

Lecture 34. Visceral Senses & the Autonomic Nervous System

Professor Nilay Yapici

Pre-lecture preparation – Posted on the course website before the lecture

Reading – Human Anatomy by Elaine N. Marieb, Patricia Brady Wilhelm, Chapter 15, pdf file will be posted on the course website

Optional Readings - : Posted on the course website before the lecture

Lecture Objectives

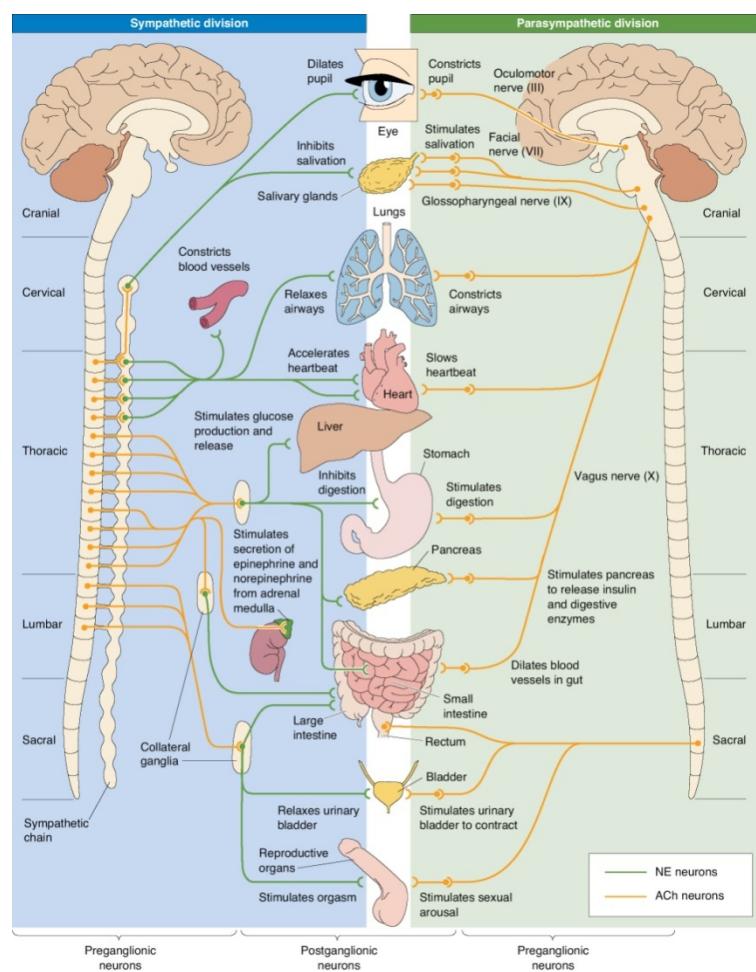
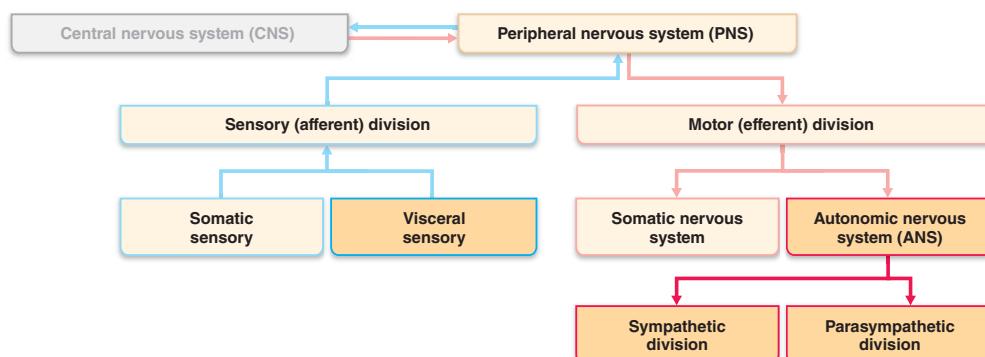
- Be able to understand the divisions of the autonomic nervous system (ANS) and their functions
- Be able to understand the functions of the ANS and differentiate between its sympathetic and parasympathetic divisions.
- Be able to understand the location and composition of the enteric division of the ANS, its functions and the inputs to this division.
- Be able to understand the function and divisions of the vagus nerve.

Lecture outline

- 1) Somatic Nervous System (SNS) is composed of somatic sensory receptors: special senses (sight, smell, hearing, taste & equilibrium). Somatic sensations are consciously received.
- 2) Autonomic nervous system maintains internal homeostasis; responds to subconscious visceral stimuli and excites or inhibits smooth & cardiac muscle as well as glands (endocrine & exocrine). It operates via reflex arcs.
- 3) Autonomic (Visceral) Sensory Receptors rely mostly on interceptors. Interceptors are sensory receptors located in visceral organs, smooth & cardiac muscles. Visceral senses are normally not received consciously. These receptors can be chemoreceptors or mechanoreceptors.
- 4) Sympathetic Division – “fight-or-flight”; increased alertness & metabolic activity.
- 5) Parasympathetic Division – “rest-and-digest”; conserve & restore energy.
- 6) Enteric Division – GI homeostasis; can & does function independently of CNS controlling GI, pancreas & GB by regulating motility and secretory activity.
- 7) Visceral sensory fibers run within the autonomic nerves, especially within the vagus and the sympathetic nerves. Most pain fibers from the visceral organs of the body follow the sympathetic pathway to the CNS and are carried in the spinothalamic tract to the thalamus and then to the visceral sensory cortex.
- 8) General visceral sensory neurons monitor temperature, pain, irritation, chemical changes, and stretch in the visceral organs.
- 9) Visceral pain is induced by stretching, infection, and cramping of internal organs but seldom by cutting or scraping these organs. Visceral pain is referred to somatic regions of the body that receive innervation from the same spinal cord segments.

