Systems Neuroscience

November 23, 2021

The autonomic nervous system

Daniel C. Kiper
kiper@ini.ethz.ch

http: www.ini.unizh.ch/~kiper/system_neurosci.html

How is the organization of the autonomic nervous system different from that of the somatic nervous system?

Autonomic Nervous System (ANS)

- Operates without conscious instruction
- Coordinates systems functions:
  - cardiovascular
  - respiratory
  - digestive
  - urinary
  - reproductive

Organization Similarities of SNS and ANS

Are efferent divisions

Carry motor commands:

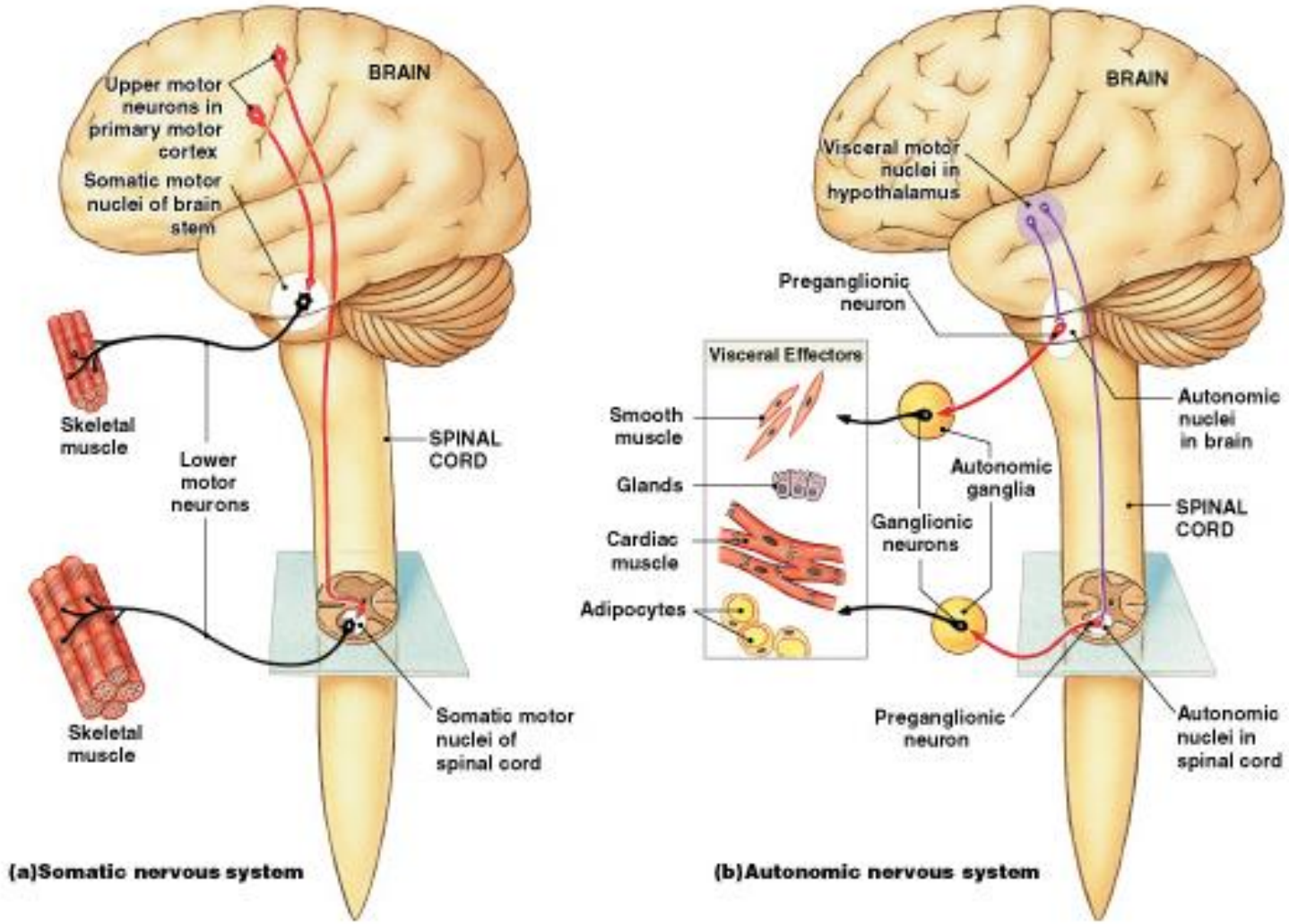
- SNS controls skeletal muscles
- ANS controls visceral effectors

