Autonomic Nervous System

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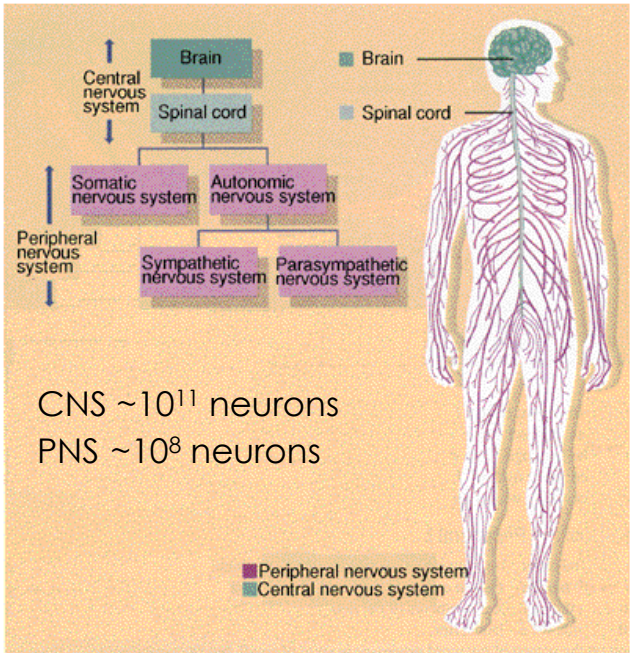
PHSL2101 - PHSL2121 – PHSL2501

Objectives for this lecture on the ANS

- Outline the operation of reflex control in the autonomic nervous system.
- Describe the anatomical organization of the sympathetic and parasympathetic systems.
- List the neurotransmitters and receptor classes used by the sympathetic & parasympathetic systems at pre-ganglionic & post-ganglionic synapses.
- List the effects of the autonomic nervous system on three organs.

Divisions of the nervous system

Human Nervous System



from Brown & Benchmark Introductory Psychology Image Bank copyright 1995 Times Mirror Higher Education Group, Inc.

Reflex control in the ANS

Roles of parasympathetic and sympathetic systems

Parasympathetic	- dominant at rest
Sympathetic	- dominant for "fight or flight"
Enteric	- autonomous 100 000 000 neurons control gut motility and secretion

Parasympathetic and Sympathetic tend to work in opposition like a brake and accelerator in a car.

Sympathetic and parasympathetic nerves also carry sensory information: mainly pain sense in sympathetic, and visceral senses such as distension or blood chemistry in the parasympathetic.

