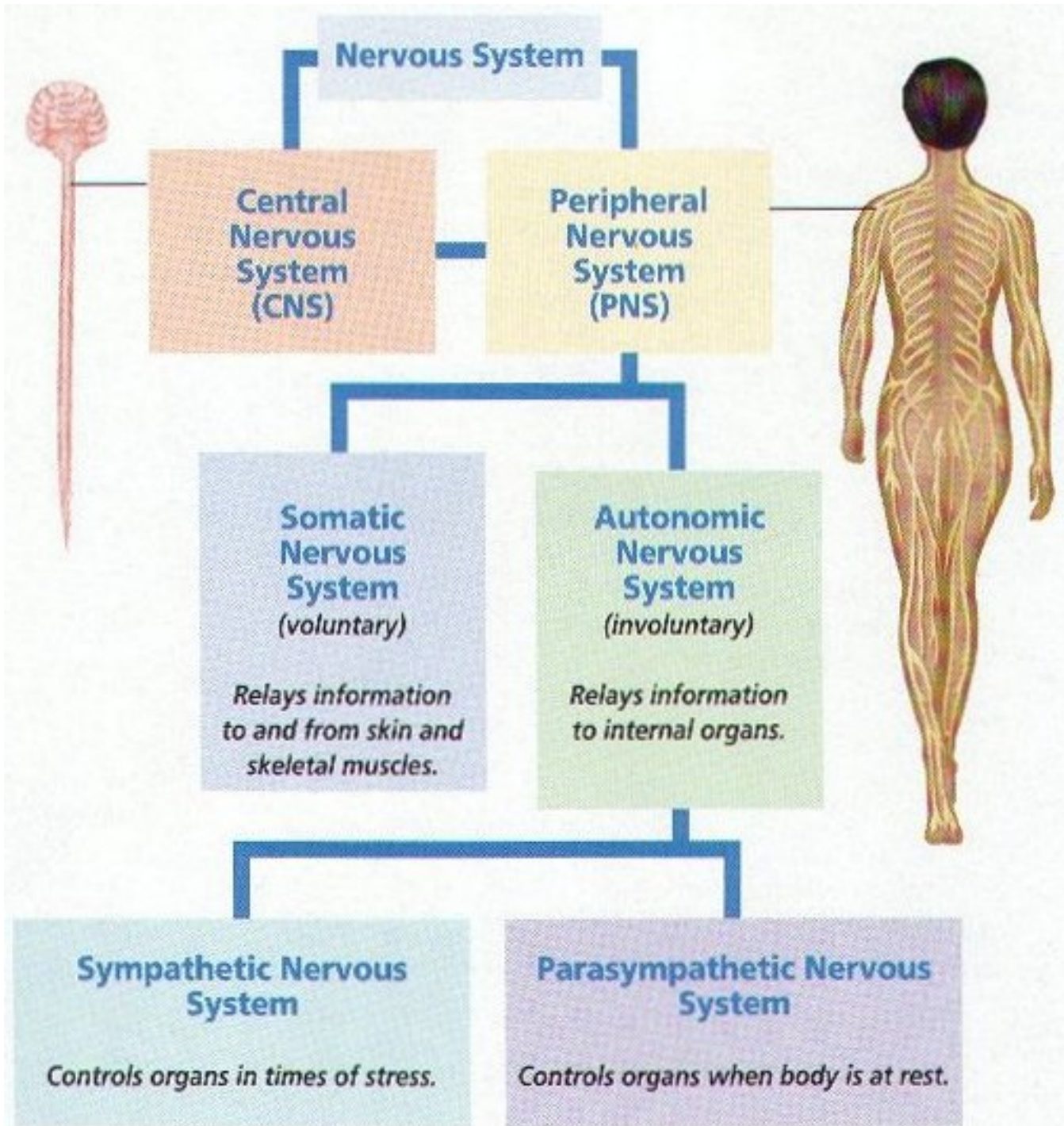
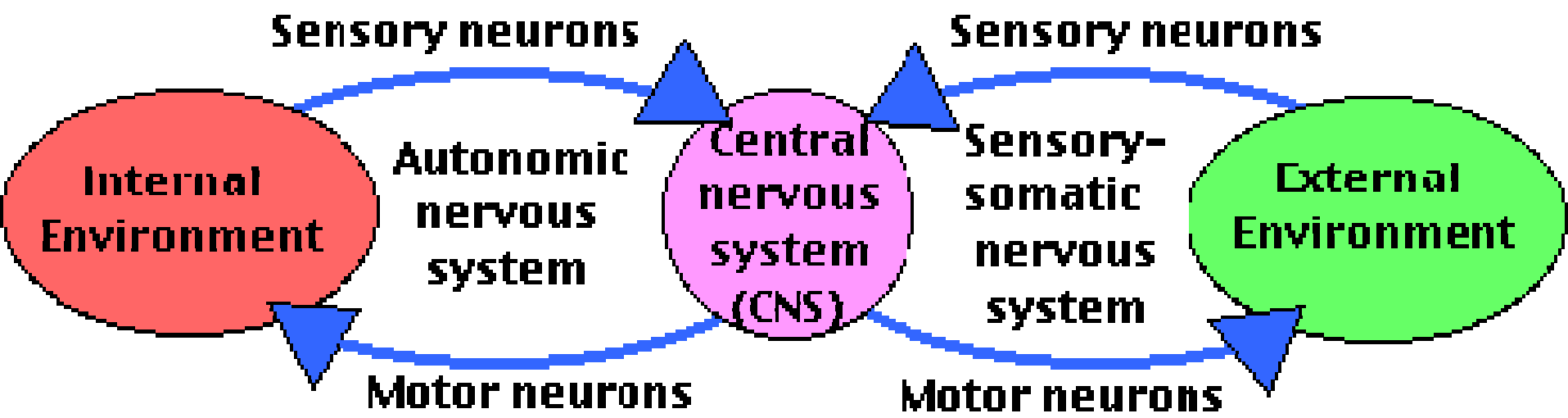


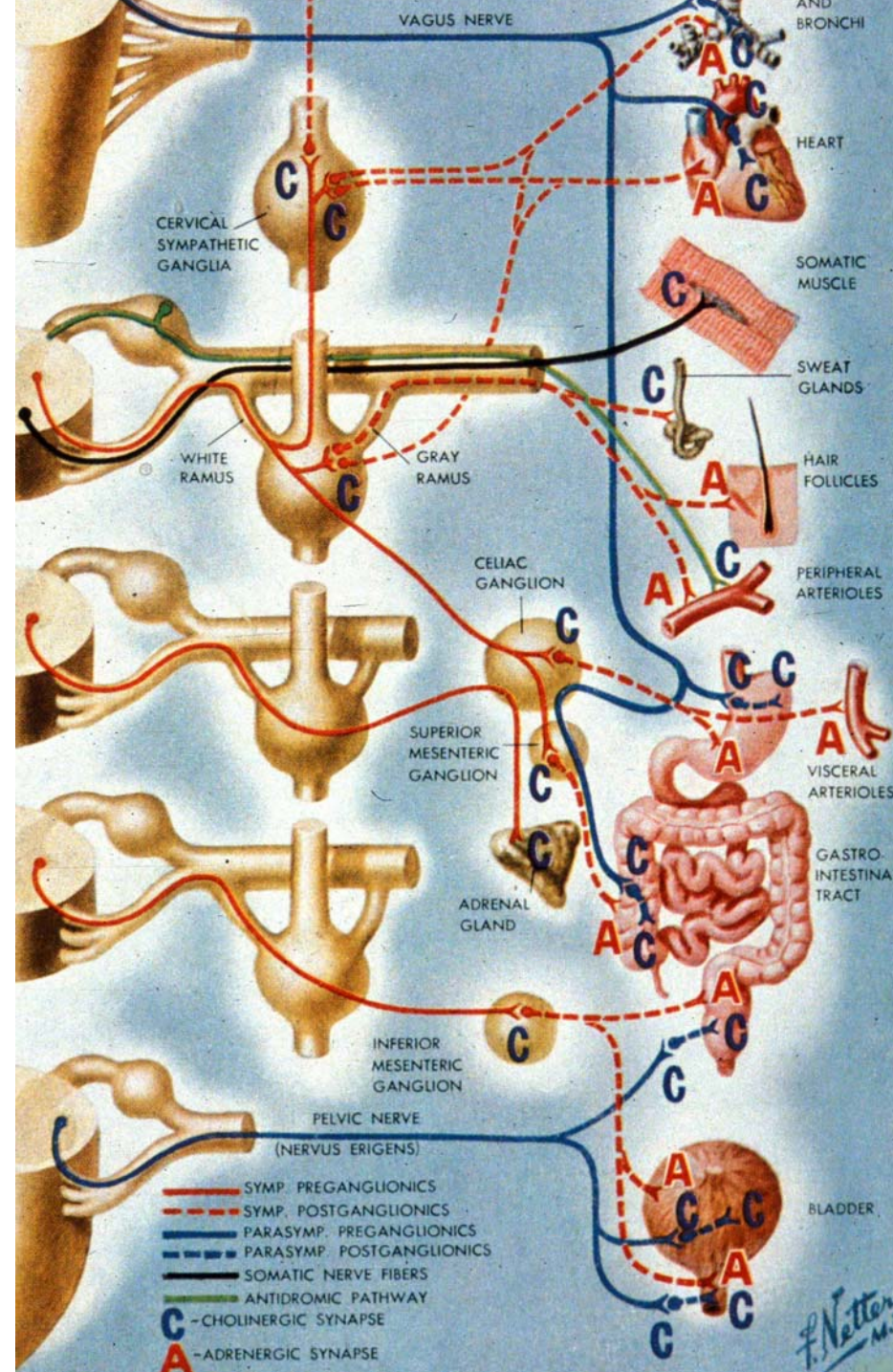
The Autonomic Nervous System and Visceral Reflexes





Autonomic Nervous System

- part of the nervous system that controls the motor systems of
 - cardiac muscles
 - smooth muscles of
 - glands
 - vessels
 - thoracic cavity
 - abdominal cavity
 - piloerector muscles
- Also called the visceral motor system to distinguish it from the somatic motor system that controls skeletal muscles

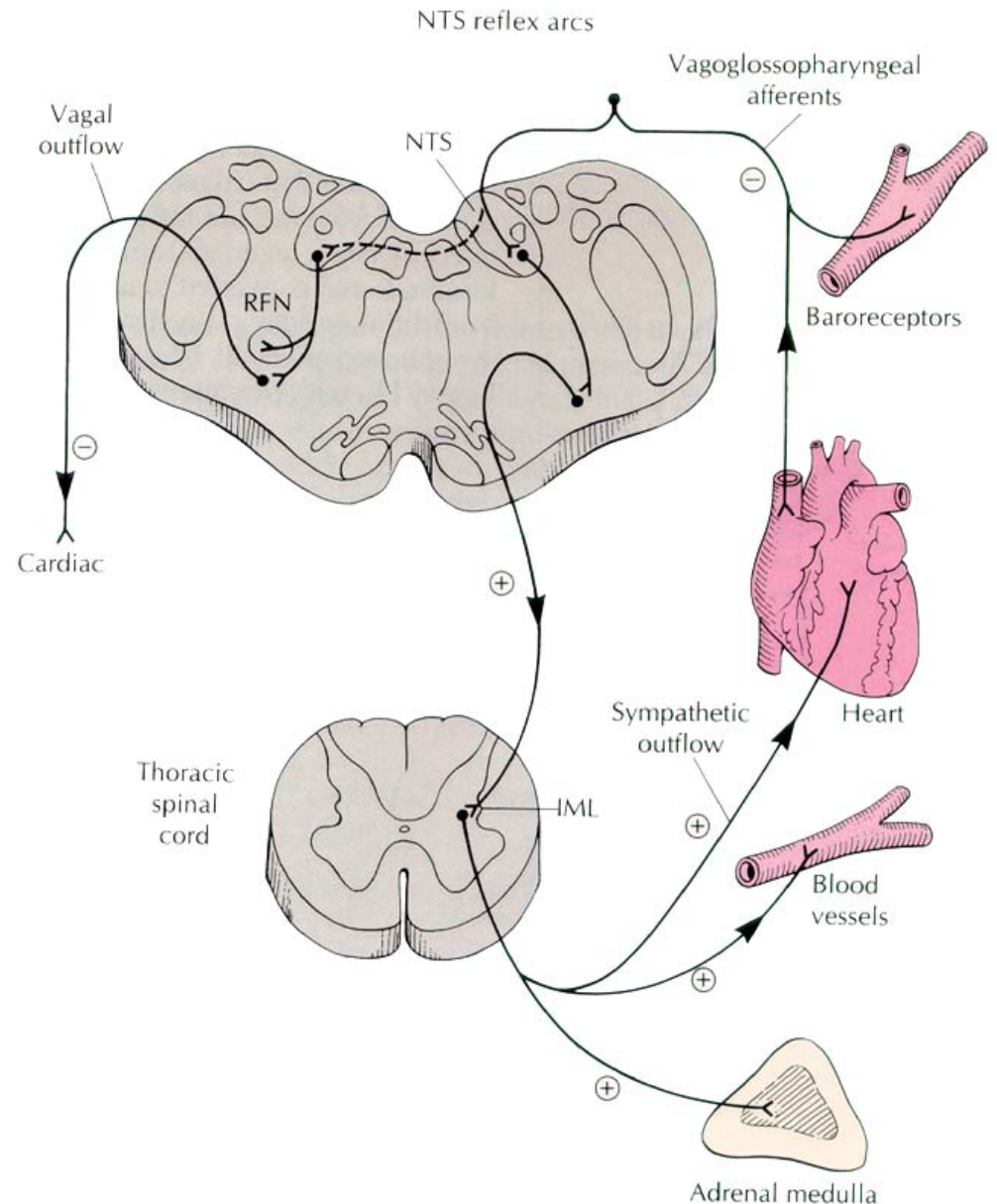


Autonomic Nervous System

- carries out its actions involuntarily, without conscious awareness
- end organ effectors do not depend entirely on the ANS for proper function, but only **serve to adjust their activity** in accordance to the bodies changing needs.
 - ex: the heart can function if nerves are severed.

Visceral Reflexes

- Reflex arc similar to somatic reflex arch including
 - receptor, efferent neuron to CNS, interneuron, efferent neuron carrying motor signal away from CNS, effector
- Ex: baroreceptors in controlling decreased blood pressure