The ANS

Motor neurons synapse on visceral motor neurons in autonomic ganglia

Ganglionic neurons control visceral effectors

Organization Similarities of SNS and ANS



Preganglionic Fibers

Axons of preganglionic neurons

Leave CNS and synapse on ganglionic neurons

Autonomic Ganglia

Peripheral ganglia

Contain many ganglionic neurons

Ganglionic neurons innervate visceral effectors:

- cardiac muscle
- smooth muscle
- glands
- adipose tissues

Postganglionic Fibers

Axons of ganglionic neurons

Begin at autonomic ganglia:

- extend to peripheral target organs

Somatic or Visceral Sensory Information

Trigger visceral reflexes

Motor commands of reflexes distributed by ANS

What are the divisions and functions of the ANS?

Sympathetic Division

"Kicks in" only during exertion, stress, or emergency

Parasympathetic Division

Controls during resting conditions

Divisions of the ANS

2 divisions may work independently:

- some structures innervated by only 1 division

2 divisions may work together:

- each controlling one stage of a complex process

Sympathetic Division

Preganglionic fibers (thoracic and superior lumbar) synapse in ganglia near spinal cord

Preganglionic fibers are short

Postganglionic fibers are long

Fight or Flight

Sympathetic division readies body for crisis

Increase in sympathetic activity:

- stimulates tissue metabolism
- increases alertness

Parasympathetic Division

- Preganglionic fibers originate in brain stem and sacral segments of spinal cord
- Synapse in ganglia close to (or within) target organs
- Preganglionic fibers are long
- Postganglionic fibers are short

Rest and Repose

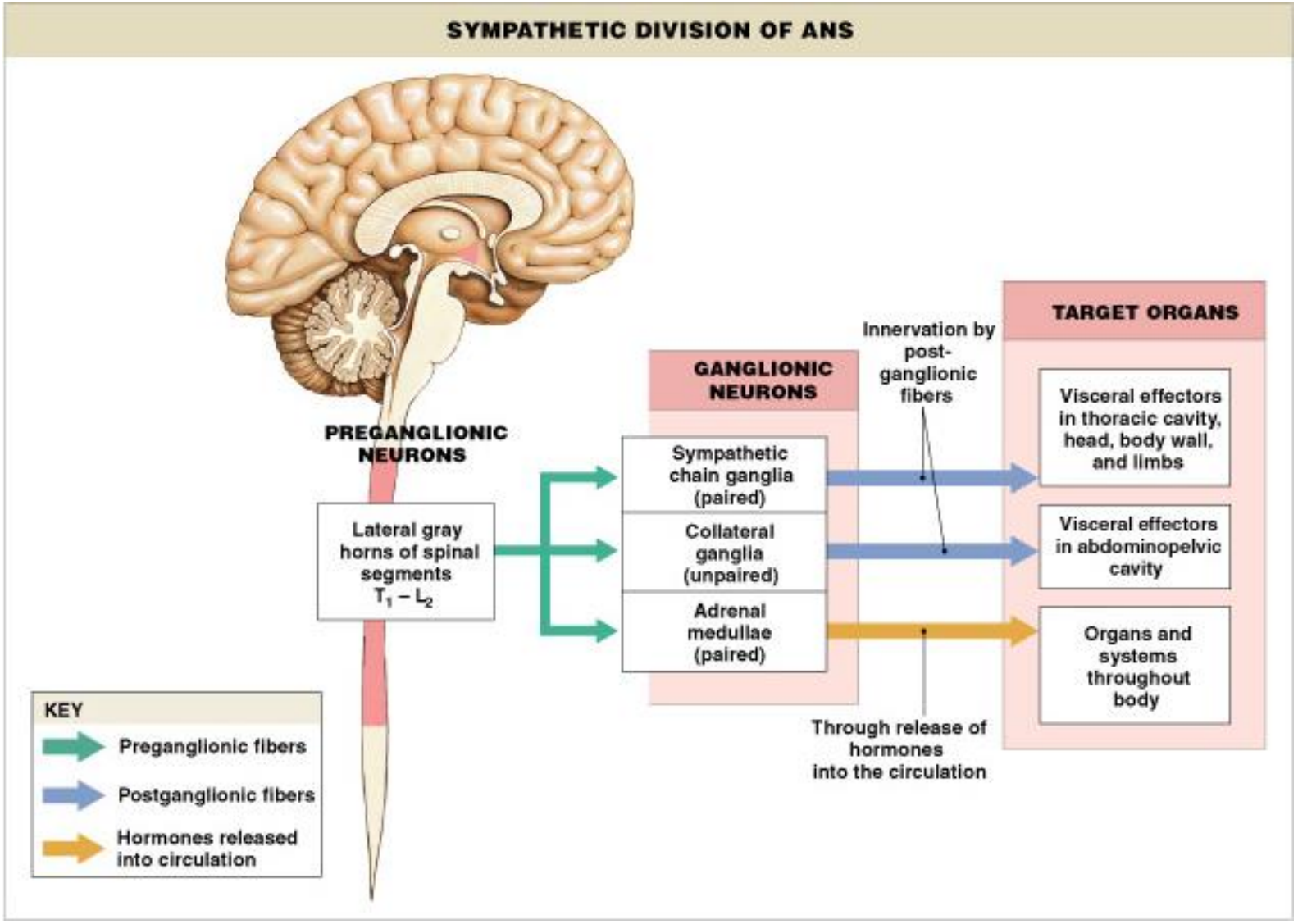
Parasympathetic division stimulates visceral activity