Study questions:

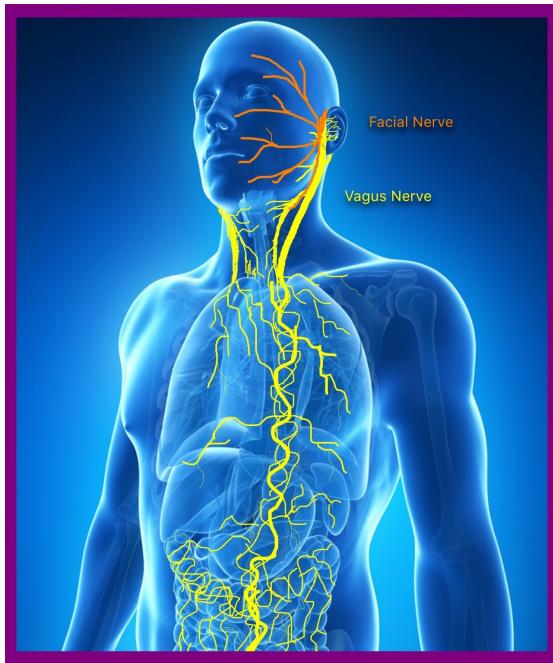
- 1) What is the difference between somatic and visceral sensory neurons?
- 2) What is the best way to describe how the autonomic nervous system (ANS) is controlled?
- 3) What effect does sympathetic activation have on each of the following structures? Sweat glands, pupils of the eye, adrenal medulla, heart, lungs, blood vessels of skeletal muscles, blood vessels of digestive viscera, salivary glands?
- 4) Why does a person with a spinal cord injury have no deficits in digestive function?



Lecture 34: Visceral Senses & the Autonomic Nervous System

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Office Hours: Wednesdays 2PM-5PM

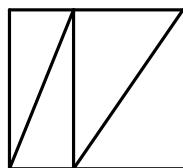


Learning objectives

- Be able to understand the divisions of the **autonomic nervous system (ANS)** and their functions
↑ things we do without knowing
- Be able to understand the functions of **the ANS** and differentiate between its **sympathetic** and **parasympathetic** divisions.
- Be able to understand the location and composition of **the enteric division** of the ANS, its functions and the inputs to this division.
- Be able to understand the function and divisions of the **vagus nerve**.

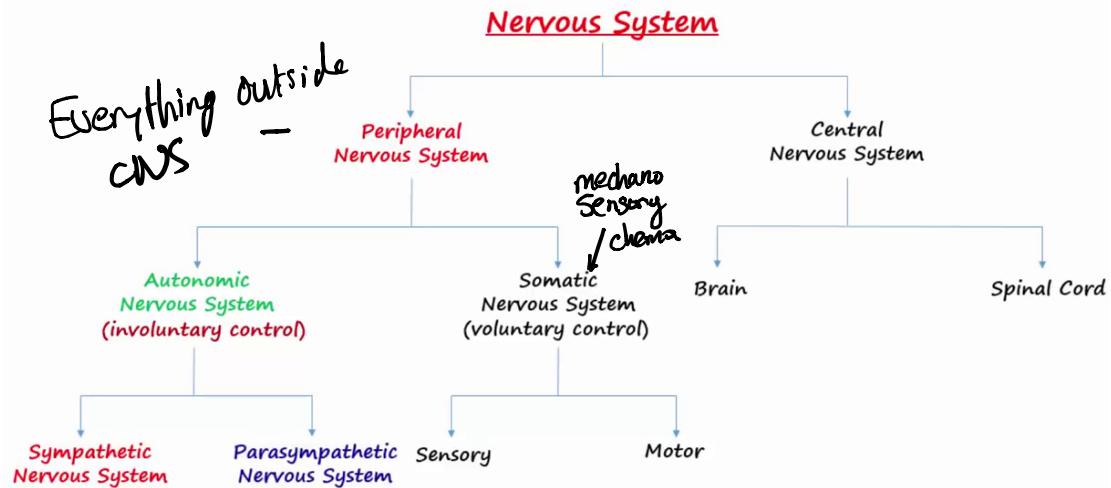
Autonomic nervous system (ANS)

- The autonomic nervous system is the system of neurons that innervate the smooth muscle, cardiac muscle, digestive system and glands of the body.



Autonomic nervous system (ANS)

- The ANS regulates such visceral functions as **heart rate**, **blood pressure**, **digestion**, and **urination**, which are essential for maintaining the stability of the body's internal environment.



