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Autonomic nervous system

ANS vs. somatic NS

Comparison of Somatic Motor and Autonomic Divisions		
	SOMATIC MOTOR	**AUTONOMIC**
Number of neurons in efferent path	1	2
Neurotransmitter/receptor at neuron-target synapse	ACh/nicotinic	ACh/muscarinic or NE/α- or β-adrenergic
Target tissue	Skeletal muscle	Smooth and cardiac muscle; some endocrine and exocrine glands; some adipose tissue
Neurotransmitter released from	Axon terminals	Varicosities and axon terminals
Effects on target tissue	Excitatory only: muscle contracts	Excitatory or inhibitory
Peripheral components found outside the CNS	Axons only	Preganglionic axons, ganglia, postganglionic neurons
Summary of function	Posture and movement	Visceral function, including movement in internal organs and secretion; control of metabolism

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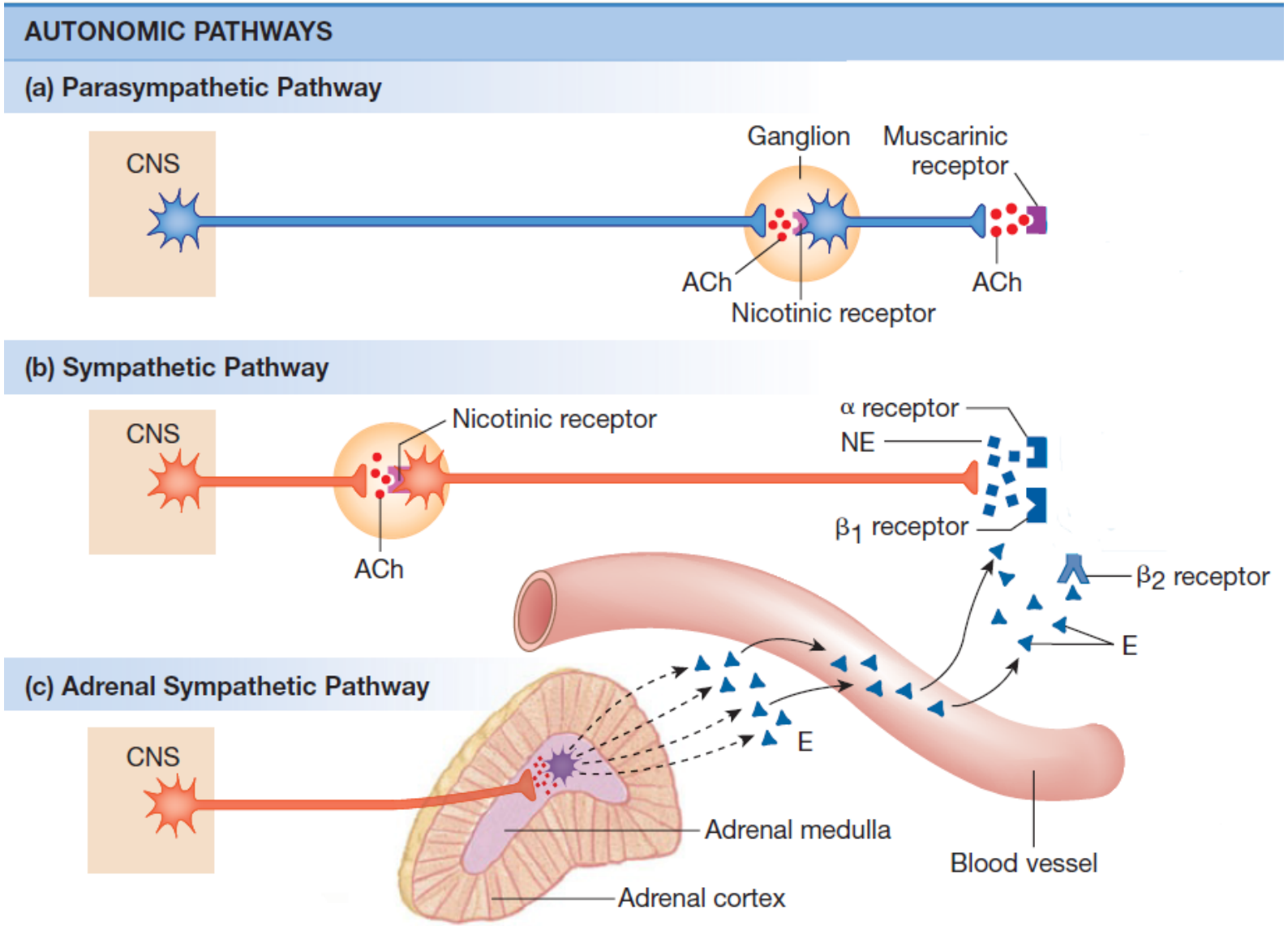
Autonomic nervous system



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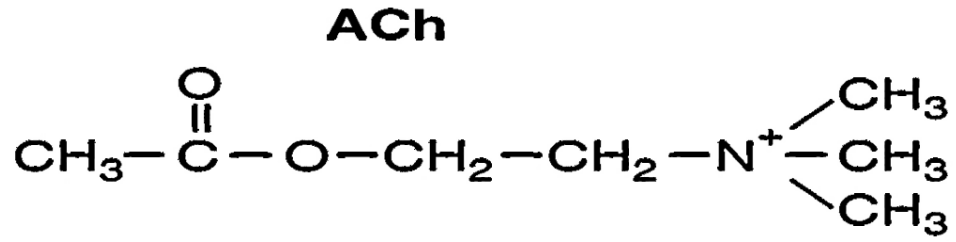
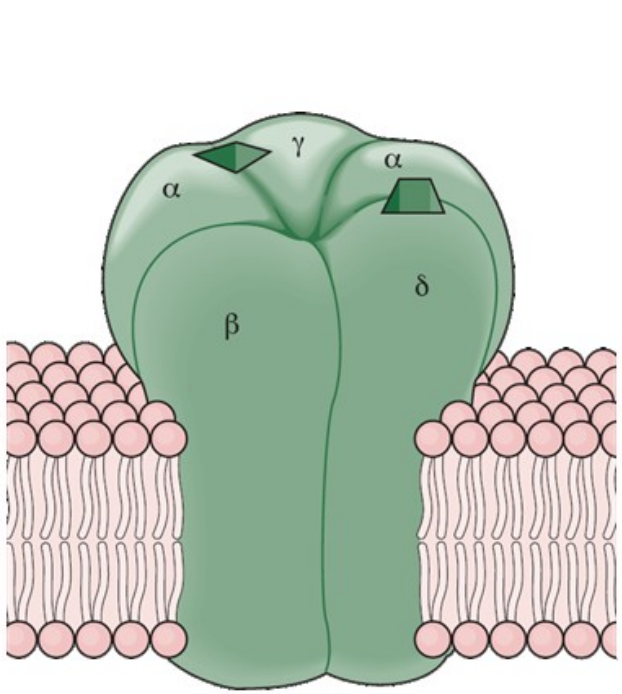
Autonomic nervous system

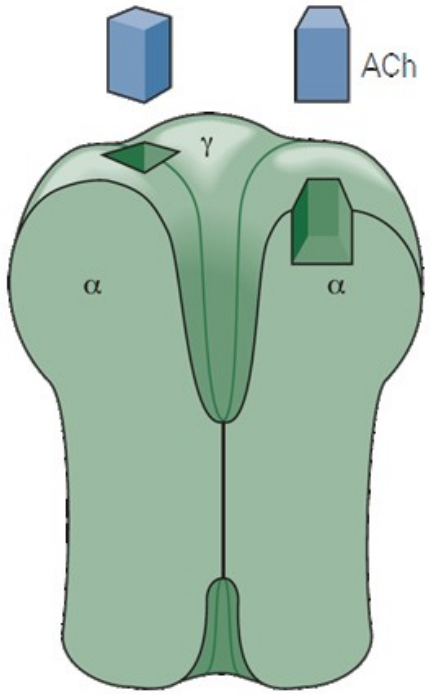
Preganglionic fibers

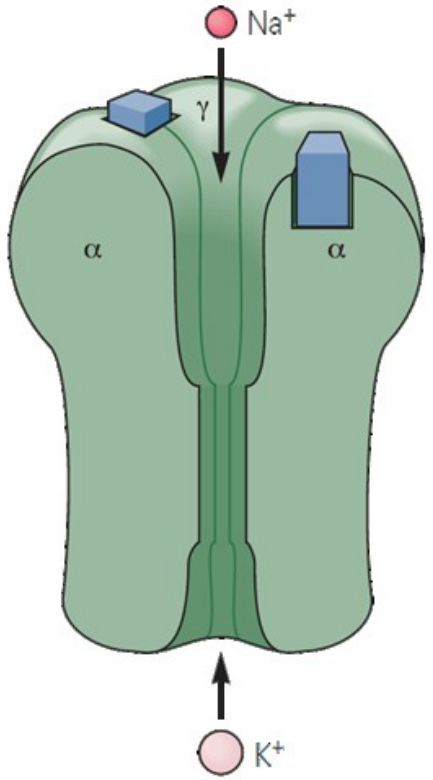
- SNS, PNS
- *Nikotinic recep*
  - N_N type and N_M typ
  - Excitatory receptor

