release acetylcholine
- Always excitatory
- Controlled by the cerebrum

- 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

Motor Pathways of the SNS and ANS



Anatomy of the Motor Output in Sympathetic and Parasympathetic nerves



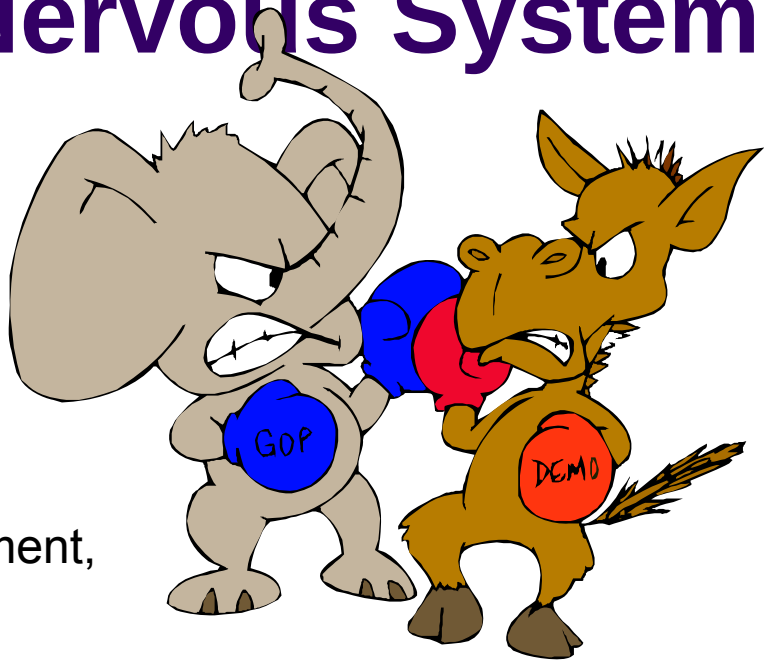
Describe the following comparisons:

- *location of pre-ganglionic neuron cell body*
- *location of **ganglia***
- ***neurotransmitter** released at effectors*

What neurotransmitter is released at <u>all</u> Autonomic ganglia?

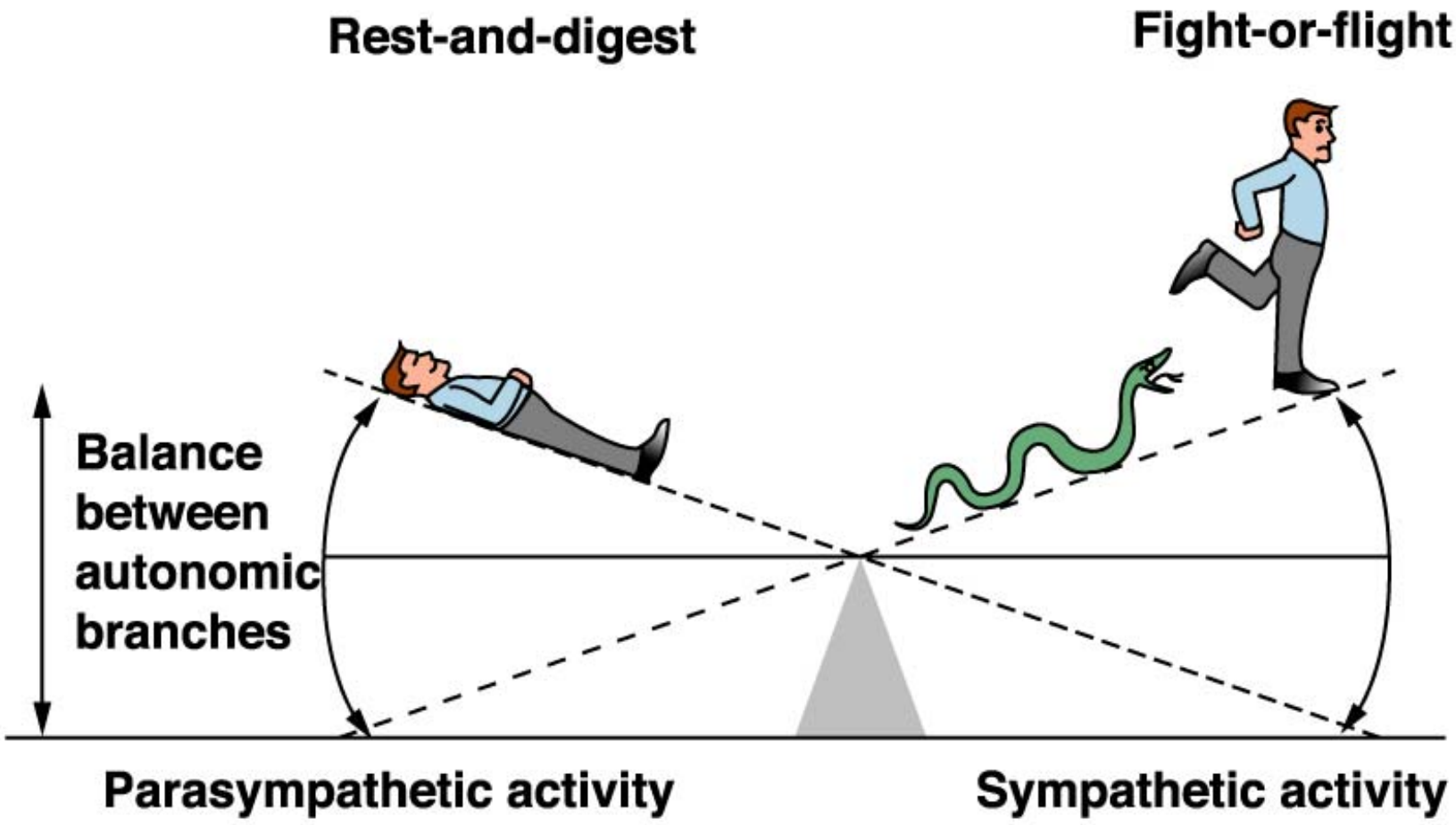
Autonomic Nervous System

- 2 divisions:
  - Sympathetic
    - “Fight or flight”
    - “E” division
      - Exercise, excitement, emergency, and embarrassment
  - Parasympathetic
    - “Rest and digest”
    - “D” division
      - Digestion, defecation, and diuresis



These 2 systems are antagonistic.

Typically, we balance these 2 to keep ourselves in a state of dynamic balance.

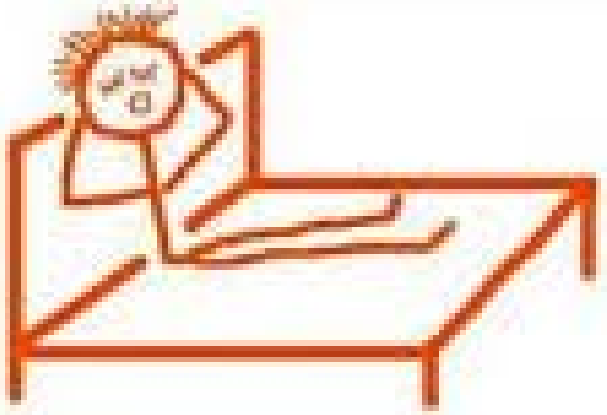



FIGHT or FLIGHT

Autonomic Nervous System

Sympathetic - "Fight or Flight"

Parasympathetic - "Rest and Digest"



ANS Structure

Both ANS divisions share same general structure

Autonomic pathways always consist of 2 neurons in series

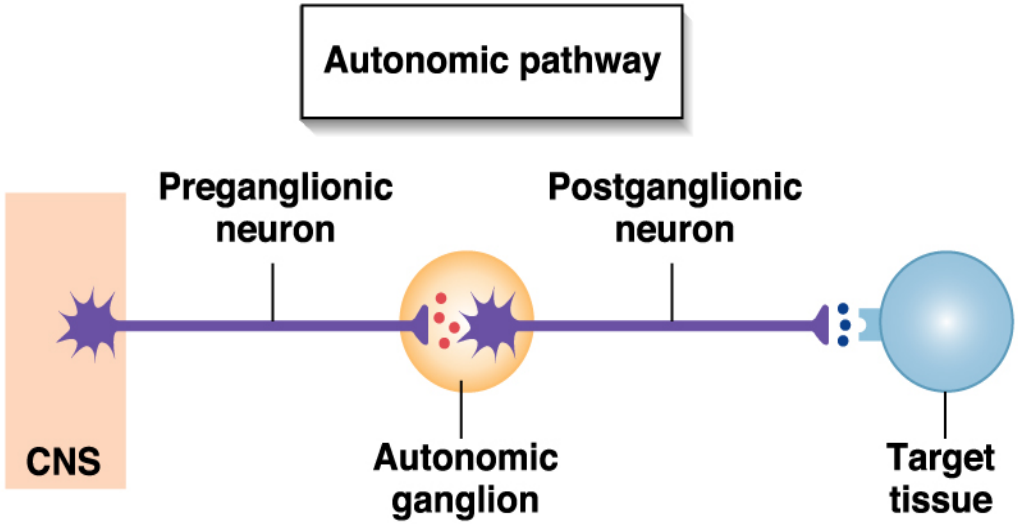
They synapse in an autonomic ganglion

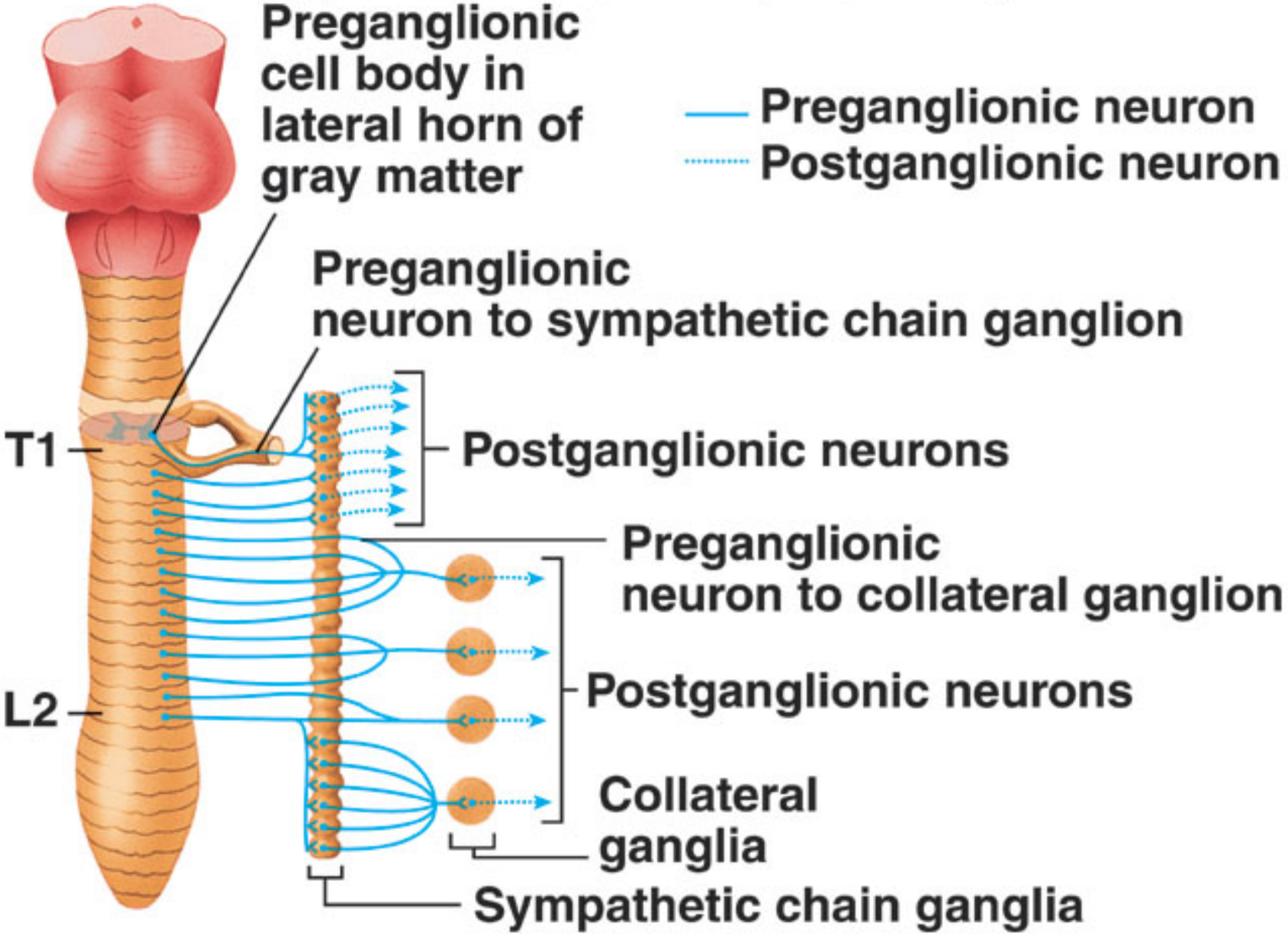
1st neuron in the autonomic pathway is the preganglionic neuron