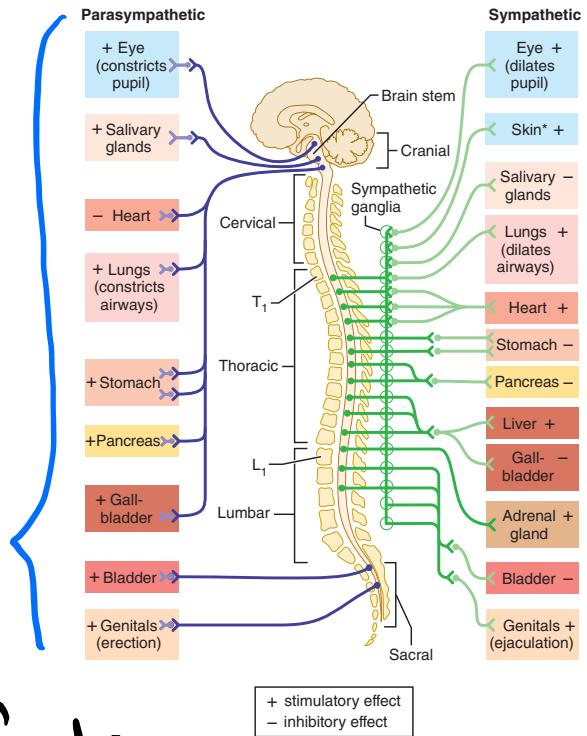
Autonomic nervous system (ANS)

- The ANS has two divisions, the **sympathetic** and **parasympathetic** divisions.
 - Both divisions have chains of **two neurons** that mostly innervate the same visceral organs, but they cause opposite effects.

Sympathetic

parasympathetic

cause opposite effects

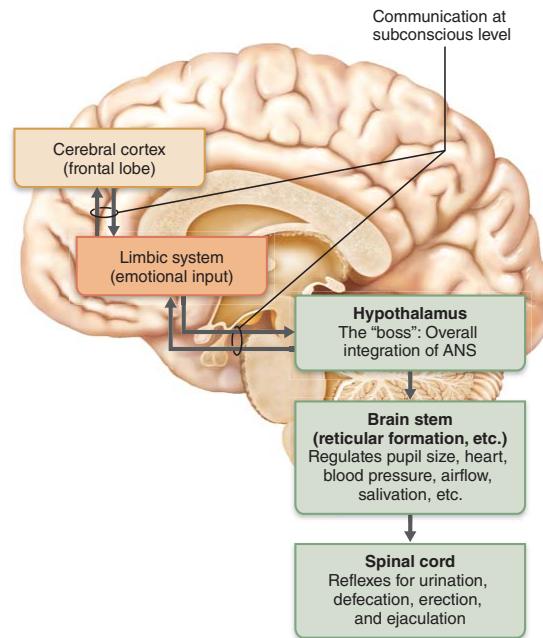


Autonomic nervous system (ANS)

ANS is NOT considered to be **under direct voluntary** control, but many of its activities are regulated by the **central nervous system**.

Several sources of central control exist

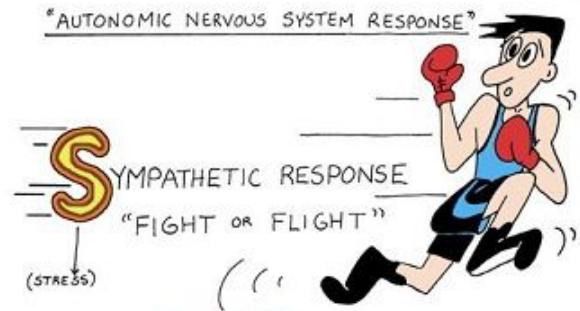
- ❖ the brain stem
- ❖ spinal cord,
- ❖ the hypothalamus
- ❖ amygdala, *emotions, fears*
- ❖ cerebral cortex



we are just unconscious of its control

Sympathetic and *Parasympathetic* neurons

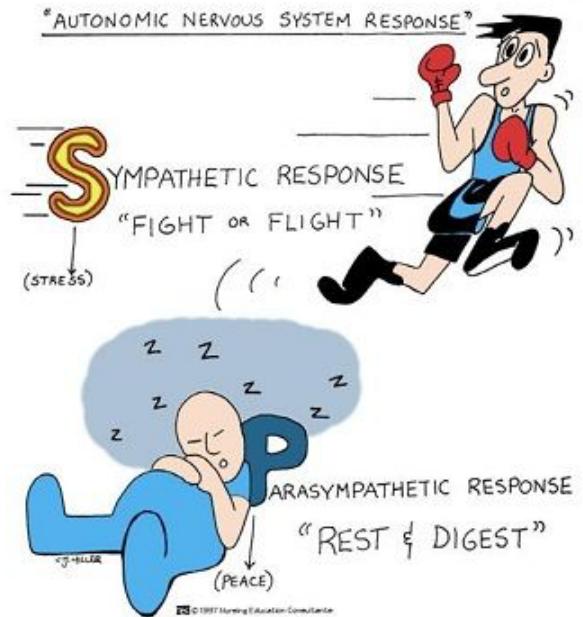
- The **sympathetic division** mobilizes the body during extreme situations such as fear, exercise, or rage. (**Stress**)
 - A pounding heart, dilated eye pupils, and cold, sweaty skin are signs that the **sympathetic** division has been mobilized*



Sympathetic division mobilizes body during stress

Sympathetic and *Parasympathetic* neurons

- The **sympathetic division** mobilizes the body during extreme situations such as fear, exercise, or rage. (**Stress**)
 - *A pounding heart, dilated eye pupils, and cold, sweaty skin are signs that the sympathetic division has been mobilized*
- The **parasympathetic division** enables the body to unwind and relax and works to conserve body energy. (**Peace**)
 - *Heart rate and respiratory rates are at low-normal levels, and the gastrointestinal tract is digesting food. The pupils are constricted as the eyes focus for close vision.*