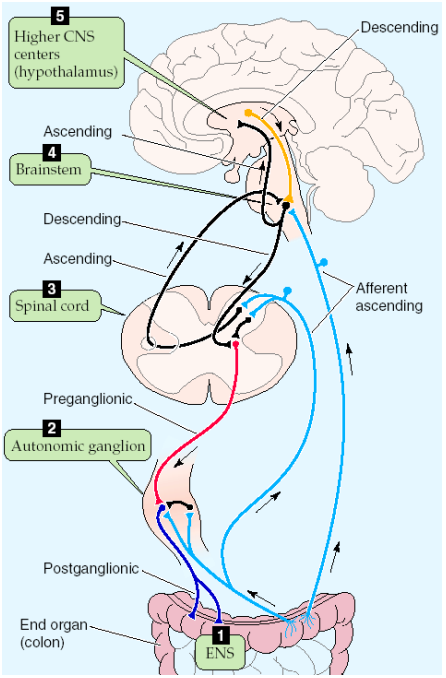
Reflex control in the ANS

ANS controls the four F's

from *cartoonspot.net* & www.acartoonchristmas.com

Reflex control in the ANS

Reflex loops control autonomic function



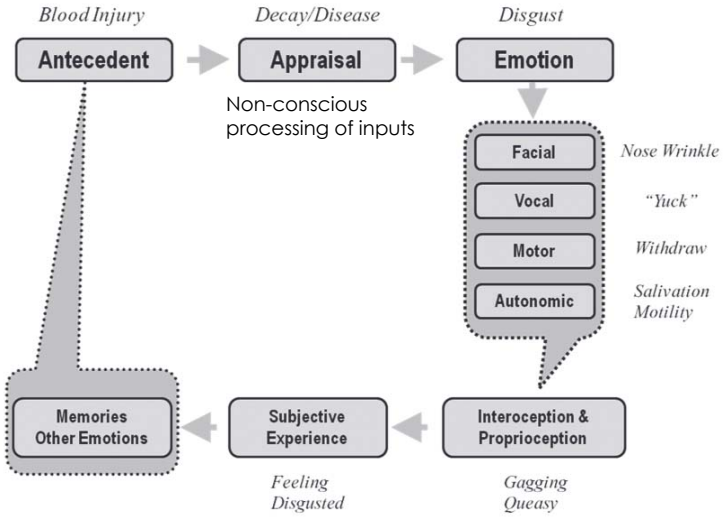
Sensory input leads to autonomic effects at local, and at higher, more integrated, levels.

1. enteric nervous system or effector organ
2. ganglion: integrate sensory, preganglionic, and interneurons
3. spinal cord: integrate across spinal levels
4. brain stem: integrate across organs
5. higher centres: integrate with motivation and desires

from *Medical Physiology* by Boron and Boulpaep, Saunders, Philadelphia, 2003

Reflex control in the ANS

The ANS, reflexes, and emotions

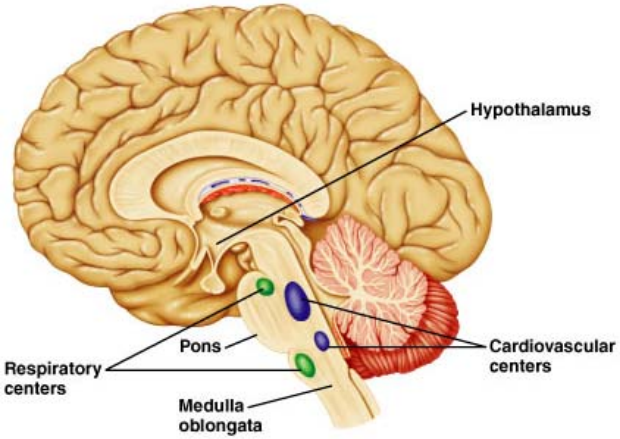


The ANS is intimately involved with our emotions: in their physical expression, and perhaps in their generation.
This also provides a path for conscious influence over the ANS.

from Levenson (2014) *Emotion Review* 6:100

Reflex control in the ANS

Many brain regions including brain stem, are part of the autonomic nervous system

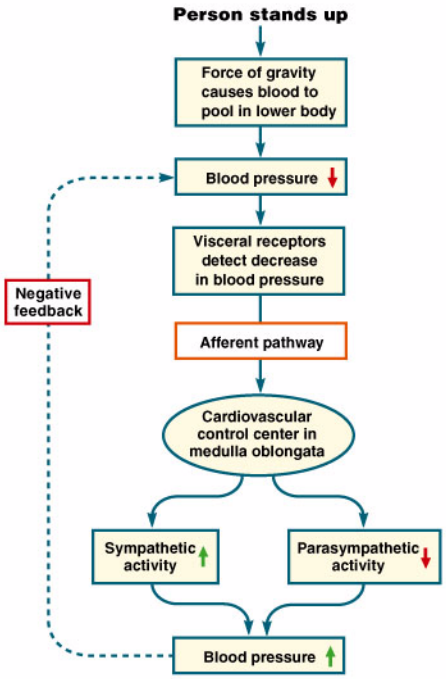


These regions integrate sensory inputs from diverse sources to produce a coordinated output. They usually influence sympathetic and parasympathetic systems in tandem.