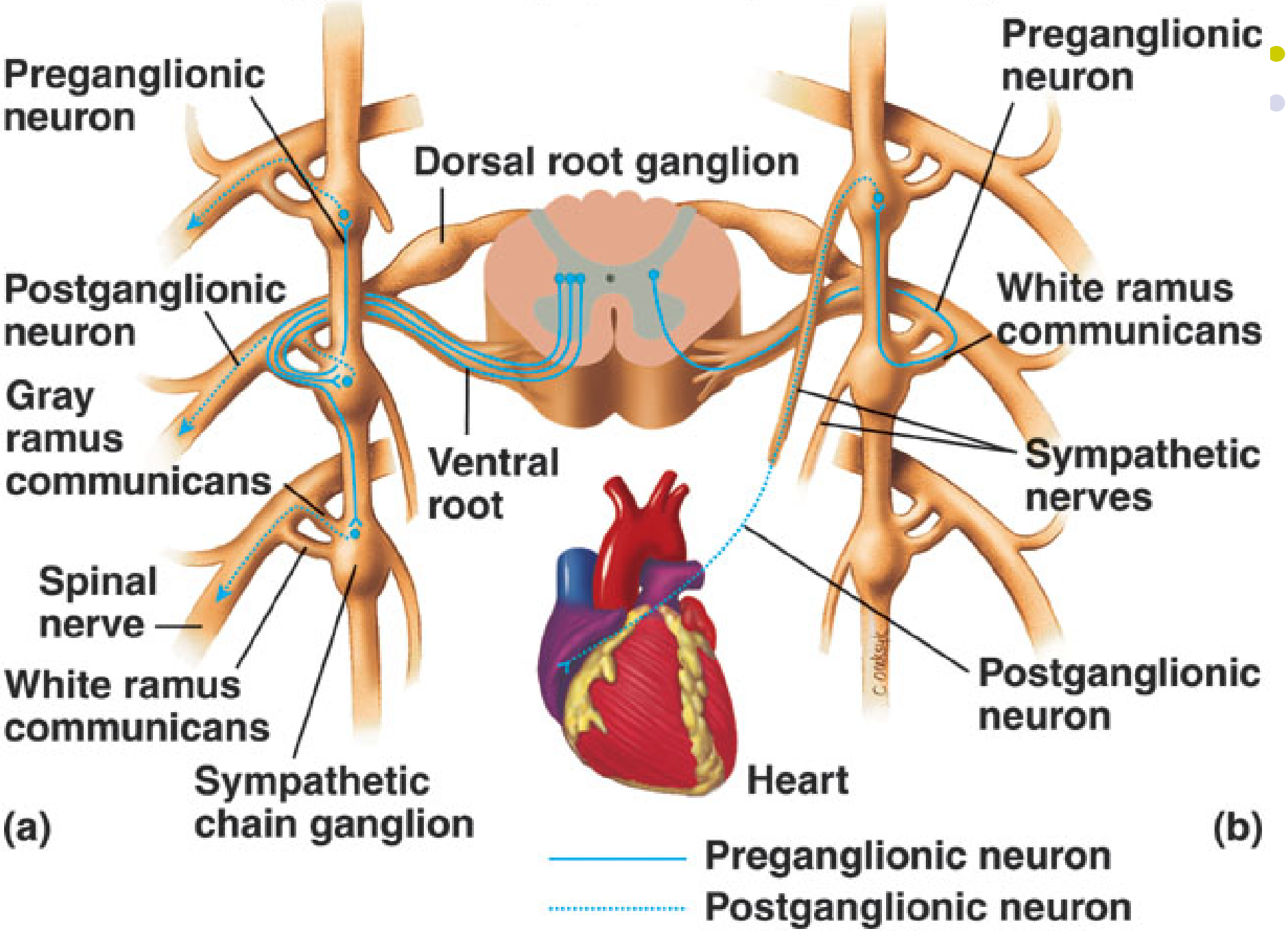
Cell body in CNS, myelinated, and projects to the autonomic ganglion

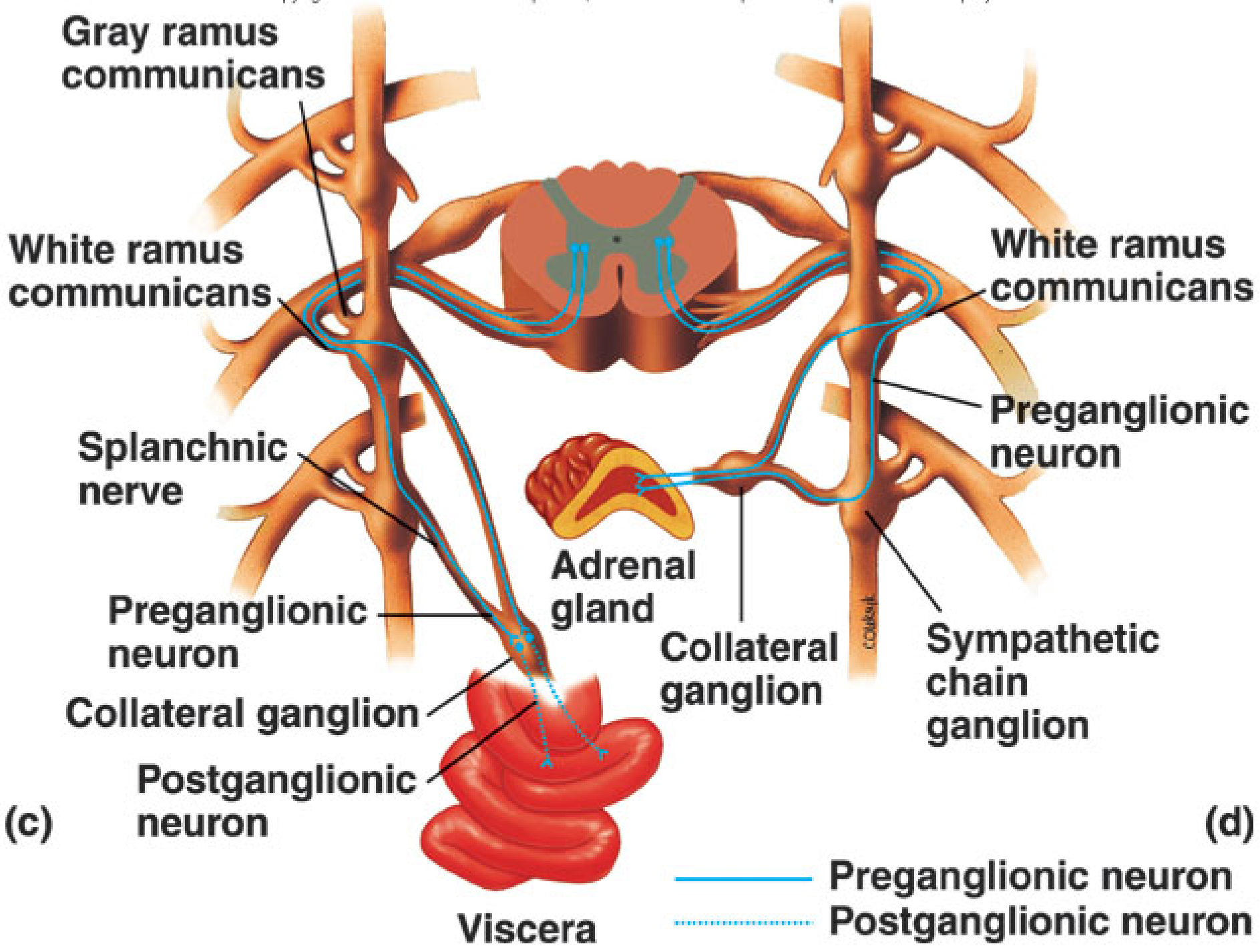
2nd neuron is the postganglionic neuron.

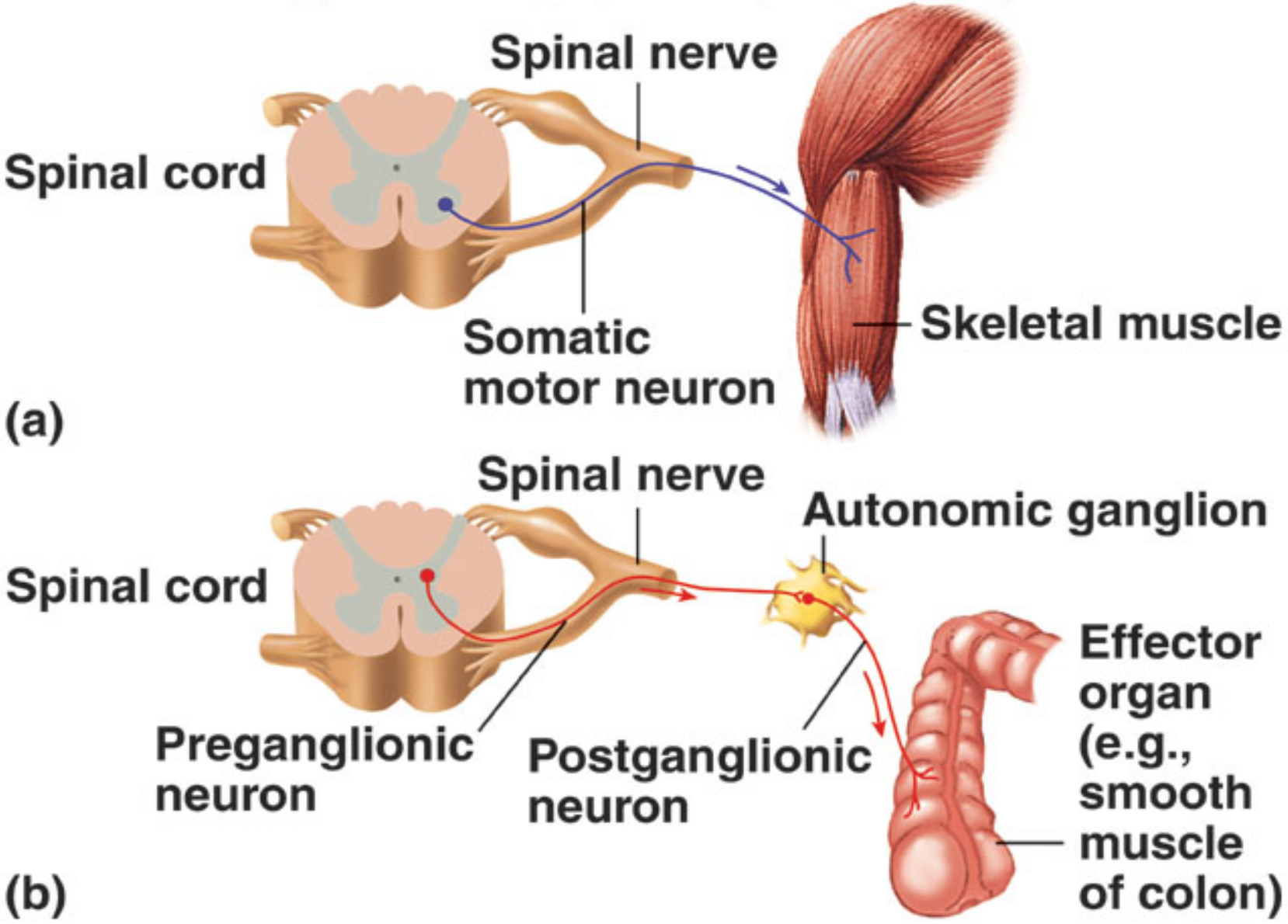
Cell body in autonomic ganglion, unmyelinated, and projects to the effector.