Conserves energy and promotes sedentary activities

Enteric Nervous System (ENS)

- Third division of ANS
- Extensive network in digestive tract walls
- Complex visceral reflexes coordinated locally
- Roughly 100 million neurons
- All neurotransmitters are found in the brain

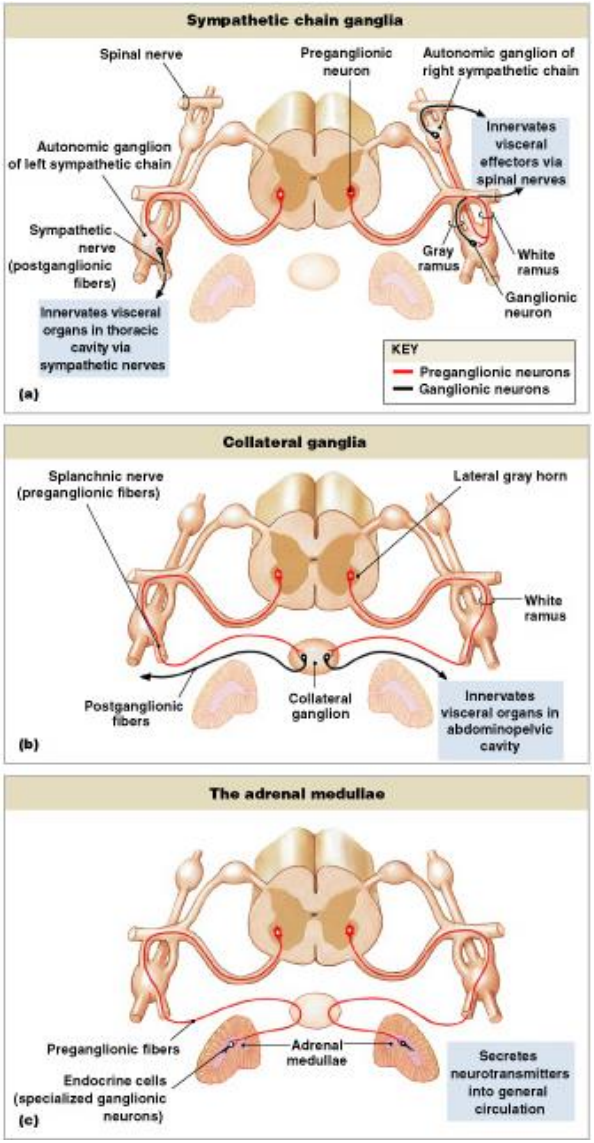
ANS: Sympathetic Division



Structure of the Sympathetic Division

- Preganglionic neurons located between segments T_1 and L_2 of spinal cord
- Ganglionic neurons in ganglia near vertebral column
- Cell bodies of preganglionic neurons in lateral gray horns
- Axons enter ventral roots of segments