ACh









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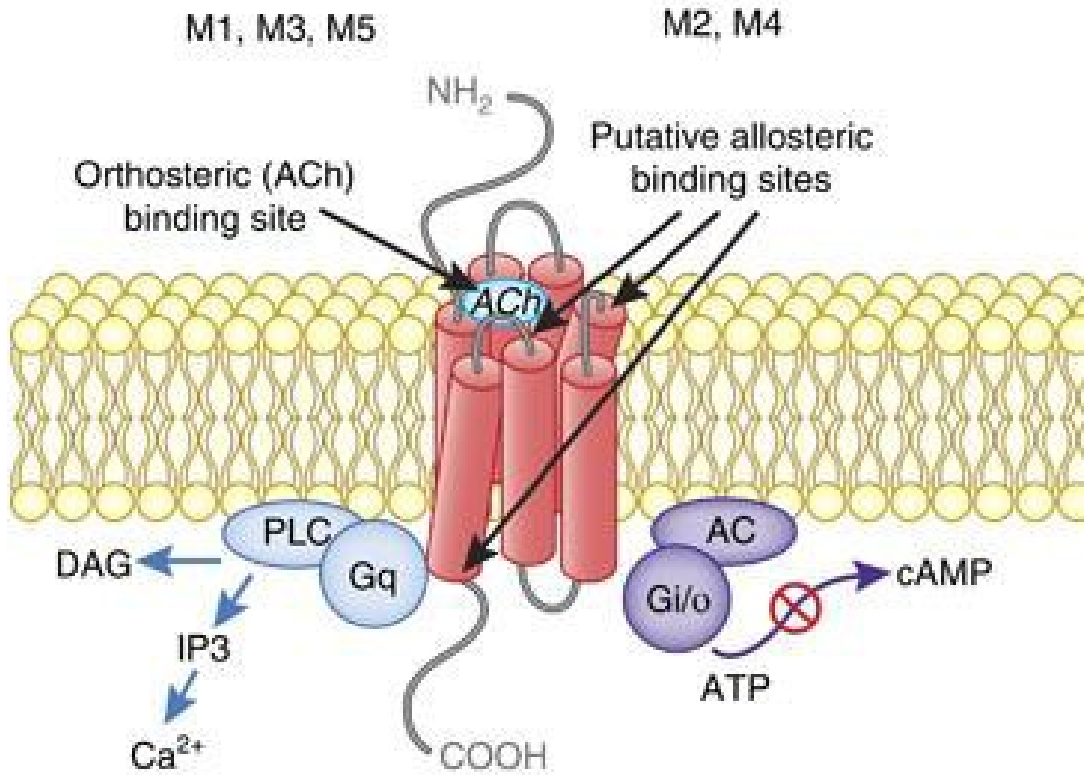
Autonomic nervous system

Postganglionic fibers

- PNS
- ***Muscarinic receptor***
  - G-protein coupled
  - Excitatory receptors (M_1, M_3, M_5)
  - Inhibitory receptors (M_2, M_4)



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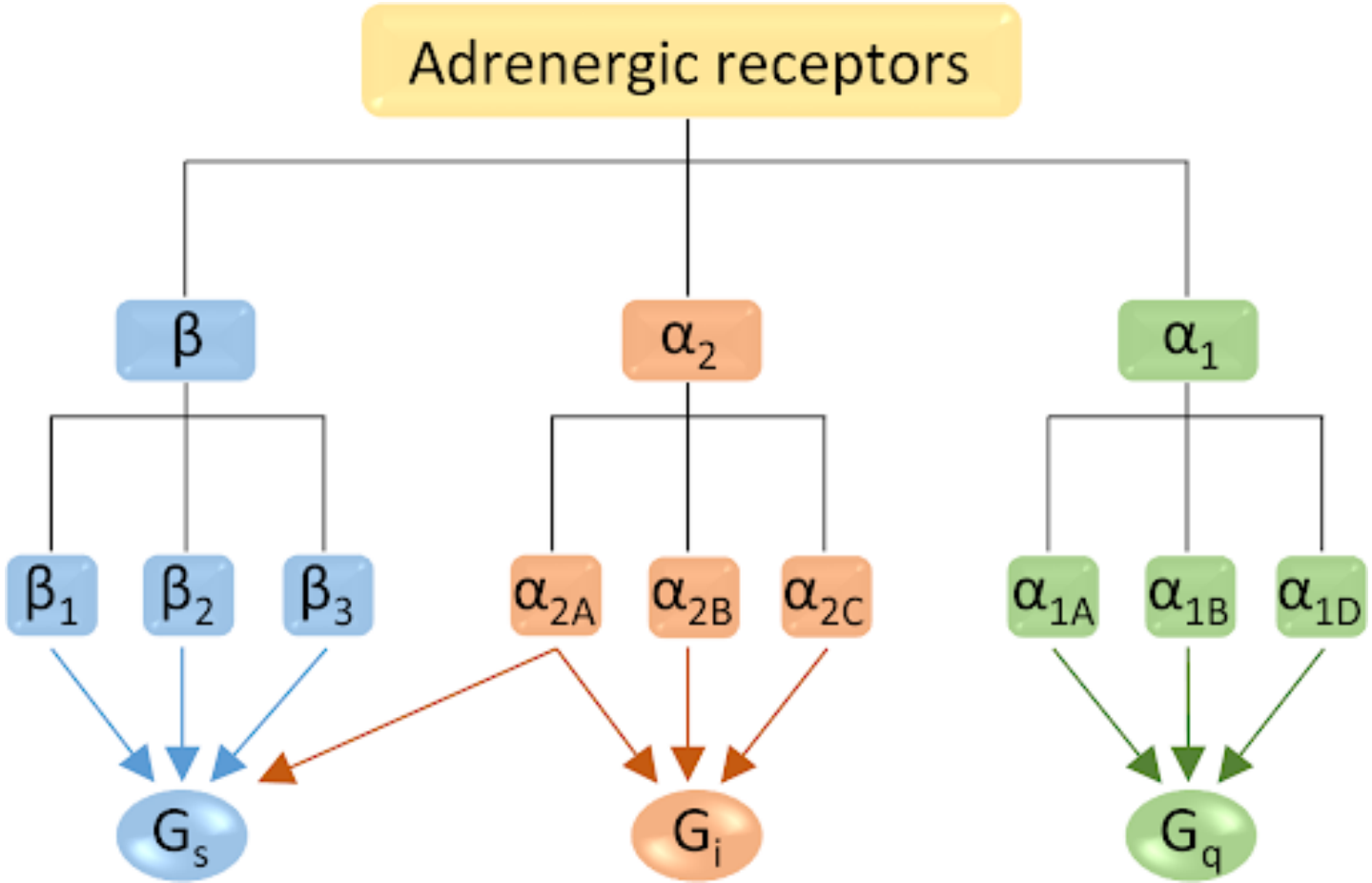
Autonomic nervous system

- **Postganglionic fibers**
- SNS
- ***Adrenergic receptor***
  - G-protein coupled