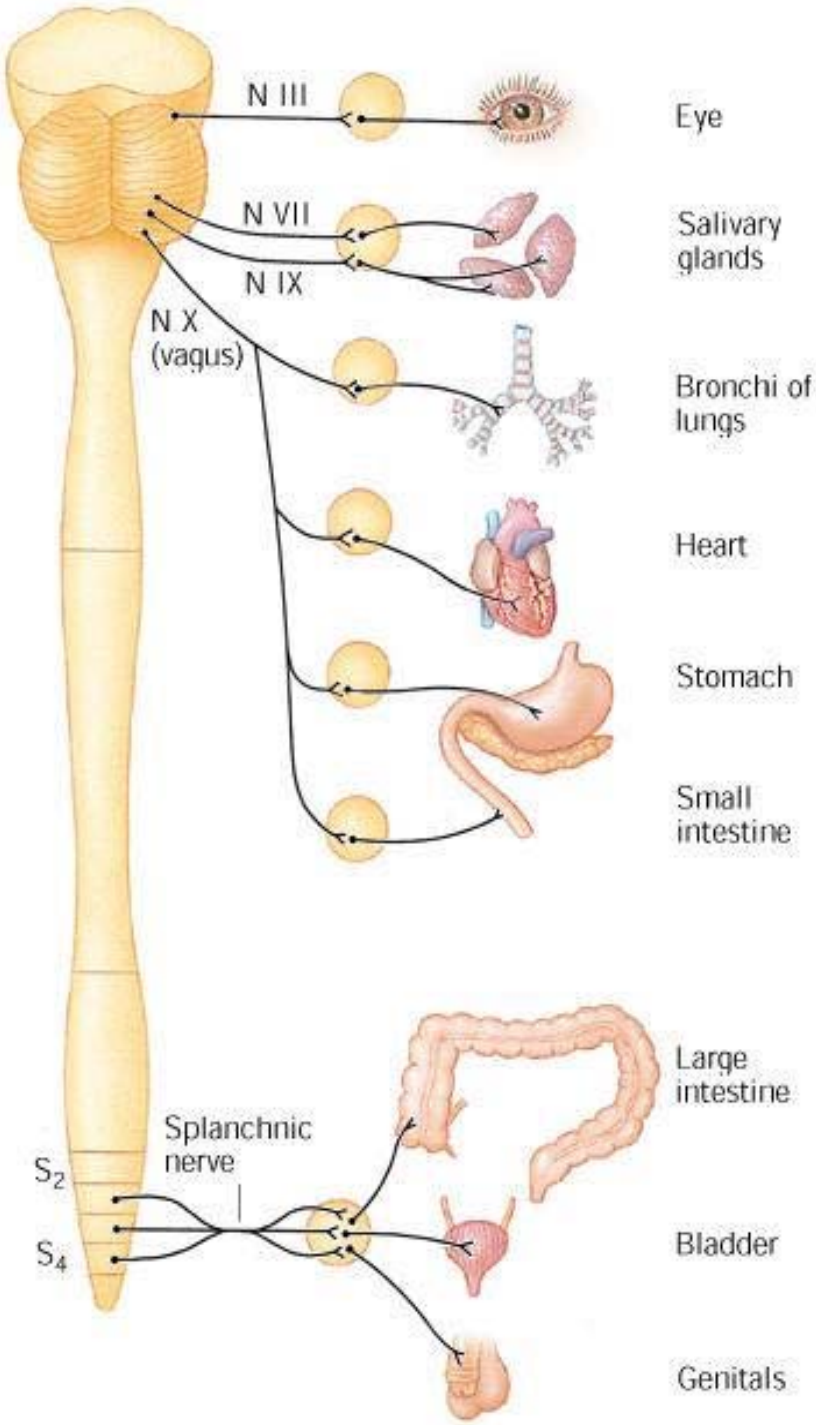


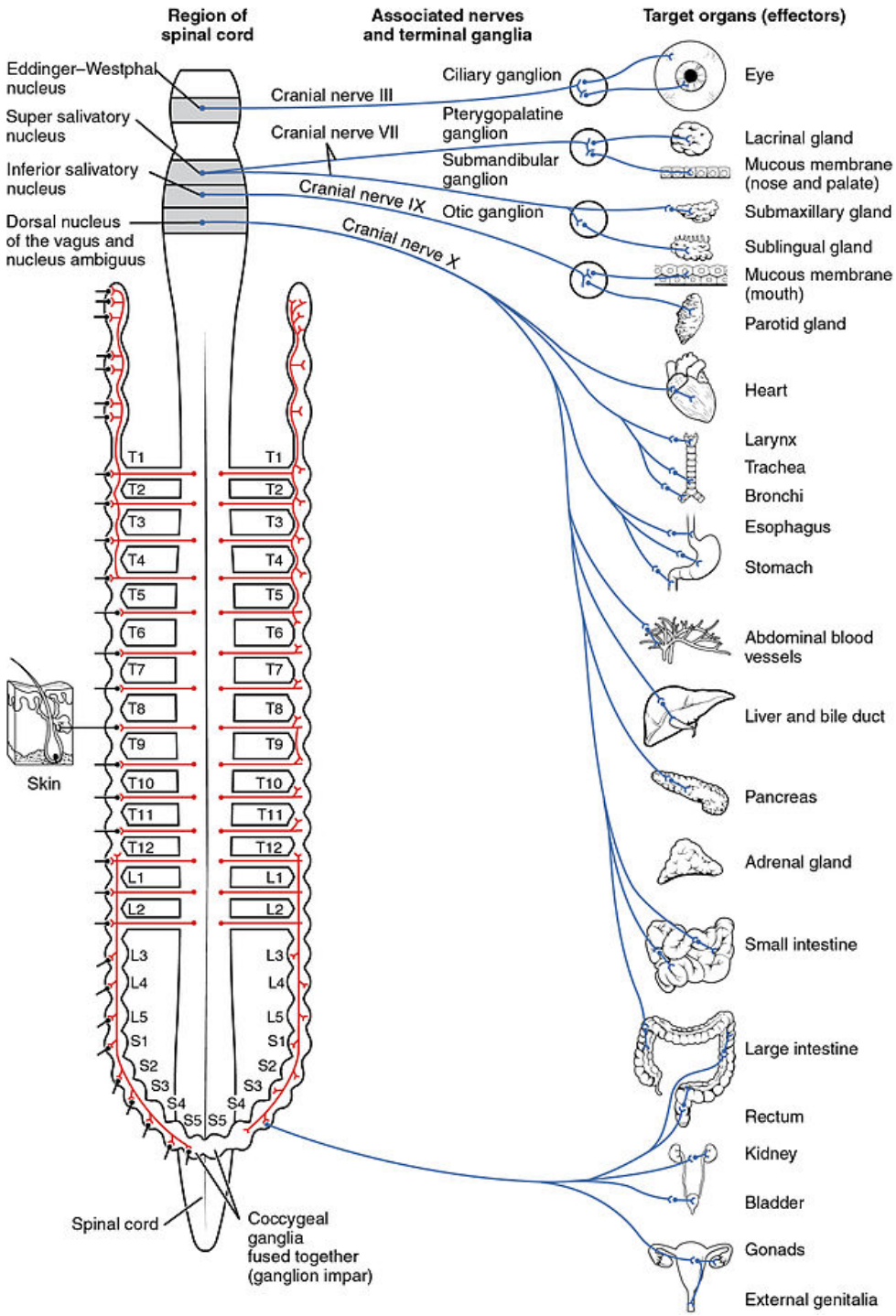




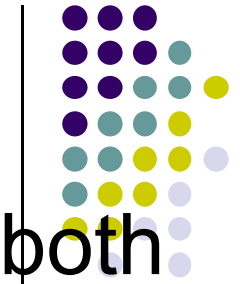




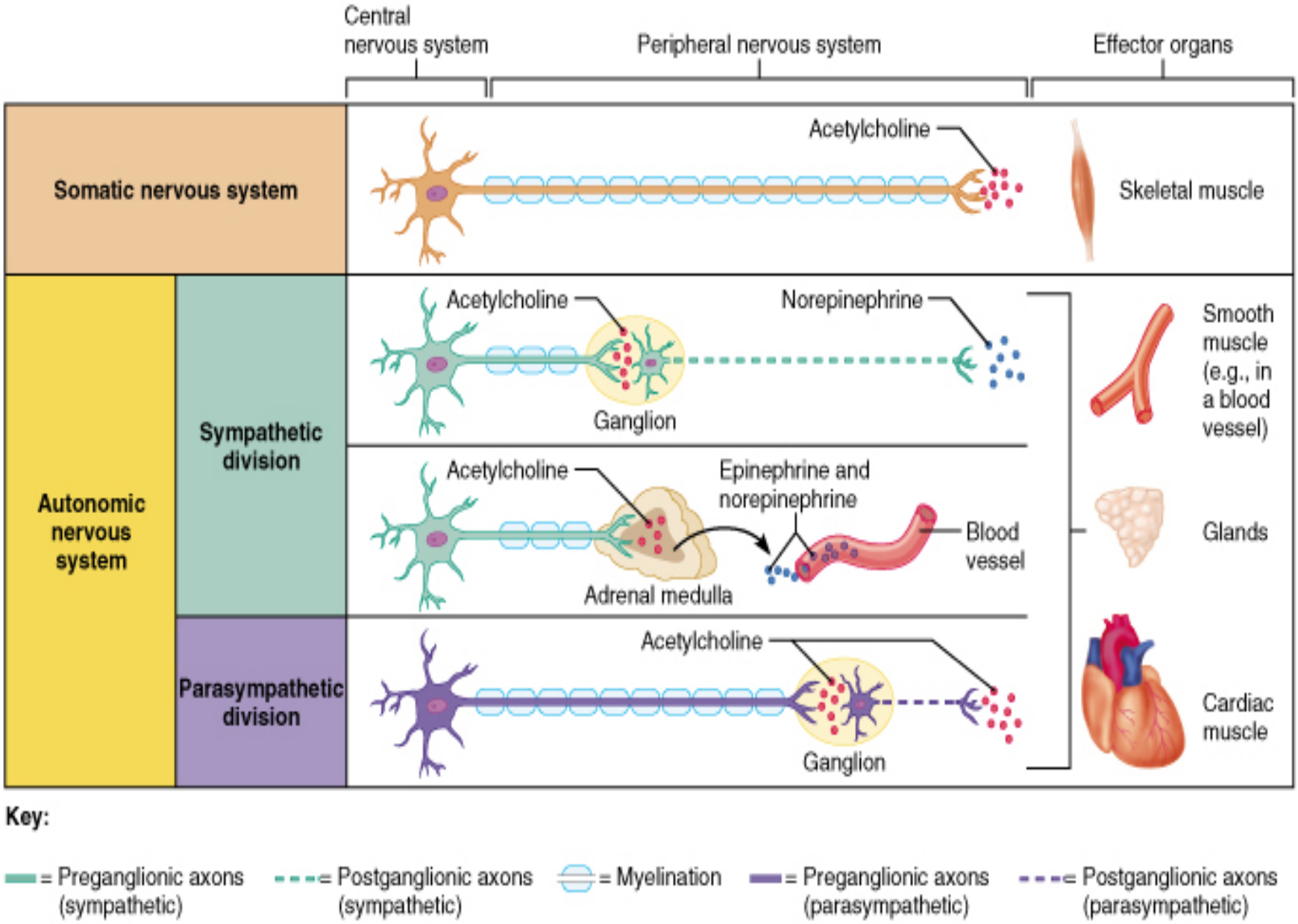

N III
Eye
N VII
Salivary glands
N IX
N X (vagus)
Bronchi of lungs
Heart
Stomach
Small intestine
Large intestine
Splanchnic nerve
S_2
S_4
Bladder
Genitals


Region of spinal cord
Associated nerves and terminal ganglia
Target organs (effectors)
Eddinger–Westphal nucleus
Super salivatory nucleus
Inferior salivatory nucleus
Dorsal nucleus of the vagus and nucleus ambiguus
Cranial nerve III
Cranial nerve VII
Cranial nerve IX
Cranial nerve X
Ciliary ganglion
Pterygopalatine ganglion
Submandibular ganglion
Otic ganglion
Eye
Lacrinal gland
Mucous membrane (nose and palate)
Submaxillary gland
Sublingual gland
Mucous membrane (mouth)
Parotid gland
Heart
Larynx
Trachea
Bronchi
Esophagus
Stomach
Abdominal blood vessels
Liver and bile duct
Pancreas
Adrenal gland
Small intestine
Large intestine
Rectum
Kidney
Bladder
Gonads
External genitalia
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
T12
L1
L2
L3
L4
L5
S1
S2
S3
S4
S5
Skin
Spinal cord
Coccygeal ganglia fused together (ganglion impar)

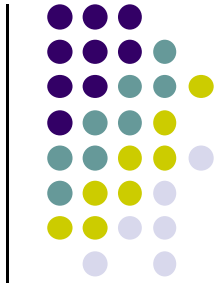
Cholinergic and Adrenergic fibers



- All preganglionic neurons are cholinergic both symp & parasymp
- Ach / ach like substance --- will excite both symp & parasymp
- All postgang parasymp are cholinergic
- Most of postgang symp are adrenergic
- Posgang symp to sweat gland, piloerector muscle, skeletal muscle blood vessels are cholinergic


Central nervous system
Peripheral nervous system
Effector organs
Somatic nervous system
Acetylcholine
Skeletal muscle
Autonomic nervous system
Sympathetic division
Acetylcholine
Norepinephrine
Ganglion
Smooth muscle (e.g., in a blood vessel)
Acetylcholine
Epinephrine and norepinephrine
Blood vessel
Adrenal medulla
Glands
Parasympathetic division
Acetylcholine
Ganglion
Cardiac muscle
Key:
= Preganglionic axons (sympathetic)
= Postganglionic axons (sympathetic)
= Myelination
= Preganglionic axons (parasympathetic)
= Postganglionic axons (parasympathetic)