SANS Ganglionic Neurons



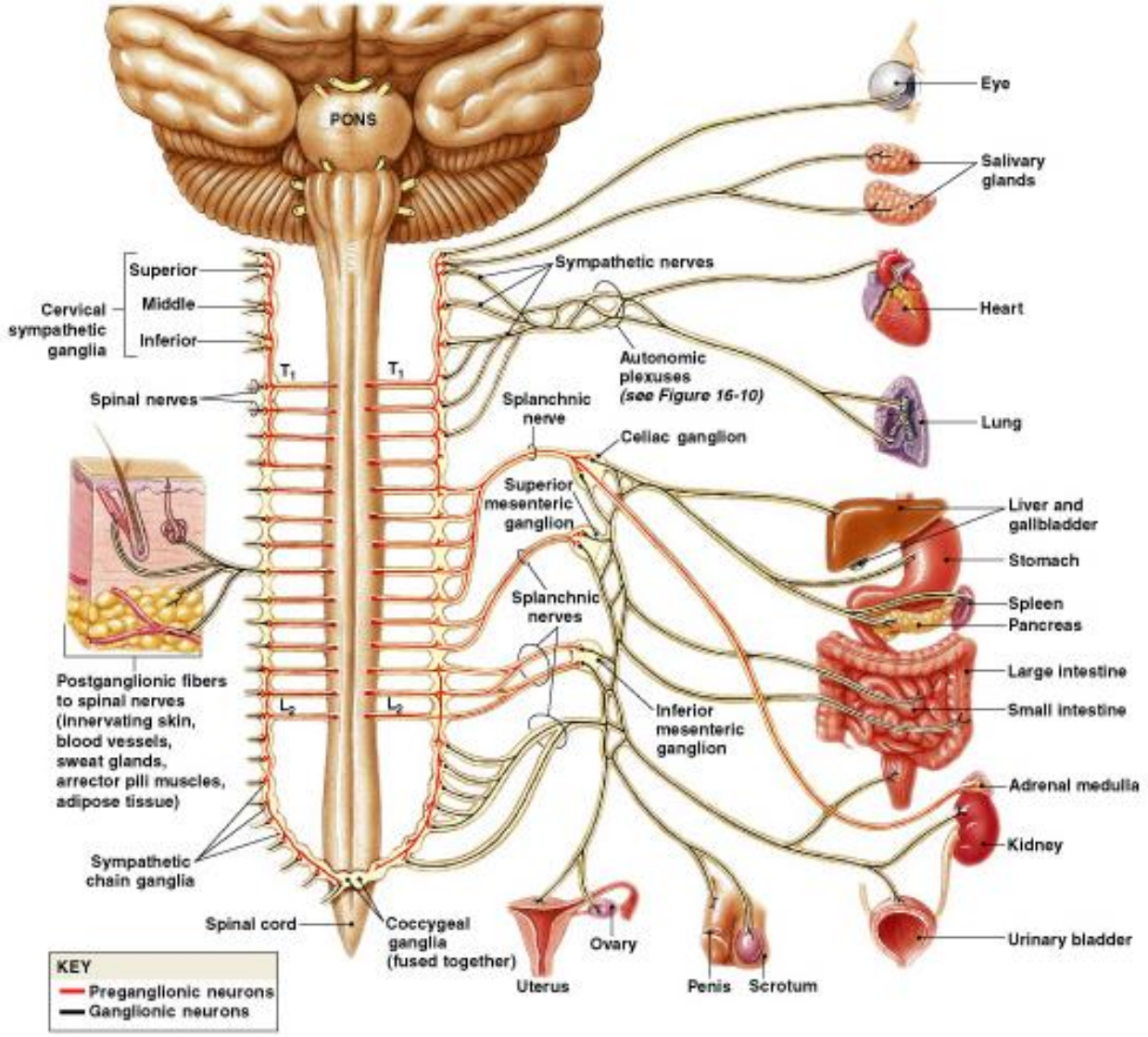
Occur in 3 locations:

- sympathetic chain ganglia
- collateral ganglia – innervate organs
- adrenal medullae

Organization of Sympathetic Division

Ventral roots of spinal segments T_1–L_2 contain sympathetic preganglionic fibers

Sympathetic Innervation



Adrenal Medulla

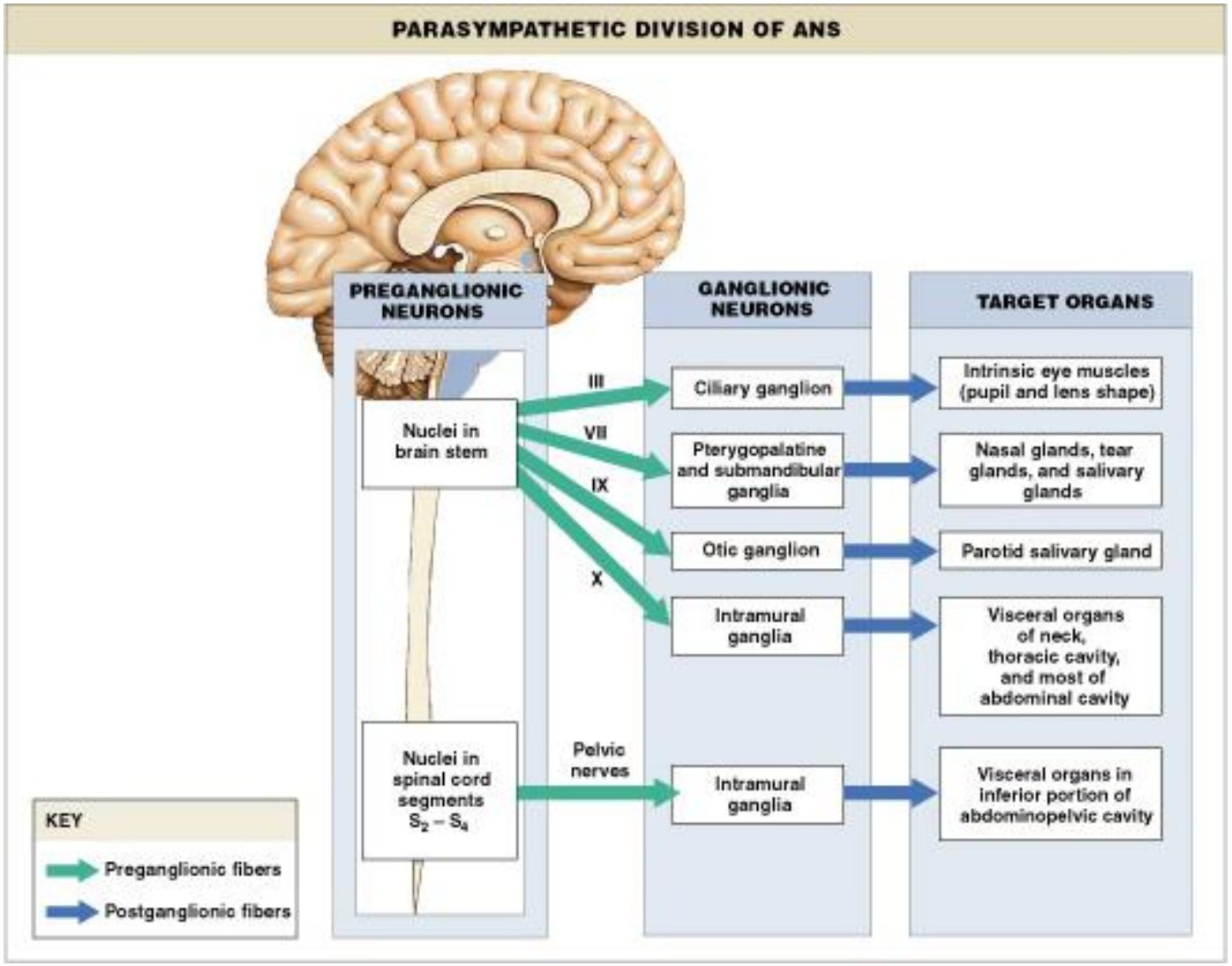
- Preganglionic fibers entering adrenal gland proceed to center (adrenal medulla)
- Modified sympathetic ganglion
- Preganglionic fibers synapse on neuroendocrine cells
- Specialized neurons secrete hormones into bloodstream

Generalized Sympathetic Activation

- Release of E by adrenal medulla
- Affect alpha and beta receptors throughout body
  - These work through G Proteins

What are the structures and functions of the parasympathetic division of the autonomic nervous system?