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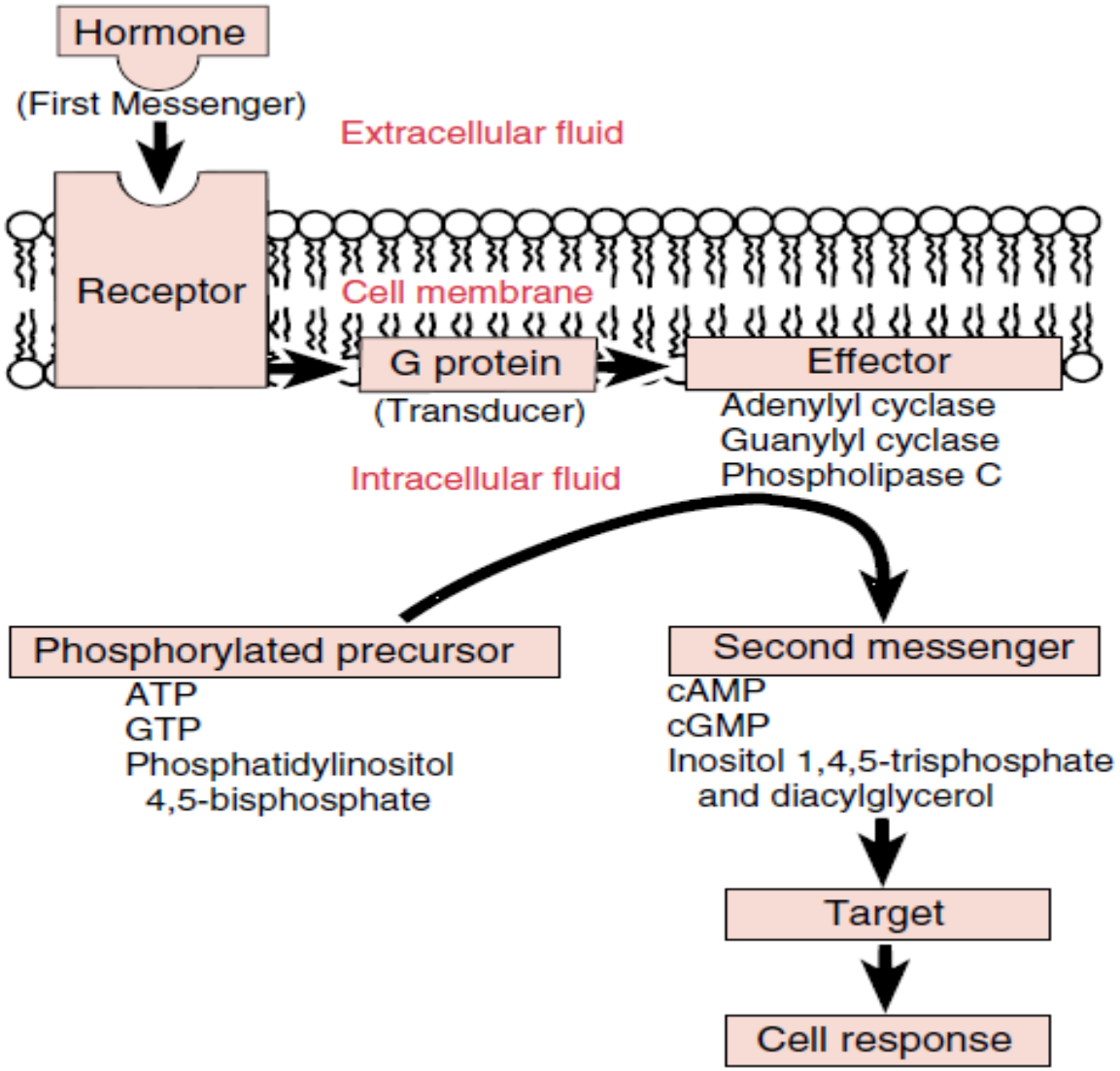
Second messenger systems



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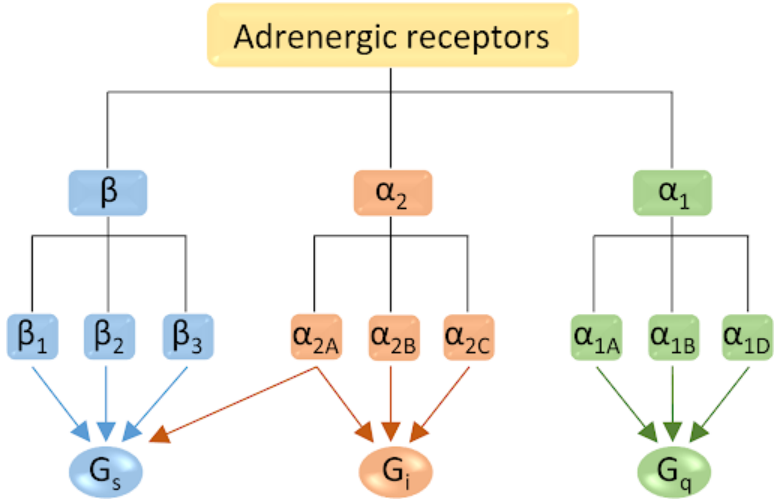
Autonomic nervous system

Adrenergic receptor

- G-protein coupled
  - Type α –Excitatory receptors
  - Type β – Inhibitory receptors



Receptor Type	Primary Mechanism of Action	Examples of Tissue Distribution	Examples of Action
α_1	↑ IP3 and Ca^{++}, DAG	Sympathetic postsynaptic nerve terminals	Increase vascular smooth muscle contraction
α_2	↓ cAMP	Sympathetic presynaptic nerve terminals, beta cell of pancreatic islets	Inhibit norepinephrine release, inhibit insulin release
β_1	↑ cAMP	Heart	Increase cardiac output
β_2	↑ cAMP	Liver; smooth muscle of vasculature, bronchioles, and uterus	Increase hepatic glucose output; decrease contraction of blood vessels, bronchioles, and uterus
β_3	↑ cAMP	Liver, adipose tissue	Increase hepatic glucose output, increase lipolysis

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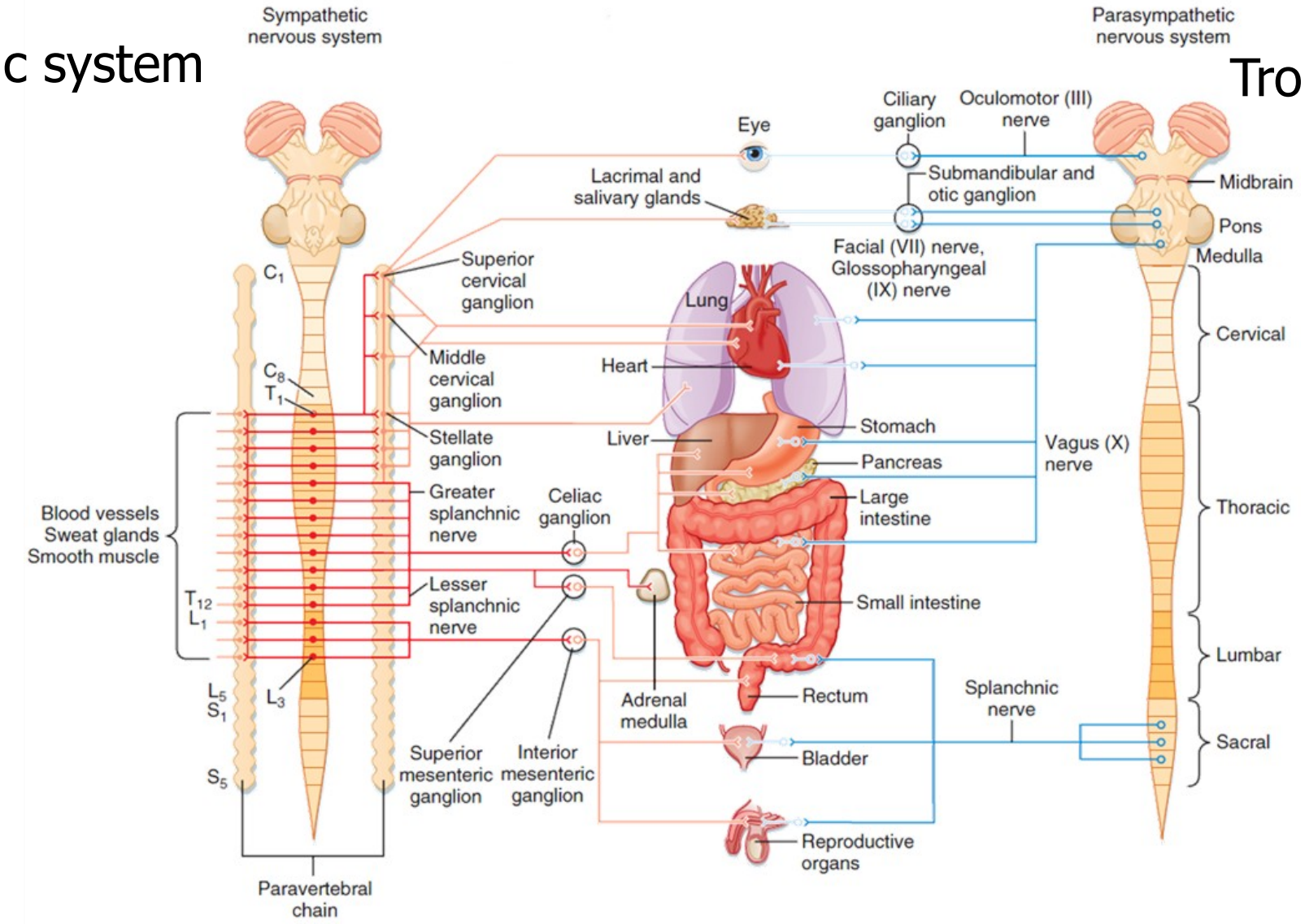
Autonomic nervous system