Receptors



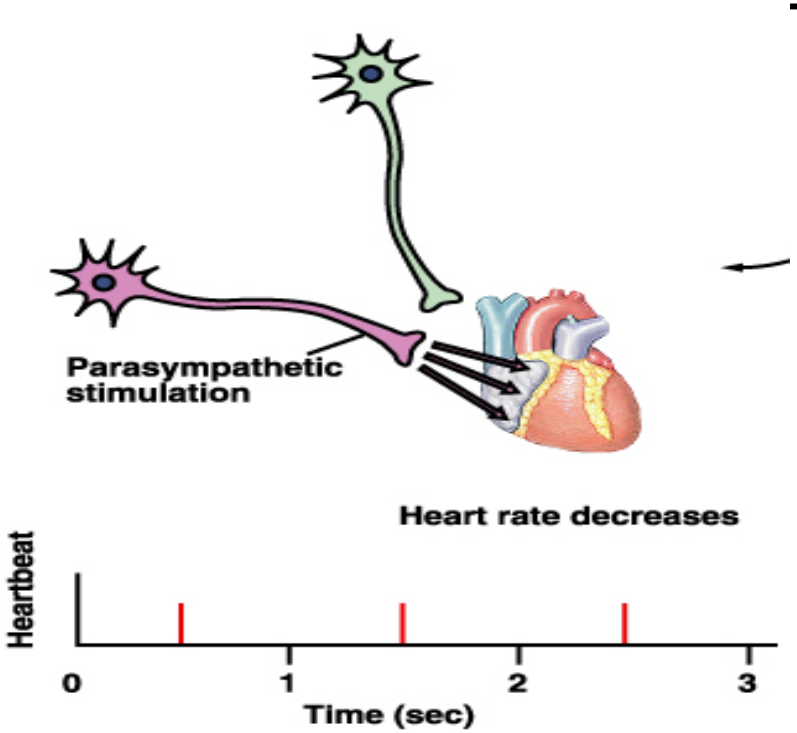
- Adrenergic R

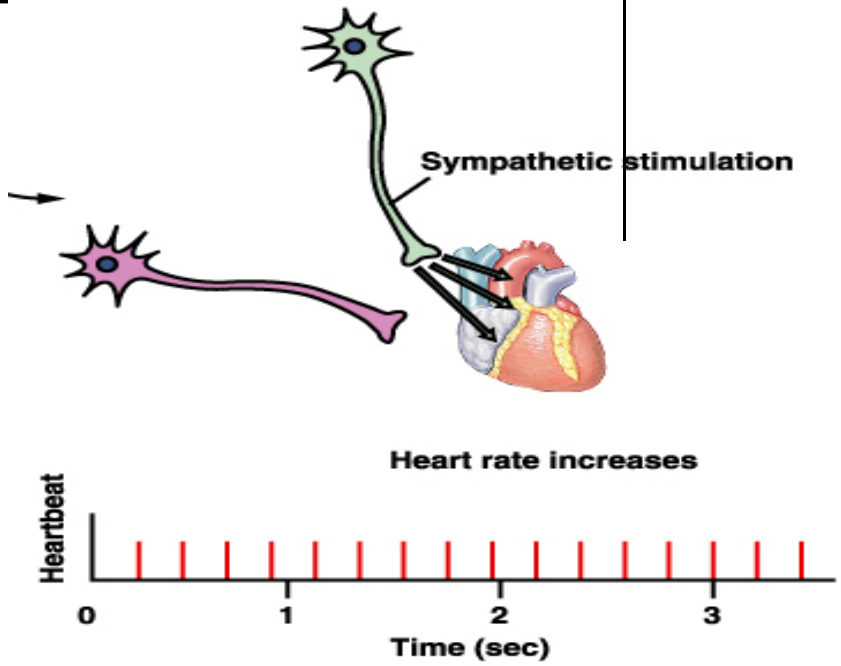
  α & β

- Cholinergic R

  Nicotinic and Muscrinic

Antagonistic Control

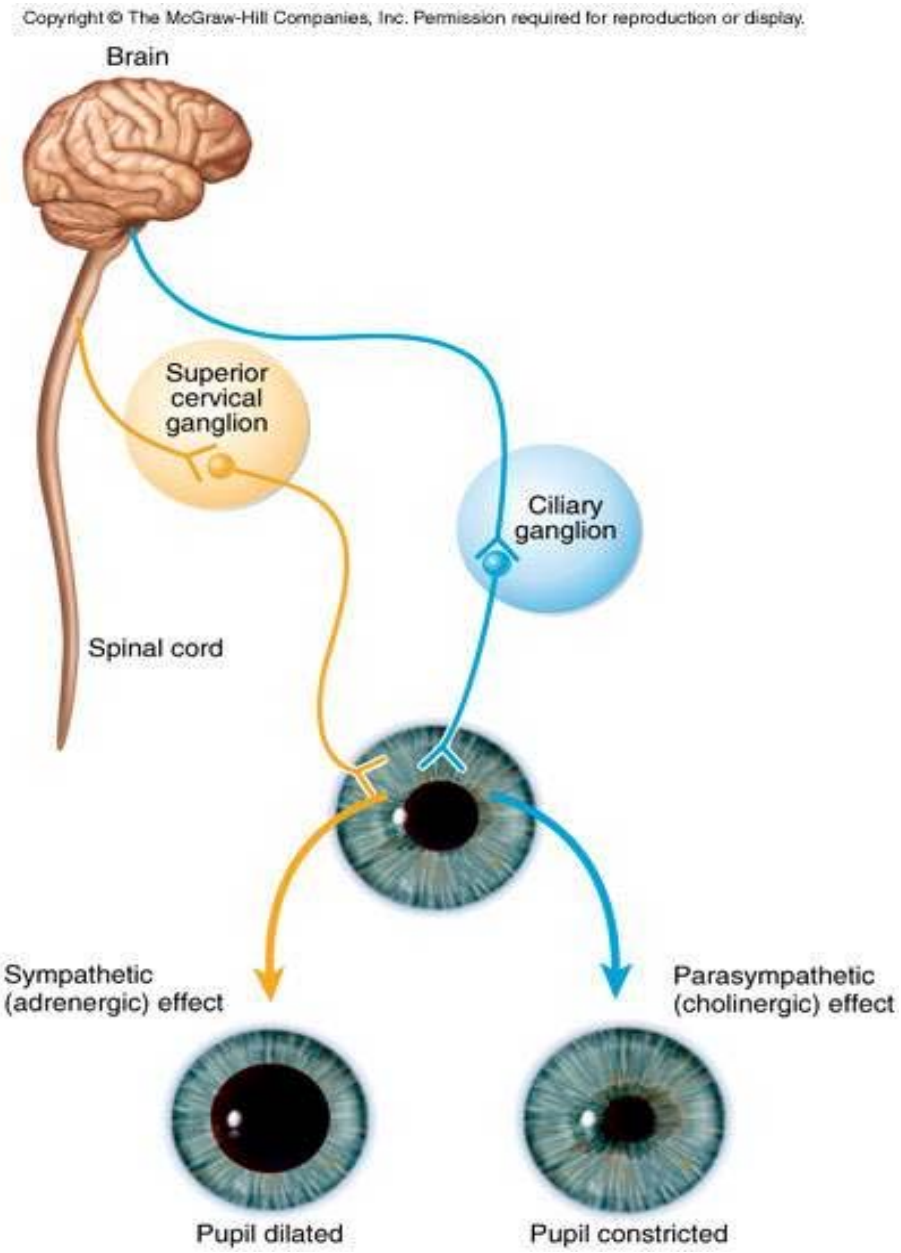




Most internal organs are innervated by both branches of the ANS which exhibit antagonistic control

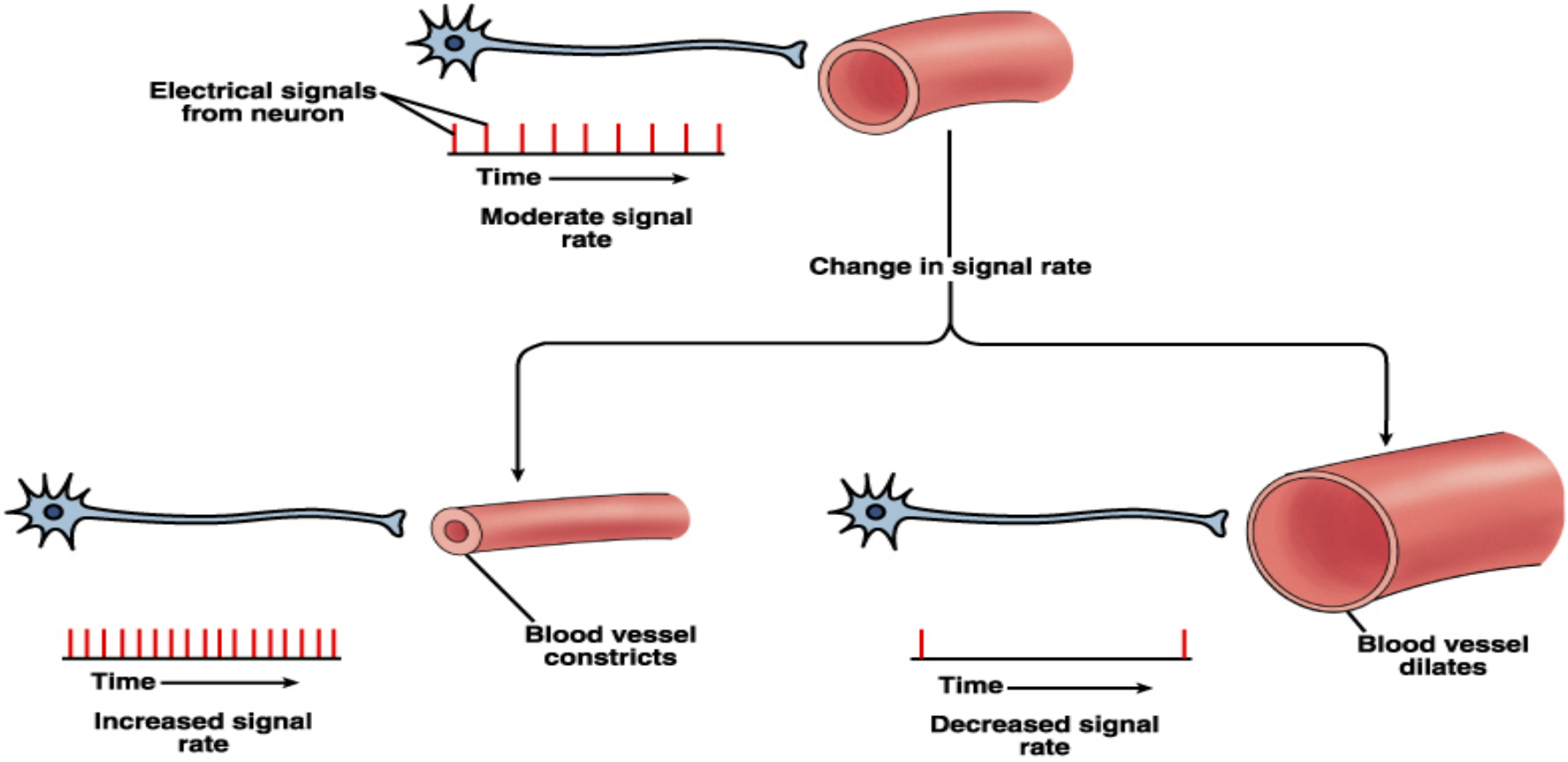
A great example is heart rate. An increase in sympathetic stimulation causes HR to increase whereas an increase in parasympathetic stimulation causes HR to decrease

Dual Innervation of the Iris



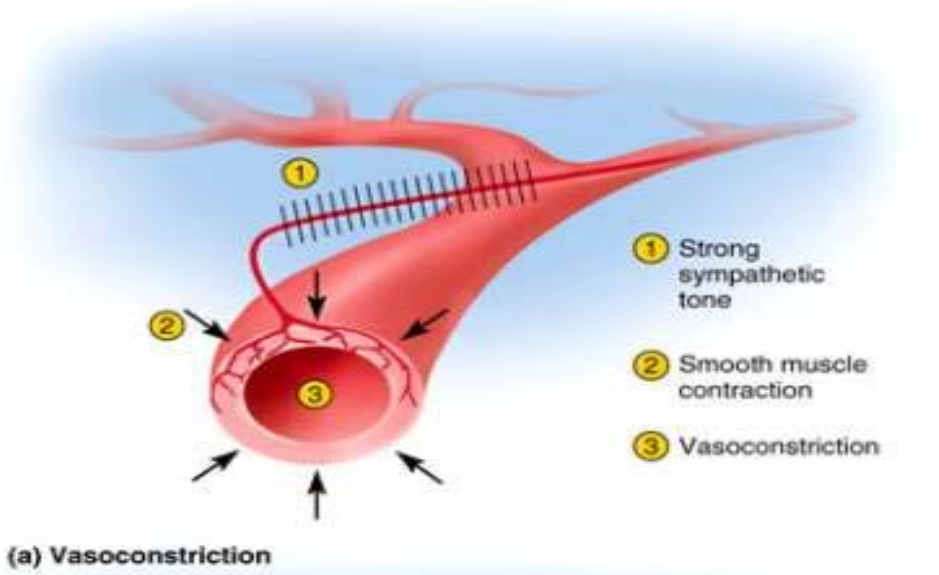
Exception to the dual innervation rule

Sweat glands and blood vessel smooth muscle are only innervated by sympathetic and rely strictly on up-down control


Electrical signals from neuron
Time
Moderate signal rate
Change in signal rate
Blood vessel constricts
Time
Increased signal rate
Blood vessel dilates
Time
Decreased signal rate

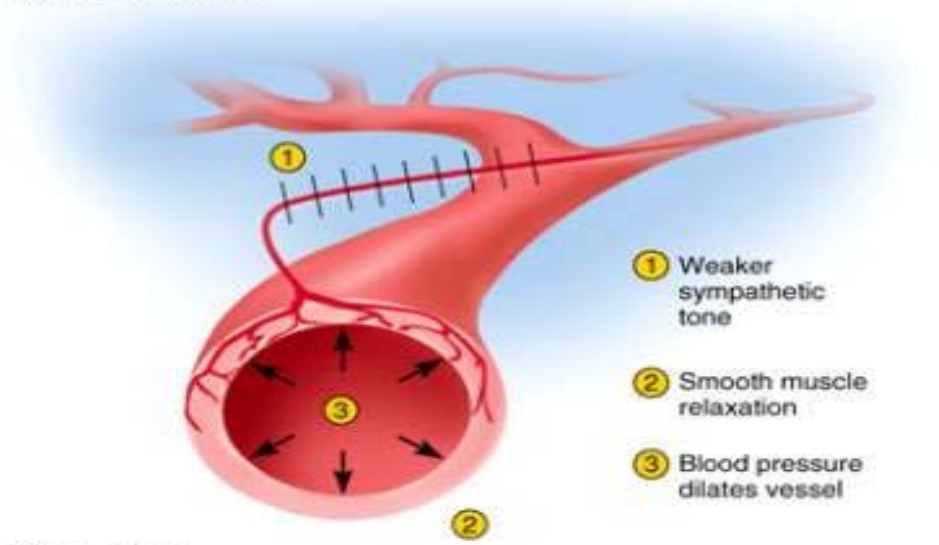
Sympathetic and Vasomotor Tone

Blood vessels to skin vasoconstrict to minimize bleeding if injury occurs during stress or exercise.