from Germann and Stanfield, Benjamin Cummings, 2005

Reflex control in the ANS

Reflex loops depend on sensory input



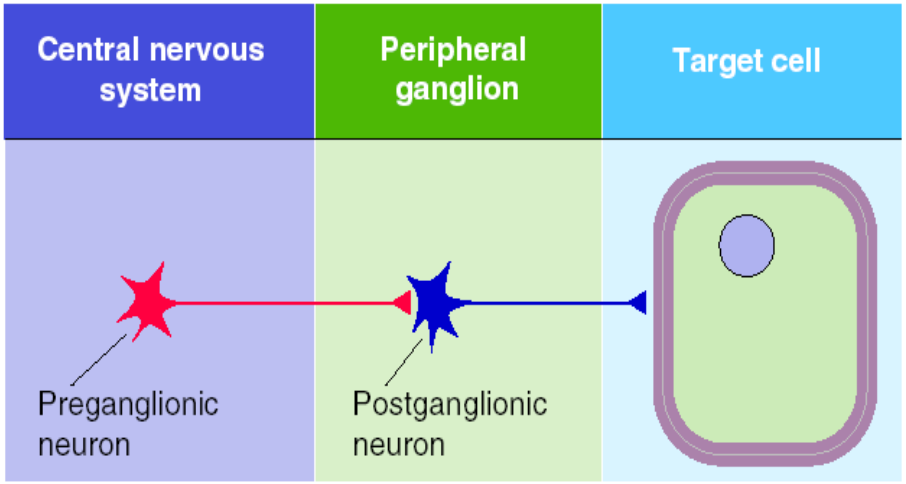
Sensory input comes mainly from autonomic/ visceral afferents.

1. These afferents are mainly located in the innervated tissue and travel in the same nerve as efferents.
2. Higher centres integrate inputs from a broader region.
3. Somatic inputs are integrated to provide fast or predictive responses, like to posture adjustment.