Ergotropic system

Trophotropic system

FIGHT OR FLIGHT

REST OR DIGEST



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ANS innervates

- The secretory glands (salivary,sweat, tear, and various mucus-producing glands; smooth muscles, cardiac muscles)
- The heart and blood vessels to control blood pressure and flow
- The bronchi of the lungs to meet the oxygen demands of the body
- **ANS regulates:**
- The digestive and metabolic functions of the liver, GIT, pancreas
- The functions of the kidney, urinary bladder, large intestine, rectum
- ANS is essential to the sexual responses of the genitals and reproductive organs
- Interacts with the body´s immune systém

- Mnemonic used:
- The sympathetic division tends to Fs: fight, flight, fright,and sex
- The parasympathetic division facilitates various non-fourF processes – as digestion, growth, immune response, energy storage
- In most cases the activity levels of the 2 ANS divisions are reciprocal- when one is high, the other tends to be low, and vice versa.

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Sympathetic nervous system

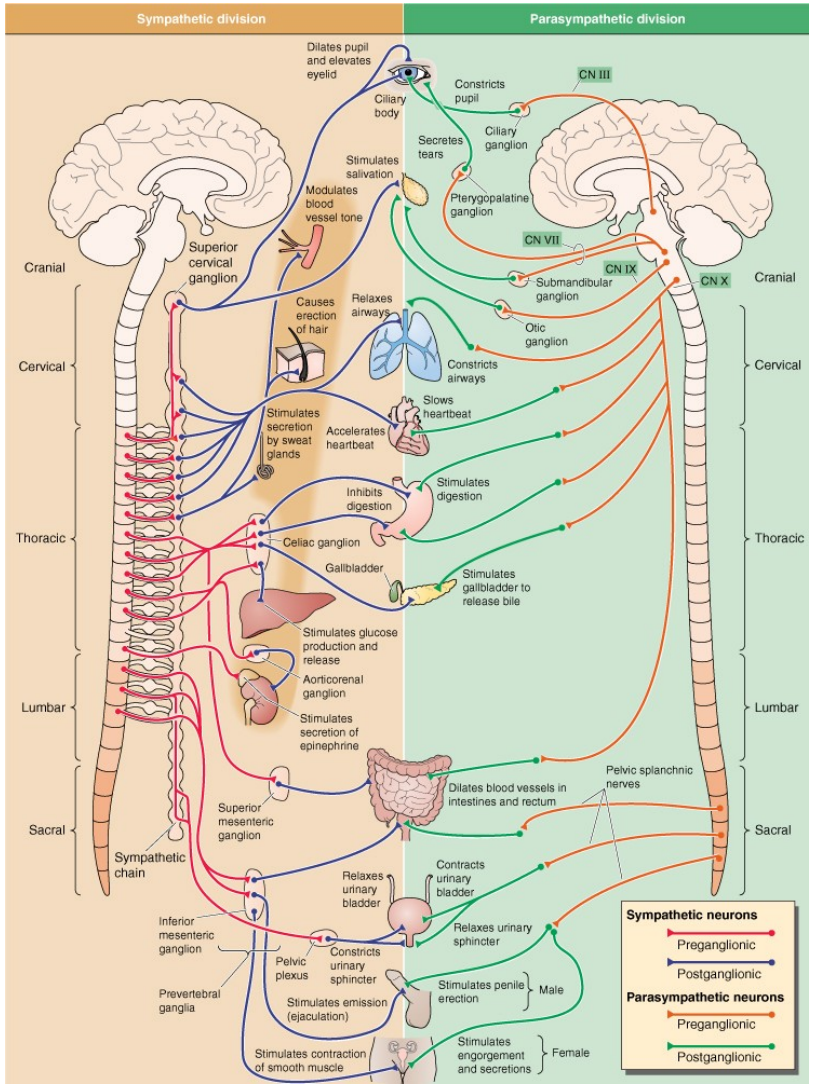
Fight or flight response

Energy/store consumption

Preganglionic neuron
– Spinal cord
-Thoraco - lumbar system

Ganglia
Paravertebral
-Truncus sympathicus
- Majority
Prevertebral
-Plexus aorticus

Mostly diffuse effect



Parasympathetic nervous system

Rest and digest response

Energy conservation/en. store production

Preganglionic neuron
– Brain stem and spinal cord
– cranio-sacral system

Ganglia
Close to target organs or intramurally

Mostly local effect

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Sympattheti c nervous syst

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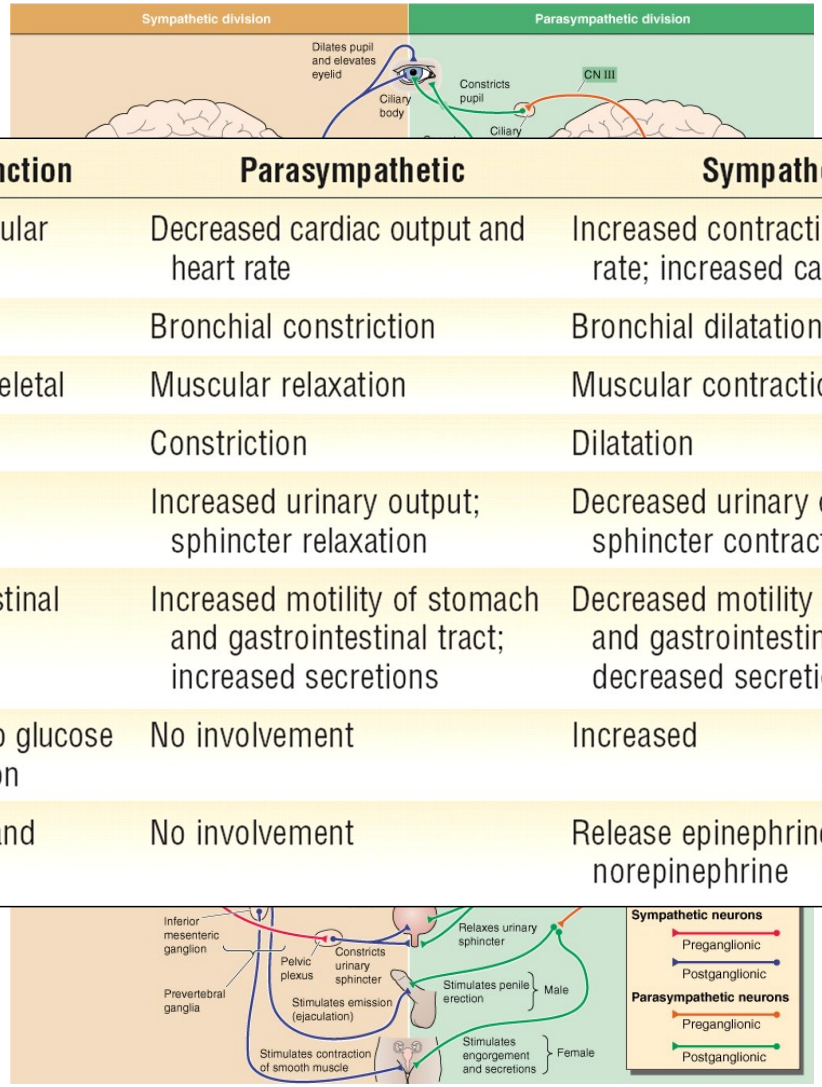
- Majority
Prevertebral
-Plexus aorticus