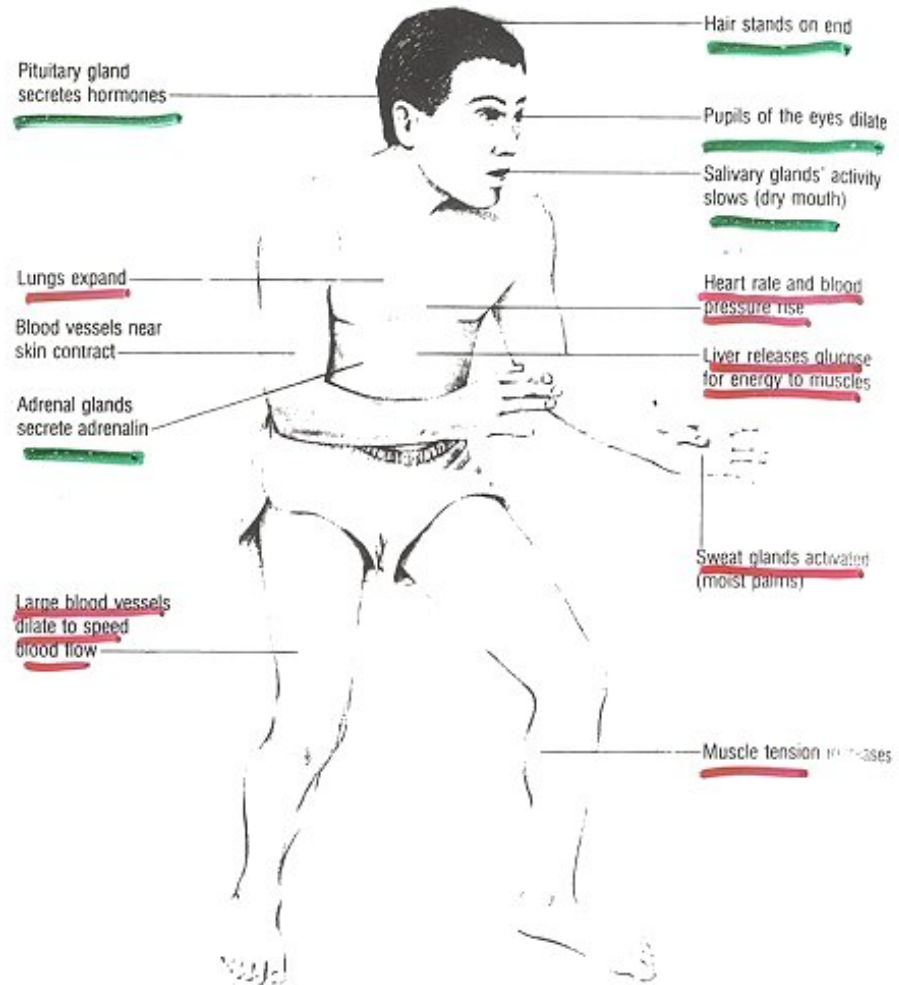


Divisions of the Autonomic NS

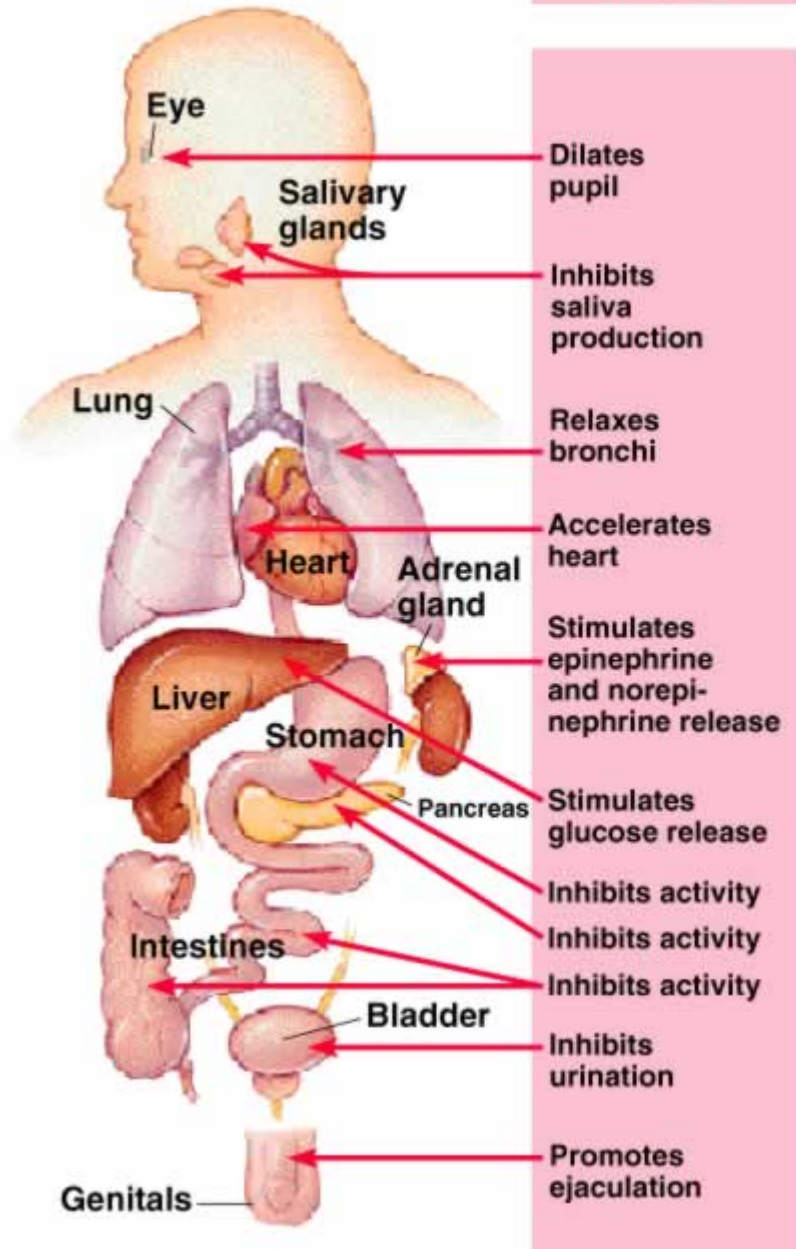
- ANS has two divisions
 - Sympathetic
 - Parasympathetic

Sympathetic

- extreme responses referred to as “fight or flight”
 - responses involved in emotions of stress, anger, fear
- Ordinary responses are subtle and hardly noticed, if at all.
 - mild increase in heart rate, breathing rate, increase blood pressure, increased blood flow to muscles



SYMPATHETIC DIVISION

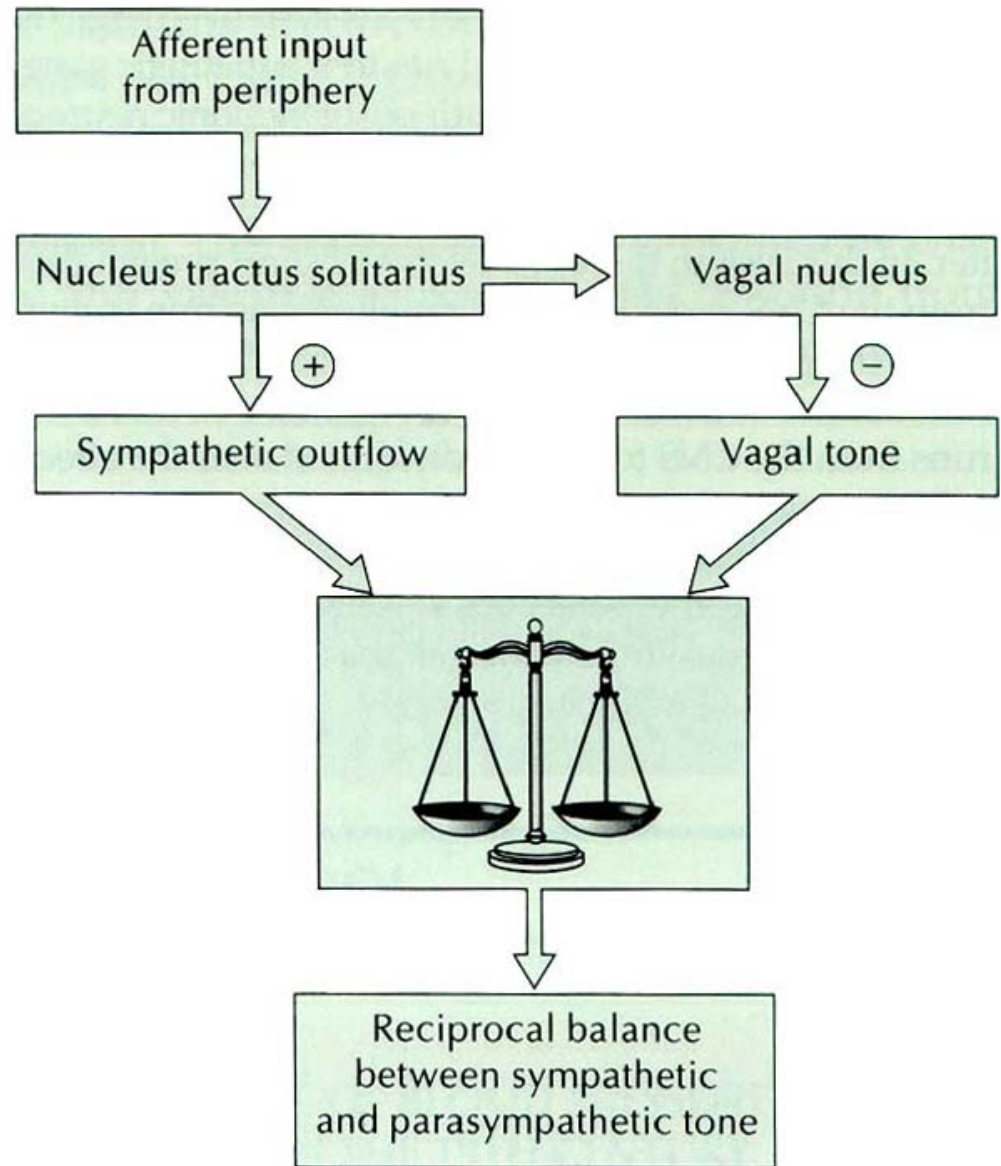


Divisions of the Autonomic NS

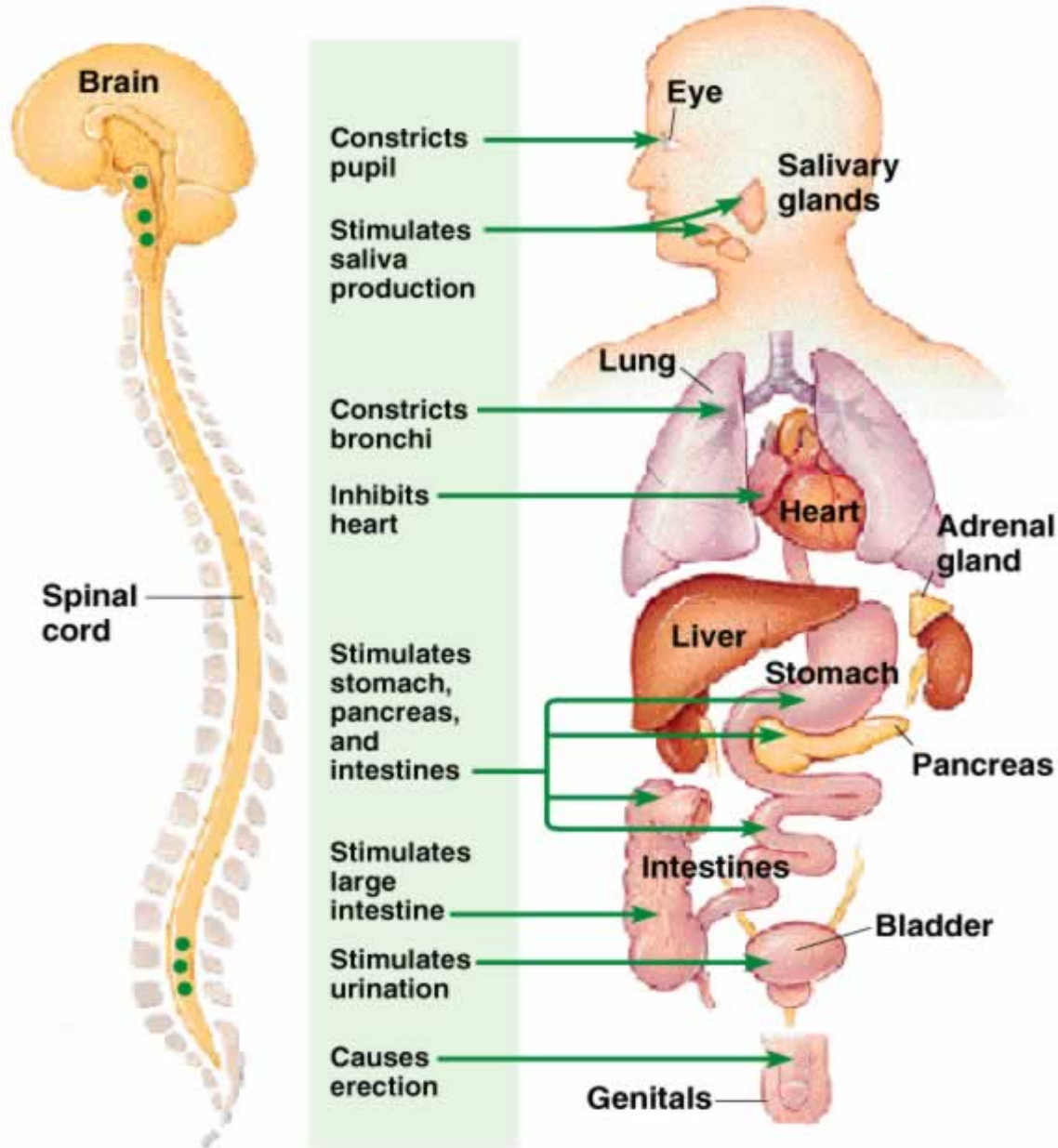
Parasympathetic

- responses opposite that of sympathetic
- responses have a calming effect on body functions seen as “resting and digestion” state
 - associated with reduced energy expenditure and normal body maintenance
 - digestion, and waste elimination

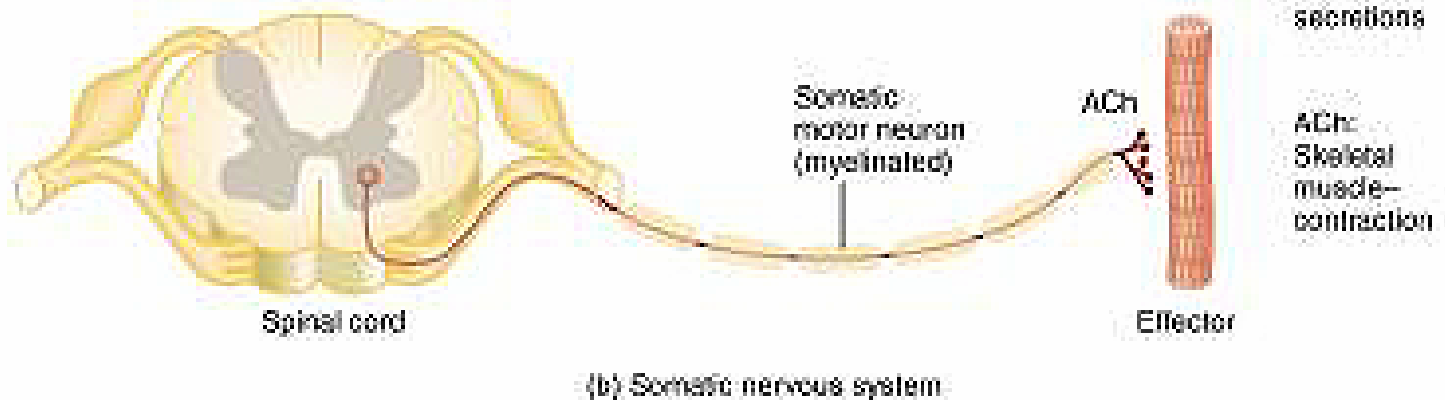
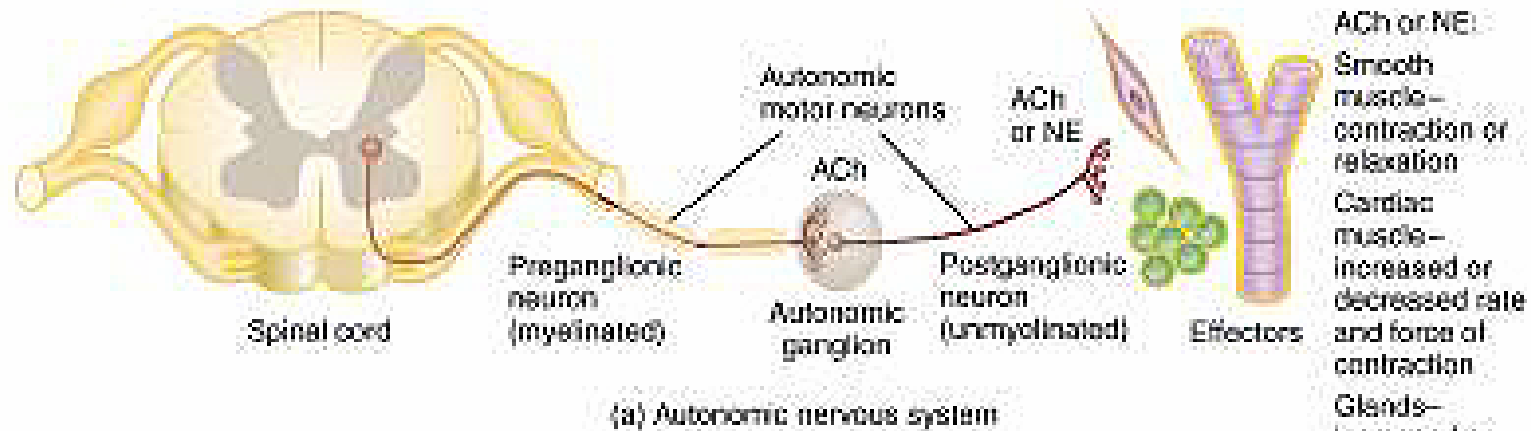
- Both systems acting simultaneously on the same target organ produces a state of **autonomic tone**
- shifts of predominance determined by mental and physiological states