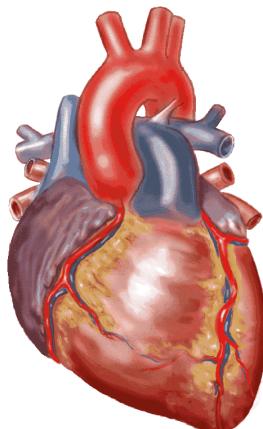
↳ Counterbalances sympathetic division

↳ little control by cortex, major control by hypothalamus

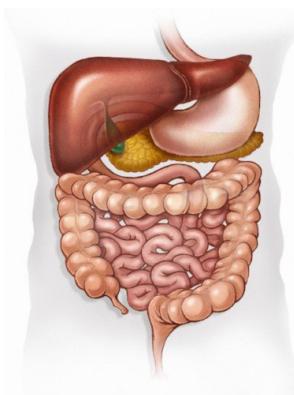
Autonomic nervous system (ANS)

Neurons of the ANS innervate organs and tissues that are not under voluntary control

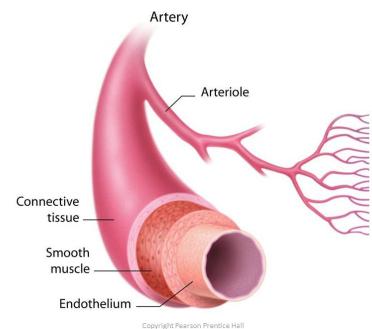
Heart



Smooth muscle in the GI tract



Smooth muscle in blood vessels

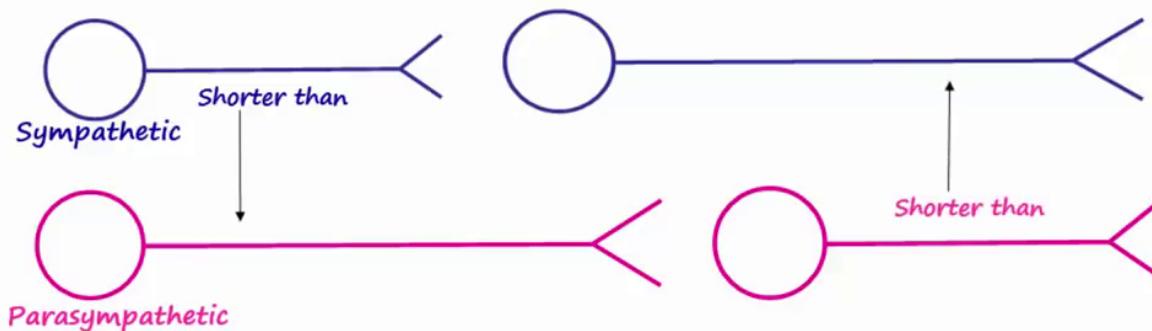


ANS is connected to internal organs and tissues via two neurons



First neuron = Preganglionic

Second neuron = Postganglionic

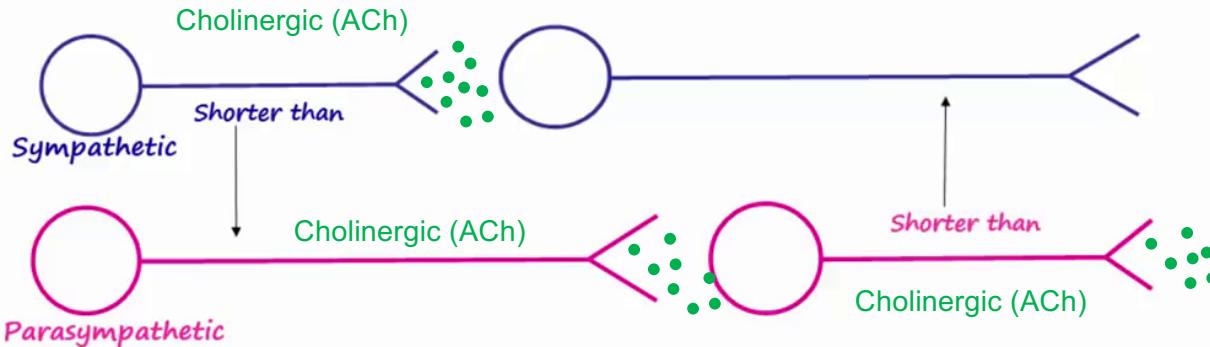


Neurons in ANS similar to motor neurons

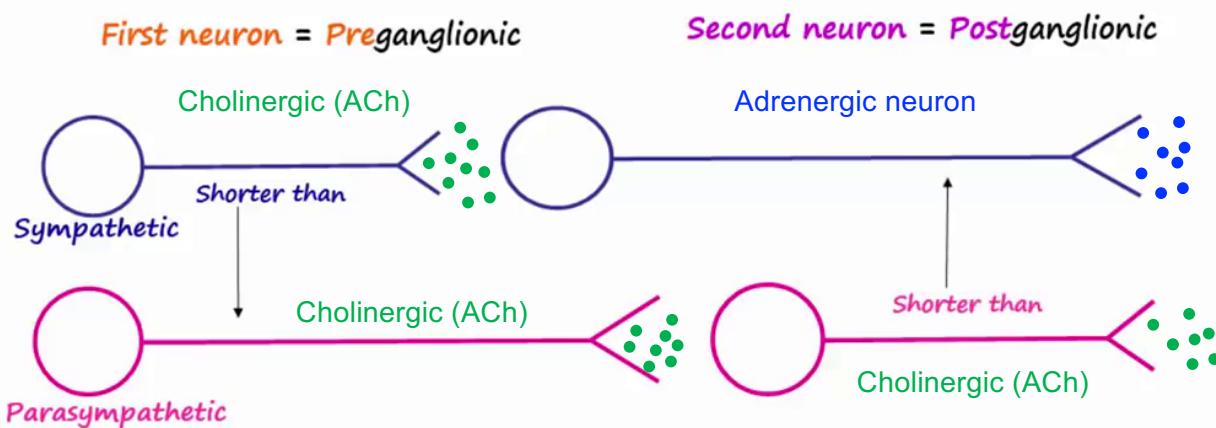
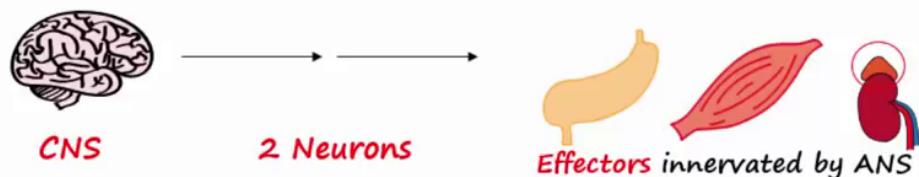
ANS is connected to internal organs and tissues via two neurons



First neuron = Preganglionic

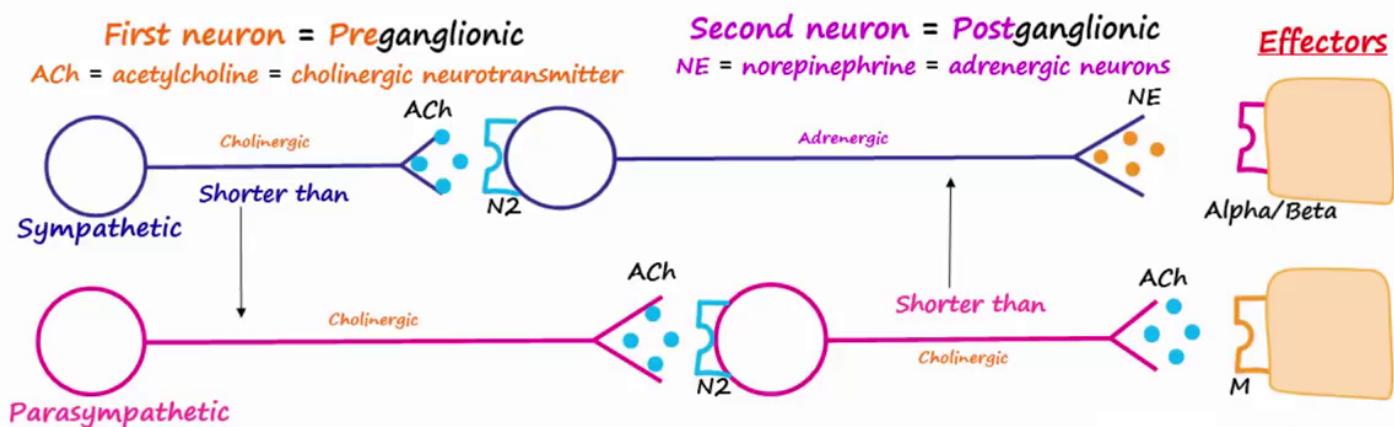