(a) Vasoconstriction

Sympathetic division prioritizes blood vessels to skeletal muscles and heart in times of emergency.

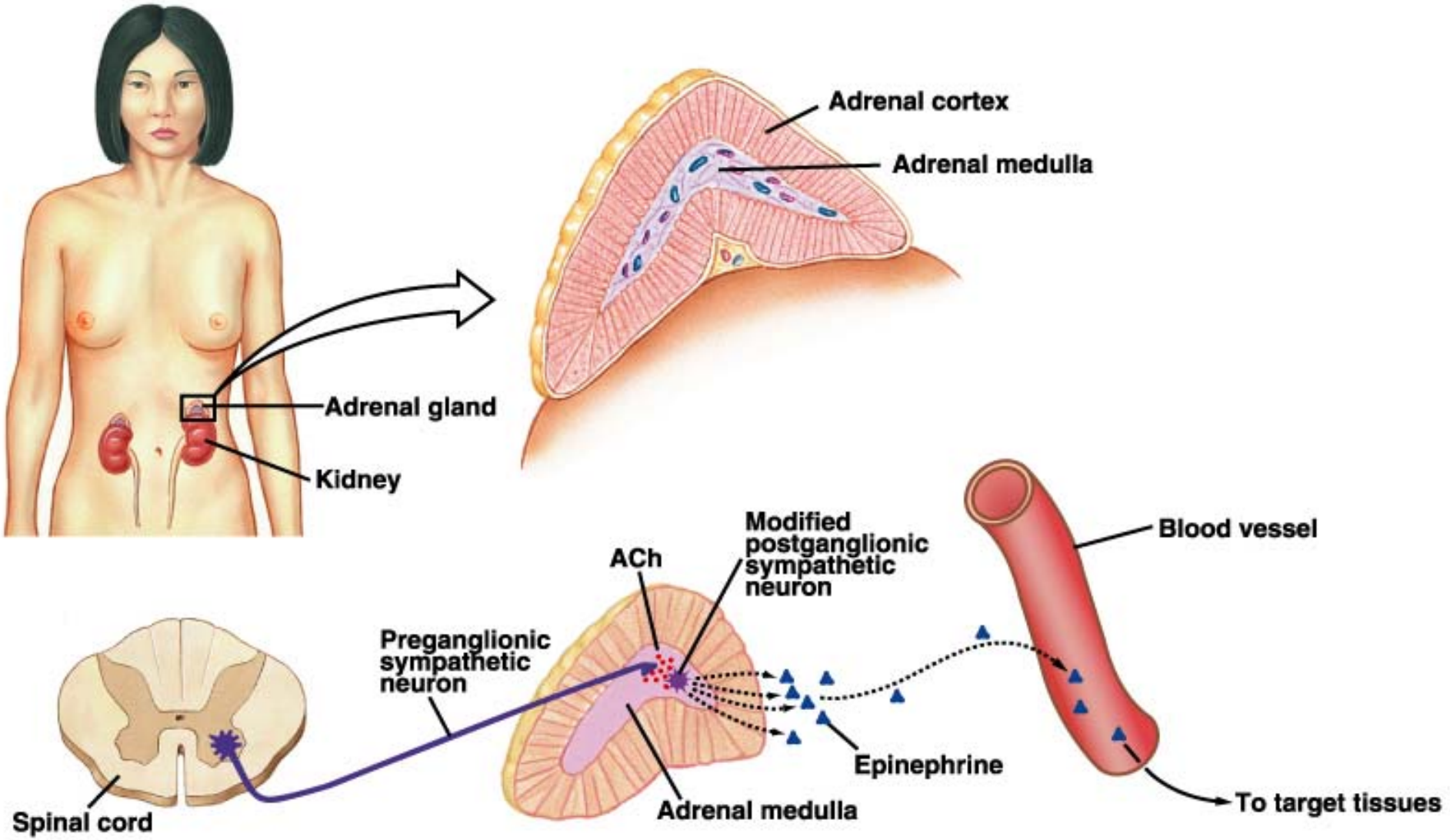


(b) Vasodilation

Exception to the antagonism rule

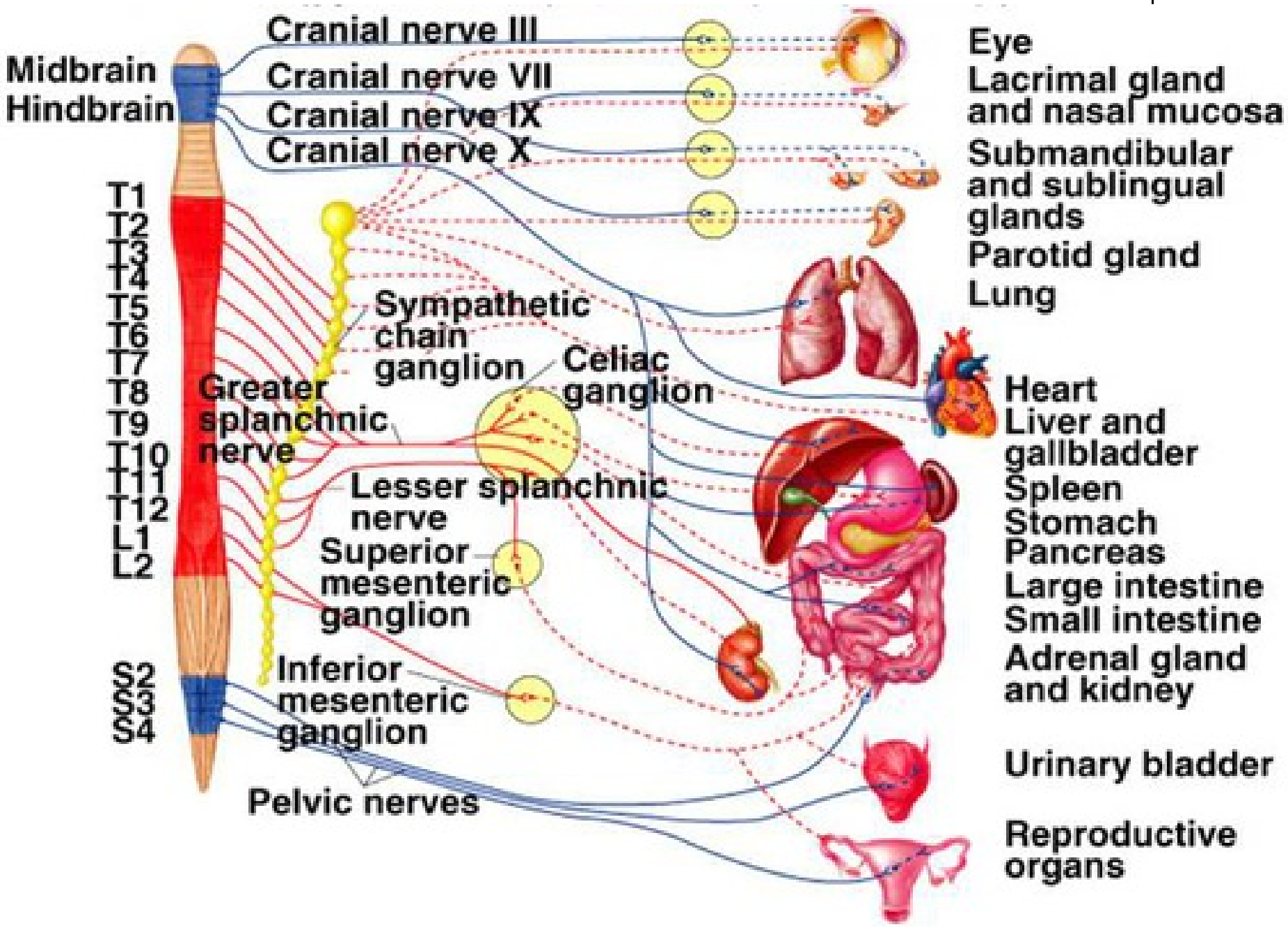
Symp and parasymp work cooperatively to achieve male sexual function.
Parasympathetic is responsible for erection while sympathetic is responsible to ejaculation
There's similar ANS cooperation in the female sexual response.

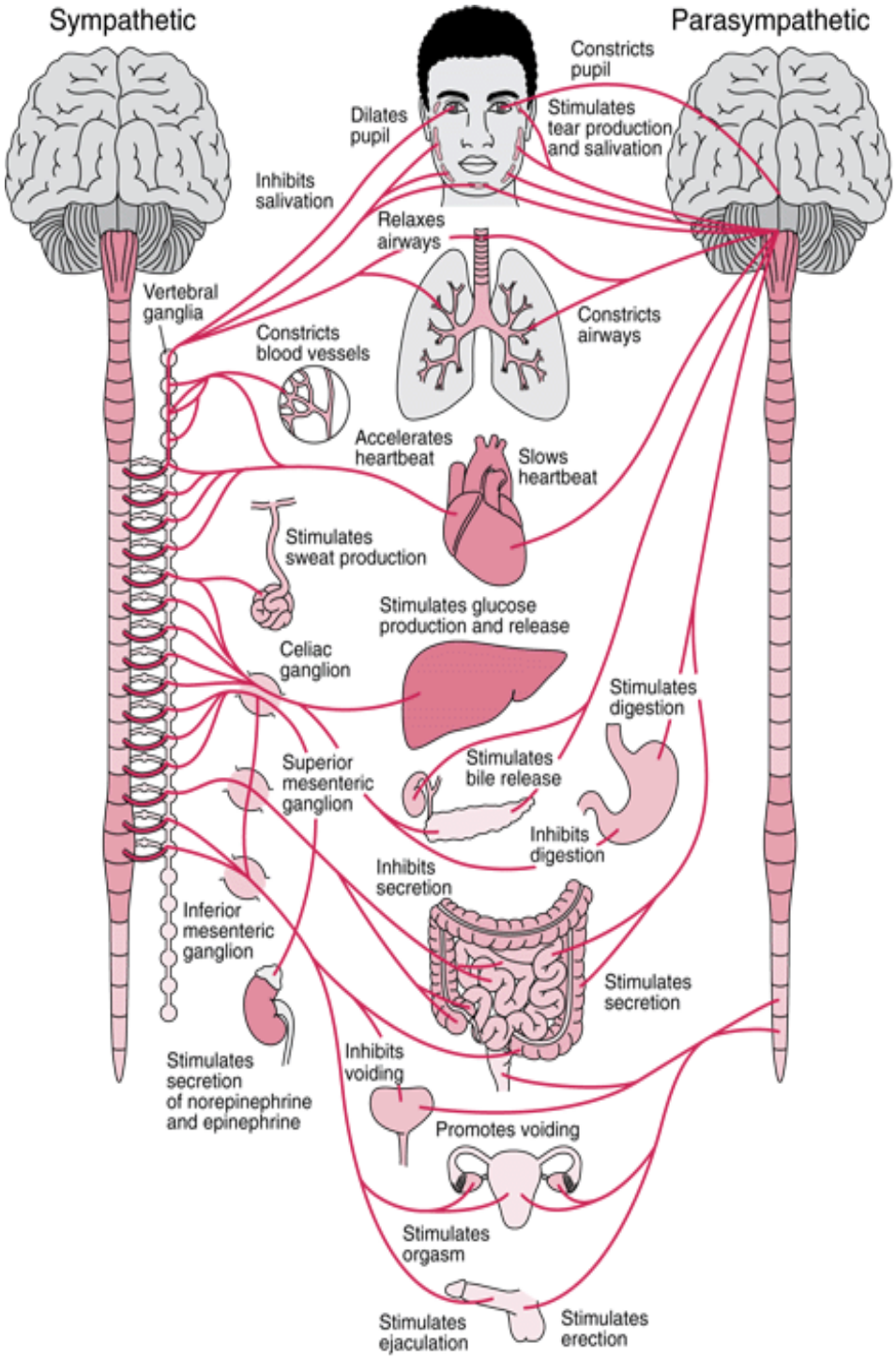
Adrenal medulla special - Certain splanchnic nerves synapse on hormone-producing cells of adrenal medulla