PARASYMPATHETIC DIVISION

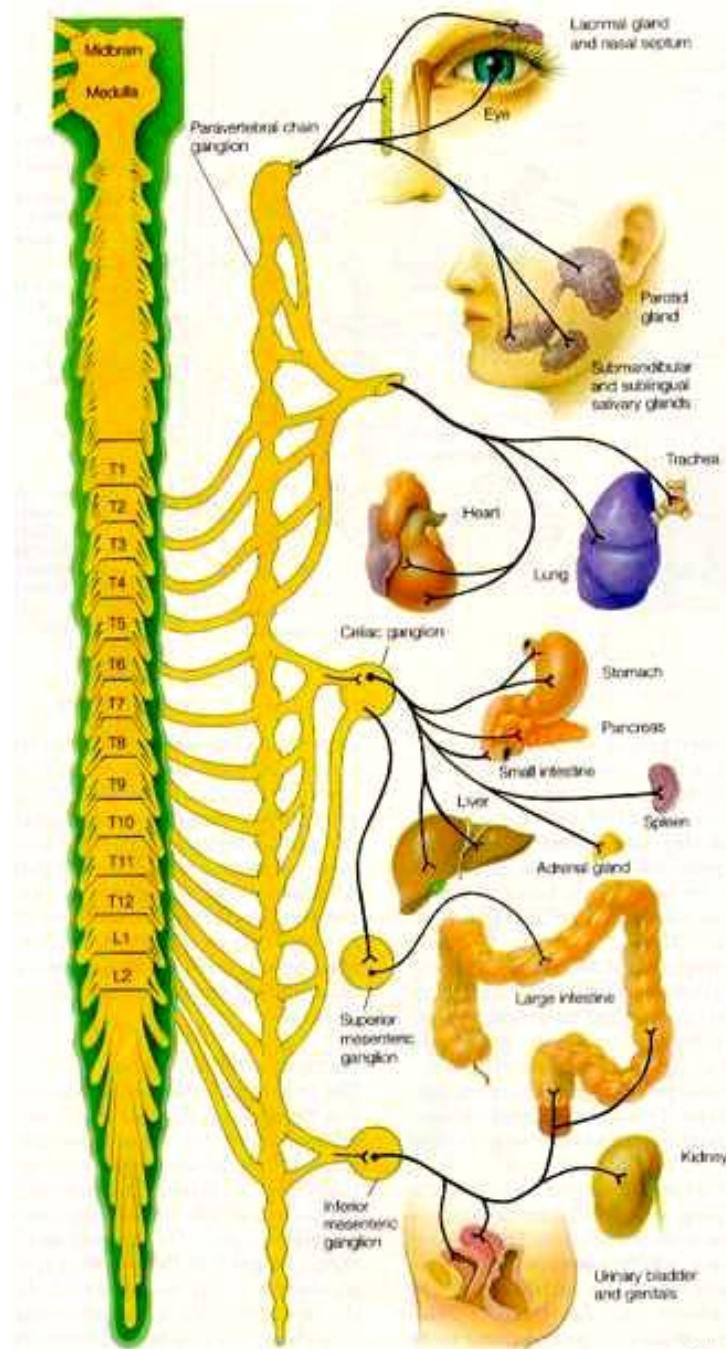


Neural Pathways



Sympathetic Division

- also called **thoracolumbar division** because they arise from the thoracic and lumbar regions of the cord.
- has short preganglionic and long postganglionic fibers
- **preganglionic somas are in the lateral horns** and nearby regions of the gray matter
- fibers exit by way of spinal nerves T1-L2
- fibers lead to **sympathetic chain of ganglia (paravertebral ganglia)** along each side of the cord

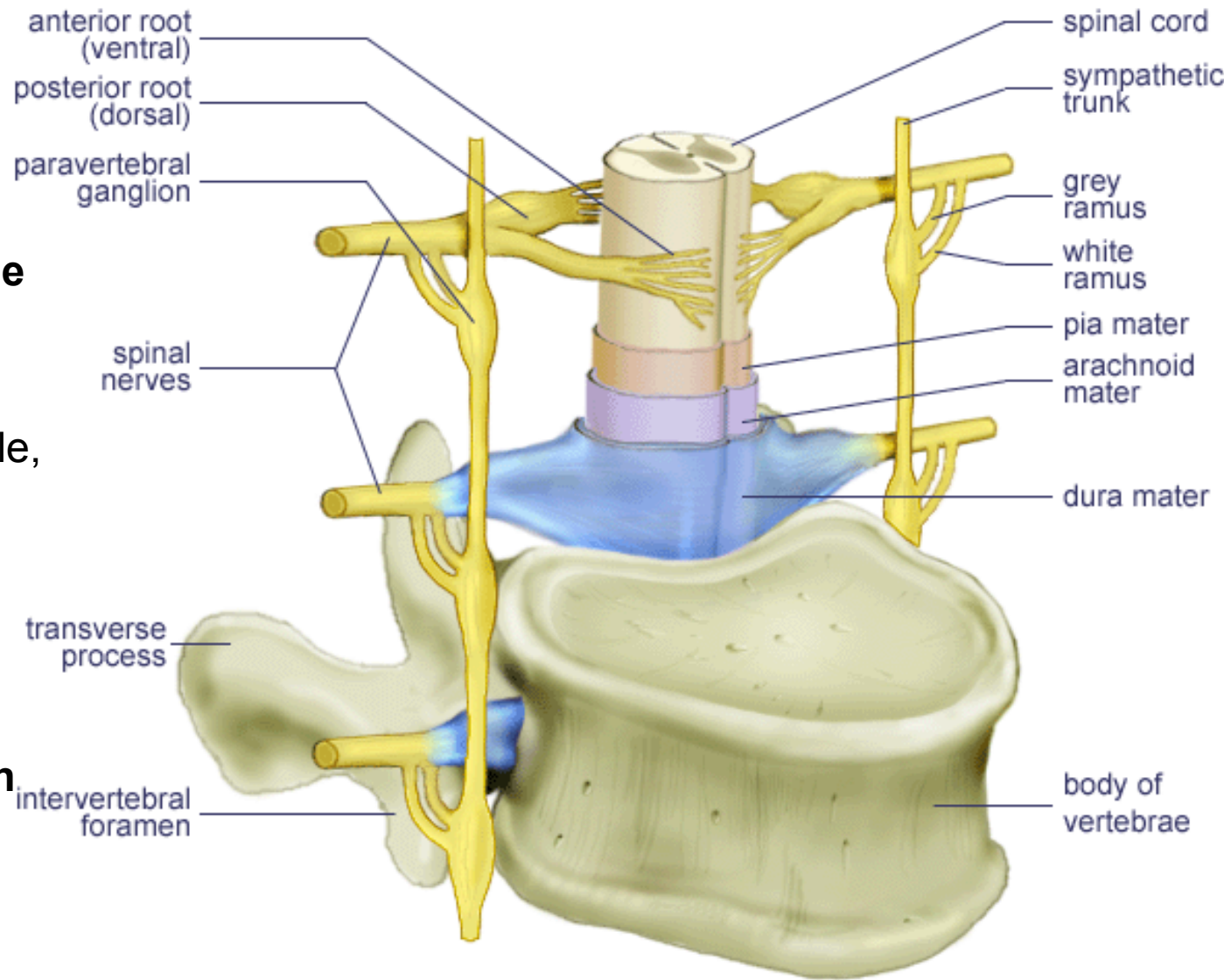


Paravertebral Ganglia

- although the chains receive input from only the thoracolumbar regions, they **extend from the cervical to the sacral cord**

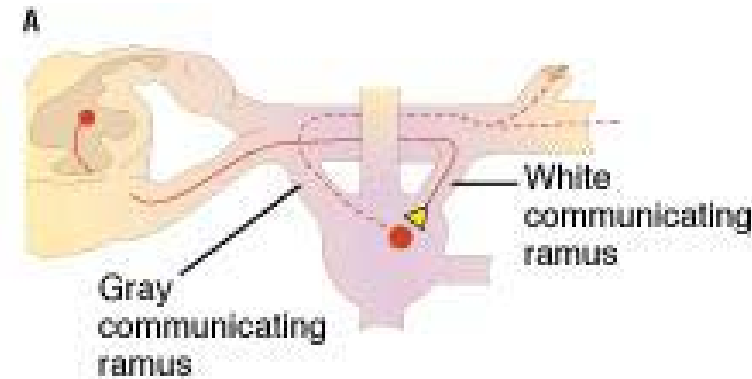
- usually there are 3 cervical (superior, middle, inferior), 11 thoracic, 4 lumbar, 4 sacral, and 1 coccygeal

- In the thoracolumbar region, each **paravertebral ganglion is connected to the spinal nerve by two branches called communicating rami**



Sympathetic Division

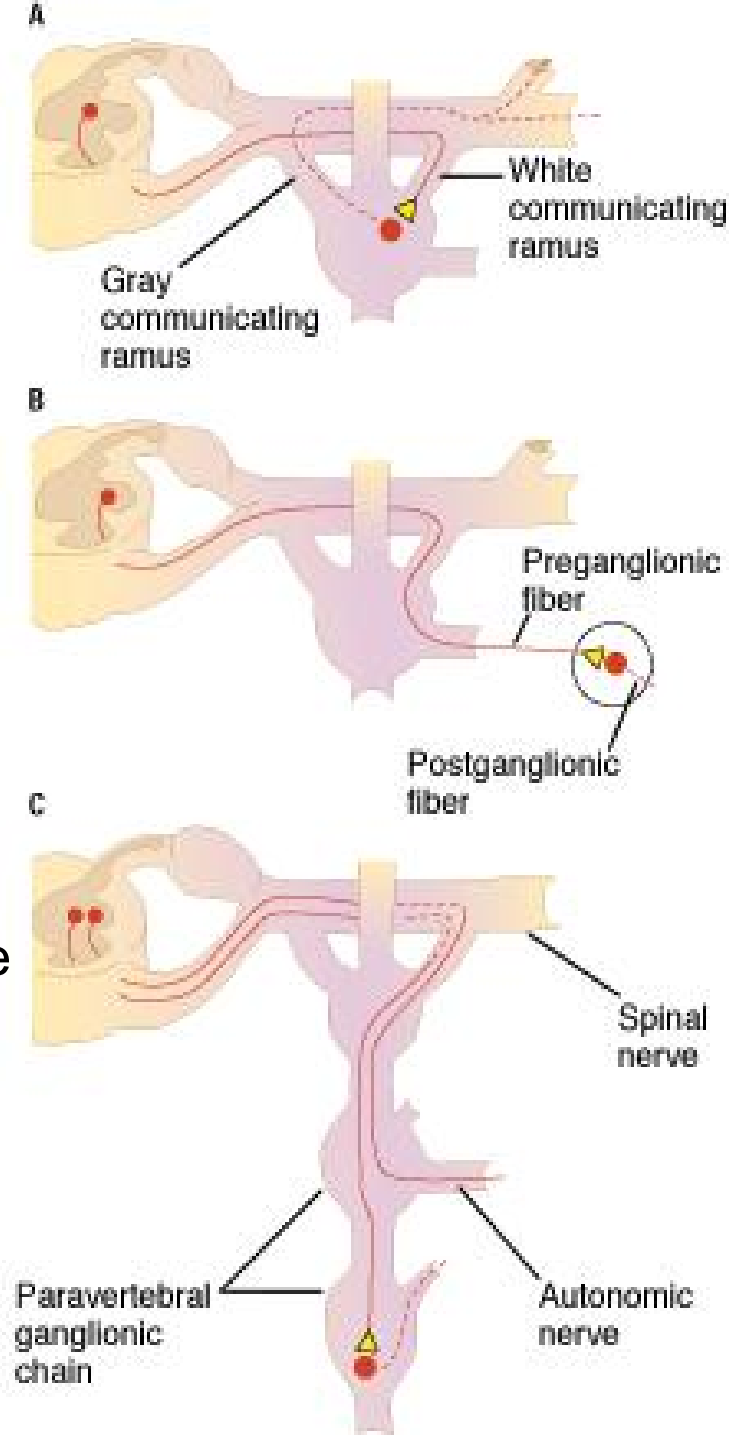
- preganglionic myelinated fibers travel from spinal nerve to ganglia through **white communicating ramus**
- unmyelinated postganglionic fibers leave the ganglion by way of the **gray communicating ramus**



Sympathetic Division

Once in paravertebral chain, fiber may take one of three paths

- A) May synapse in ganglion with postganglionic neuron, postganglionic neuron sends axon in gray communicating ramus (gray because unmyelinated) back to spinal nerve and out to body organ
- B) Axon may pass through sympathetic ganglion without synapsing, exit the ganglion via an autonomic nerve, and synapse in a more distant ganglion in the body cavity, such as **celiac** or **superior mesenteric ganglion (prevertebral ganglia)**
- C) If axon leaves cord via an upper thoracic or lower lumbar spinal nerve, it may ascend or descend to another ganglion



Sympathetic Division

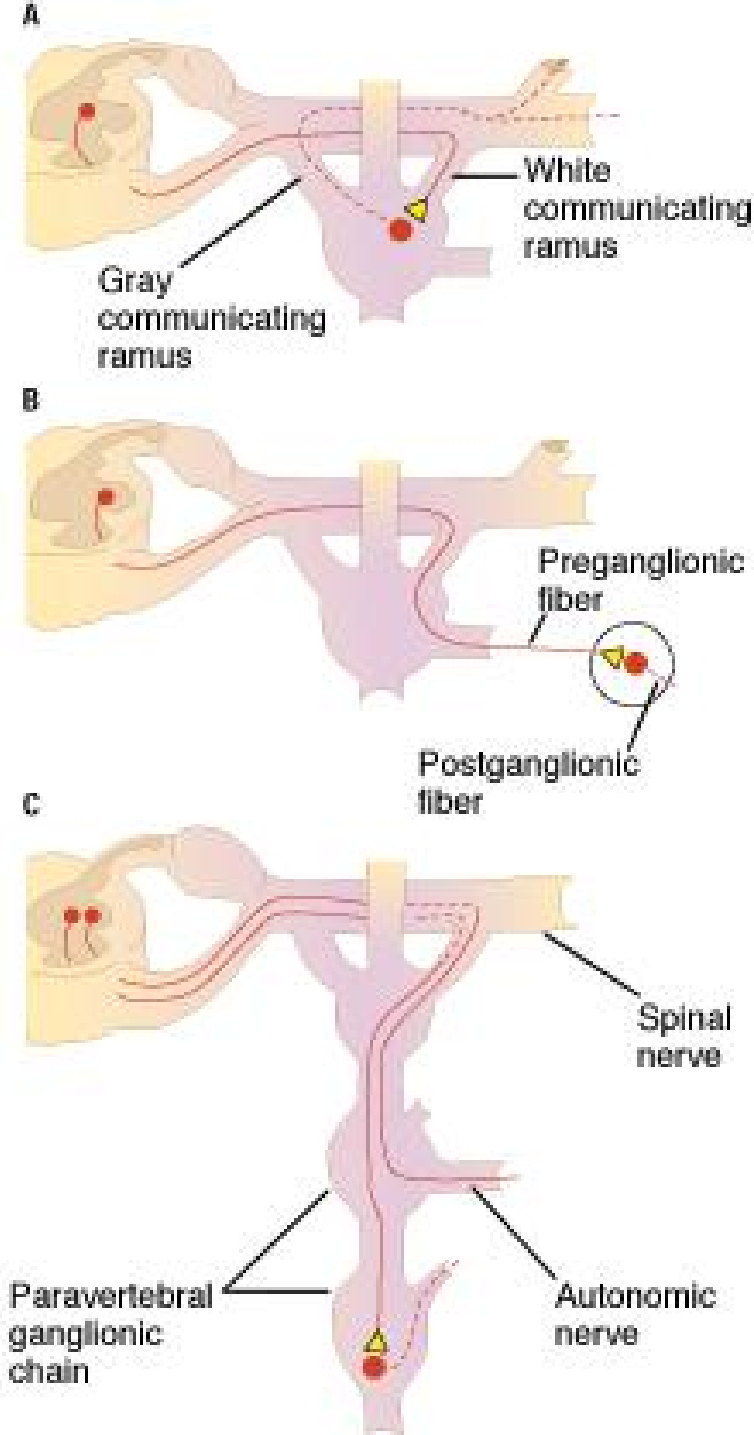
- Pre and post ganglionic fibers demonstrate convergence and divergence
 - there is no simple one-to-one relationship between pre and post ganglionic neurons
 - each postganglionic cell may receive synapses from multiple preganglionic cells: **neuronal convergence**
 - each preganglionic fiber branches and synapses with multiple postganglionic fibers: **neuronal divergence**
 - **allows sympathetic division to have a relatively widespread effect**

Sympathetic Division

- Sympathetic nerve fibers leave the paravertebral ganglia by three routes:
 - spinal nerves
 - sympathetic nerves
 - splanchnic nerves