ANS is connected to internal organs and tissues via two neurons



ANS is connected to internal organs and tissues via two neurons

- Postganglionic parasympathetic and sympathetic neurons express Nicotinic ACh receptors (N2).
- Organs that are innervated by parasympathetic neurons express Muscarinic acetylcholine receptors (M).
- Organs that are innervated by sympathetic neurons express Alpha/Beta Adrenergic receptors.

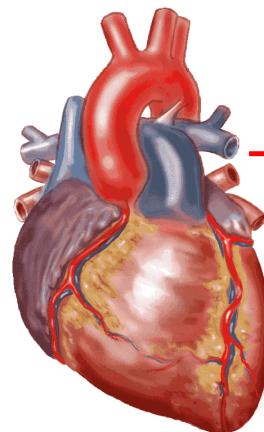


Sympathetic and *Parasympathetic* neurons are in opposition to each other

Dual autonomic innervation

*Parasympathetic neurons
slow down heart rate*

Heart

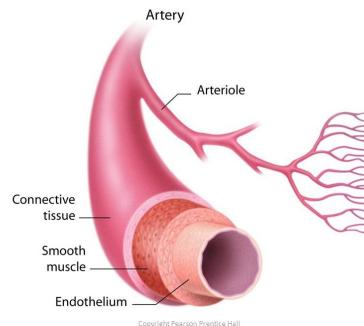


*Sympathetic neurons
increase heart rate*

Sympathetic and **Parasympathetic** neurons are in opposition to each other

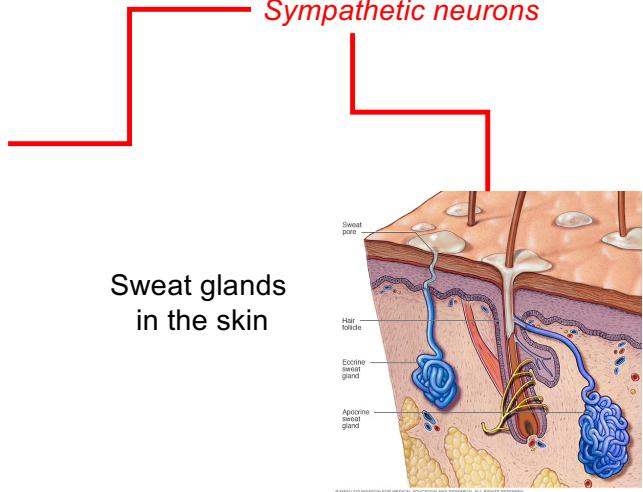
Exception to dual autonomic innervation rule

