Autonomic nervous system (visceral motor system):

- Adjust our basic life support sytem without our consious control
- Somatic (or visceral sensory) can trigger visceral reflex (responses to stimuli in visceral organs) -> the ANS distributes the motor commands of those reflexes
- Visceral motor neurons in the brainstem and spinal cord are known as **preganglionic neurons** (because they extend ganglia)
    - They are part of visceral reflex arcs
- The axons of preganglionic neurons are called **preganglionic fibres**
    - They leave the CNS and synapse on **ganglionic neurons or postganglionic neurons** (visceral motor neurons in peripheral ganglia)
    - These ganglia are called **autonomic ganglia**
    - Ganglionic neurons innervate visceral effectors such as smooth muscle, glands, cardiac muscle and adipocytes
    - The axons of ganglionic neurons are called **postganglionic fibres** because they begin at the autonomic ganglia and extend to the peripheral target organs

Divisions of the ANS:

- Two subdivisions of ANS: sympathetic and parasympathetic
- They work separately and together

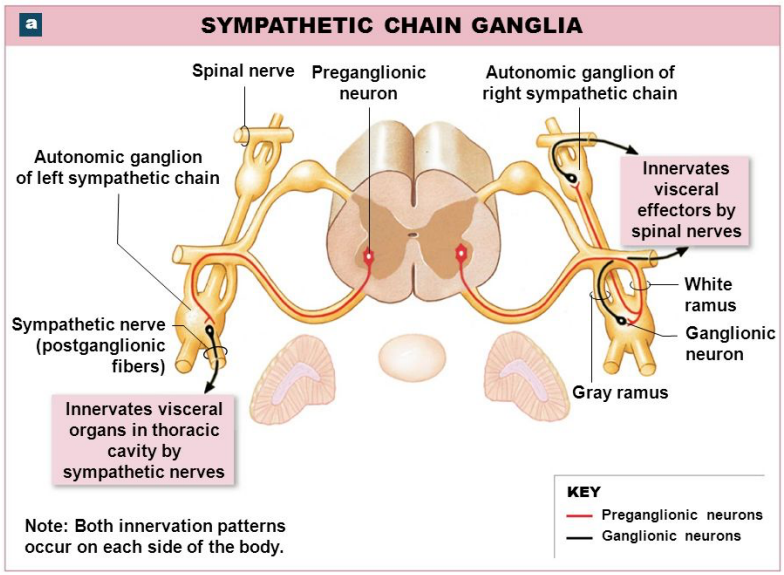
Sympathetic Division:

- fight or flight
- Heightened mental alertness, increased metabolic rate, decreased digestive and urinary functions, activation of energy reserves, increased respiratory rate and dialation of respiratory passageways, increased heart rate and blood pressure, activation of seat glands
- Sympathetic division has short preganglionic fibres and long postganglionic fibres and is involved in using energy and increasing metabolic rate
- Short preganglionic fires in thoracic and lumbar segment of the spinal cord
    - This division is also called thoracolumbar division (preganglionic neurons are located between segments T1 and L2 of the spinal cord)
    - The cell bodies of preganglionic neurons are in the lateral horns, and their axons enter the anterior roots of these segments
- The preganglionic fibres are relatively short because the ganglia are located near the spinal cord-> they release Ach, stimulating ganglionic neurons
- The postganglionic fibres are relatively long -> they are targeting organs
- Where ganglionic neurons synapse, or which pathway they follow, determines which target organs they will affect–> these neurons may synapse in three locations:
    - **Sympathetic chain ganglia:** also called paravertebral ganglia, lie on each side of the vertebral column -> neurons in these ganglia control effectors in the body wall, the thoracic cavity, head, neck and limbs
    - **Collateral ganglia:** also known as prevertebral ganglia, are anterior to the vertebral column ->ganglionic neurons innervate abdominopelvic tissues and viscera
    - **Adrenal medulla:** the centre of each adrenal gland, modified sympathetic ganglion. The ganglionic neurons have very short axons-> when these medullary cells are stimulated, they secrete neurotransmitters directly into the bloodstream, not at a synapse -> neurotransmitters function as hormones -> affects target cells throughout the body

