

Autonomic Nervous System (ANS)

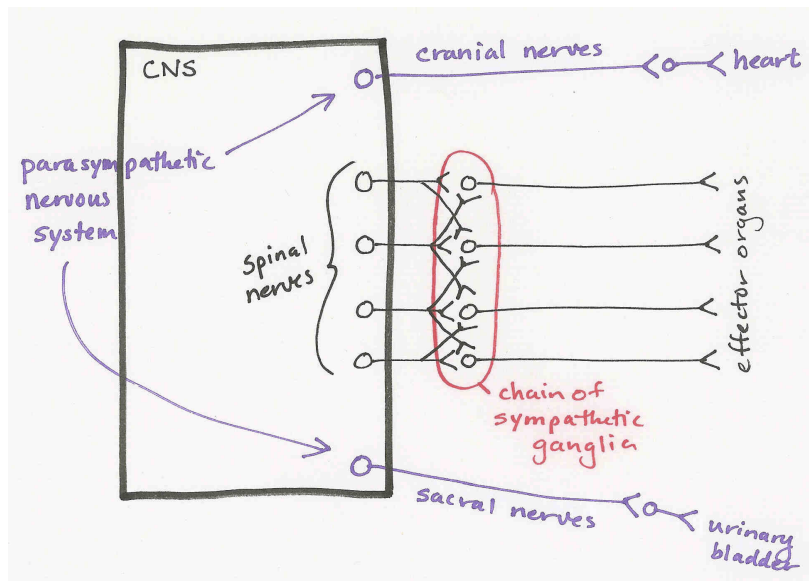
The ANS controls the smooth muscle, cardiac muscle, and glands.

Two major divisions:

Sympathetic and Parasympathetic

preganglionic neurons release ACh, sympathetic postganglionic neurons release NE and parasympathetic postganglionic neurons release ACh. (Exception to the rule: Some sympathetic neurons release ACh instead of NE. For example those neurons that innervate blood vessels in skeletal muscles. These blood vessels have both beta-adrenergic and muscarinic receptors.)

Structure defines function:



Note the placement of the sympathetic and parasympathetic ganglia. The sympathetic ganglia are right next to the spinal cord and are interconnected to each other by nerve fibers running up and down. This forms a **chain of sympathetic ganglia** that tend to be activated all at once. In contrast the parasympathetic ganglia are next to or within the tissue they innervate. This suggests a more selective regulation of each tissue/organ.

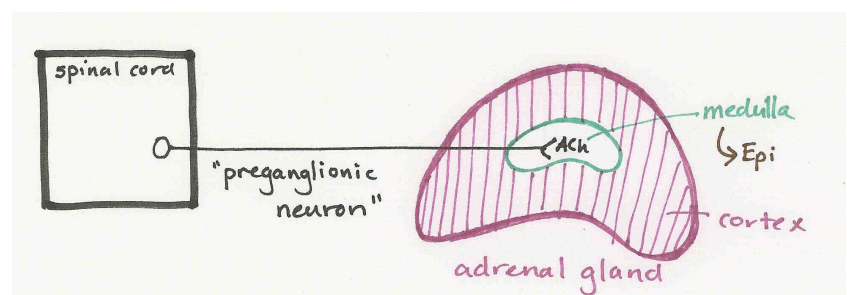
Figure 9.6 illustrates this structural difference. Also note that parasympathetic nerves exit the CNS at the **cranial and sacral** levels. In contrast sympathetic nerves exit the CNS from the spinal cord only, via **spinal nerves**.

The differences between the two systems are summarized in the **table on the next page** (also FOX table 9.4)

Adrenal Medulla

Adrenal glands are found above the kidneys. They consist of two distinct layers. The adrenal cortex we will cover with the endocrine system, chapter 11. The adrenal medulla (innermost layer) makes up 10% of the gland and could be considered a sympathetic ganglia. It is innervated by preganglionic fibers that secrete ACh. In response to ACh the cells of the adrenal medulla release epinephrine (Epi) and some norepinephrine (NE). This release of catecholamines is similar to the release from postganglionic fibers.