Mostly diffuse effect



System/function	Parasympathetic	Sympathetic
Cardiovascular	Decreased cardiac output and heart rate	Increased contraction and heart rate; increased cardiac output
Pulmonary	Bronchial constriction	Bronchial dilatation
Musculoskeletal	Muscular relaxation	Muscular contraction
Pupillary	Constriction	Dilatation
Urinary	Increased urinary output; sphincter relaxation	Decreased urinary output; sphincter contraction
Gastrointestinal	Increased motility of stomach and gastrointestinal tract; increased secretions	Decreased motility of stomach and gastrointestinal tract; decreased secretions
Glycogen to glucose conversion	No involvement	Increased
Adrenal gland	No involvement	Release epinephrine and norepinephrine

Parasympath etic nervous syst

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Mostly local effect

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ANS

Effector Response	Anatomical Pathway	Neurotransmitter	Receptor	G Protein	Enzyme or Protein	Second Messenger
Tachycardia	Sympathetic	NE	β_1 on cardiac pacemaker	$G\alpha_s$	↑AC	↑$[cAMP]_i$
Bradycardia	Parasympathetic	ACh	M_2 on cardiac pacemaker	Direct action of dimeric $G\beta\gamma$	GIRK1 K^+ channels	ΔV_m
Increase cardiac contractility	Sympathetic	NE	β_1 on cardiac myocyte	$G\alpha_s$ Direct action of $G\alpha_s$ on Cav1.2	↑AC	↑$[cAMP]_i$
Decrease cardiac contractility	Parasympathetic	ACh	M_2 on cardiac myocyte Presynaptic M_2 receptor on noradrenergic neuron M_3 receptor on cardiac myocyte	$G\alpha_i$ $G\alpha_i$ $G\alpha_q$	↓AC ↓AC ↑PLC → ↑$[Ca^{2+}]_i$ → ↑NOS → ↑GC	↓[cAMP] ↓$[cAMP]_i$ in neuron ↑$[cGMP]_i$ → ↑Cav1.2
Vasoconstriction in most blood vessels (e.g., skin)	Sympathetic	NE	α_1 on VSMC	$G\alpha_q$	↑PLC	↑$[Ca^{2+}]_i$
Vasoconstriction in some blood vessels	Sympathetic	NE	α_2 on VSMC	$G\alpha_{i/o}$	↓AC	↓[cAMP]$_i$
Vasodilation in most blood vessels (e.g., muscle)	Adrenal medulla	Epi	β_2 on VSMC	$G\alpha_s$	↑AC	↑[cAMP]$_i$
Vasodilation in erectile blood vessels	Parasympathetic	ACh ACh NO VIP	Presynaptic M_2 receptor on noradrenergic neurons M_3 on endothelial cell NO receptor (i.e., GC) inside VSMC VIP receptor on VSMC	$G\alpha_i$ $G\alpha_q$ – $G\alpha_s$	↓AC ↑PLC → ↑$[Ca^{2+}]_i$ → ↑NOS ↑GC ↑AC	↓[cAMP]$_i$ in neuron NO diffuses to VSMC ↑[cGMP]$_i$ ↑$[cAMP]_i$
Vasodilation in blood vessels of salivary gland	Parasympathetic	ACh	M_3 receptor on gland cell	$G\alpha_q$	↑Kallikrein	Kinins
Vasodilation in blood vessels of muscle in fight-or-flight response	Sympathetic	ACh NANC	Presynaptic M_2 receptor on noradrenergic neurons Receptor on VSMC	$G\alpha_i$	↓AC	↓$[cAMP]_i$ in neuron

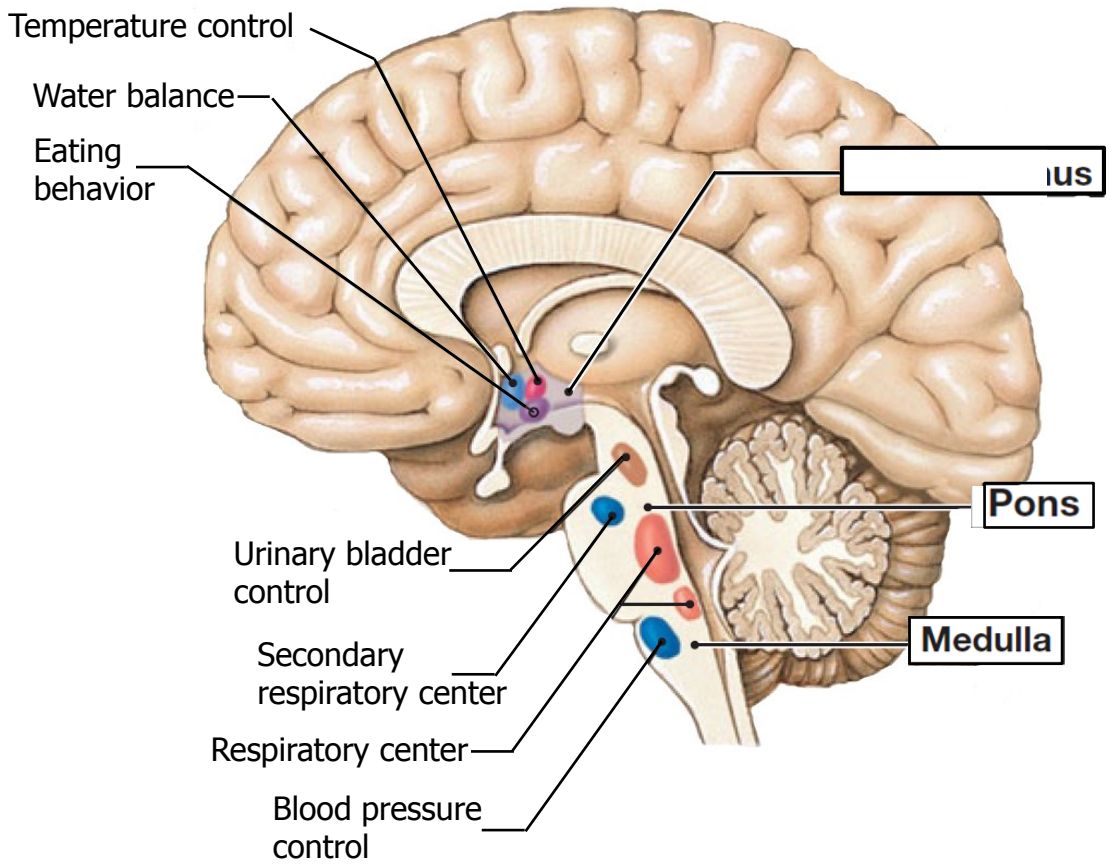
AC, adenylyl cyclase; ACh, acetylcholine; cAMP, cyclic adenosine monophosphate; cGMP, cyclic guanosine monophosphate; Epi, Epinephrine; GC, guanylyl cyclase; GIRK1, G protein–activated/inwardly rectifying K^+ channel (Kir3.1); NANC, nonadrenergic, noncholinergic; NE, norepinephrine; NO, nitric oxide; NOS, nitric oxide synthase; PLC, phospholipase C; VIP, vasoactive intestinal peptide; VSMC, vascular smooth muscle cell.