Sympathetic Division

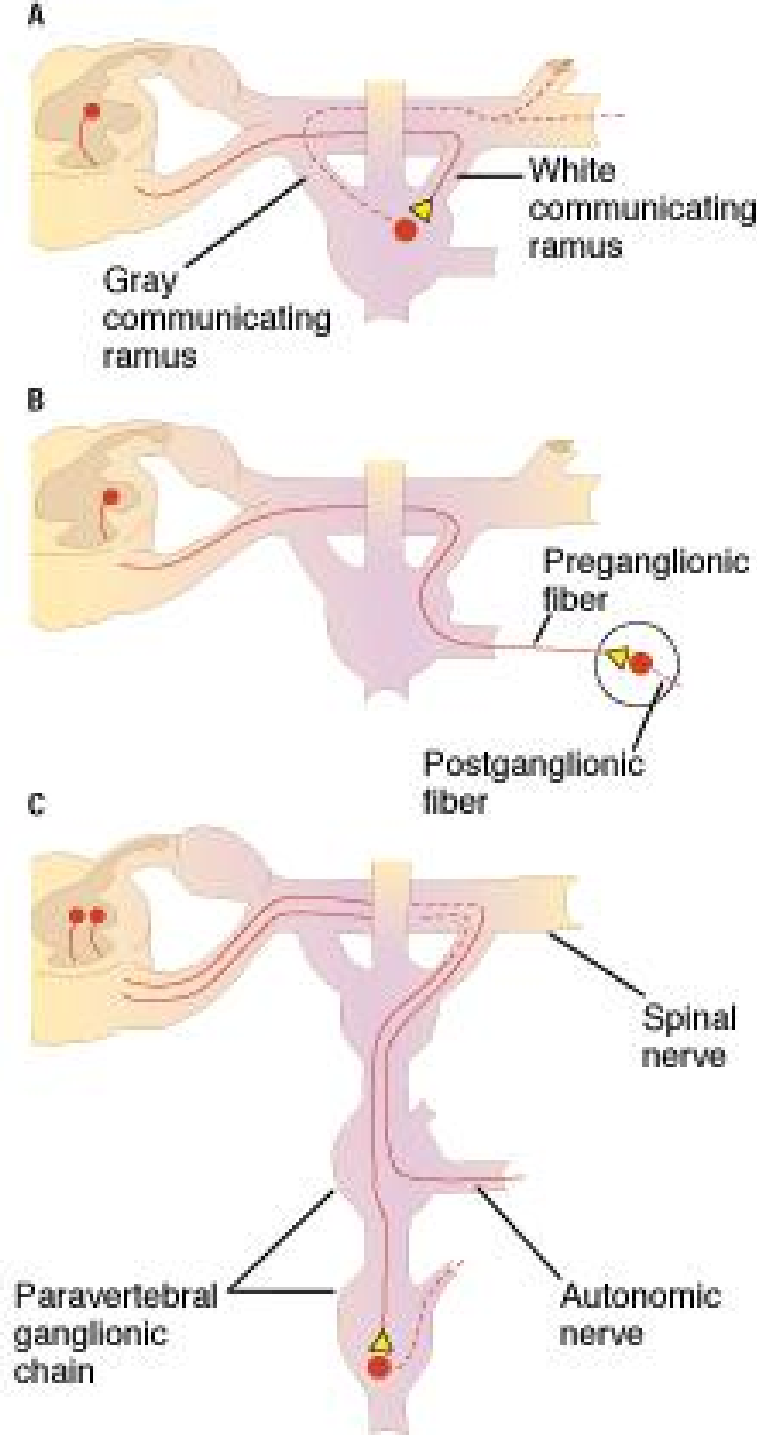
- **A. spinal nerve-** postganglionic fibers exit by way of the gray ramus, return to the spinal nerve or its subdivision, and travel the rest of the way to the target organ
- **This is the route innervates mostly effectors in the body wall** (sweat glands, piloerector muscles, and blood vessels of the skin and skeletal muscles)



Sympathetic Division

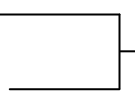
- **C. Sympathetic nerve route-** postganglionic fibers leave by way of sympathetic nerves that extend to the heart, lungs, esophagus, and thoracic blood vessels
- these fibers form plexus around each carotid artery and issue fibers from there to effectors in the head (sweat glands, salivary and nasal glands: piloerector muscles: blood vessels:, and dilators of the iris)
- Some fibers from the superior cervical ganglion form the **cardiac nerves** to the heart.

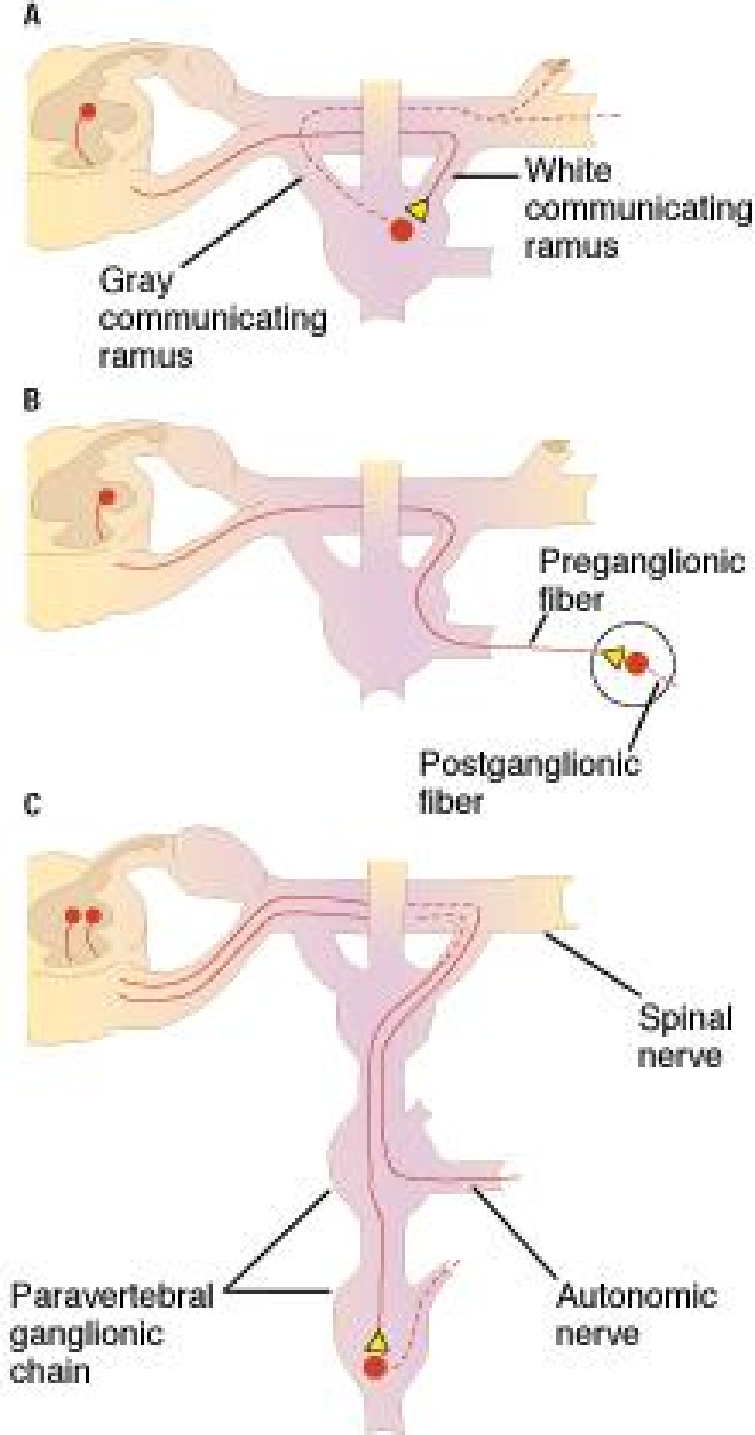
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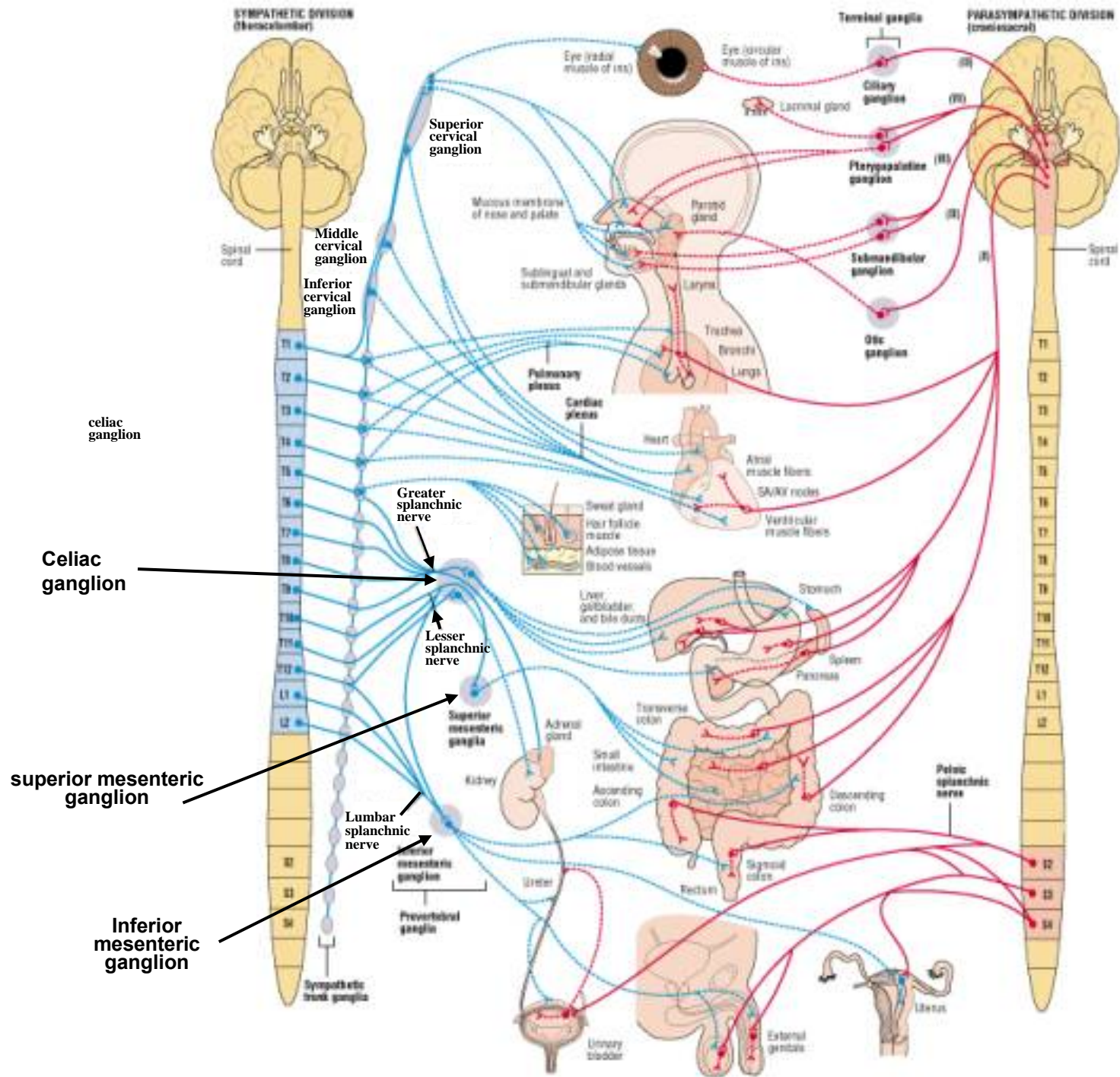


Sympathetic Division

- **B. splanchnic nerve** (any nerve which innervates viscera) **route-** formed from fibers originating predominately from T5-T12 and pass through the chain ganglia without synapsing.
- beyond the ganglia, they form **greater, lesser, and lumbar (least) splanchnic nerves**
- these lead to the collateral (prevertebral ganglia which contribute to a network called the **abdomino aortic plexus** that wraps around the aorta
- three major collateral ganglia
 - **celiac** (solar plexus)
 - **superior mesenteric**
 - **inferior mesenteric**


 solar plexus





SYMPATHETIC DIVISION (thoracolumbar)

PARASYMPATHETIC DIVISION (craniosacral)

Superior cervical ganglion

Middle cervical ganglion

Inferior cervical ganglion

celiac ganglion

Celiac ganglion

Greater splanchnic nerve

Lesser splanchnic nerve

superior mesenteric ganglion

Lumbar splanchnic nerve

Inferior mesenteric ganglion

Pelvic splanchnic nerves

Sympathetic trunk ganglia

Spinal cord

T1

T2

T3

T4

T5

T6

T7

T8

T9

T10

T11

T12

L1

L2

L3

L4

L5

Eye (radial muscle of iris)

Eye (ciliary muscle of iris)