The systemic release of Epi from the adrenal medulla activates all organs and tissues that the blood reaches and that have the receptors for Epi and NE.



Sympathetic vs. Parasympathetic

Effector Organ	Sympathetic Nervous System “Fight or Flight”	Parasympathetic Nervous System “Rest and Digest”
In general	“tense, excitable, alert”	“juicy, soft, relaxed”
Blood flow	decreased blood flow to viscera and skin and increased blood flow to muscles, heart and brain <i>Sympathetic nerves that enervate blood vessels found in the muscle release Ach!</i>	Dilation in a few organs (i.e. erectile tissue)
Lungs	dilate bronchioles inhibit secretion of mucus	constrict bronchioles stimulate secretions
Heart	increase heart rate increase rate of conduction increase strength of contraction	decrease heart rate decrease rate of conduction
Spleen	expulsion (contraction) of red blood cells stored so increased oxygen carrying capacity of the blood.	
Gastrointestinal Tract	movement inhibited pancreatic secretions inhibited ---- thick saliva (less of it too)	movement stimulated pancreatic secretions stimulated other gut secretions stimulated copious thin saliva
Sweat glands	secretions stimulated	---
Eye	relaxed (far vision) pupil dilated	contracted (near vision) pupil constricted
Liver	glycogen hydrolysis	---
Adipose cells	lipolysis	---
Sexual function	orgasm	arousal

Adrenergic receptors (Receptors for epinephrine and norepinephrine)

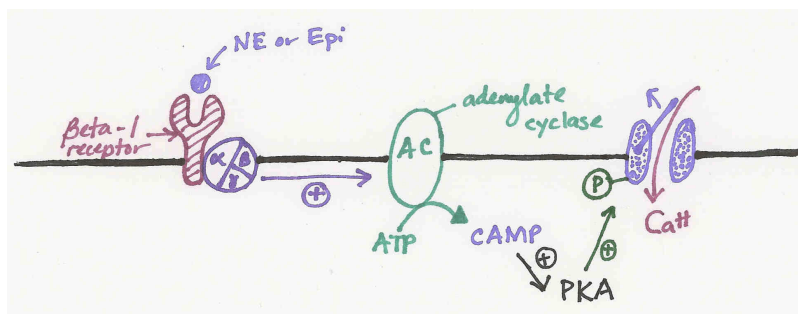
Two main classes: alpha (α) and beta (β) receptors

Can be further divided: **alpha (α):** α_1 and α_2 **beta (β):** β_1 and β_2

adrenergic receptor	All are G-protein coupled	effector
β_1-receptor	G-protein activates AC (adenylate cyclase); leads to an increase in cAMP, which then increases Ca^{2+}	heart
β_2-receptor	G-protein activates AC; leads to an increase in cAMP	lungs (smooth muscle of bronchioles) blood vessels found in the skeletal muscles
α_1-receptor	G-protein activates PLC (phospholipase C); leads to an increase in intracellular calcium	blood vessels found in the skin and viscera
α_2-receptor	G-protein inhibits AC; leads to a decrease in cAMP	presynaptic axon terminals

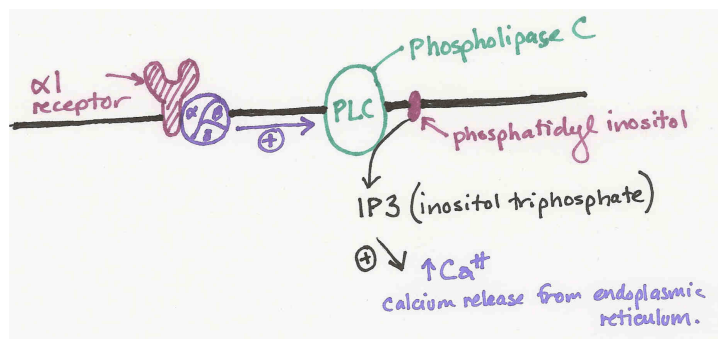
β_1 -receptor

Activation of beta-1 receptors in the heart results in increased cellular calcium which causes a depolarization of the cardiac cells and increased heart rate. More later...