Sympathetic chain ganglia pathway: Upper body

- If a preganglionic fiber carries motor commands targeting structures in the body wall, thoracic cavity, head, neck, limbs it synapses in one or more sympathetic chai ganglia
- Preganglionic neurons are limited to spinal cord segments T1-L2 -> these spinal nerves have both white rami communicants (myelinated preganglionic fibers) and grey rami (unmyelinated postganglionic fibres)
- The unmyelinated postganglionic fibres follows one of two different paths, depending where the targets lie:
    1. Postganglionic fibres that control visceral effectors in the body wall, head, neck and limbs enter the grey ramus communicans and return to the spinal nerve for subsequent distribution. These postganglionic fibres innervate sweat glands, smooth muscle in superficial blood vessels, and arreceptor pili muscles in the skin (Goosebumps)
    2. Postganglionic fibres innervating visceral organs in thoracic cavity, such as heart and lungs, form bundles known as **sympathetic nerves**
- The cervical, inferior lumbar, and sacral chain ganglia receive preganglionic fibres from spinal segments T1-L2
- Only the thoracic and superior lumbar ganglia receive preganglionic fibres from white rami communicates
- Every spinal nerve receives a grey ramus communicans from a ganglion of the sympathetic chain

Figure 16-3a Sites of Ganglia in Sympathetic Pathways.



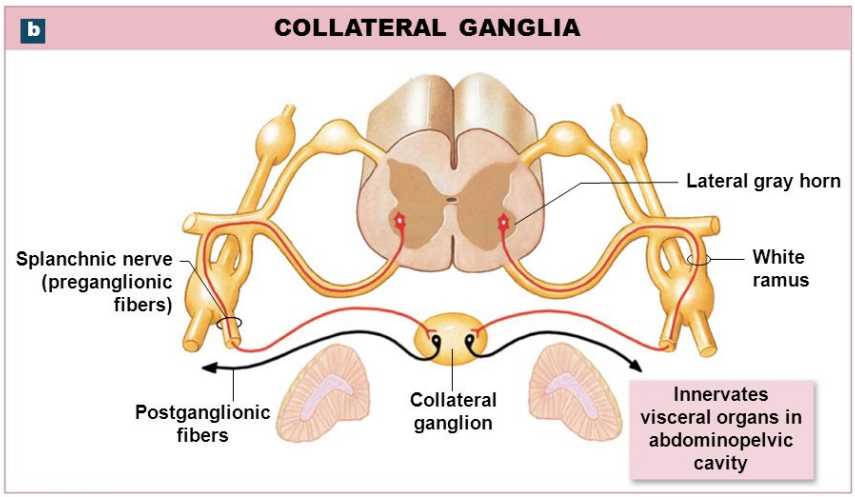
Collateral ganglia pathway: Abdominopelvic cavity

- The abdominopelvic viscera receive sympathetic innervation by sympathetic preganglionic fibres that synapse in separate collateral ganglia
- These fibres pass through the sympathetic chain without synapsing
- -> they form the splanchnic nerves, which lie in the posterior wall of the abdominal cavity
- Postganglionic fibres leaving the collateral ganglia extend throughout the abdominopelvic cavity, innervating a variety of visceral organs and tissues
    - They general function is to reduce blood flow and energy use by organs that are not important to immediate survival and released stored energy
- The preganglionic splanchnic nerves innervate three collateral ganglia (preganglionic fibres from the seven inferior thoracic spinal segments end at either the celiac ganglion or superior

mesenteric ganglion, preganglionic fibres from the lumbar segments form splanchnic nerves that end at the inferior mesenteric ganglion)

- **Celiac ganglion:**
  - Named after celiac trunk (major artery and its branches supplying the stomach, spleen and liver)
  - Commonly consists of a pair of interconnected masses of grey matter located at the base of that artery
  - Celiac ganglion may also form a single mass of many small interwoven masses
  - Postganglionic fibres from this ganglion innervate stomach, liver, gallbladder, pancreas and spleen
- **Superior mesenteric ganglion:**
  - Found near the base of the superior mesenteric artery (provides blood to the stomach, small intestine, pancreas)
  - Postganglionic fibres leaving the superior mesenteric ganglion innervate the small intestine and the proximal 2/3 of the large intestine
- **Inferior mesenteric ganglion:**
  - Located near base of the inferior mesenteric artery (supplies the large intestine and the other organs in the inferior portion of the abdominopelvic cavity)
  - Postganglionic fibres from this ganglion provide sympathetic innervation to the kidneys, urinary bladder, terminal segments of the large intestine and the sex organs

Figure 16-3b Sites of Ganglia in Sympathetic Pathways.