Lacrimal gland

Ciliary ganglion

Pterygopalatine ganglion

Submandibular ganglion

Otic ganglion

Mucous membrane of nose and palate

Parotid gland

Sublingual and submandibular glands

Larynx

Trachea

Bronchi

Lungs

Pulmonary plexus

Cardiac plexus

Heart

Atrial muscle fibers

SA/AV nodes

Ventricular muscle fibers

Sweat gland

Hair follicle muscle

Adipose tissue

Blood vessels

Liver

Gallbladder and bile ducts

Stomach

Spleen

Pancreas

Transverse colon

Small intestine

Ascending colon

Descending colon

Sigmoid colon

Rectum

Ureter

Urinary bladder

External genitalia

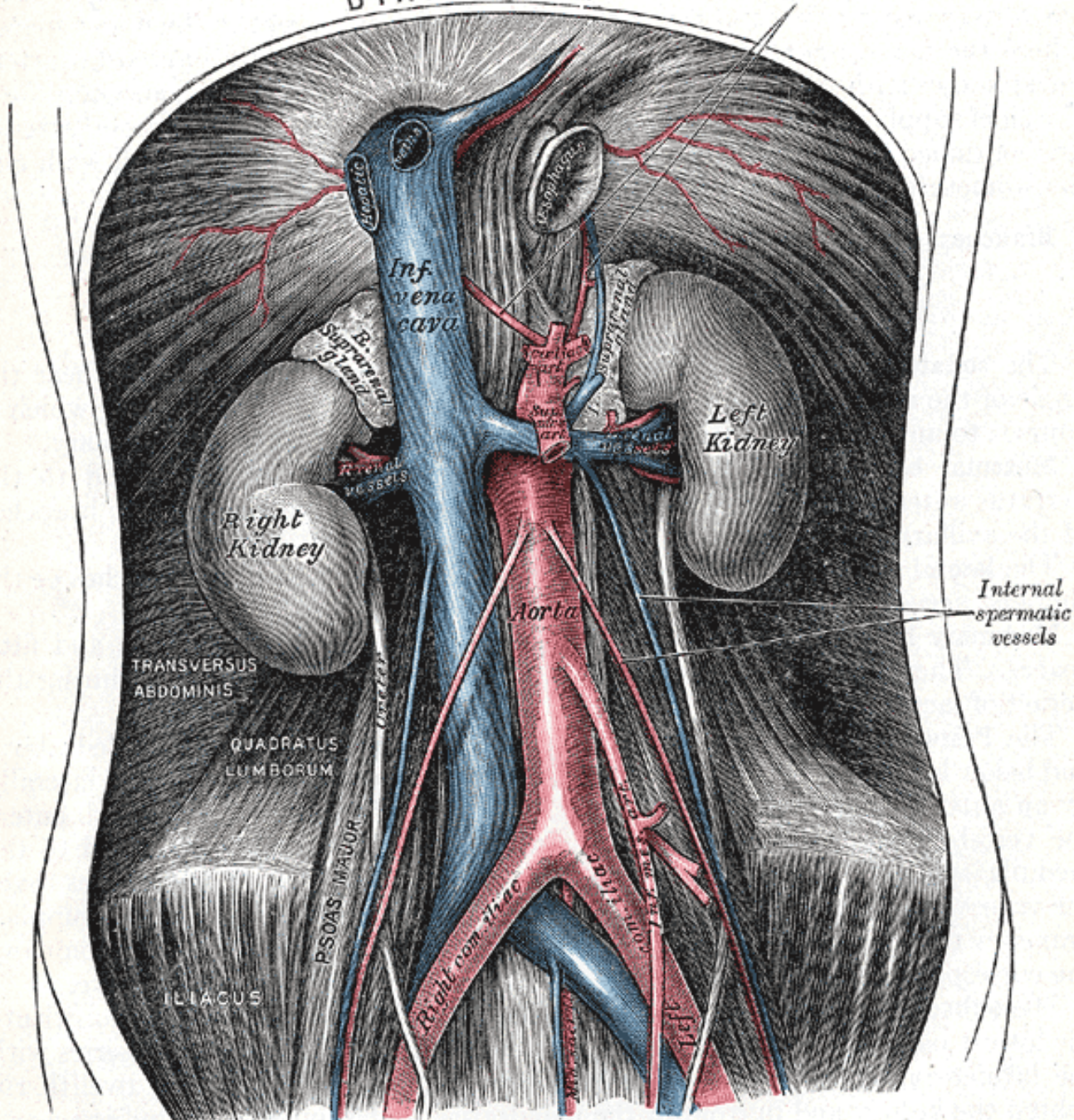
Uterus

Inferior mesenteric ganglion

Prevertebral ganglion

DIAPHRAGM

Inferior phrenic arteries



Inf. vena cava

Suprarenal gland

Right Kidney

Left Kidney

Aorta

Internal spermatic vessels

TRANSVERSUS ABDOMINIS

QUADRATUS LUMBORUM

PSOAS MAJOR

ILIACUS

Right common iliac

Left common iliac

Hepatic vein

Inf. phrenic vein

Renal vessels

Superior vena cava

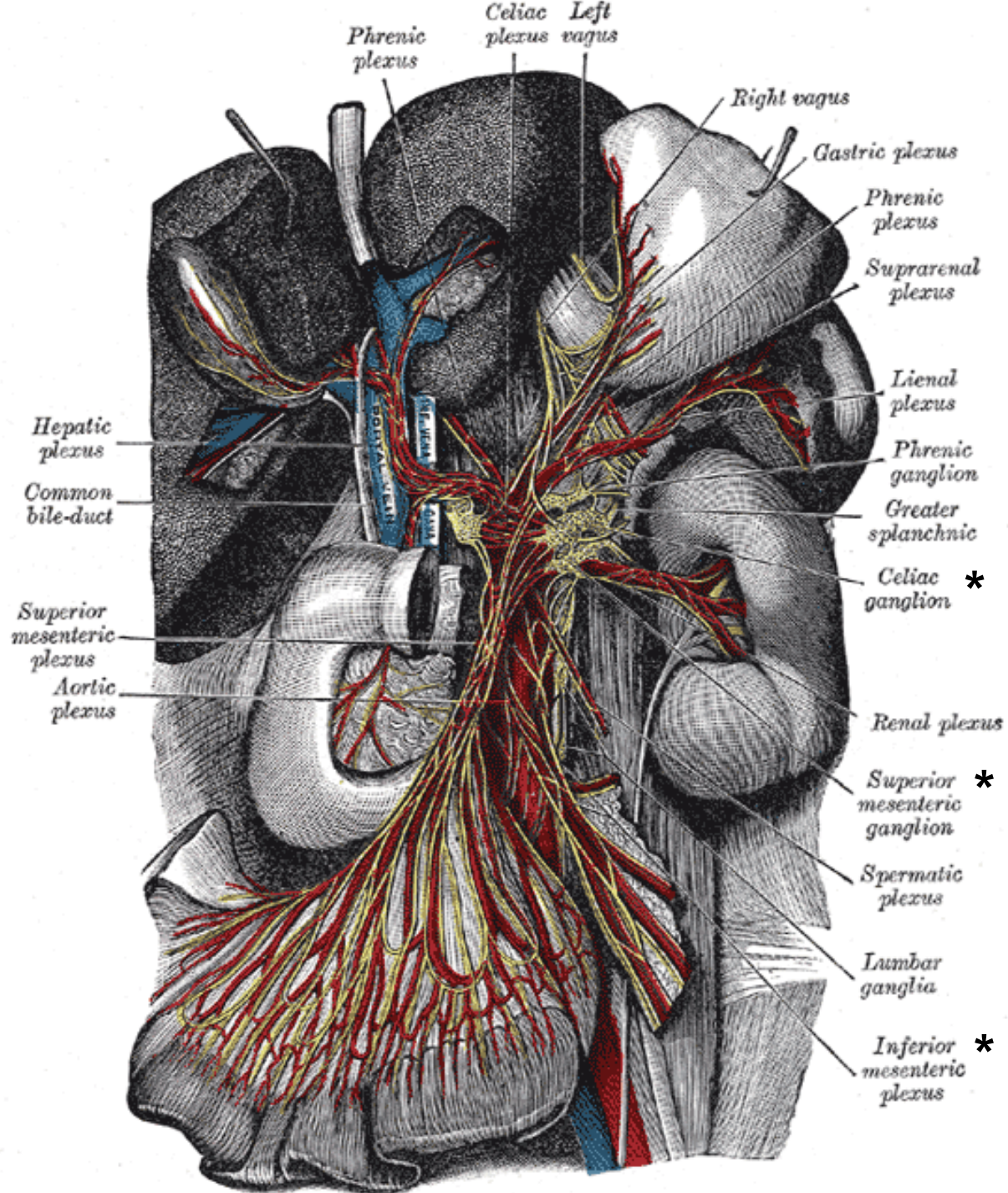
Superior vena cava

Common iliac vein

Common iliac artery

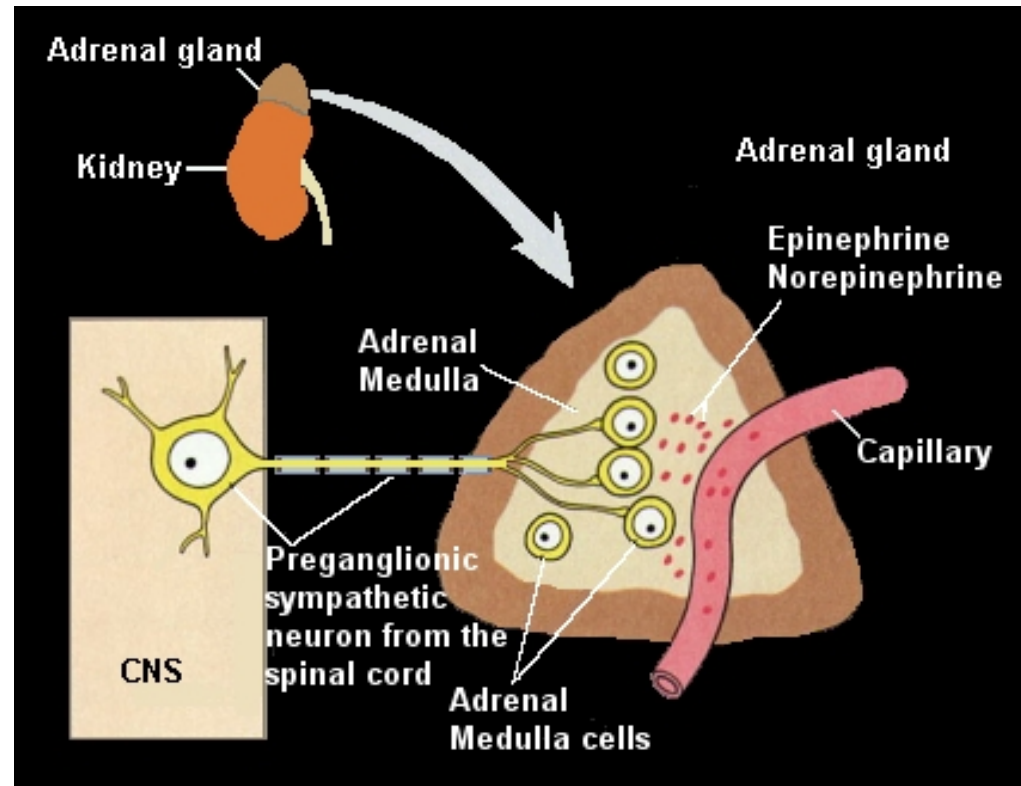
Internal iliac vein

Internal iliac artery



Adrenal Gland

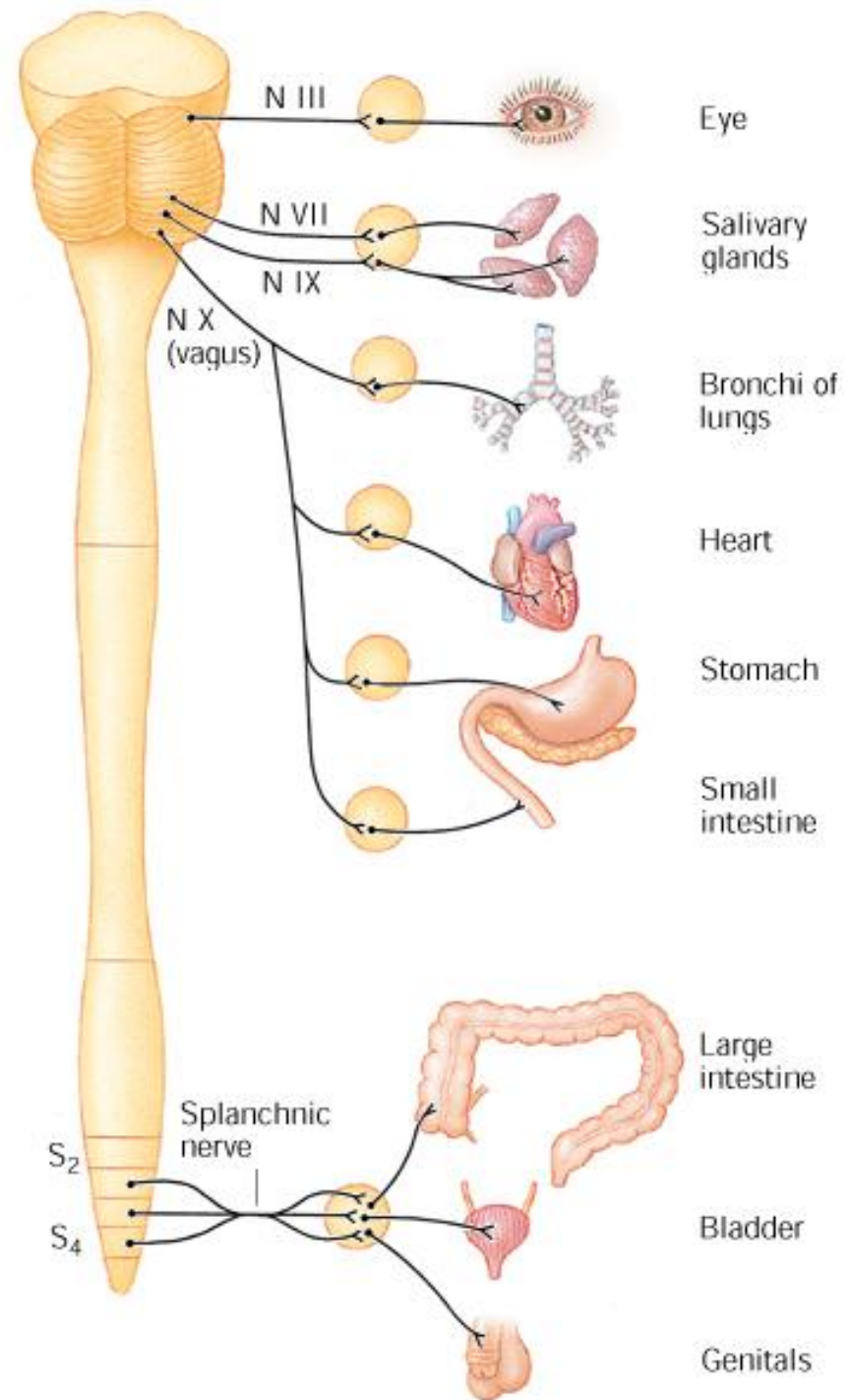
- Each gland is actually two glands in one
- outer cortex secretes cortisol when stimulated
- inner medulla **is a modified sympathetic ganglion**
 - consist of modified postganglionic neurons without dendrites or axons
 - sympathetic preganglionic fibers penetrate through the cortex and terminate on these cells
- when stimulated it **secretes epinephrine and norepinephrine and a trace of dopamine into the blood stream**



preganglionic fibers from the greater splanchnic nerve, via the celiac ganglion, supplies the adrenal medulla

Parasympathetic Division

- also called **craniosacral division**
 - arises from brain and sacral cord
 - fibers travel in certain cranial and sacral nerves
 - preganglionic neurons located in the pons, medulla, and segments S2-S4 of cord
 - they issue **long preganglionic fibers** which end in **terminal ganglia** in the wall (**intramural ganglion**) or near the target organ, thus, **short postganglionic fibers**
- there is some neural divergence, but much less than in the sympathetic
 - **thus is relatively selective in its stimulation of target organs**



Parasympathetic Division

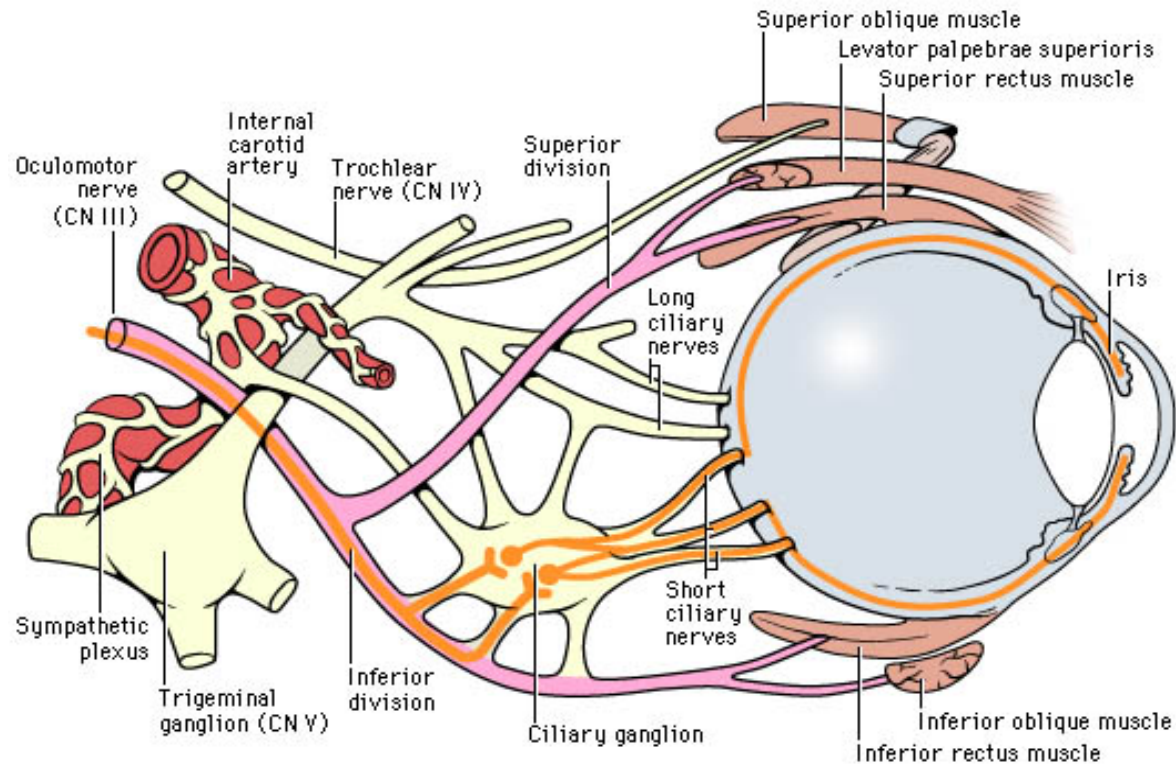
Parasympathetic fibers leave the brain stem by way of four cranial nerves

1. Oculomotor nerve (CN III)
2. Facial nerve (CN VII)
3. Glossopharyngeal nerve (CN IX)
4. Vagus nerve (CN X)

Parasympathetic Division: Oculomotor Nerve (CN III)

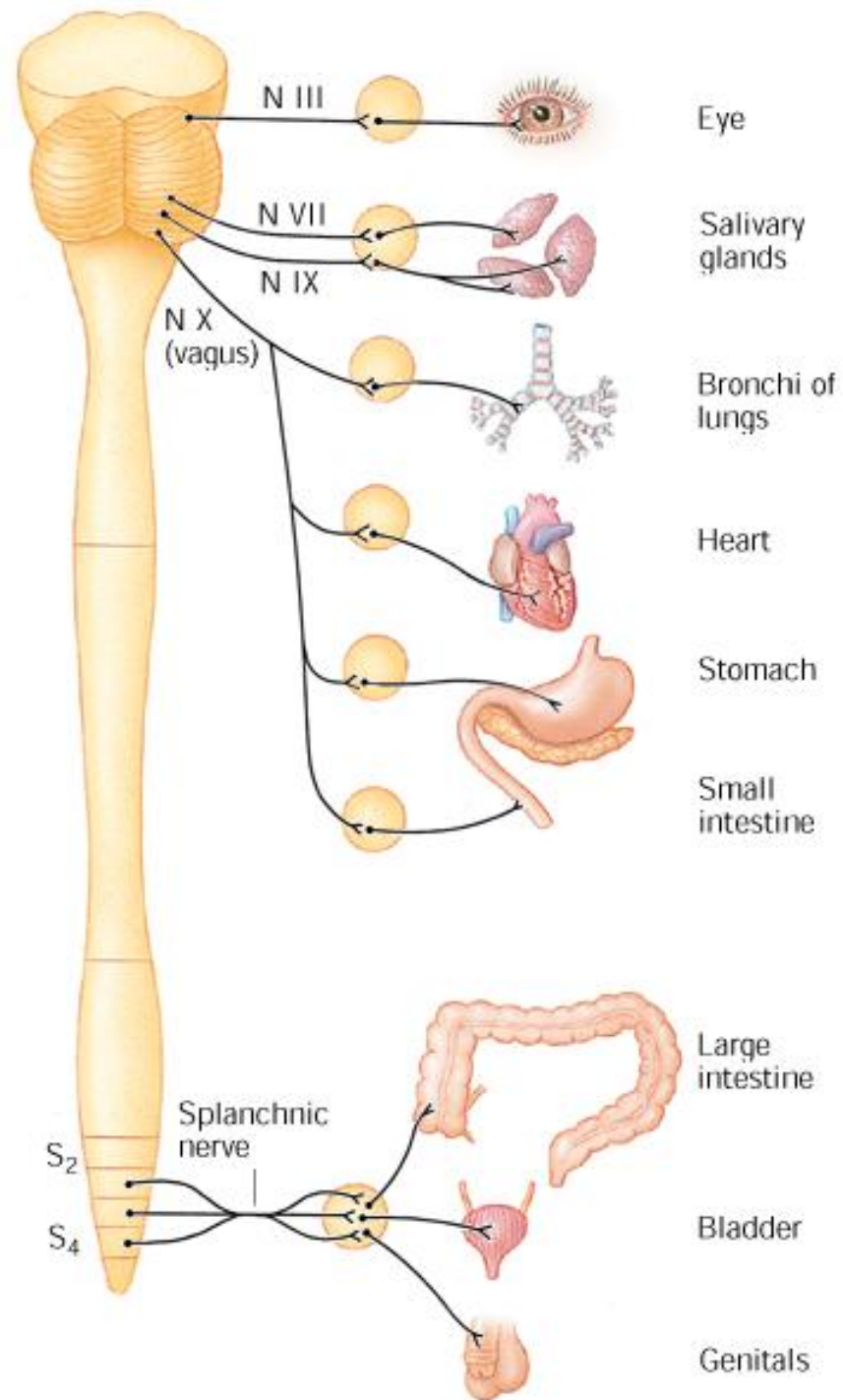
oculomotor (III)- fibers control lens and pupil of eye