Smooth muscle in blood vessels

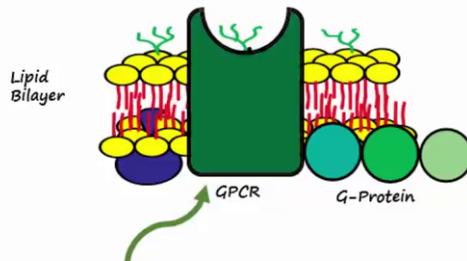


Sympathetic neurons

Sweat glands
in the skin



Receptors of the *Sympathetic* and *Parasympathetic* system



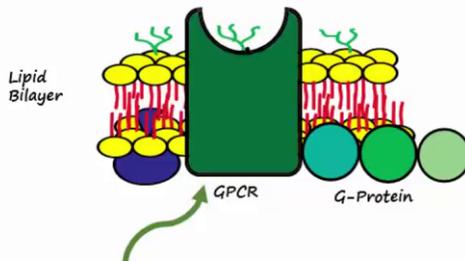
G-protein Coupled Receptors (GPCRs)

- All **Adrenergic** receptors
- All **Muscarinic ACh** receptors
- They can be excitatory or inhibitory

Organs innervated with Sympathetic neurons express Adrenergic receptors

Organs innervated with Parasympathetic neurons express Muscarinic ACh receptors

Receptors of the *Sympathetic* and *Parasympathetic* system

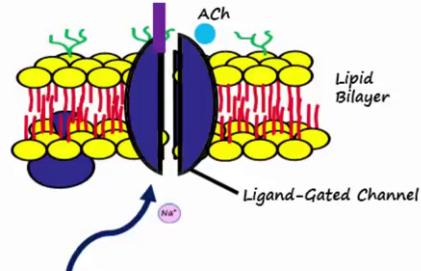


G-protein Coupled Receptors (GPCRs)

- All **Adrenergic** receptors
- All **Muscarinic ACh** receptors
- They can be excitatory or inhibitory

Organs innervated with **Sympathetic neurons** express **Adrenergic** receptors

Organs innervated with **Parasympathetic** neurons express **Muscarinic ACh** receptors



Ligand-Gated Ion Channels

- All **Nicotinic ACh** receptors
- They allow Na^+ and Ca^+ cations to pass
- They are always excitatory

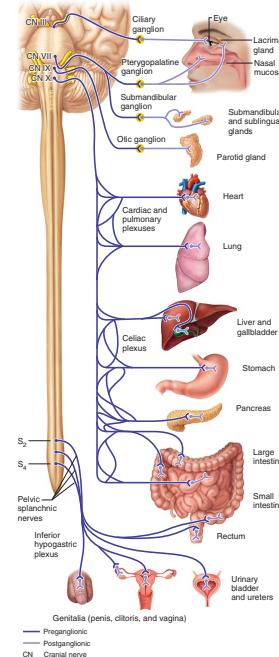
Post ganglionic **Sympathetic** and **Parasympathetic** neurons express these receptors.

for aCh over

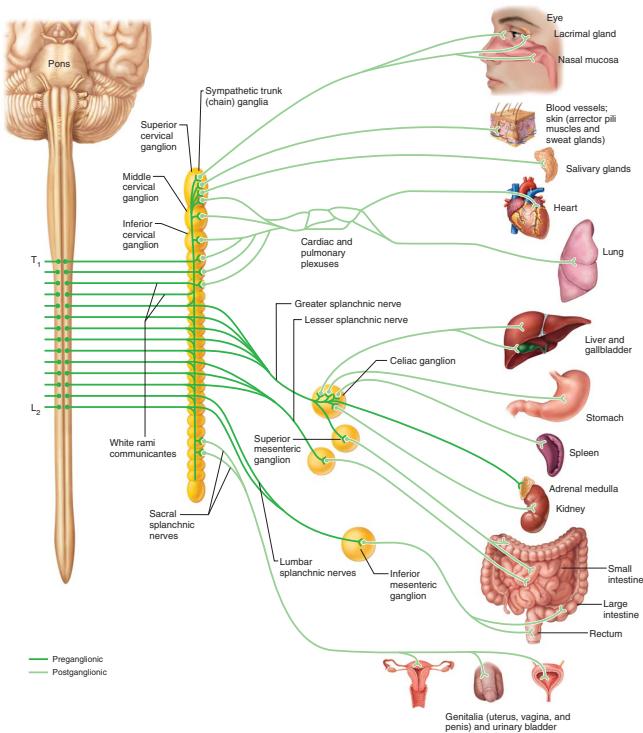
Projections of *Parasympathetic* neurons

Parasympathetic tract

- Cell bodies of *preganglionic parasympathetic* neurons are located in the gray matter of the brain stem and the sacral region of the spinal cord.
- The preganglionic axon synapses with the postganglionic neuron in *an autonomic ganglion close to or within the target organ*.