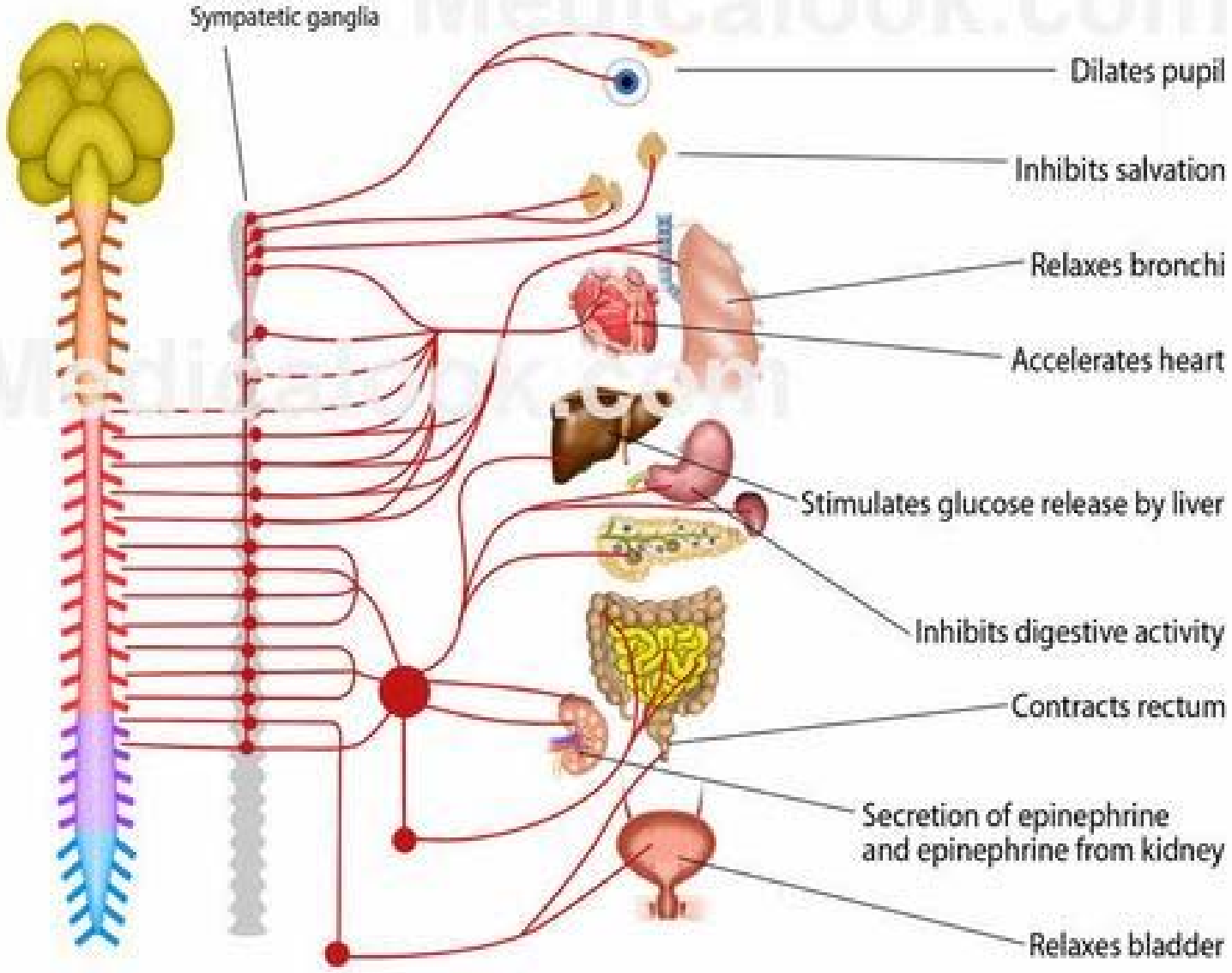


How does this contribute to the "diffuseness" of sympathetic activity?

Mass Sympathetic Response

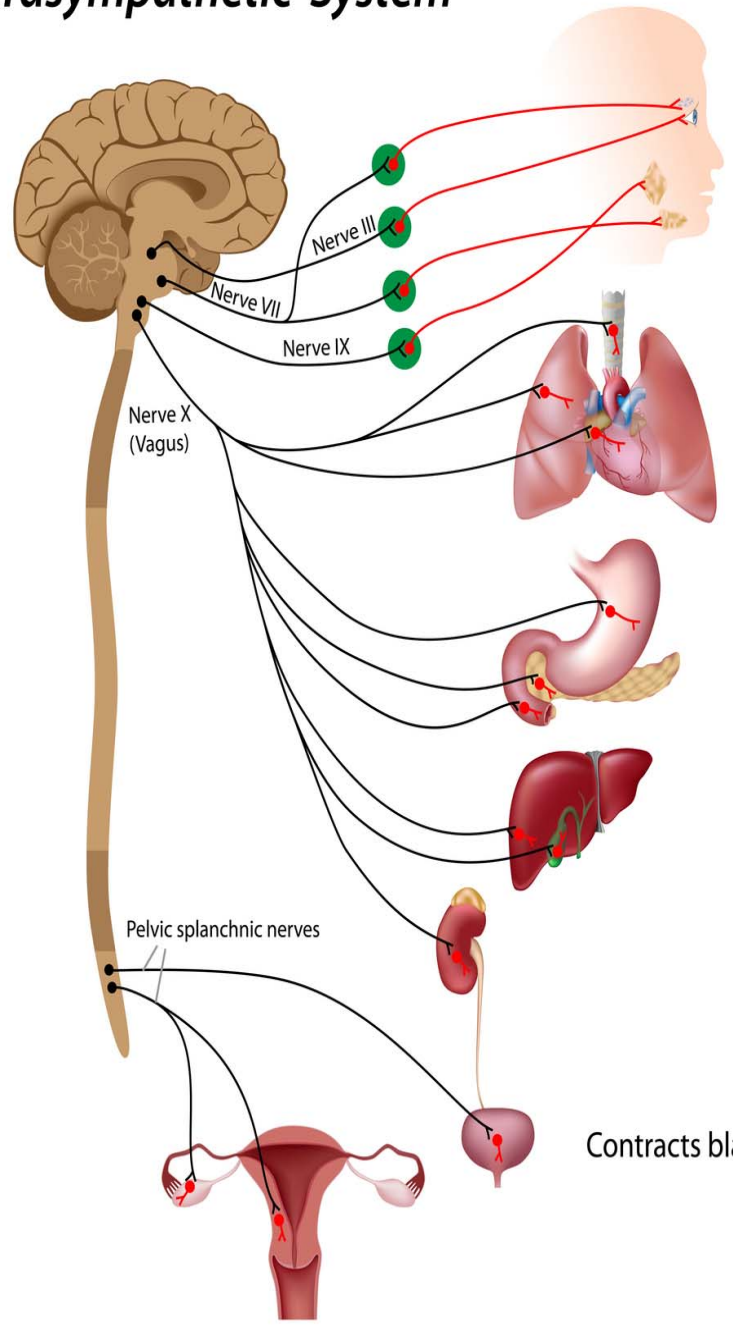

Midbrain
Hindbrain
Cranial nerve III
Cranial nerve VII
Cranial nerve IX
Cranial nerve X
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
T12
L1
L2
S2
S3
S4
Sympathetic chain ganglion
Celiac ganglion
Greater splanchnic nerve
Lesser splanchnic nerve
Superior mesenteric ganglion
Inferior mesenteric ganglion
Pelvic nerves
Eye
Lacrimal gland and nasal mucosa
Submandibular and sublingual glands
Parotid gland
Lung
Heart
Liver and gallbladder
Spleen
Stomach
Pancreas
Large intestine
Small intestine
Adrenal gland and kidney
Urinary bladder
Reproductive organs


Sympathetic
Parasympathetic
Constricts pupil
Dilates pupil
Stimulates tear production and salivation
Inhibits salivation
Relaxes airways
Vertebral ganglia
Constricts blood vessels
Constricts airways
Accelerates heartbeat
Slows heartbeat
Stimulates sweat production
Stimulates glucose production and release
Celiac ganglion
Stimulates digestion
Superior mesenteric ganglion
Stimulates bile release
Inhibits digestion
Inhibits secretion
Inferior mesenteric ganglion
Stimulates secretion
Stimulates secretion of norepinephrine and epinephrine
Inhibits voiding
Promotes voiding
Stimulates orgasm
Stimulates ejaculation
Stimulates erection