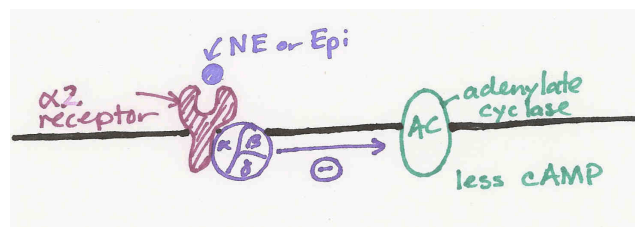


β_2 -receptor- Activation of this receptor results in relaxation of smooth muscle in the bronchioles (bronchiole dilation) and relaxation of smooth muscle in the blood vessels (vasodilation) in the skeletal muscle.

α_1 -receptor Activation of alpha-1 receptors on blood vessels leads to increased cellular calcium and vasoconstriction.



α_2 -receptor (inhibitory effects)



Hey! alpha-1 receptors use the same second messenger system as M1 receptors!

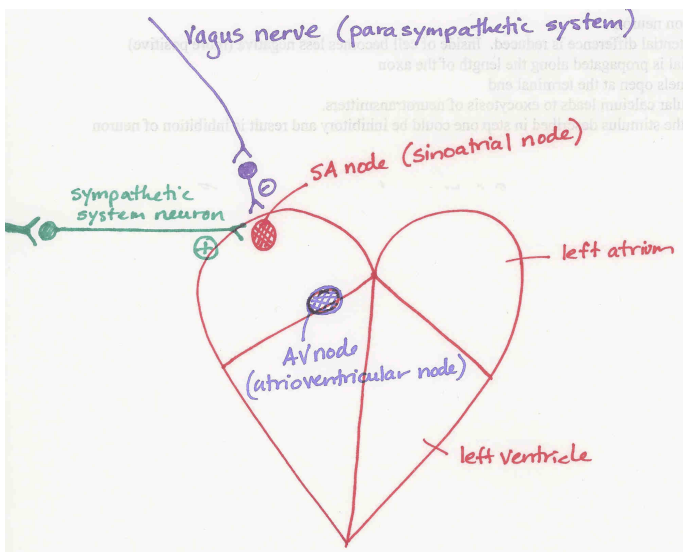
Dual innervation

Most visceral organs are innervated by both sympathetic and parasympathetic neurons. In most cases the effects are antagonistic, meaning that one system stimulates the opposite effect compared to the other system.

We will consider heart rate as an example.

Example: Heart rate

The sinoatrial node of the heart (SA node) contains cells that spontaneously depolarize at a set rate. We will talk about these more when we cover the cardiovascular system. These cells are called “pacemaker” cells and will continue to beat without any connection to the nervous system. (An example of a back-up mechanism for control of heart rate.) They beat at a rate of 70 to 80 beats per minute and drive the entire cardiac muscle to beat.



Neurons from both the sympathetic and parasympathetic systems innervate the SA node.

The vagus nerve (**parasympathetic system**) inhibits the firing of the pacemaker cells. This is a parasympathetic neuron, so ACh is the neurotransmitter released. Since the end result is inhibition, the receptors on the heart are M2 (muscarinic receptors). (*These open potassium channels - so do they depolarize or hyperpolarize the pacemaker cells?*)

The **sympathetic neurons** stimulate the firing of the pacemaker cells. Sympathetic neurons release NE. The heart has beta1- receptors. These receptors are coupled to a G-protein that activates adenylate cyclase, which makes cAMP and that activates PKA that phosphorylates a calcium channel which opens that channel and leads to increase intracellular calcium. (See beta receptor picture earlier.)

Increased calcium does what to the cell?

depolarizes it - so the pacemaker cells fire more often.

Summary figure at the right gives the rate of heart contractions in three situations.