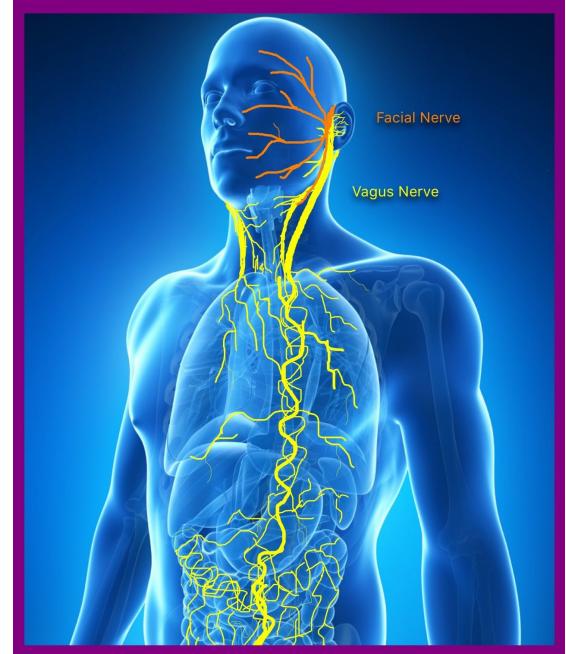
Projections of *Sympathetic* neurons



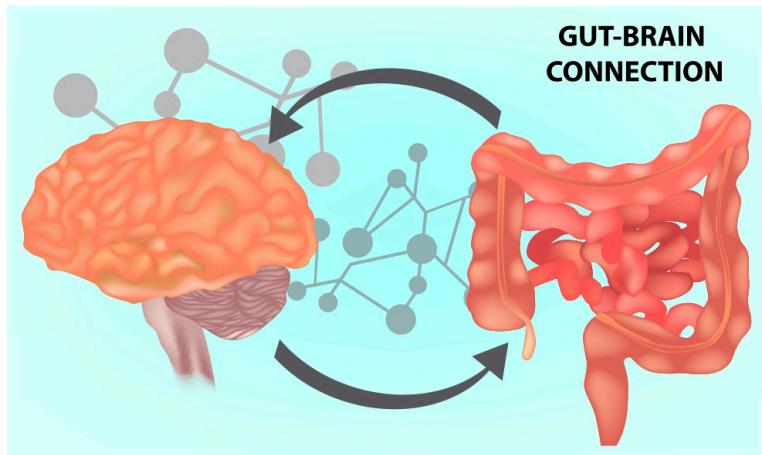
- Cell bodies of *preganglionic sympathetic* neurons are located in the **spinal cord** between regions T1 to L2.
- The preganglionic axon synapses with the postganglionic neuron in **an autonomic ganglion** close **the spinal column**.
- A long **postganglionic axon** extends from the autonomic ganglion to the target organ.

The Vagus Nerve

- The **vagus nerve** represents the main component of the **parasympathetic nervous system**, which oversees a vast array of crucial bodily functions, including control of mood, immune response, digestion, and heart rate.
- It establishes one of the connections between **the brain and the gastrointestinal tract** and sends information about the state of the inner organs to the brain via afferent fibers.



The Vagus Nerve is a critical connection between the gut and the brain



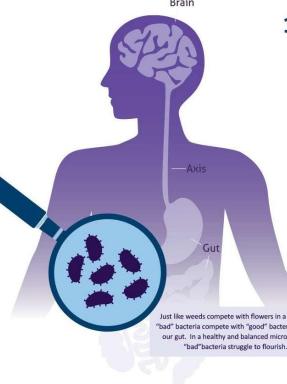
HEALTHY GUT HEALTHY MIND

TWO Brains?

Did you know that we have two brains? One in our head and one in our gut—the

2nd brain. They are connected by a communication axis.

The emerging science of the **Gut-Brain Axis (GBA)** indicates that many mental wellness issues originate as imbalances in the GBA.



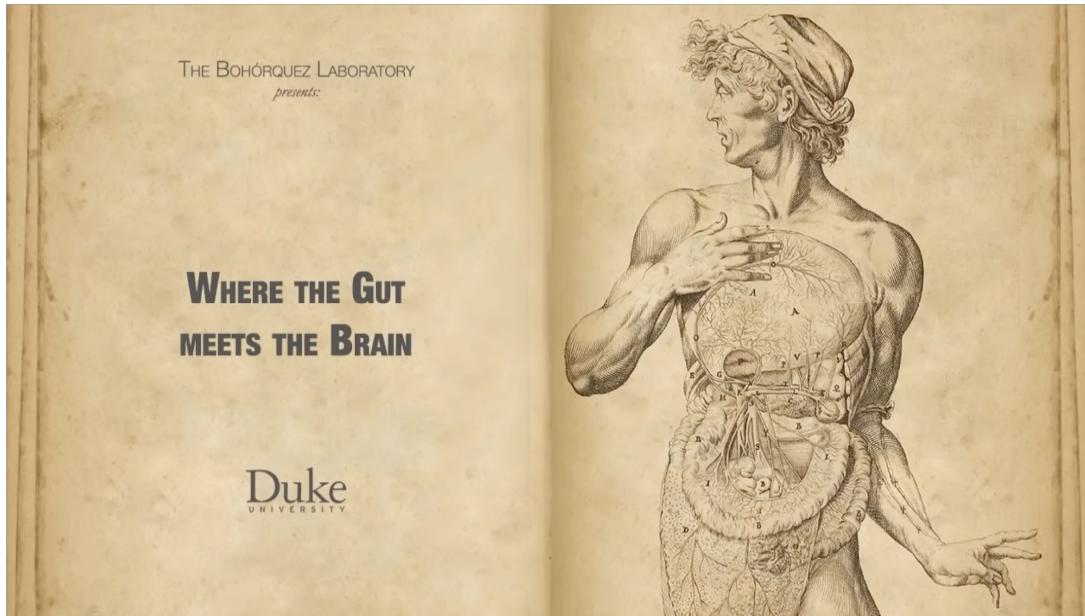
100% Human?