ANS: The Parasympathetic Division



Autonomic Nuclei

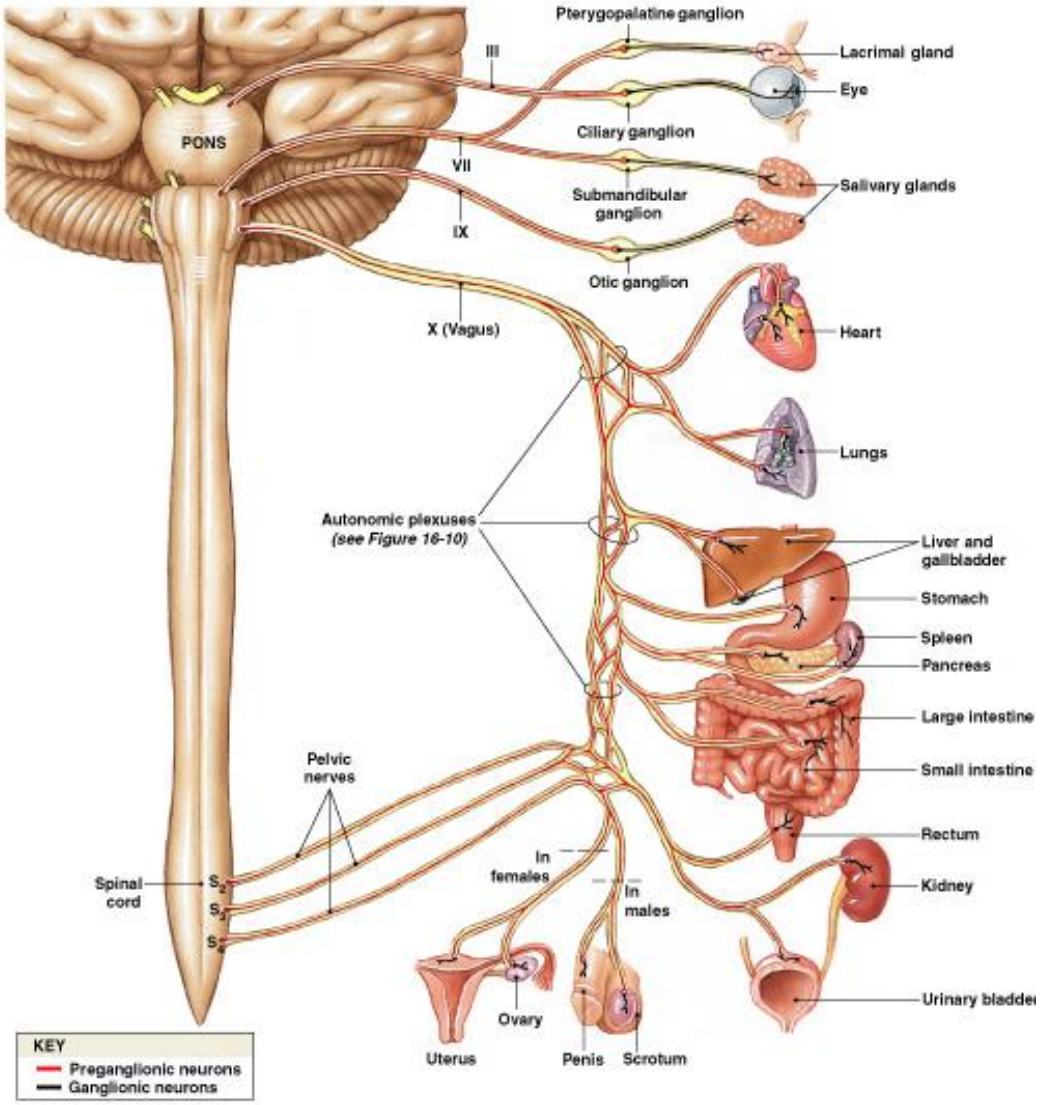
Are contained in the mesencephalon, pons, and medulla oblongata:

In lateral gray horns of spinal segments S_2–S_4

Ganglionic Neurons in Peripheral Ganglia

- Preganglionic fiber synapses on 6–8 ganglionic neurons:
  - terminal ganglion:
    - near target organ
  - intramural ganglion:
    - embedded in tissues of target organ

Parasympathetic Innervation



Vagus Nerve

Provides 75% of all parasympathetic outflow

Branches intermingle with fibers of sympathetic division

What are the effects of parasympathetic neurotransmitters on target organs and tissues?