- preganglionic fibers enter the orbit and terminate in the **ciliary ganglion**
- postganglionic fibers enter the eyeball and innervate the **ciliary muscle** (thickens the lens), and the **pupillary constrictor**, which narrows the pupil



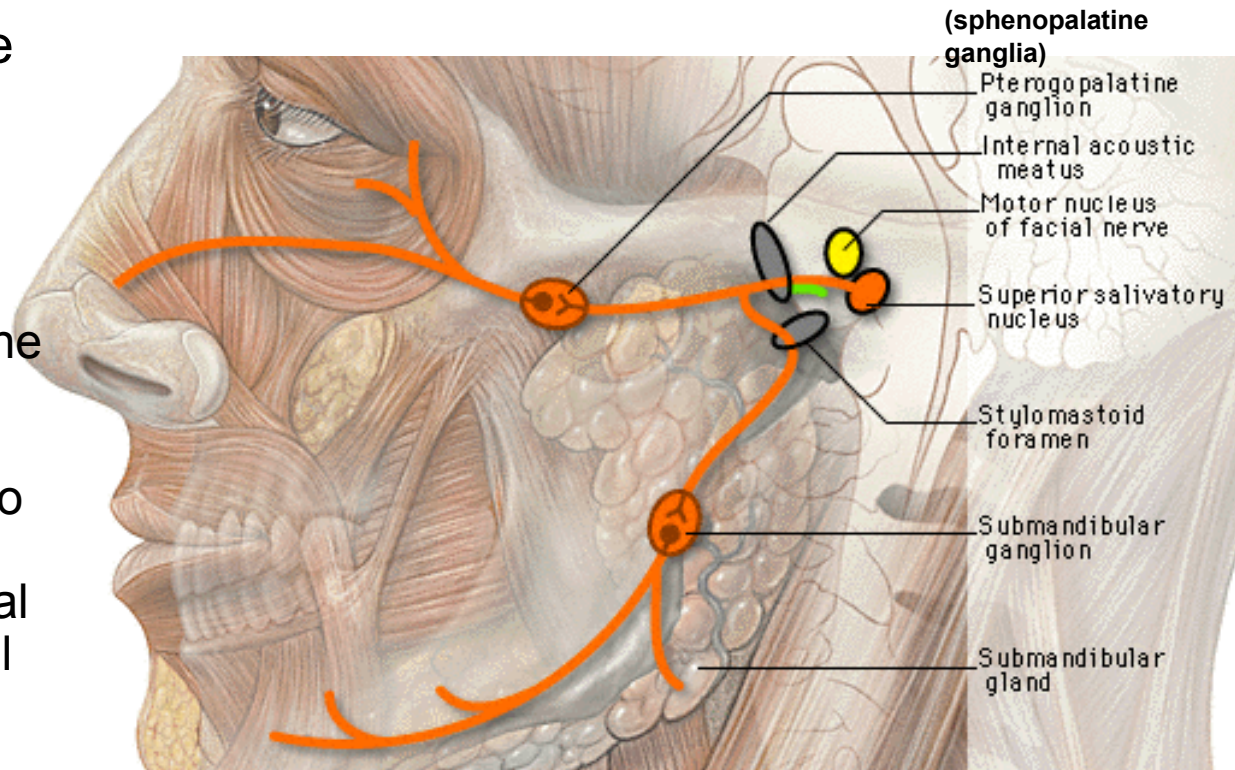
Parasympathetic Division: Facial Nerve (CN VII)

- **Facial nerve (VII)**
 - fibers regulate the tear glands, salivary glands, and nasal glands
 - parasympathetic fibers leave pons and form two branches that end at the
 - **sphenopalatine ganglion**
 - **submandibular ganglion**



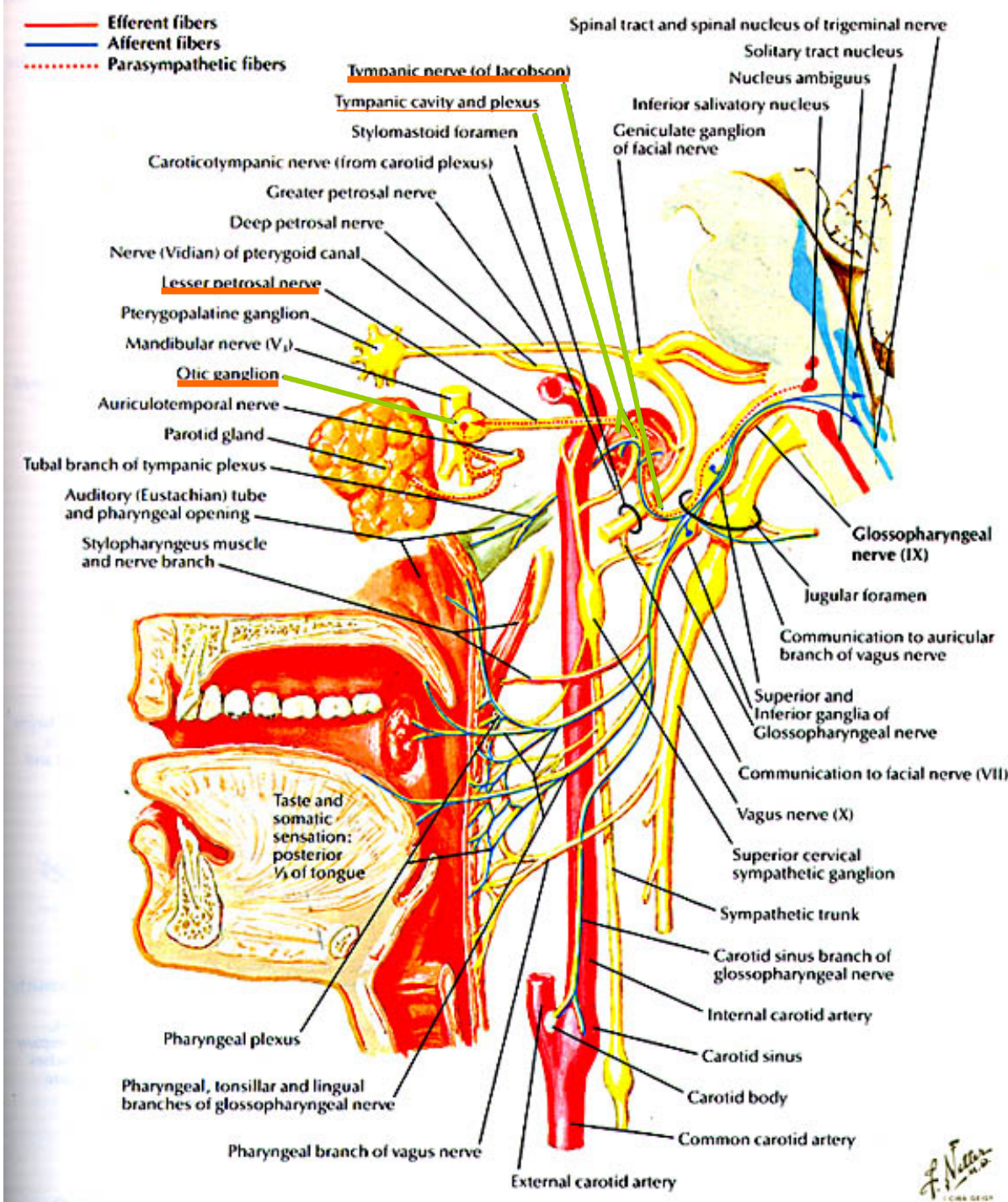
Facial Nerve (CN VII)

- soon after the facial nerve emerges from the pons, its parasympathetic fibers split and form two smaller branches
 - upper branch end at the **sphenopalatine ganglia** whose postganglionic fibers to innervate tear glands and glands of the nasal cavity, palate, and oral cavity
 - lower branch ends at the **submandibular ganglion** and whose postganglionic fibers supply the salivary glands in the floor of the mouth



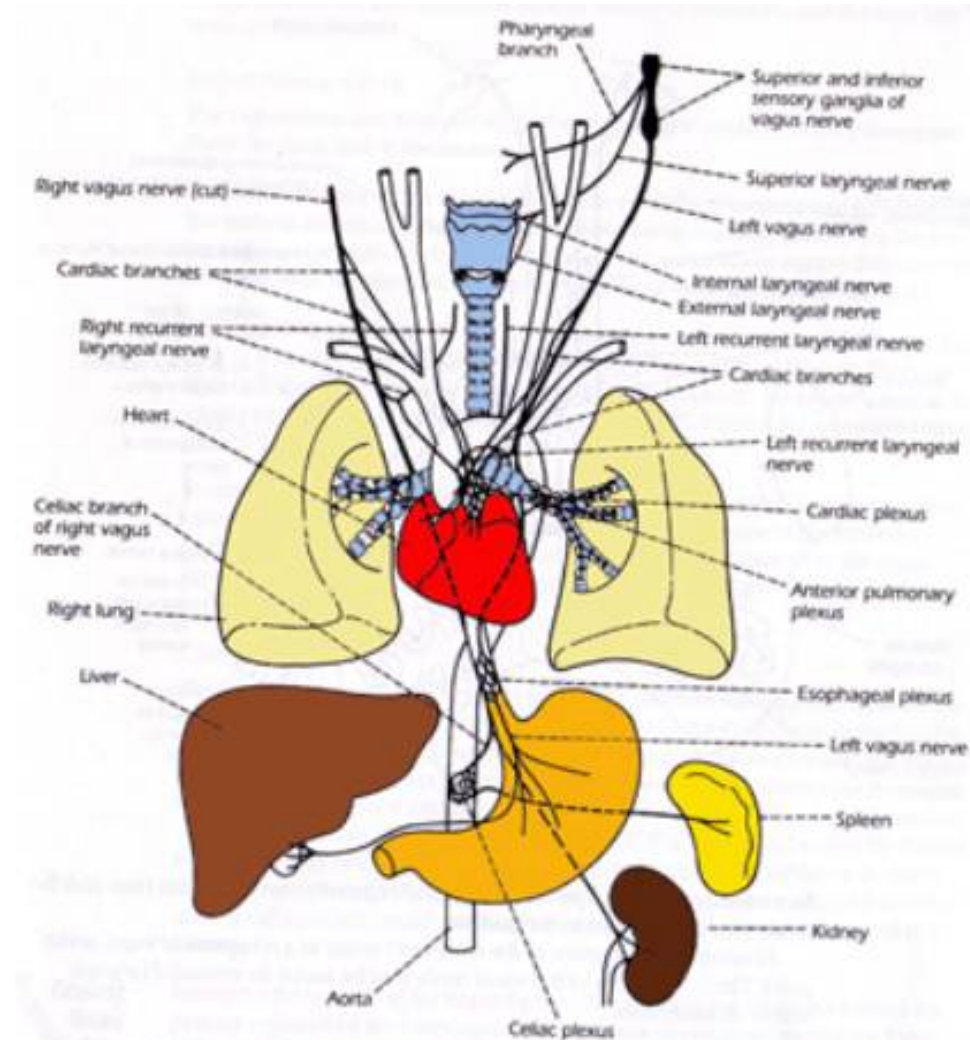
Glossopharyngeal Nerve (CN IX)

- parasympathetic fibers **concerned with salivation**
- leaves origin to form the **tympanic nerve** which crosses the eardrum and end at the **otic ganglion**
- postganglionic fibers terminate at the **parotid gland**

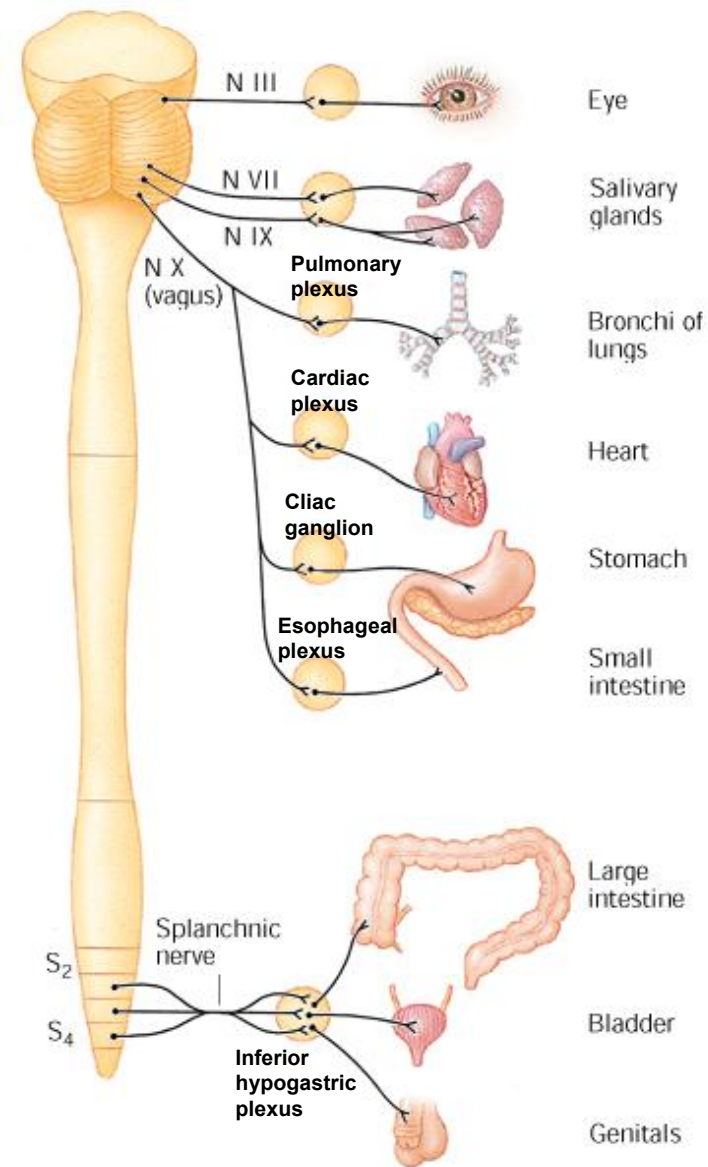


Vagus Nerve (CN X)

- carries about 90% of all parasympathetic fibers
- travels down the neck and forms three networks in the mediastinum
 - **cardiac plexus-** fibers to heart
 - **pulmonary plexus-** accompany bronchi and vessels into lungs
 - **esophageal plexus-** regulate swallowing



- The remaining parasympathetic fibers arise from S2-S4 to form the **pelvic splanchnic nerve** that leads to the inferior **hypogastric (pelvic) plexus**
- most fibers do not synapse here but pass on to their respective terminal ganglia in their target organs (distal half of the large intestine, the rectum, urinary bladder, and reproductive organs)
- **Parasympathetic fibers do not innervate body wall structures (sweat glands, piloerector muscles, or cutaneous blood vessels)**