from Germann and Stanfield, Benjamin Cummings, 2005

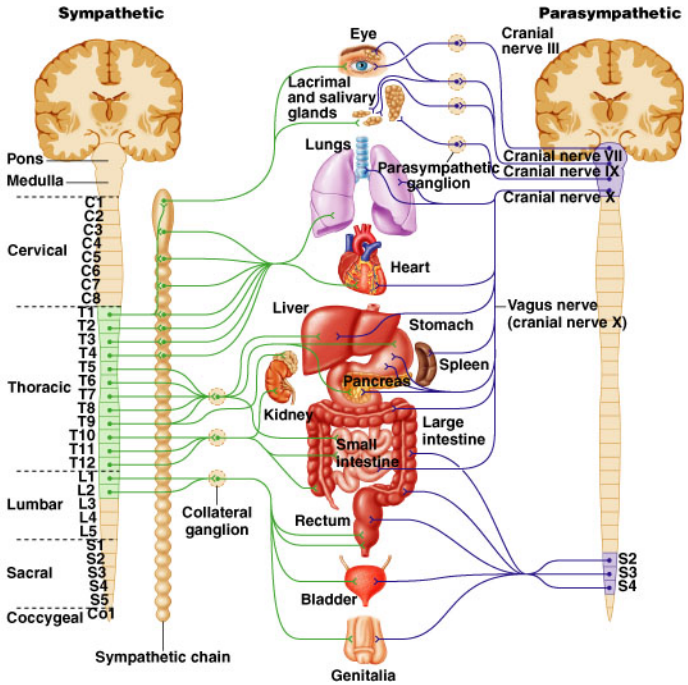
Organization of the ANS

Basic plan of the efferent autonomic nervous system



Organization of the ANS

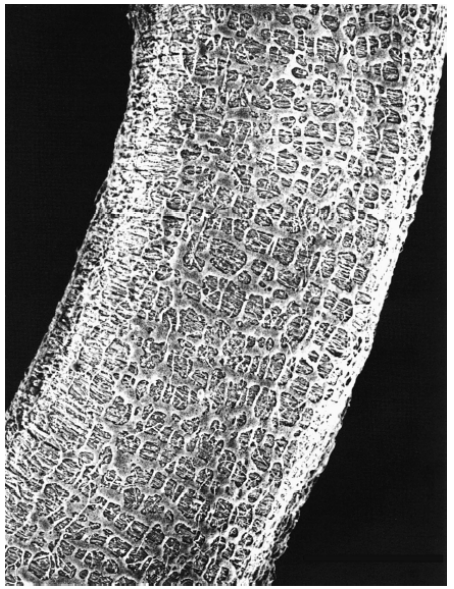
Anatomical organization of the ANS



from Germann and Stanfield, Benjamin Cummings, 2005

Organization of the ANS

The enteric nervous system is a complex network of different neurons

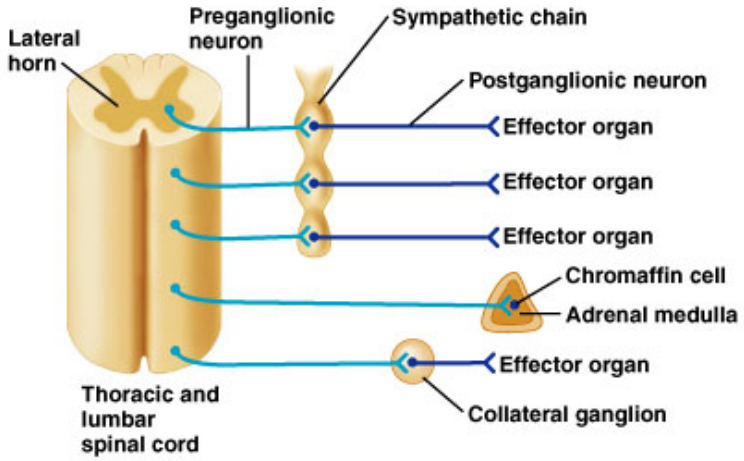


A scanning electron micrograph of the myenteric plexus of the mouse large intestine. The plexus is the highly interconnected meshwork spreading over the deeper circular layer of muscle.

from *Medical Physiology* by Boron and Boulpaep, Saunders, Philadelphia, 2003

Organization of the ANS

Three divisions of the sympathetic system

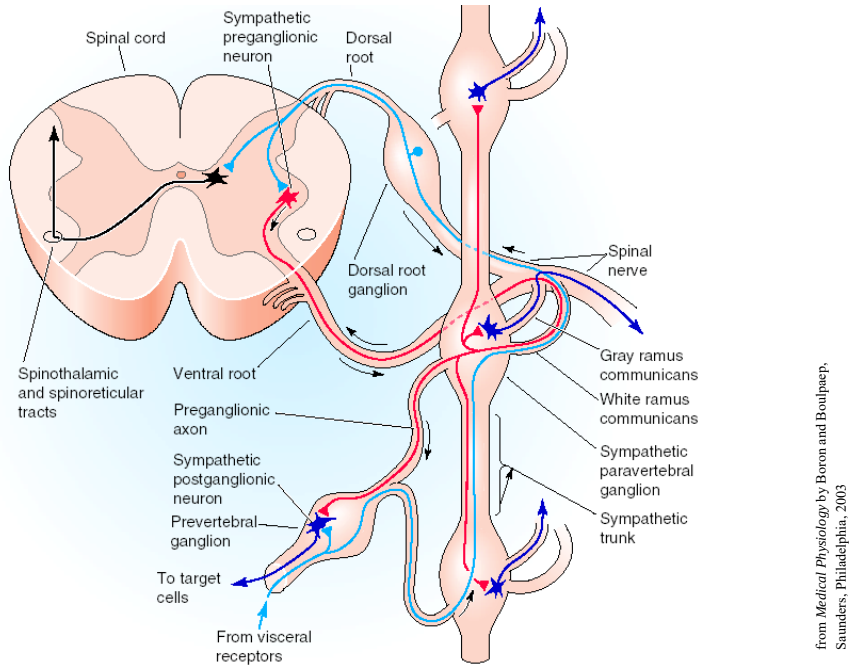


Most sympathetic activity goes via the sympathetic chain, but more specific effects can be via collateral ganglia, whereas general effects can be produced by adrenaline released from the adrenal medulla.
Parasympathetic works on basically a collateral ganglion model.