Parasympathetic Activation

Centers on relaxation, food processing, and energy absorption

Localized effects, last a few seconds at most

Parasympathetic Neurons

All release ACh as neurotransmitter

Effects vary widely

Adrenergic and Cholinergic Receptors

| SUMMARY TABLE 16–1 | ADRENERGIC AND CHOLINERGIC RECEPTORS OF THE ANS

Receptor	Location(s)	Response(s)	Mechanism
ADRENERGIC			
α_1	Widespread, found in most tissues	Excitation, stimulation of metabolism	Enzyme activation; release of intracellular Ca^{2+}
α_2	Sympathetic neuromuscular or neuroglandular junctions	Inhibition of effector cell	Reduction of cAMP concentrations
	Parasympathetic neuromuscular or neuroglandular junctions	Inhibition of neurotransmitter release	Reduction of cAMP concentrations
β_1	Heart, kidneys, liver, adipose tissue*	Stimulation, increased energy consumption	Enzyme activation
β_2	Smooth muscle in vessels of heart and skeletal muscle; smooth muscle layers in intestines, lungs, bronchi	Inhibition, relaxation	Enzyme activation
CHOLINERGIC			
Nicotinic	All autonomic synapses between preganglionic and ganglionic neurons; neuromuscular junctions of SNS	Stimulation, excitation; muscular contraction	Opening of chemically regulated Na^+ channels
Muscarinic	All parasympathetic and cholinergic sympathetic neuromuscular or neuroglandular junctions	Variable	Enzyme activation causing changes in membrane permeability to K^+

*Adipocytes also contain an additional receptor type, β_3, not found in other tissues. Stimulation of β_3 receptors causes lipolysis.

Comparing Sympathetic and Parasympathetic Divisions

Sympathetic:

- widespread impact
- reaches organs and tissues throughout body

Parasympathetic:

- innervates only specific visceral structures

Sympathetic and Parasympathetic Divisions

| SUMMARY TABLE 16–2 | A STRUCTURAL COMPARISON OF THE SYMPATHETIC AND PARASYMPATHETIC DIVISIONS OF THE ANS

Characteristic	Sympathetic Division	Parasympathetic Division
Location of CNS visceral motor neurons	Lateral gray horns of spinal segments T_1–L_2	Brain stem and spinal segments S_2–S_4
Location of PNS ganglia	Near vertebral column	Typically intramural
Preganglionic fibers		
Length	Relatively short	Relatively long
Neurotransmitter released	Acetylcholine	Acetylcholine
Postganglionic fibers		
Length	Relatively long	Relatively short
Neurotransmitter released	Normally NE; sometimes NO or ACh	Acetylcholine
Neuromuscular or neuroglandular junction	Varicosities and enlarged terminal knobs that release transmitter near target cells	Junctions that release transmitter to special receptor surface
Degree of divergence from CNS to ganglion cells	Approximately 1 : 32	Approximately 1 : 6
General function(s)	Stimulates metabolism; increases alertness; prepares for emergency ("fight or flight")	Promotes relaxation, nutrient uptake, energy storage ("rest and repose")

What is the relationship between the two divisions of the autonomic nervous system, and the significance of dual innervation?

Dual Innervation

Most vital organs receive instructions from both sympathetic and parasympathetic divisions

2 divisions commonly have opposing effects

Autonomic Tone

Is an important aspect of ANS function:

- if nerve is inactive under normal conditions, can only increase activity
- if nerve maintains background level of activity, can increase or decrease activity

Somatic and Visceral Motor Pathways

Many parallels in organization and function

Integration at brain stem

Both systems under control of higher centers