Boron et al: Medical Physiology, 2017

Brain control of ANS

Autonomic centers—brain stem and hypothalamus

1. **Medulla**
   - Vasomotor center
   - Respiratory center
   - Swallowing, coughing, and vomiting centers
2. **Pons**
   - Pneumotaxic center
3. **Midbrain**
   - Micturition center
4. **Hypothalamus**
   - Temperature regulation center
   - Thirst and food intake regulatory centers



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Hypothalamus

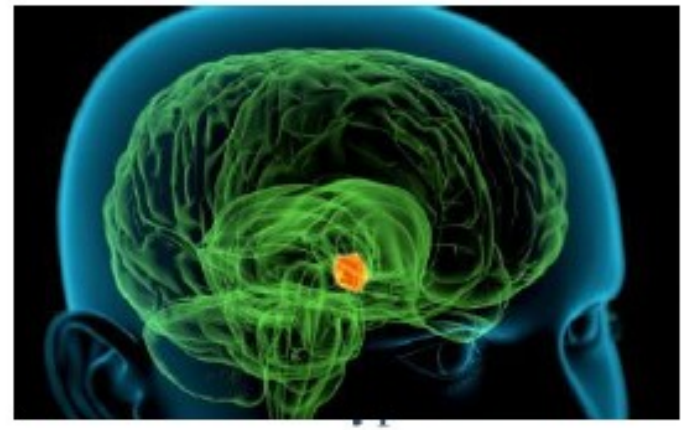
- Key center of autonomic regulations and coordination
- Integration of the information from inner and outer environment

↓

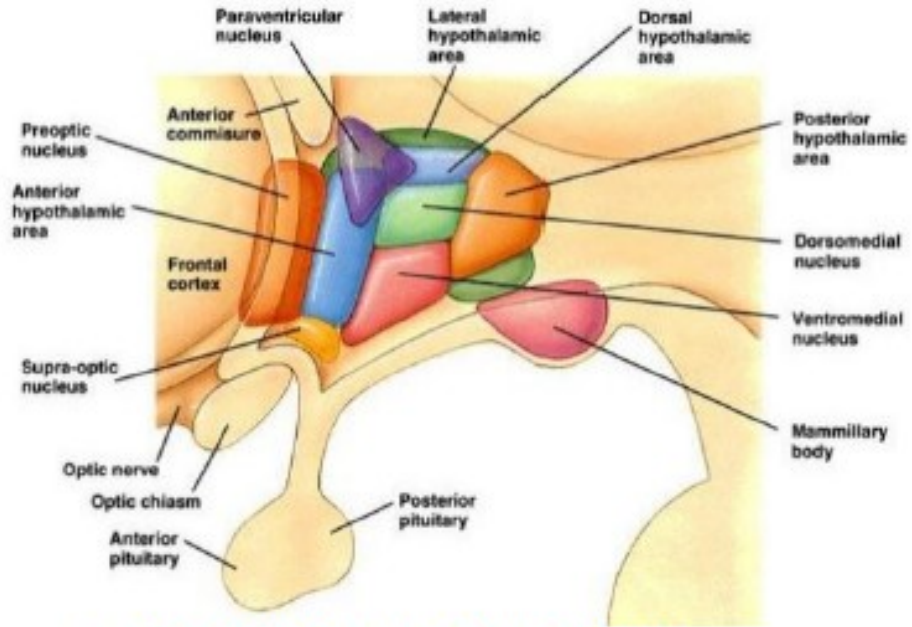
- Behavioral modulation
- Regulation of autonomic nervous system

↓

- **Maintenance of homeostasis**



http://biology.about.com/od/anatomy/ss/Hypothalamus.htm



http://www.slideshare.net/physiologymgmcri/hypothalamus-15-apr-2016

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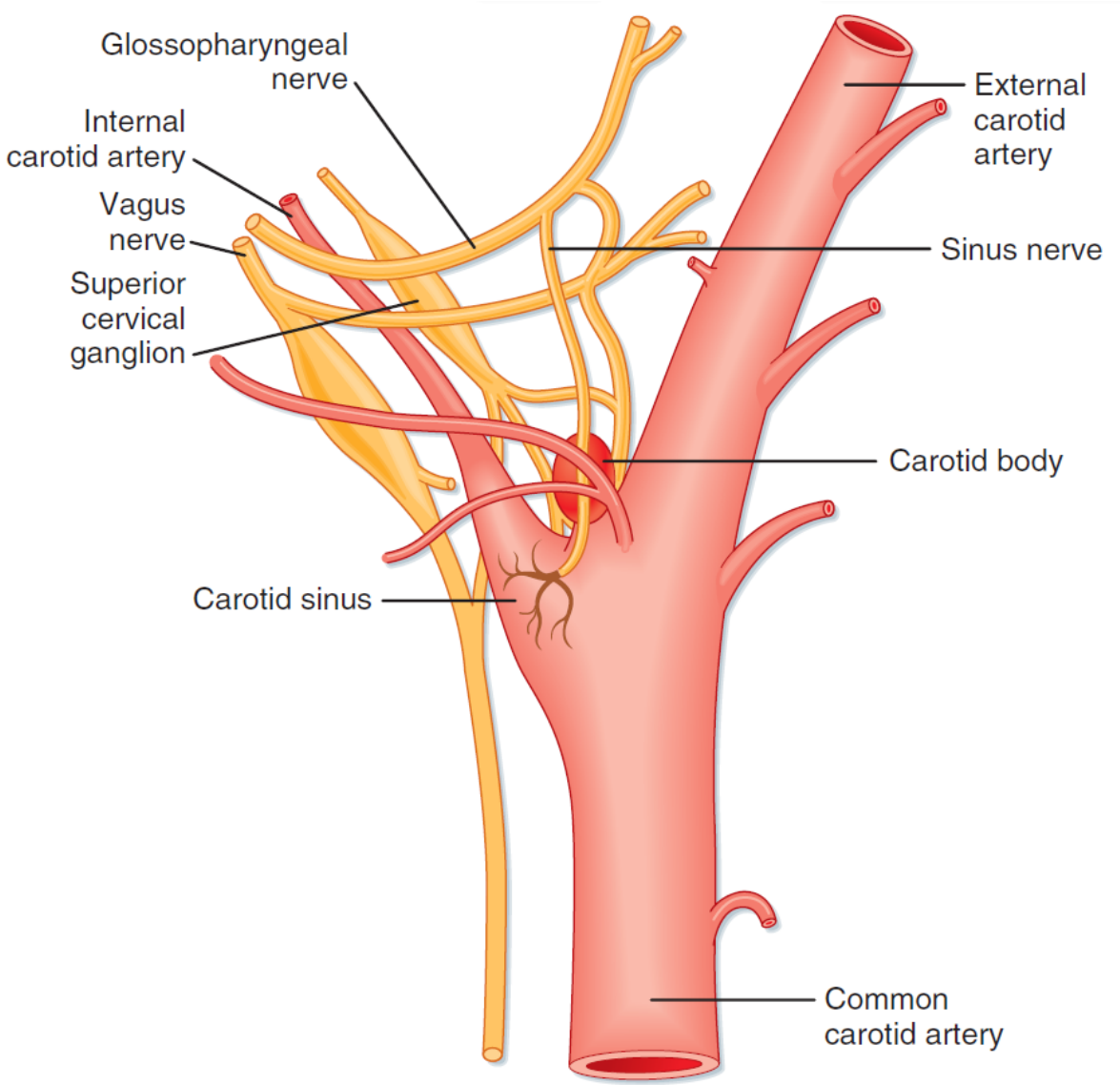
Baroreceptor vs. Chemoreceptor