from Germann and Stanfield, Benjamin Cummings, 2005

Organization of the ANS

Organization of the sympathetic chain



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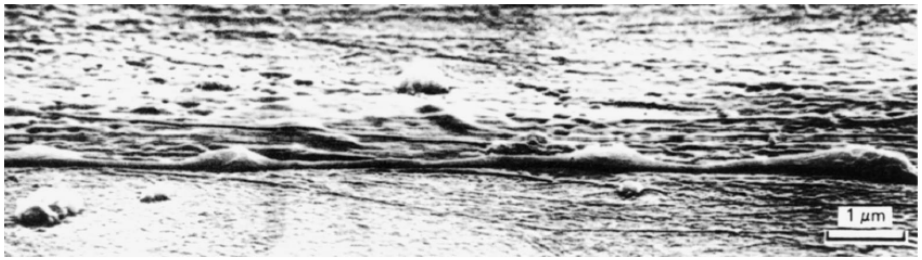
Organization of the ANS

Autonomic synapses on target organ: each neuron makes many synapses



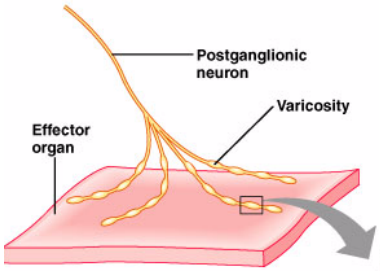
The autonomic system is like the skeletal muscle system. It has axons that form synapses on the target tissue. Like the NMJ, these axons often produce strong effects by acting at a lot of release sites.

(G. Burnstock G, J. Anat 146: 1-30, 1986)

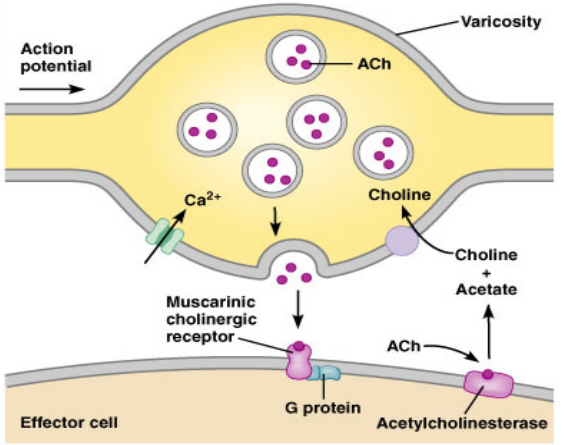
from *Medical Physiology* by Boron and Boulpaep, Saunders, Philadelphia, 2003

Organization of the ANS

Synaptic cleft may be wider than at somatic synapses



The autonomic synapse works basically like the NMJ. The space the transmitter has to diffuse is a bit greater; this may allow more spill-over effects.