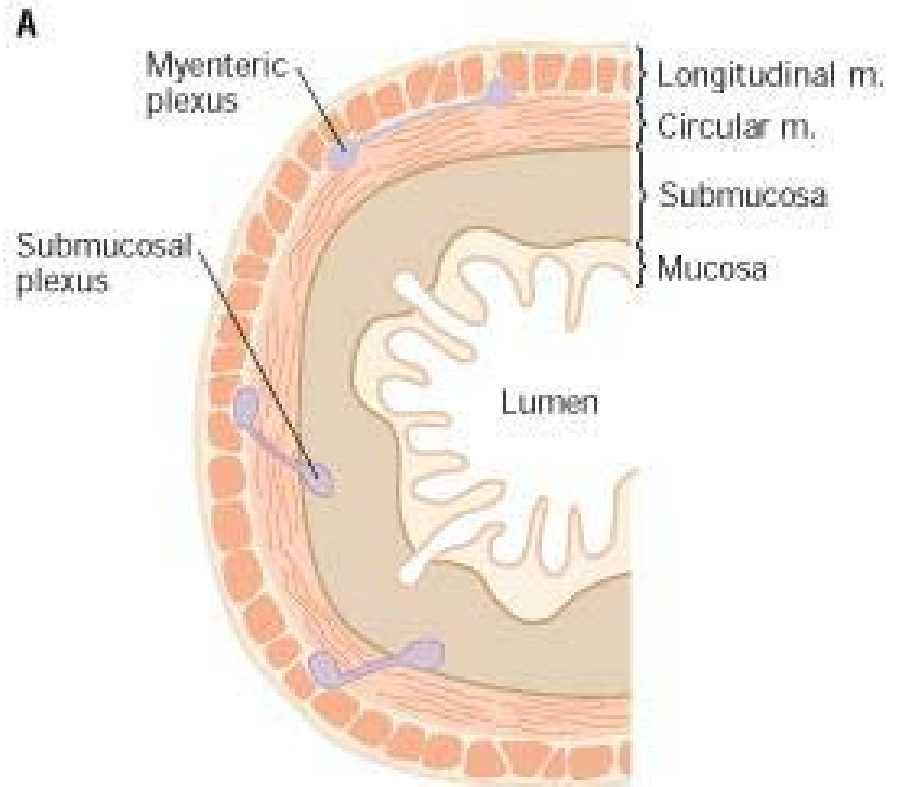
Feature	Sympathetic	Parasympathetic
Origin in CNS	thoracolumbar	craniosacral
Location of ganglia	paravertebral (adjacent to cord) & prevertebral	terminal ganglia or within target organ
Fiber lengths	short preganglionic long postganglionic	long preganglionic short postganglionic
neural divergence	extensive	minimal
effects of system	often wide spread and general	more specific and local

Enteric Nervous System

- Unlike the ANS, it does not arise from the brain stem or spinal cord
- Like the ANS, it innervates smooth muscles and glands
- Consist of millions of neurons embedded in the wall of the digestive tract.
- Forms two plexi
 - **Myenteric plexus**
 - Lies between layers of longitudinal and circular muscles of alimentary canal
 - Extends from pharynx to anus
 - **Submucosal plexus**
 - lies within submucosal layer of intestines, from the junction with the stomach to the anus

Controls activity of gastrointestinal tract in three ways:

- 1) controlling intestinal peristalsis
 - 2) modulating blood flow through gut
 - 3) regulating the release of secretions from gastrointestinal glands
- **Each of these activities can be influenced by sympathetic and parasympathetic input**

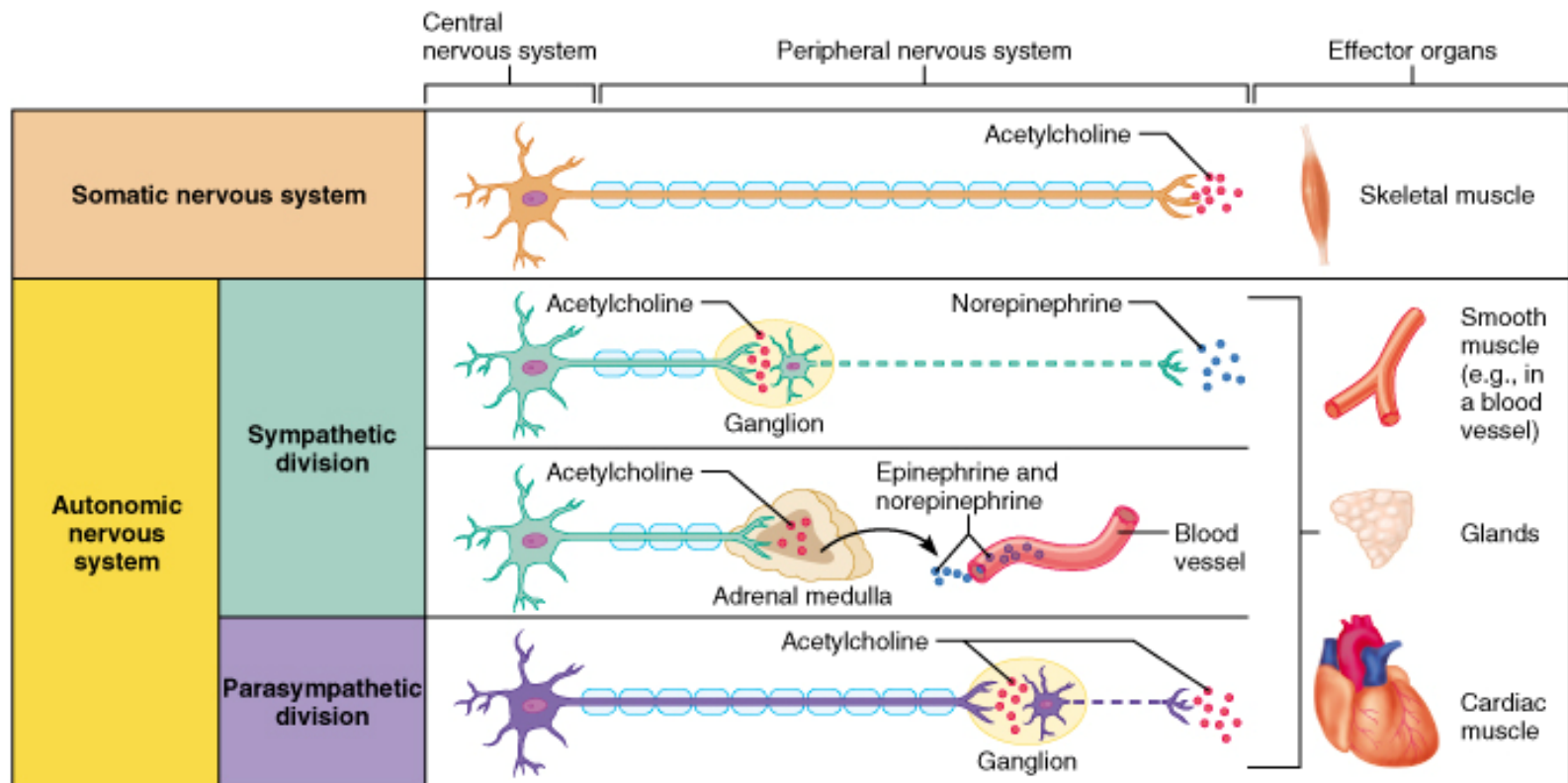


ANS Neurotransmitters

- The key to understanding the effects of the ANS lies in knowing **which neurotransmitter it releases** and **what kind of receptors occur on the target cells.**
- Neurotransmitters can be classified as either cholinergic or adrenergic neurons based upon the neurotransmitter released
Adrenergic

Neurotransmitters

- The ANS has both **cholinergic fibers** which secrete **acetylcholine (Ach)** and **adrenergic fibers** which secrete **norepinephrine (NE)**

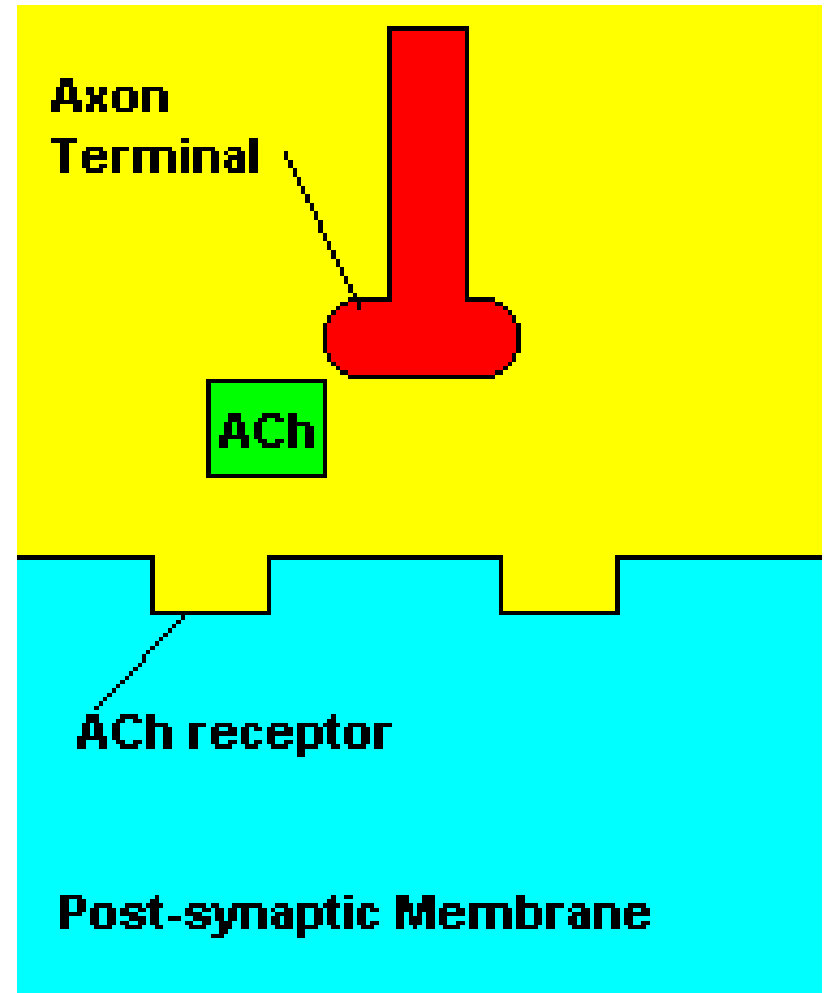


Key:

— = Preganglionic axons (sympathetic)
 - - - = Postganglionic axons (sympathetic)
 = Myelination
 — = Preganglionic axons (parasympathetic)
 - - - = Postganglionic axons (parasympathetic)

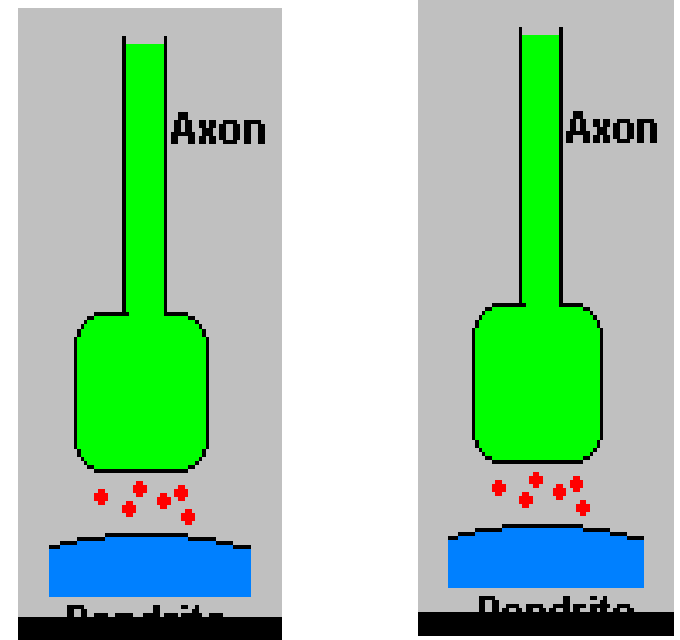
Fate of Acetylcholine

- after secretion by parasympathetic fibers, it is quickly broken down by acetylcholinesterase (AChase) in the synapse, thus its **effects last only a few seconds**



Fate of NE After Release

- some are reabsorbed by nerve fiber and either reused or broken down by the enzyme **monoamine oxidase (MAO)**
- some diffuse into the surrounding tissues, where it is degraded by another enzyme called **catechol-O-methyltransferase (COMT)**
- much of it is **picked up by the bloodstream**, where MAO and COMT are absent, then circulates throughout the body to exert synergistic effect with epinephrine from the adrenal gland
- thus sympathetic effects **tend to last longer than parasympathetic effects**

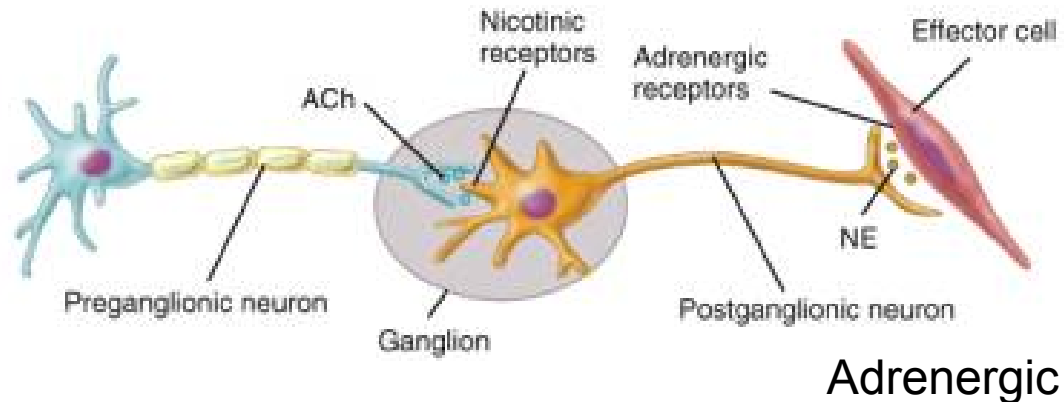
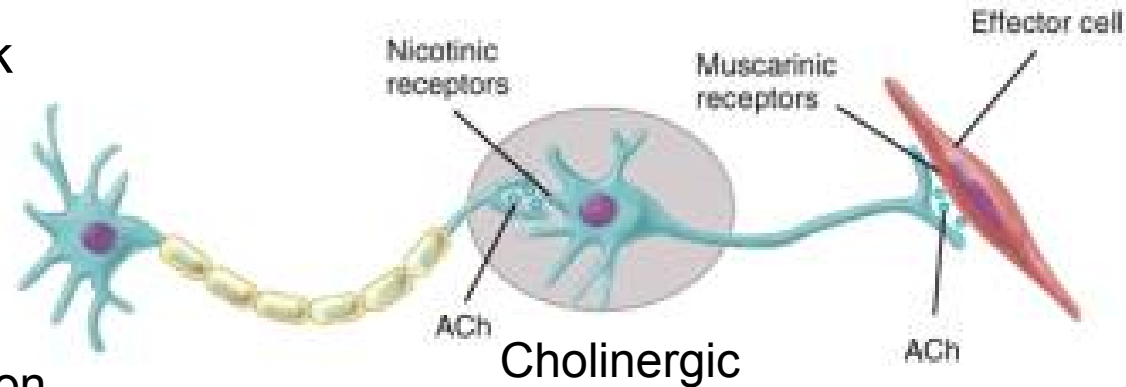


Receptors

- both the sympathetic and parasympathetic divisions have excitatory on some target cells and inhibitory effects on others
 - ex: parasympathetics contracts the urinary bladder but relaxes the urinary sphincter, using Ach for both purposes.
 - ex: sympathetics constrict most blood vessels but dilates the coronary arteries, using NE
- The different effects are not due to the transmitter but due to different receptors on the effector cells
- The receptors
 - for ACh are called **cholinergic**
 - NE are called **adrenergic**

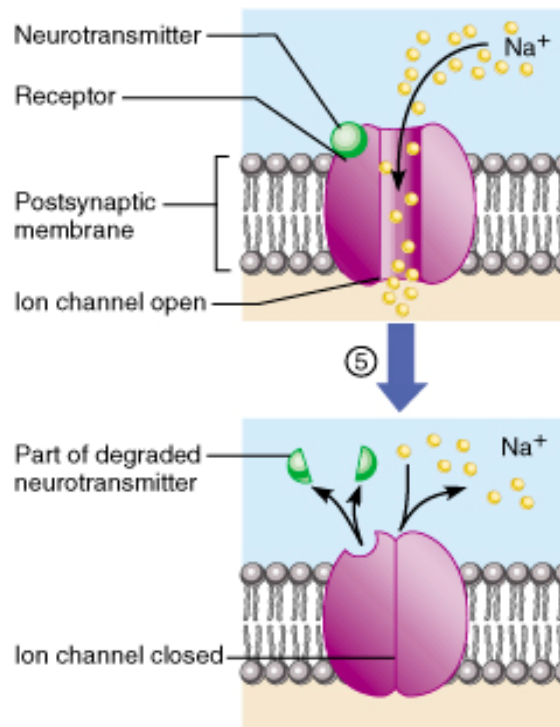
Cholinergic Receptors

- All cholinergic receptors work by opening ligand-gated ion channels and changing the postsynaptic potential of the target cell
- two classes
 - **nicotinic receptors**- occur on the postsynaptic cells, in all ganglia of the ANS, in the adrenal medulla, and in neuromuscular junctions
 - All cells with nicotinic receptors are excited by ACh
 - **muscarinic receptors**- occur on all gland, smooth muscle, and cardiac muscles cells that receive cholinergic innervation
 - some cells with muscarinic receptors are excited while others are inhibited by ACh