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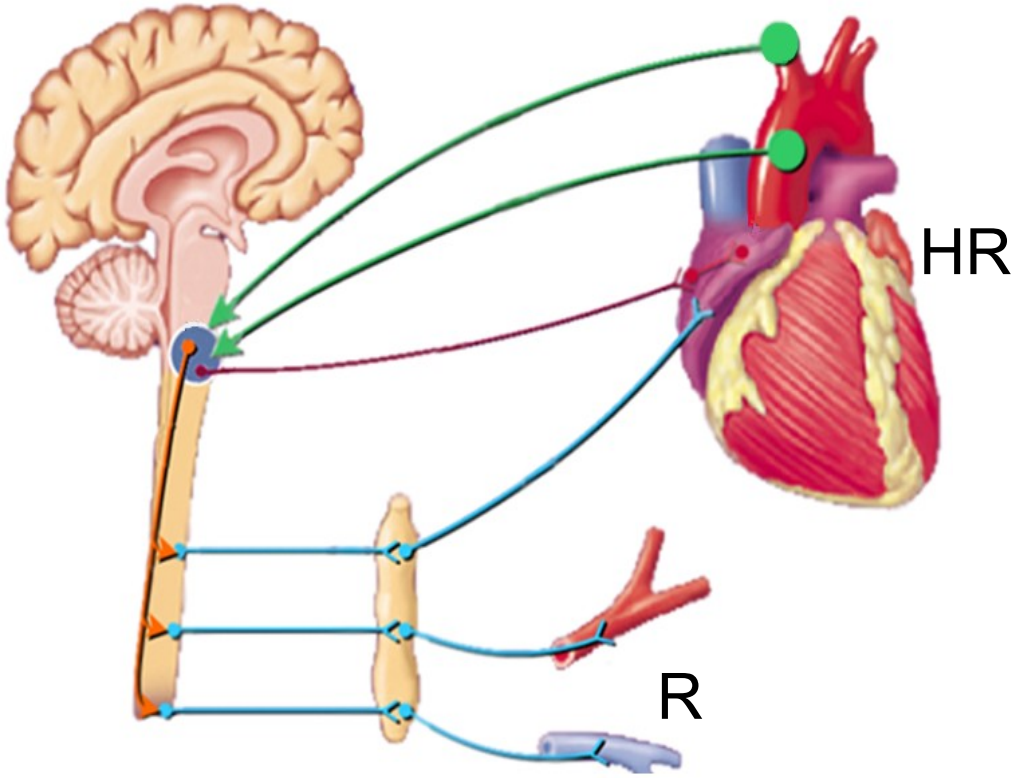
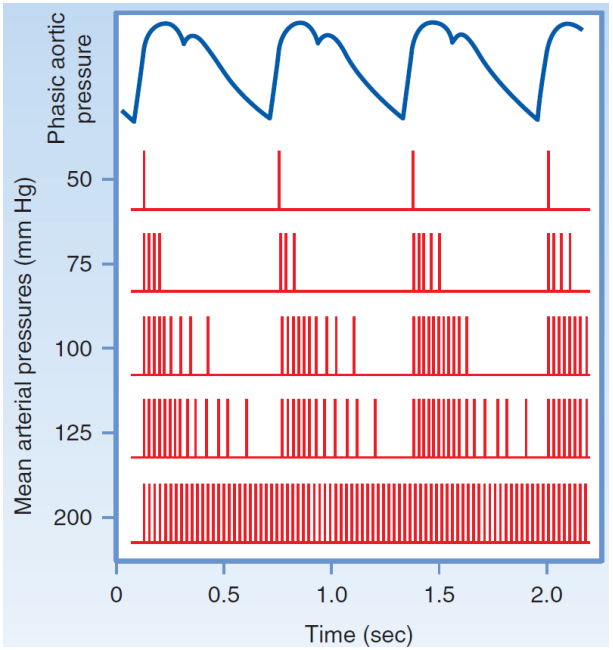
Baroreflex I

Aferent pathway
Parasympathetic pathway
Sympathetic pathway





- Inotropic
- Chronotropic
- Dromotropic
- Batmotropic

} effect

BP=HR x SV x R

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Something more…

- Oculocardial reflex
  - Pressure on the eyebulbes decreases heart rate (activation of the vagus)
  - It is used to suppress or stop atrial tachycardia
- Low pressure baroreflex
  - greater expansion of the left ventricle stimulates baroreceptors –vagus→medulla - inhibition of SNS – vasodilation, bradycardia – decrease of BP
- Diving reflex
  - Cold water on the face causes respiratory arrest, peripheral vasoconstriction and bradycardia
- Coronary chemoreflex (Bezoldov-Hirtov-Jarisch reflex)
  - Substances applied to the left coronary artery (veratridine, capsaicin, some contrast agents, substances produced by ischemic tissue) induce apnea and then hyperpnea, hypotension, bradycardia (vagal afferentation)

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Testing of autonomic nervous system

- **Tilt table test**
  - Neurocardiogene syncopa (cardioinhibitory – vasodepresory-both)
  - Cerebral vasoconstriction with syncopa
- **Pressure of the eyebulbes or sinus caroticus**
  - Cardioinhibitory-vasodepresory-both answer (hypersensitivity of sinus caroticus)
- **Farmacological tests**
  - With norepinephrine, isoprenaline, atropine

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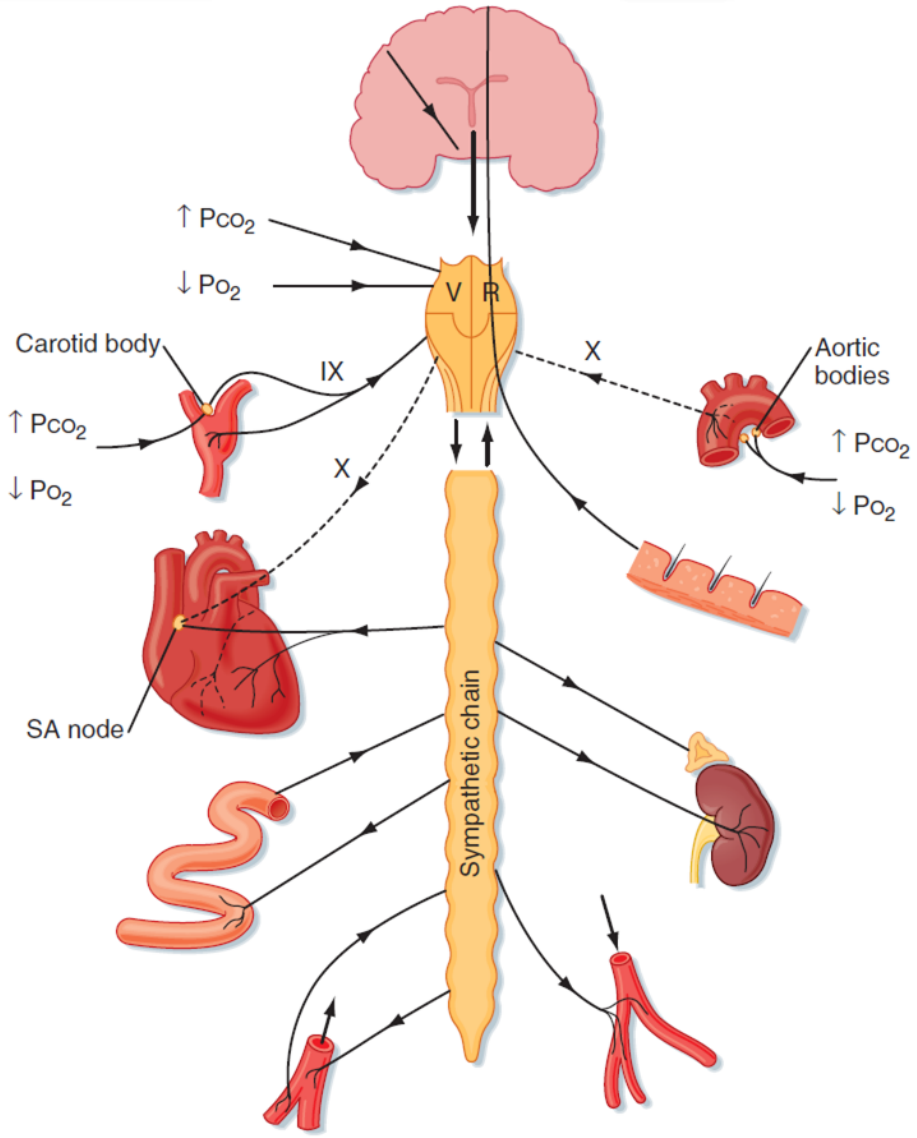
ANS and blood vessels



EFECTORS	RECEPTORS	ADRENERGIC REACTION
CORONARY A.	α, $β_2$	C, D
SKIN A.	α	C
SKELETAL MUSCLE	α, $β_2$	C, D
BRAIN A.	α	C
LUNGS A.	α, $β_2$	C, D
ABDOMINAL A.	α, $β_2$	C, D
VEINS	α, $β_2$	C, D