Sympathetic division

Parasympathetic System



Constricts pupils

Stimulates flow of saliva

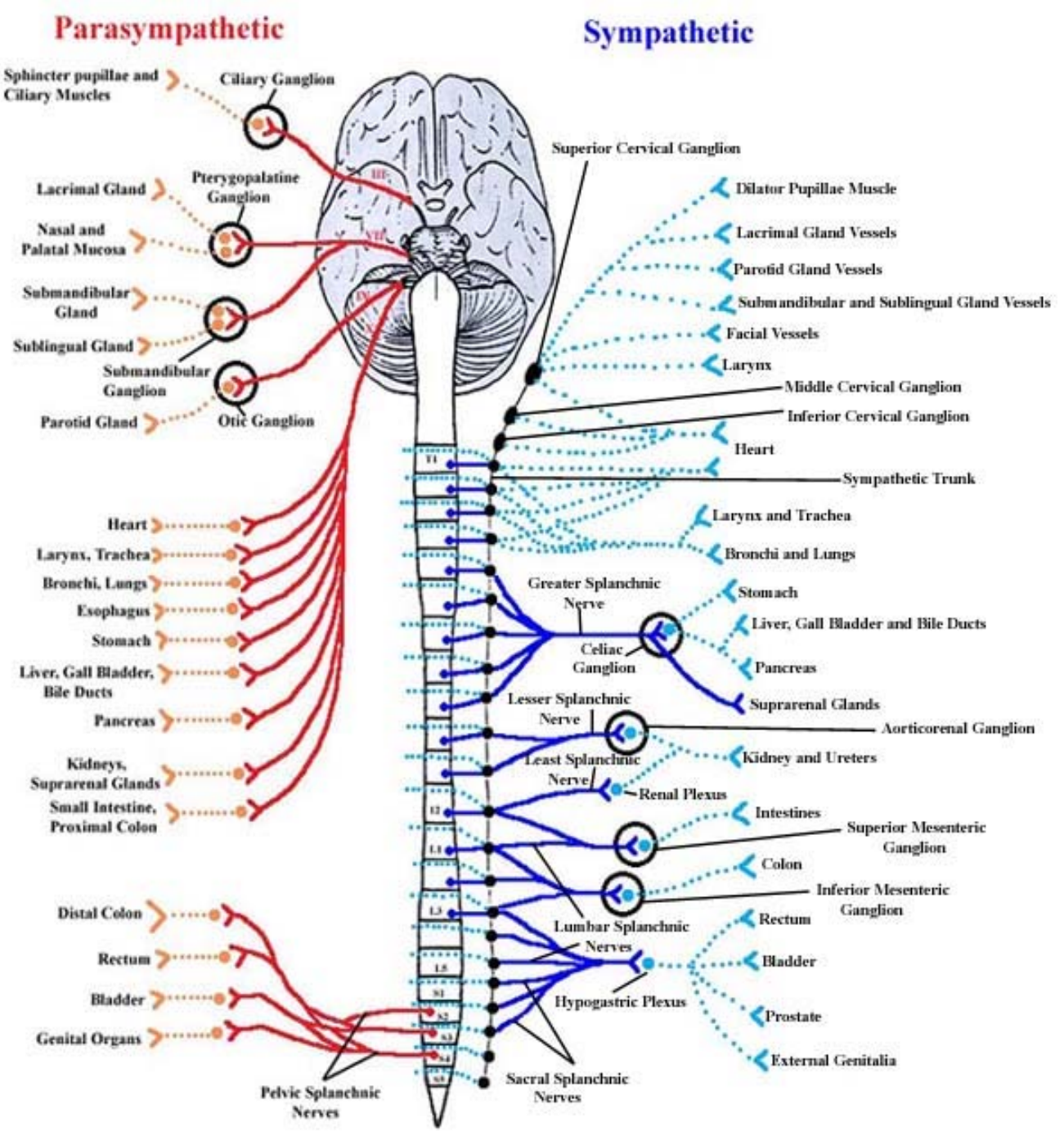
Constricts bronchi

Slows heartbeat

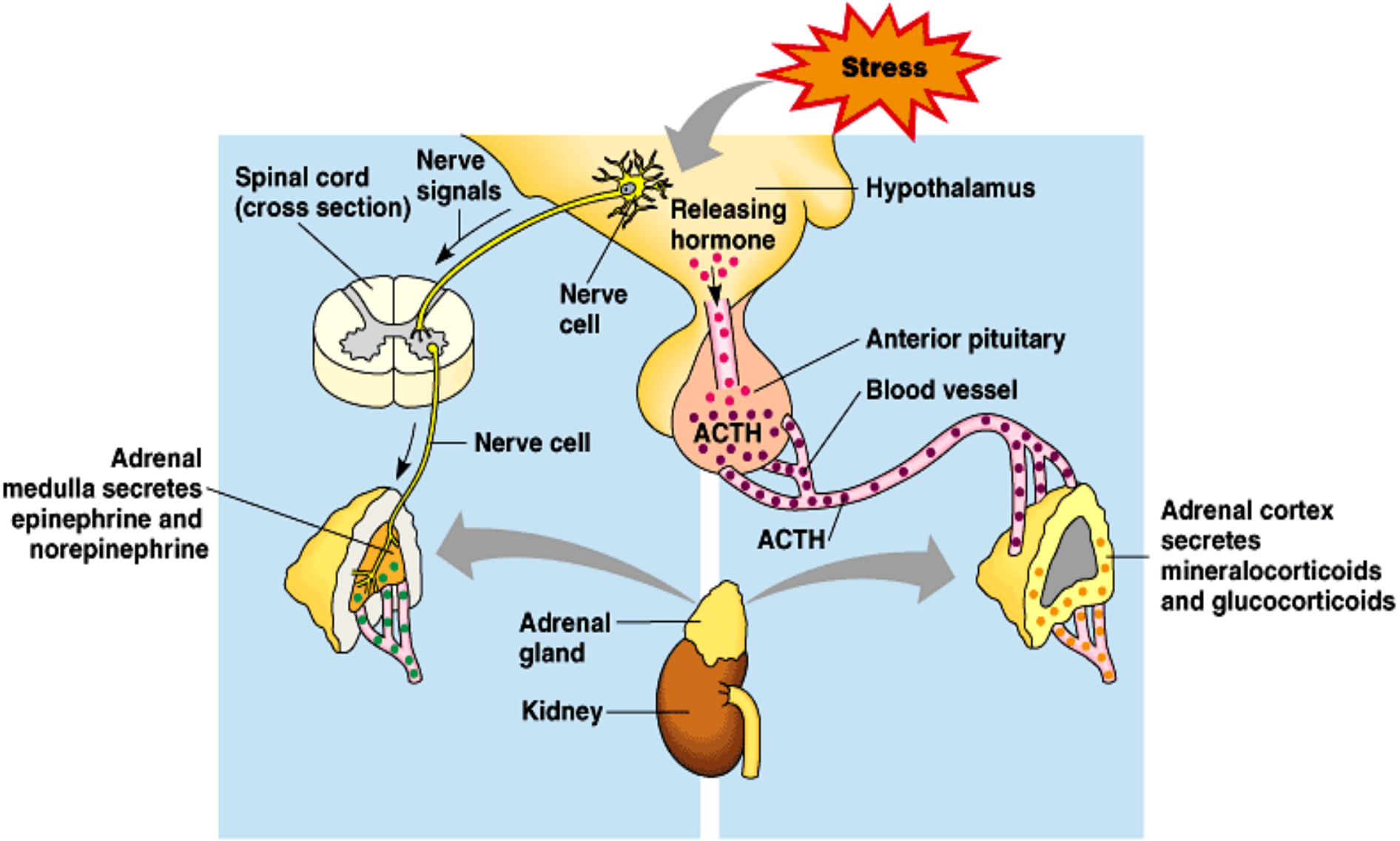
Stimulates peristalsis and secretion

Stimulates bile release

Contracts bladder


Parasympathetic
Sympathetic
Sphincter pupillae and Ciliary Muscles
Ciliary Ganglion
Lacrimal Gland
Pterygopalatine Ganglion
Nasal and Palatal Mucosa
Submandibular Gland
Sublingual Gland
Submandibular Ganglion
Parotid Gland
Otic Ganglion
Heart
Larynx, Trachea
Bronchi, Lungs
Esophagus
Stomach
Liver, Gall Bladder, Bile Ducts
Pancreas
Kidneys, Suprarenal Glands
Small Intestine, Proximal Colon
Distal Colon
Rectum
Bladder
Genital Organs
Pelvic Splanchnic Nerves
Superior Cervical Ganglion
Dilator Pupillae Muscle
Lacrimal Gland Vessels
Parotid Gland Vessels
Submandibular and Sublingual Gland Vessels
Facial Vessels
Larynx
Middle Cervical Ganglion
Inferior Cervical Ganglion
Heart
Sympathetic Trunk
Larynx and Trachea
Bronchi and Lungs
Greater Splanchnic Nerve
Celiac Ganglion
Stomach
Liver, Gall Bladder and Bile Ducts
Pancreas
Suprarenal Glands
Lesser Splanchnic Nerve
Aorticorenal Ganglion
Kidney and Ureters
Least Splanchnic Nerve
Renal Plexus
Intestines
Superior Mesenteric Ganglion
Colon
Inferior Mesenteric Ganglion
Lumbar Splanchnic Nerves
Rectum
Bladder
Hypogastric Plexus
Prostate
External Genitalia
Sacral Splanchnic Nerves

Integration of the Nervous & Endocrine Systems during Stress



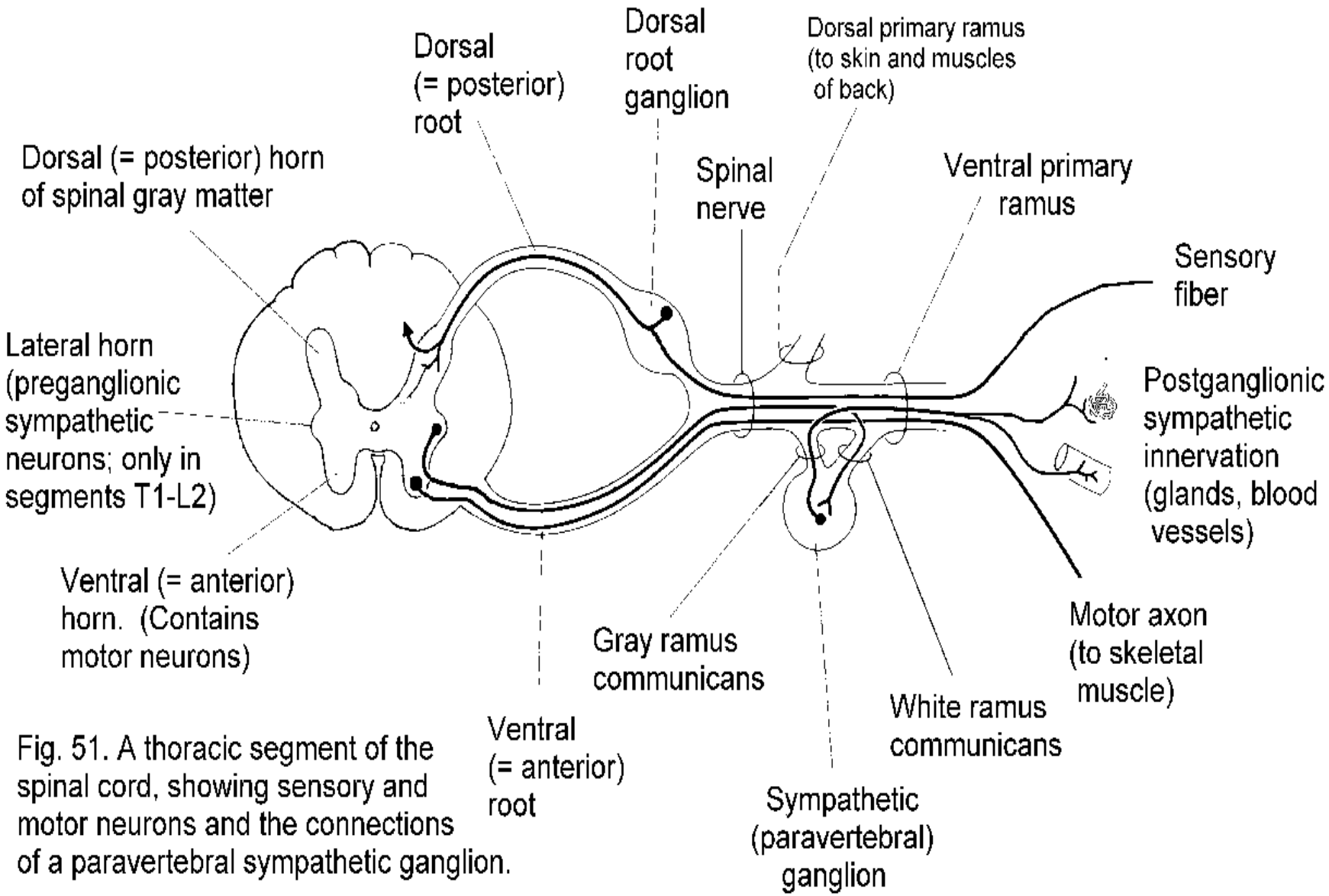


Fig. 51. A thoracic segment of the spinal cord, showing sensory and motor neurons and the connections of a paravertebral sympathetic ganglion.

Target Organ	*Parasympathetic Effects*	*Sympathetic Effects*
Eye (Iris)	Stimulates constrictor muscles. Pupil constriction.	Stimulates dilator muscles. Pupil dilates.
Eye (Ciliary muscle)	Stimulates. Lens accommodates – allows for close vision.	No innervation.
Salivary Glands	Watery secretion.	Mucous secretion.
Sweat Glands	No innervation.	Stimulates sweating in large amounts. (Cholinergic)
Gallbladder	Stimulates smooth muscle to contract and expel bile.	Inhibits gallbladder smooth muscle.
Arrector Pili	No innervation	Stimulates contraction. Piloerection (Goosebumps)

Target Organ	*Parasympathetic Effects*	*Sympathetic Effects*
Kidney	No innervation.	Releases the enzyme renin which acts to increase BP.
Penis	Vasodilates penile arteries. Erection.	Smooth muscle contraction. Ejaculation.
Vagina; Clitoris	Vasodilation. Erection.	Vaginal reverse peristalsis.
Blood Coagulation	No effect.	Increases coagulation rate.
Cellular Metabolism	No effect.	Increases metabolic rate.
Adipose Tissue	No effect.	Stimulates fat breakdown.

Target Organ	*Parasympathetic Effects*	*Sympathetic Effects*
Cardiac Muscle	Decreases HR.	Increases HR and force of contraction.
Coronary Blood Vessels	Constricts.	Dilates
Urinary Bladder; Urethra	Contracts bladder smooth muscle; relaxes urethral sphincter.	Relaxes bladder smooth muscle; contracts urethral sphincter.
Lungs	Contracts bronchiole (small air passage) smooth muscle.	Dilates bronchioles.
Digestive Organs	Increases peristalsis and enzyme/mucus secretion.	Decreases glandular and muscular activity.
Liver	No innervation	No innervation (indirect effect).

Target Organ	*Parasympathetic Effects*	*Sympathetic Effects*
Mental Activity	No innervation.	Increases alertness.
Blood Vessels	Little effect.	Constricts most blood vessels and increases BP. Exception – dilates blood vessels serving skeletal muscle fibers (cholinergic).
Uterus	Depends on stage of the cycle.	Depends on stage of the cycle.
Endocrine Pancreas	Stimulates insulin secretion.	Inhibits insulin secretion.

General Anatomy of the ANS

Sympathetic	Parasympathetic
► Fibers arise from thoracolumbar	► Fibers emerge from brain and sacral
► Short preganglionic fibers; long postganglionic	► Long preganglionic fibers; short postganglionic
► Ganglia near spinal cord	► Ganglia found in visceral effectors
► Gray and white rami	► No rami
► Extensive preganglionic branching	► Minimal preganglionic branching
► All preganglionic fibers use ACh, most postganglionic are adrenergic	► All cholinergic fibers