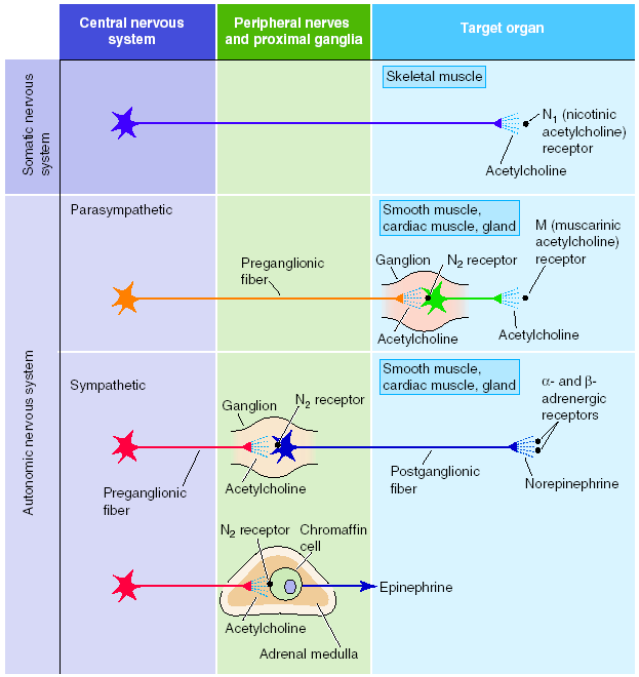


from Germann and Stanfield, Benjamin Cummings, 2005

(a) Acetylcholine release from postganglionic neuron

Transmitters & receptors

ANS uses specific neurotransmitters



Norepinephrine is American for *Noradrenaline*.

Epinephrine is American for *Adrenaline*.

from *Medical Physiology* by Boron and Boulpaep, Saunders, Philadelphia, 2003

Transmitters & receptors

Receptor classes for Acetylcholine

Receptor type	Signal transduction mechanism	Target cell	Effect on target cell
Nicotinic	Opens channels for sodium and potassium ions	Postganglionic cell body, chromaffin cells, skeletal muscle cells	Excitatory
Muscarinic	G protein–coupled; opens or closes specific ion channel	Effector organs of parasympathetic nervous system	Excitatory or inhibitory

The autonomic nervous system uses ionotropic receptors in the ganglia, and then switches to metabotropic at the target organ.

from Germann and Stanfield, Benjamin Cummings, 2005

Transmitters & receptors

Receptor classes for Noradrenaline

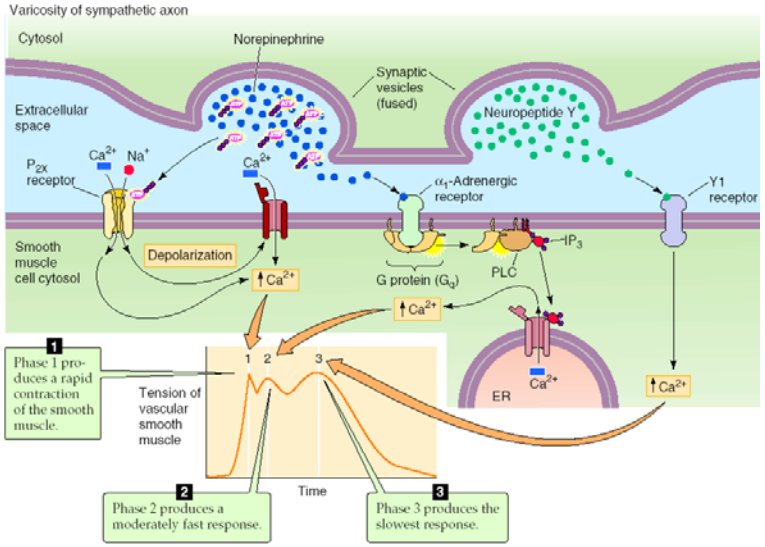
Receptor type	Effector organ with receptor type	Relative affinities*	Signal transduction mechanism	Effect on effector organ†
α_1	Most vascular smooth muscle, pupils	NE > Epi	Activates IP_3	Excitatory
α_2	CNS, platelets, adrenergic nerve terminals (autoreceptors), some vascular smooth muscle, adipose tissue	NE > Epi	Inhibits cAMP	Excitatory
β_1	CNS, cardiac muscle, kidney	NE = Epi	Activates cAMP	Excitatory
β_2	Some blood vessels, respiratory tract, uterus	Epi >> NE	Activates cAMP	Inhibitory
β_3	Adipose tissue	NE = Epi	Activates cAMP	Excitatory

*NE = norepinephrine; Epi = epinephrine; > = greater than; >> = much greater than
†Effects are generalizations and not absolute.

from Germann and Stanfield, Benjamin Cummings, 2005

Transmitters & receptors

Multiple neurotransmitters are released



Synapses often release a variety of transmitters. These can produce different effects, and my be somewhat selectable based on the rate of axon activity.