Did you know that we have ~100 trillion microorganisms across more than 10,000 different species (Microbiota) in our GI tract? These add up to our ~10 trillion human body cells and we are only **10% human!**

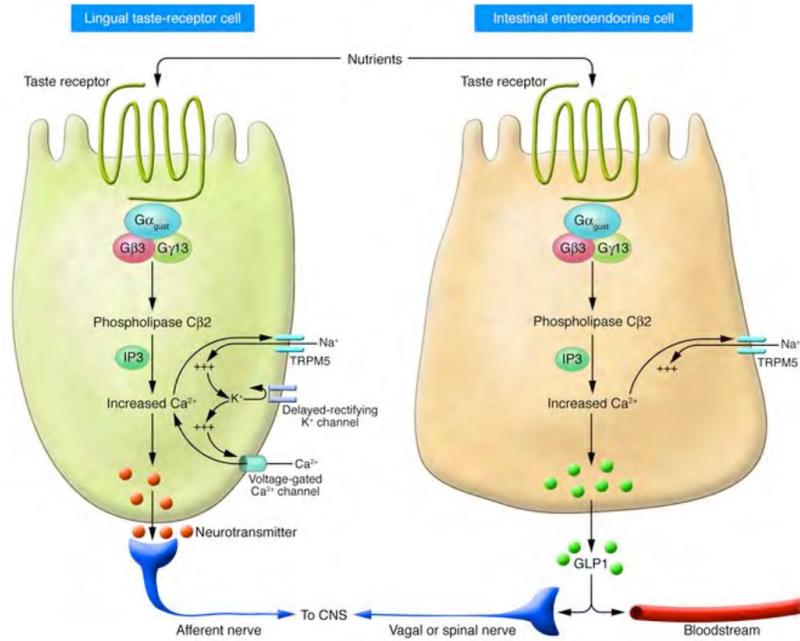
Those same microbiota have ~9 million genes (Microbiome) compared to our ~23,000 human genes. If we base this on gene count, we are **less than 1% human!**

Just like weeds compete with flowers in a garden, "bad" bacteria compete with "good" bacteria within our gut. In a healthy and balanced microbiome, "bad" bacteria struggle to flourish.

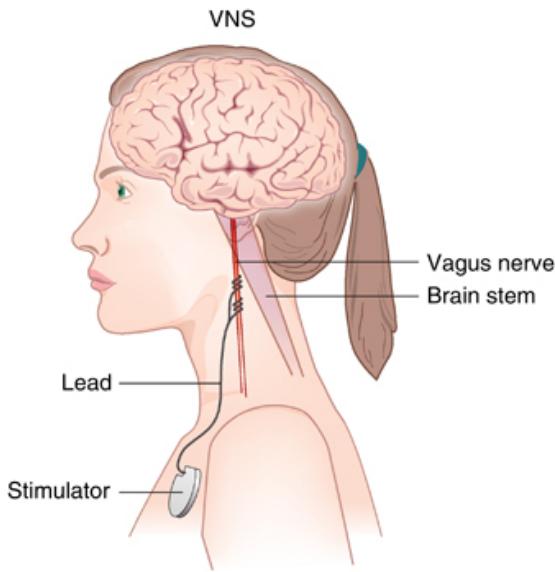
The Vagus Nerve is a critical connection between the gut and the brain



Enteroendocrine cells express taste receptors (T1Rs and T2Rs)



The Vagus Nerve Stimulation



FDA has currently approved Vagus nerve stimulation for

- Treatment of epilepsy
- Treatment of chronic or severe depression

Other potential applications

- Treatment of obesity
- Pain management
- Managing inflammatory bowel disease
- Diabetes
- And many more

Lecture summary

- The Autonomic Nervous System (ANS) regulates such visceral functions , which are essential for maintaining the stability of the body's internal environment.
- ANS is NOT considered to be **under direct voluntary** control, but many of its activities are regulated by the **central nervous system**.
- ANS has two main divisions: **Sympathetic** and **Parasympathetic**. **Sympathetic** neurons regulates responses in stress conditions; ***fight or flight***. **Parasympathetic** neurons allows body to unwind, ***rest and digest***.
- Most **Sympathetic** and **Parasympathetic** neurons release ACh, however **postganglionic sympathetic neurons** release norepinephrine.
- ANS neurons express different kinds of receptors; GCPRs (**Adrenergic** receptors and **Muscarinic ACh** receptors) or Ion channels (**Nicotinic ACh** receptors).
- Vagus nerve is the main branch of **Parasympathetic** system, it is critical for gut-brain communication.



Review session for the sensory systems will be held on

Date: May 9th

Time: 10-11 AM

Place: A106 CMH Corson/Mudd Hall