Levels of ANS Control

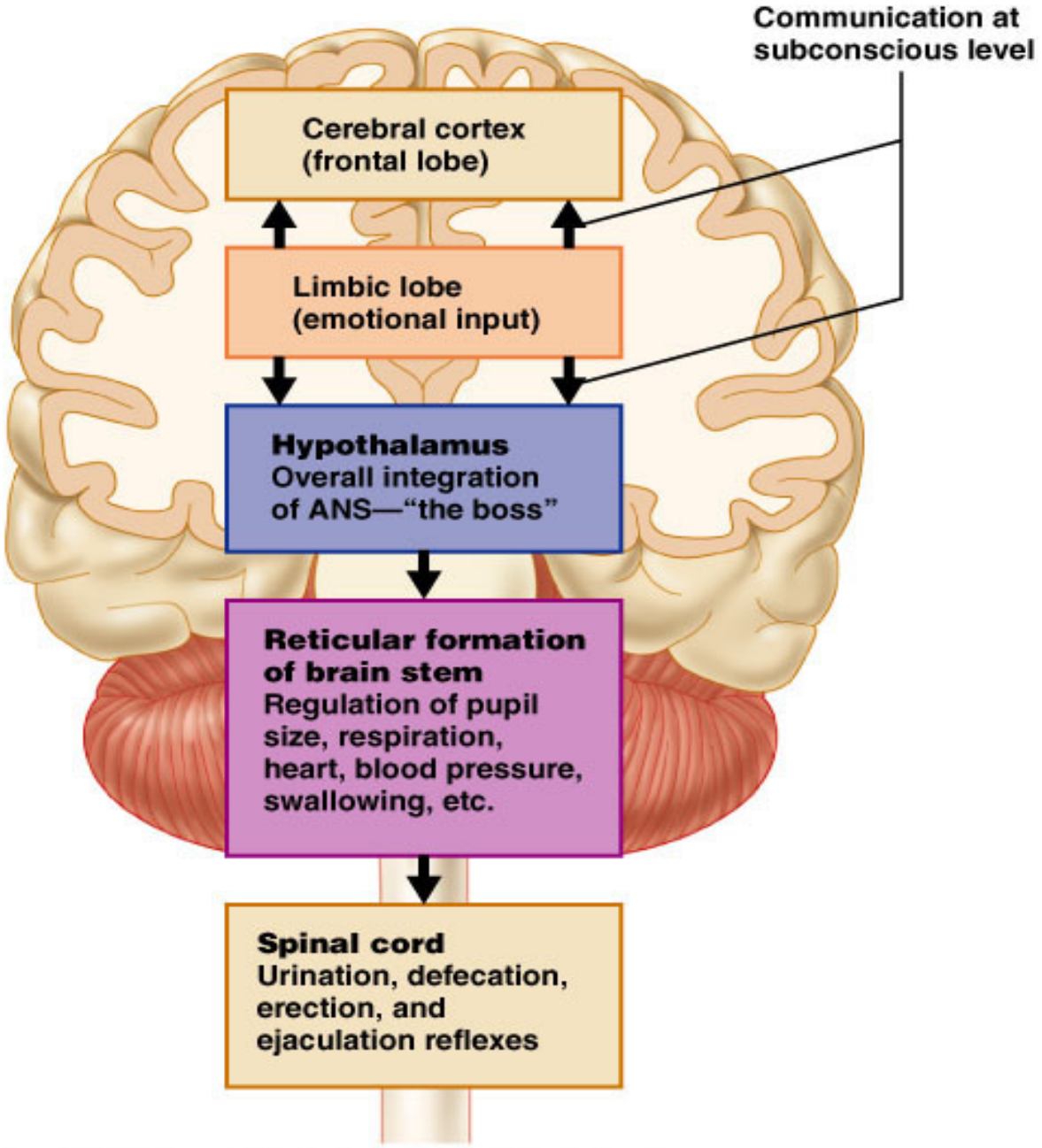
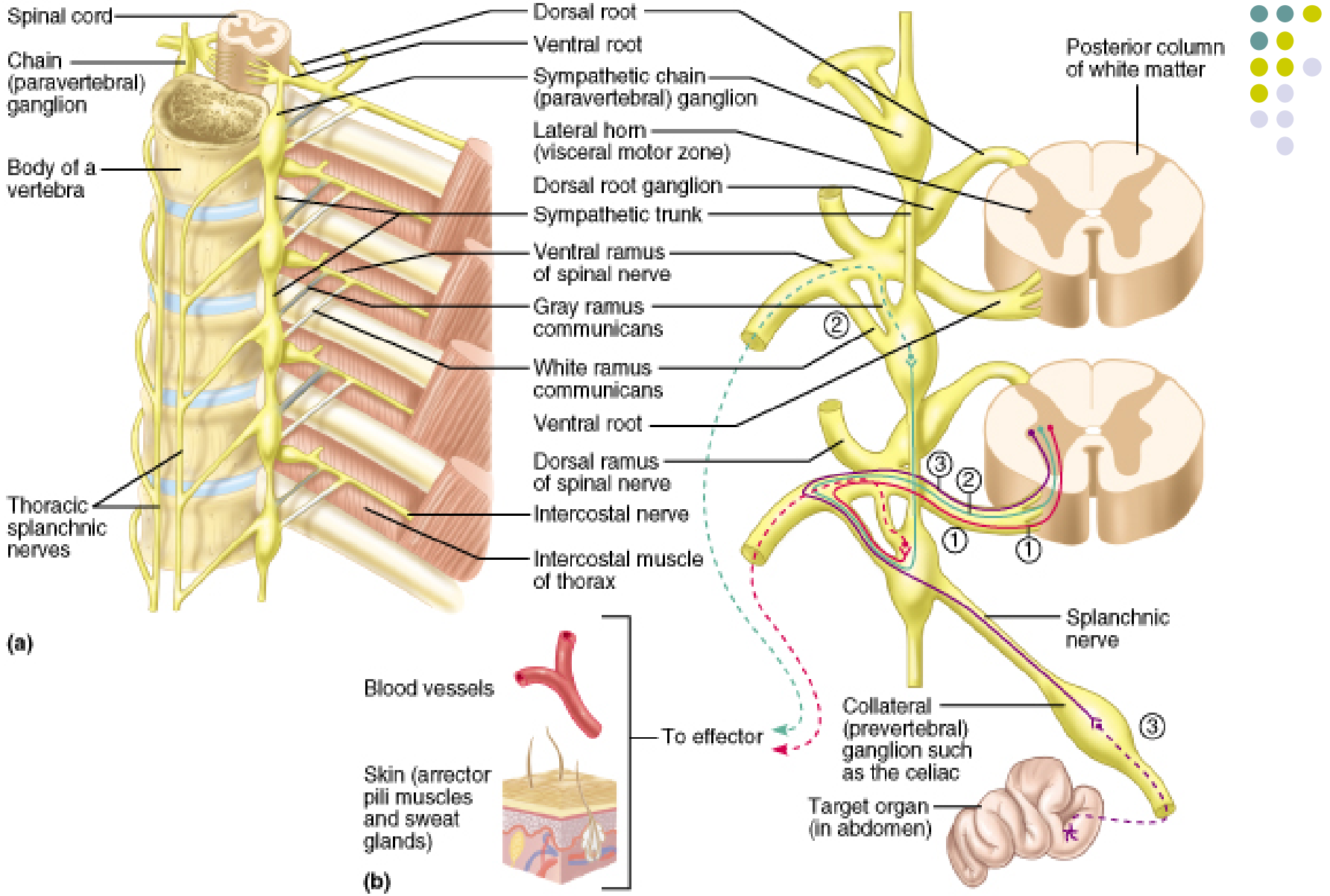
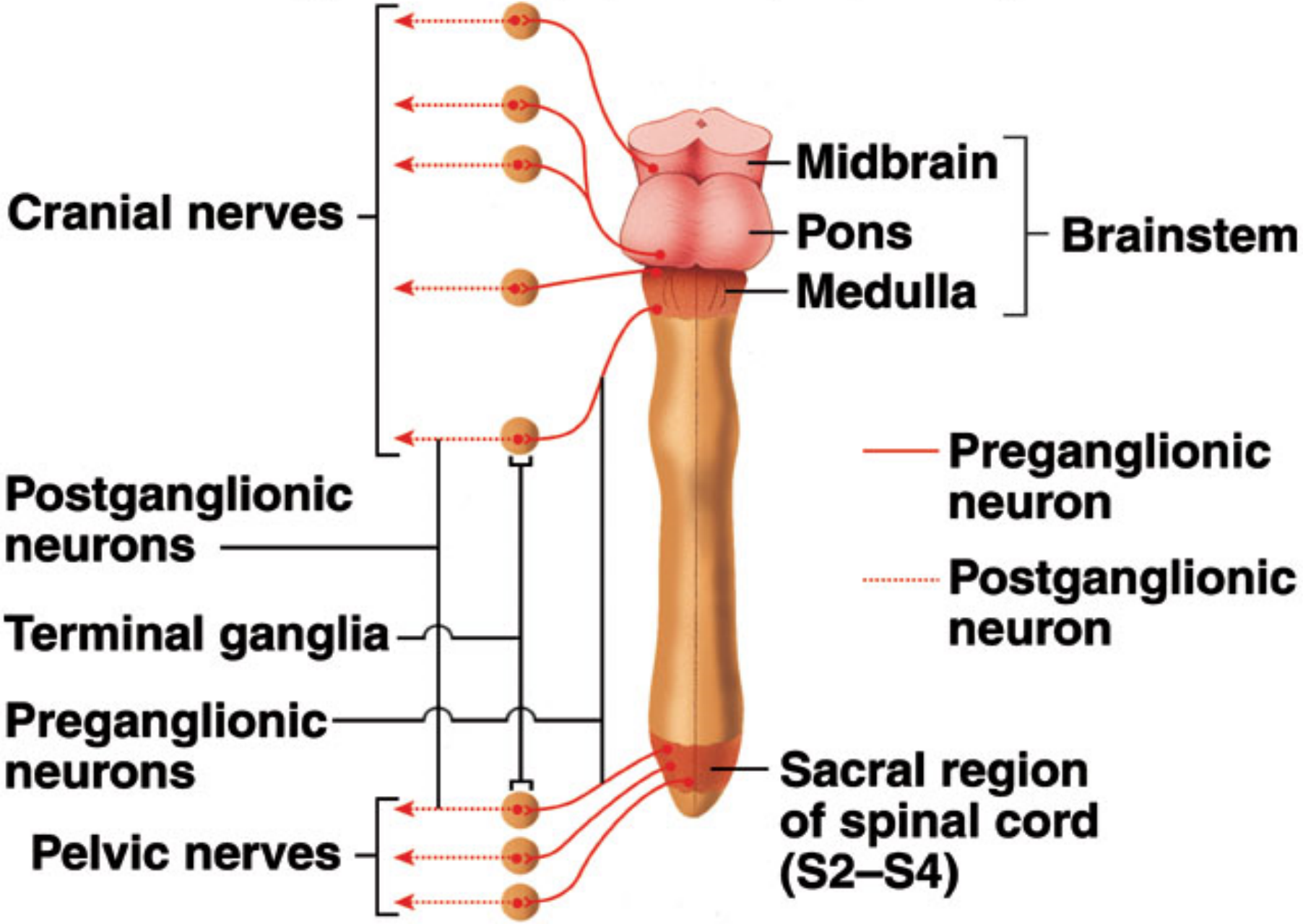
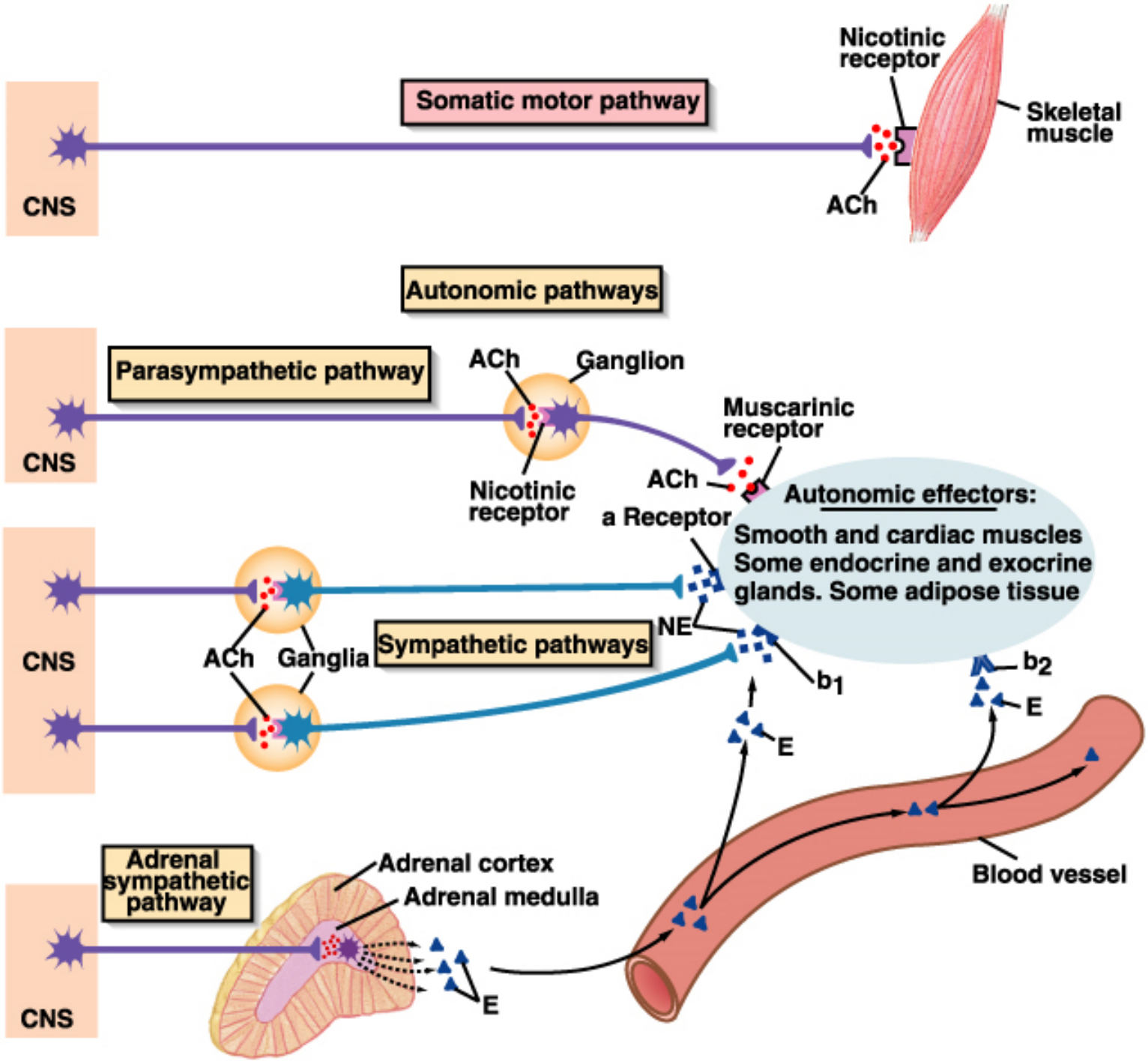


Figure 14.9


Spinal cord
Chain (paravertebral) ganglion
Body of a vertebra
Thoracic splanchnic nerves
(a)
Dorsal root
Ventral root
Sympathetic chain (paravertebral) ganglion
Lateral horn (visceral motor zone)
Dorsal root ganglion
Sympathetic trunk
Ventral ramus of spinal nerve
Gray ramus communicans
White ramus communicans
Ventral root
Dorsal ramus of spinal nerve
Intercostal nerve
Intercostal muscle of thorax
Posterior column of white matter
Splanchnic nerve
Collateral (prevertebral) ganglion such as the celiac
Target organ (in abdomen)
Blood vessels
Skin (arrector pili muscles and sweat glands)
To effector
(b)




Somatic motor pathway
CNS
Nicotinic receptor
Skeletal muscle
ACh
Autonomic pathways
Parasympathetic pathway
CNS
ACh
Ganglion
Nicotinic receptor
Muscarinic receptor
ACh
a Receptor
Autonomic effectors:
Smooth and cardiac muscles
Some endocrine and exocrine glands. Some adipose tissue
CNS
ACh
Ganglia
Sympathetic pathways
NE
b1
E
b2
E
Blood vessel
Adrenal sympathetic pathway
CNS
Adrenal cortex
Adrenal medulla
E