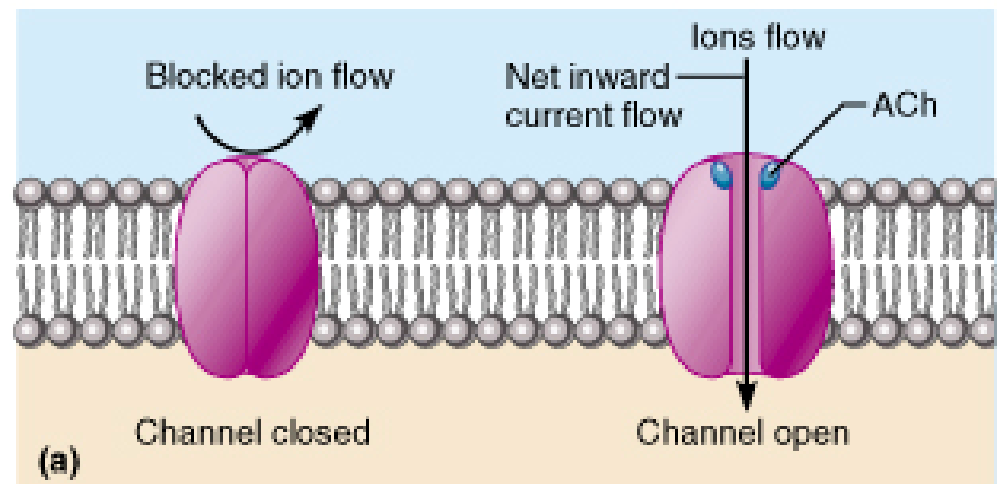


Cholinergic Nicotinic Receptors

- Mechanism of action is direct
- Use an ion-gated mechanism for signalling.
- Sufficient ligands cause an ion-channel to open, filling (or evacuating) a cell of a particular ion.
- Na^+ ion influx produces depolarization of the membrane, therefore, excitation

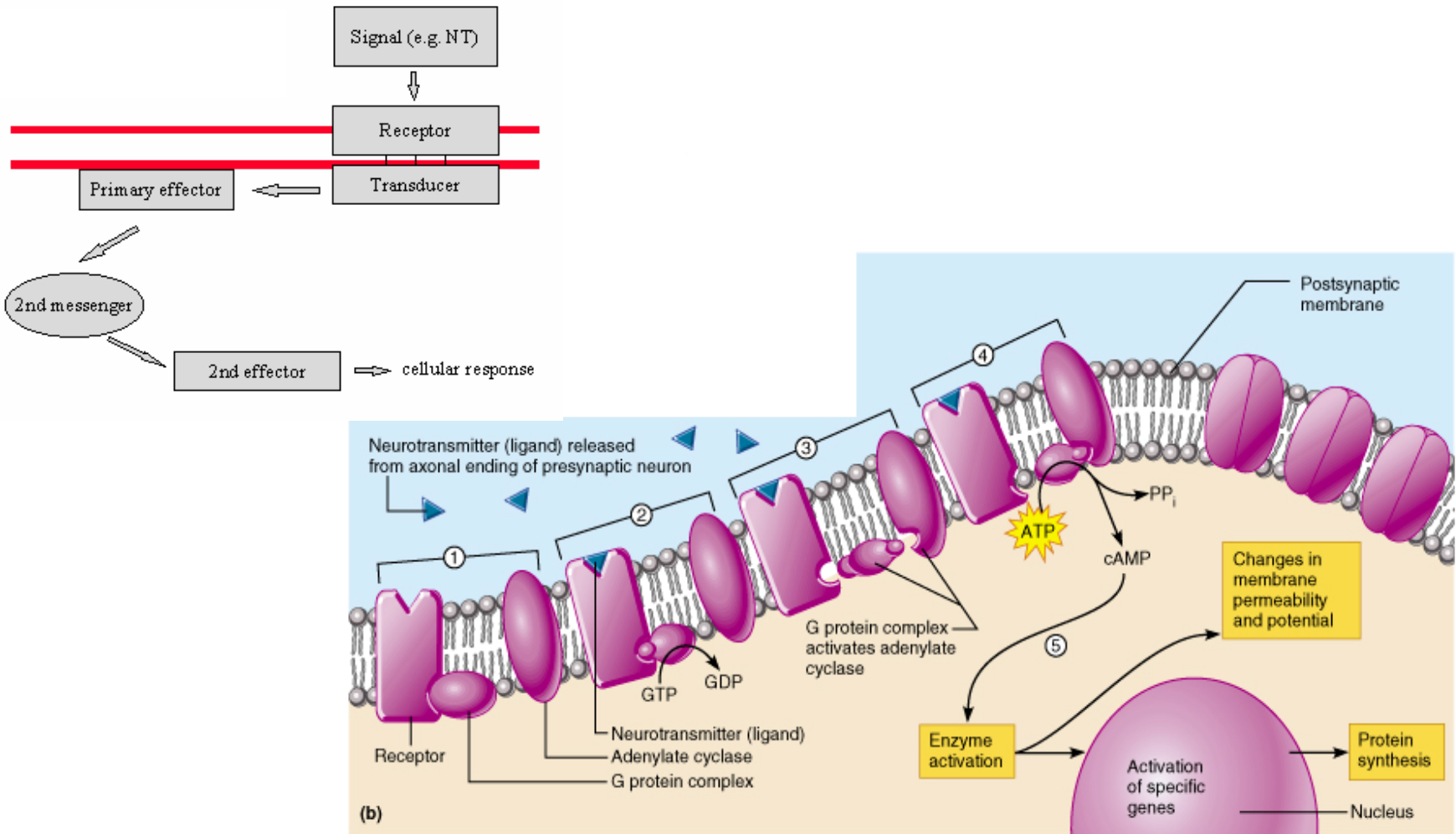


- if the efflux of k^+ ions is reduced, depolarization results and the effect is excitation
- if the efflux of k^+ ions is increased, hyperpolarization results and the effect is inhibition



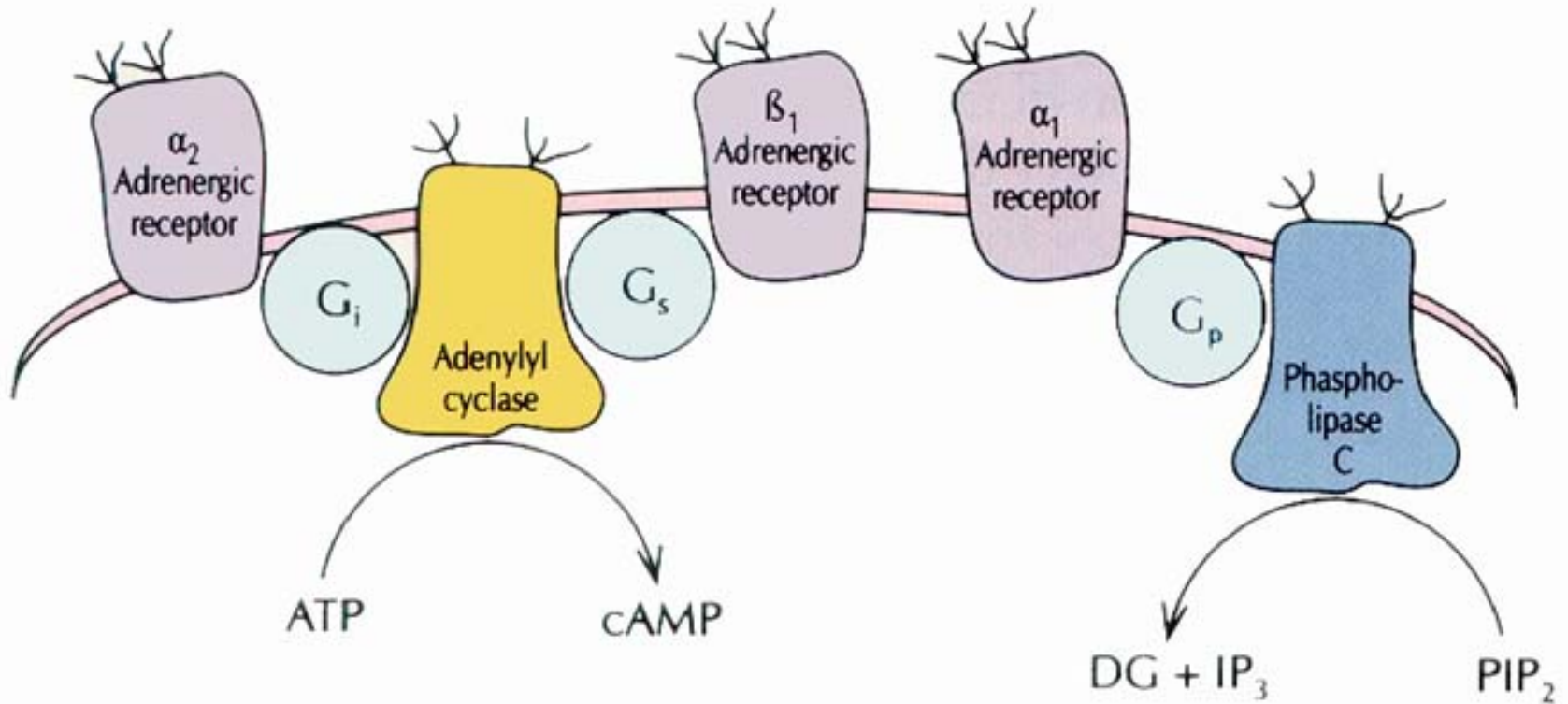
CHOLINERGIC MUSCARINIC RECEPTORS

- Mechanism of action is indirect
- Muscarinic receptors belong to a class of receptors which use G proteins as their signalling mechanism, which begin an information cascade within the cell.



Adrenergic Receptors

- Two classes
 - **alpha (α)** - usually excitatory
 - **beta (β)** - usually inhibitory
- There are exceptions to the above and it is due to the existence of subclasses of each receptor type: α_1 α_2 β_1 , β_2
 - all four types function by means of second messengers
 - both β receptors activate the production of cyclic AMP
 - α_2 suppress cAMP production and α_1 employ calcium ions as the second messenger



- Stimulation of **beta- or alph2-receptors** leads to activation of G_s or G_i , which then act as transducers to activate (G_s) or inhibit (G_i) adenylyl cyclase. This results in increased or decreased production of cAMP from ATP
- **alph1-Receptors** work through G_p , which activates phospholipase C to promote conversion of phosphatidyl inositol bisphosphate (PIP_2) to diacyl glycerol (DG) and inositol triphosphate (IP_3) which is involved in intracellular calcium regulation.

Dual Innervation

- Most of the viscera receive nerve fibers from both the sympathetic and parasympathetic divisions and thus are said to have **dual innervation**
 - divisions can either be
 - **antagonistic**- when effects oppose each other
 - ex: sympathetics speeds up heart while parasympathetics slow down the heart
 - **cooperative**- when divisions produce a unified overall effect
 - ex: salivation: parasympathetics stimulate serous cells and sympathetics stimulate mucous cells (both necessary components of saliva)
- Even though both divisions innervate a single organ, they may not always innervate it equally or have equal influence.

Control Without Dual Innervation

- Dual innervation is not always necessary to produce opposite effects.

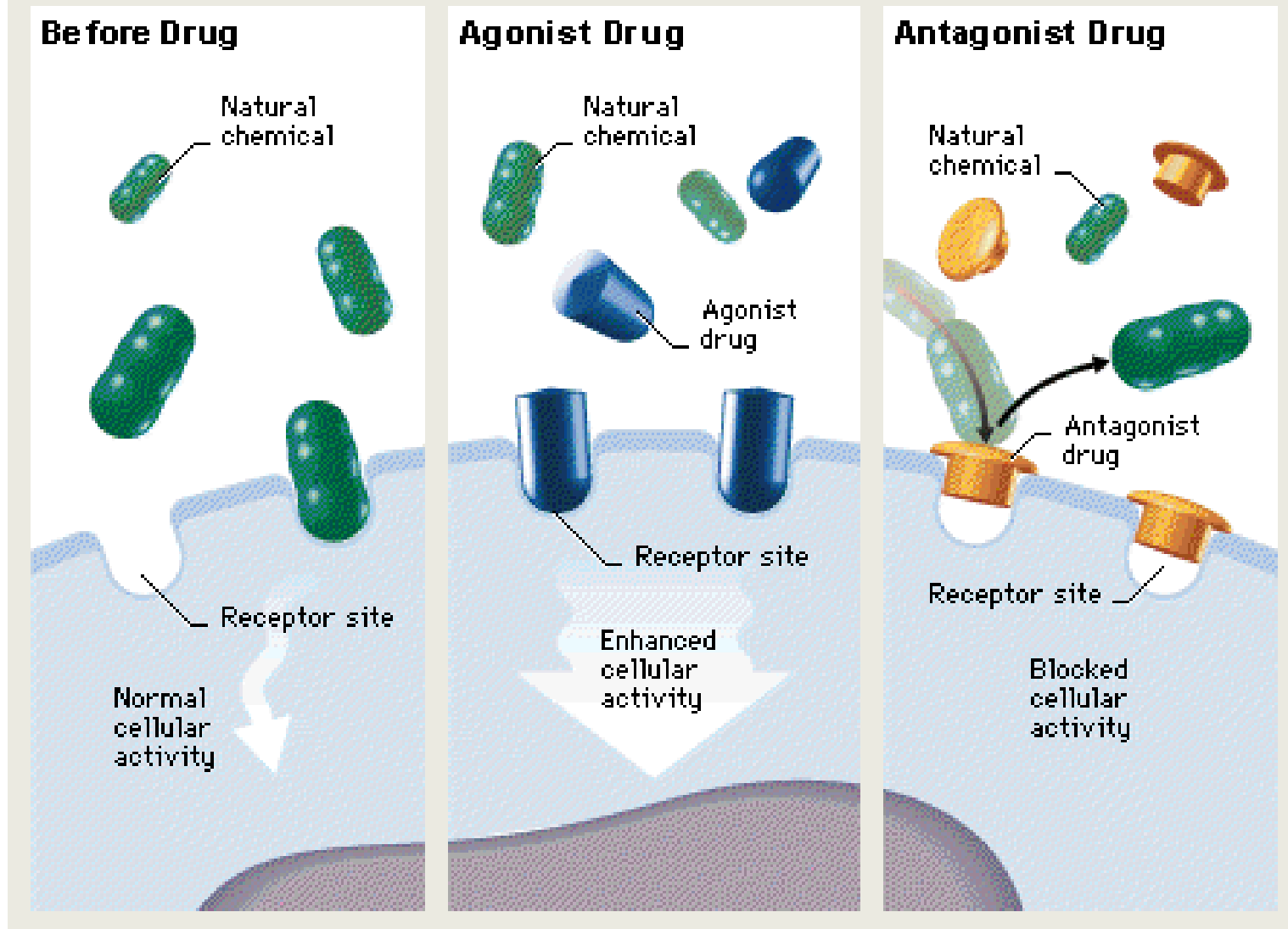
Ex: control of blood pressure

the sympathetic fibers of blood vessels have a baseline sympathetic tone which keeps the blood vessel in a state of partial constriction called **vasomotor tone**

- increase in firing rate causes vasoconstriction
- decrease in firing rate causes vasodilation (allowing the smooth muscle to relax).

The Influence of Other Systems on CNS

- **The limbic system-** provides a pathway connecting sensory and mental experiences with the autonomic nervous system
- **Hypothalamus-** the major control center of the visceral motor system
 - contains many nuclei for many primitive function (hunger, thirst, thermoregulation, emotions, and sexuality)
- **Brain stem-** houses the nuclei of cranial nerves that mediate several autonomic responses
- **Spinal cord-** autonomic responses as the defecation and micturition (urination) reflexes are integrated in the spinal cord
 - note these can be influenced by the higher brain centers
 - in severe spinal injuries, these reflexes alone control the elimination of urine and feces



- Certain drugs work by interacting with receptors
- Drugs may bind to a specific receptor, possibly preventing naturally occurring chemicals from binding to the receptor.
- if a drug enhances cell activity, it is called an *agonist*; if it blocks cell activity, it is called an *antagonist*.

Drugs and the Nervous System

- **Sympathomimetics**- drugs that enhance sympathetic action by stimulating adrenergic receptors or promoting norepinephrine release
- **Sympatholytics**- drugs that suppress sympathetic action by inhibiting norepinephrine release or by binding to adrenergic receptors without stimulating them

Drugs and the Nervous System

Parasympathomimetics- enhance
parasympathetic effects

Parasympatholytics- inhibit Ach release or
block its receptors