from *Medical Physiology* by Boron and Boulpaep, Saunders, Philadelphia, 2003

Effects of the ANS

Autonomic control of organs - 1

	PARASYMPATHETIC NERVOUS SYSTEM*	SYMPATHETIC NERVOUS SYSTEM	
Organ system	***Effect***	***Effect***	***Adrenergic receptor class***
Heart			
SA node	Decreases heart rate	Increases heart rate	β_1
AV node	Decreases conduction velocity	Increases conduction velocity	β_1
Force of contraction	Decreases (small effect)	Increases	β_1
Blood vessels			
Arterioles to most of body	None	Vasoconstriction	α_1
Arterioles to skeletal muscle	None	Vasoconstriction Vasodilation (epinephrine)	α_1 β_2
Arterioles to brain	None	None	
Veins	None	Vasoconstriction Vasodilation (epinephrine)	α_1 β_2
Lungs			
Bronchial muscle	Contraction	Relaxation	β_2
Bronchial glands	Stimulates secretion	Inhibits secretion	α
Digestive tract			
Motility	Increased	Decreased	α_1, α_2, β_2
Secretions	Stimulated	Inhibited	α_2
Sphincters	Relaxation	Contraction	α_1

from Germann and Stanfield, Benjamin Cummings, 2005

Effects of the ANS

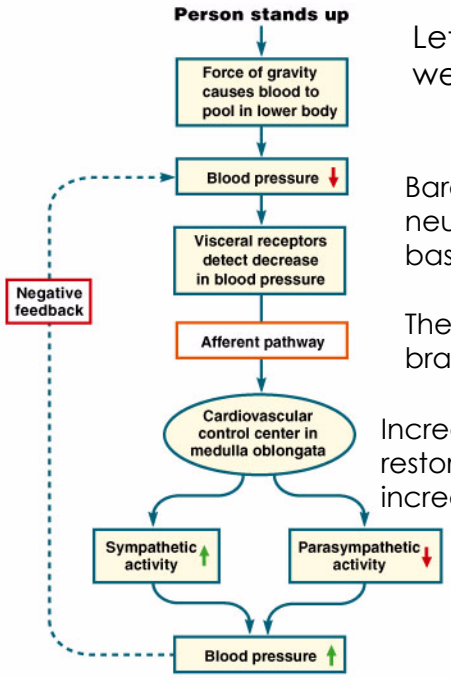
Autonomic control of organs - 2

	PARASYMPATHETIC NERVOUS SYSTEM*	SYMPATHETIC NERVOUS SYSTEM	
Organ system	***Effect***	***Effect***	***Adrenergic receptor class***
Urinary bladder			
Bladder wall	Contraction	Relaxation (small effect)	β_2
Sphincter	Relaxation	Contraction	α_1
Male reproductive tract			
Blood vessels (erection)	Vasodilation	None	
Vas deferens and seminal vesicles (ejaculation)	None	Ejaculation	α_1
Female reproductive tract			
Uterus, nonpregnant	Unknown	Relaxation	β_2
Uterus, pregnant	Unknown	Contraction	α_1
Skin			
Sweat glands	Stimulates secretion	Stimulates secretion	α_1, muscarinic†
Piloerector muscles	None	Contraction (hairs stand up)	α_1
Eye			
Iris muscles (pupil size)	Contraction of circular muscle (pupillary constriction)	Contraction of radial muscle (pupillary dilation)	α_1
Ciliary muscles (accommodation)	Contraction for near vision	Relaxation for far vision (small effect)	β_2

from Germann and Stanfield, Benjamin Cummings, 2005

Effects of the ANS

The ANS in action



Let's flesh out this reflex loop we saw earlier....

Baroreceptors are specialised neurons that alter their activity based on vessel stretch

The baroreceptors synapse on brainstem cardiovascular centres

Increased sympathetic activity restores blood pressure largely by increasing peripheral vasoconstriction

Reduced parasympathetic activity increases the rate of heart contraction

from Germann and Stanfield, Benjamin Cummings, 2005