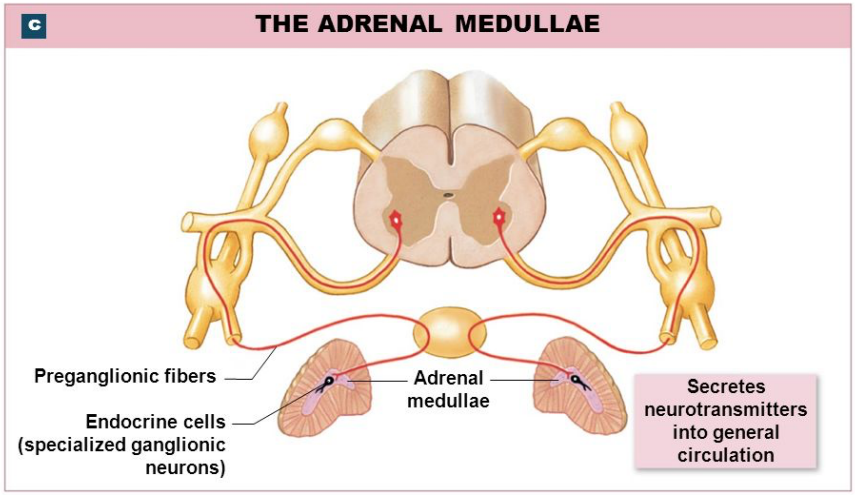


Adrenal Medulla Pathway: Metabolic Effects

- Preganglionic fibres entering an adrenal gland proceed to the central adrenal medulla
- In this modified sympathetic ganglion, preganglionic fibres synapse on secretory cells that secrete the neurotransmitters:
  - Epinephrine (or adrenaline)
  - Norepinephrine (or noradrenaline)
  - Epinephrine makes up 80% of the secretory output -> the rest is norepinephrine

- The bloodstream carries the neurotransmitter throughout the body, where they cause changes in the metabolic activities of many different cells
- Effects last much longer than those produced by direct sympathetic innervation, because chemicals continue to diffuse out of bloodstream for an extended period

Figure 16-3c Sites of Ganglia in Sympathetic Pathways.



Parasympathetic Division:

- rest and digest
- Degreased metabolic rate, decreased heart rate and blood pressure, increased secretion by salivary and digestive glands, increased motility and blood flow in the digestive tract, stimulation of urination and defecation
- Parasympathetic division has long preganglionic fibres and short postganglionic fibres and is involved in conserving energy and lowering metabolic rate
- This division consist of:
    - Long preganglionic fibres in the brainstem and in sacral segments of the spinal cord
        - All parts of the brainstem, the midbrain, pons and medulla oblongate contains autonomic. Nuclei associated with several cranial nerves. In sacral segments of the spinal cord, the parasympathetic nuclei lie in the lateral horns of spinal segments S2-S4.
    - Ganglionic neurons in peripheral ganglia within or adjacent to target organs
        - Preganglionic fibre of the parasympathetic division do not diverge as much as do those of sympathetic division
    - Short postganglionic fibres in or near target organs
- Parasympathetic fibres innervate organs of three main regions: the cranial, trunk, and pelvic regions
- Parasympathetic preganglionic fibres leave the brain in cranial nerves III (oculomotor), VII (facial), IX (glossopharyngeal) and X (vagus) -> these fibres carry the cranial parasympathetic output to visceral structures in the head -> these fibres synapse in the cilitary, pterygopalatine, submandibular and otic ganglia

- The vagus nerve alone provides 75% of all parasympathetic outflow -> it supplies preganglionic parasympathetic innervation to structures in the neck and in the thoracic and abdominopelvic cavities

Table 16–1 Adrenergic and Cholinergic Receptors of the ANS

Receptor	Location	Response	Mechanism
ADRENERGIC			
α_1	Widespread, found in most tissues	Excitation, stimulation of metabolism	Enzyme activation; intracellular release of Ca^{2+}
α_2	Sympathetic neuromuscular or neuroglandular junctions	Inhibition of effector cell	Reduction of cAMP concentrations
α_2	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 gated 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.

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 axonic terminals 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	Stimulates metabolism; increases alertness; prepares for emergency ("fight or flight")	Promotes relaxation, nutrient uptake, energy storage ("rest and digest")