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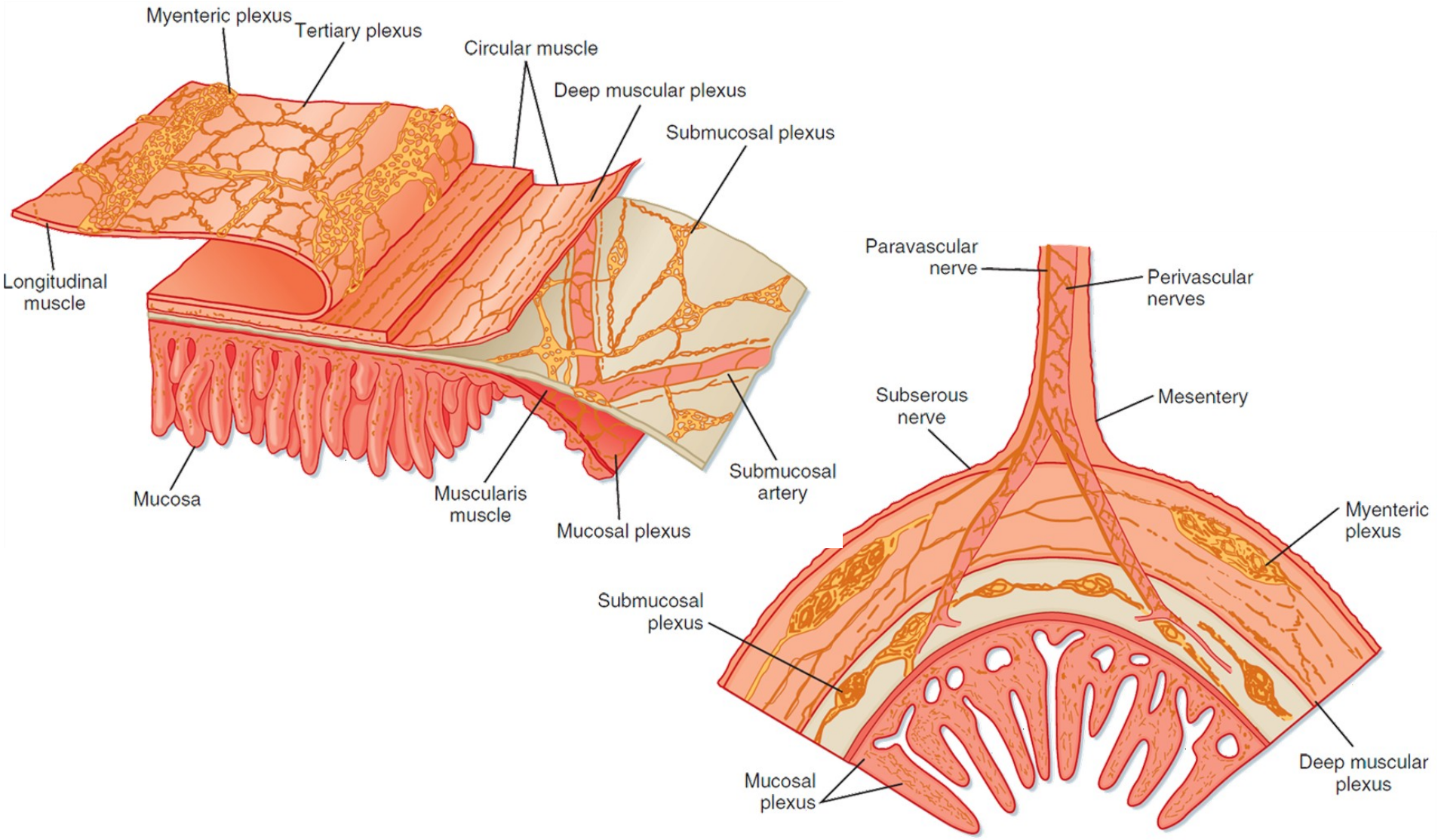
GIT - Enteric Nervous System



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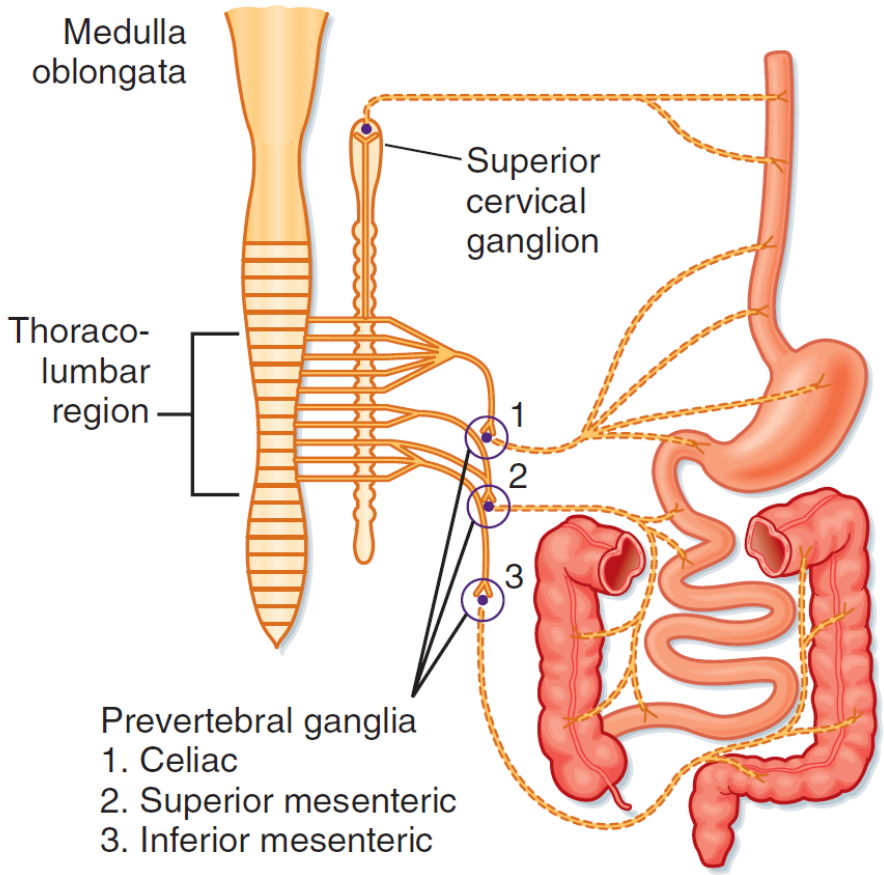
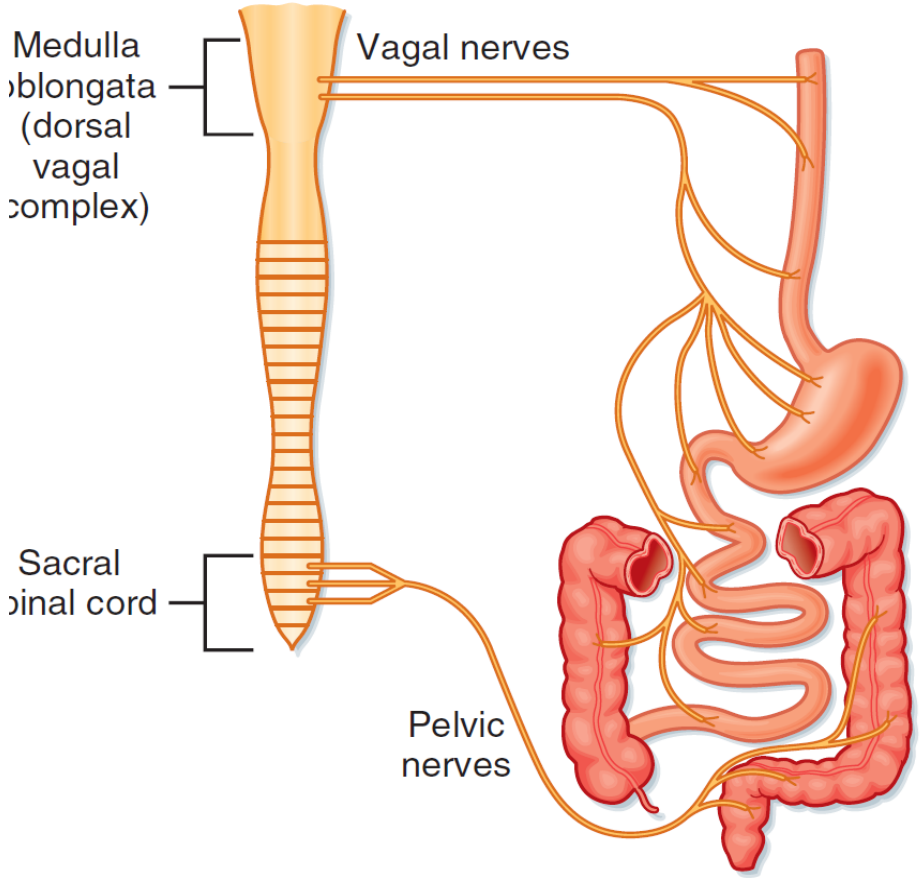
GIT and ANS

SNS



PNS



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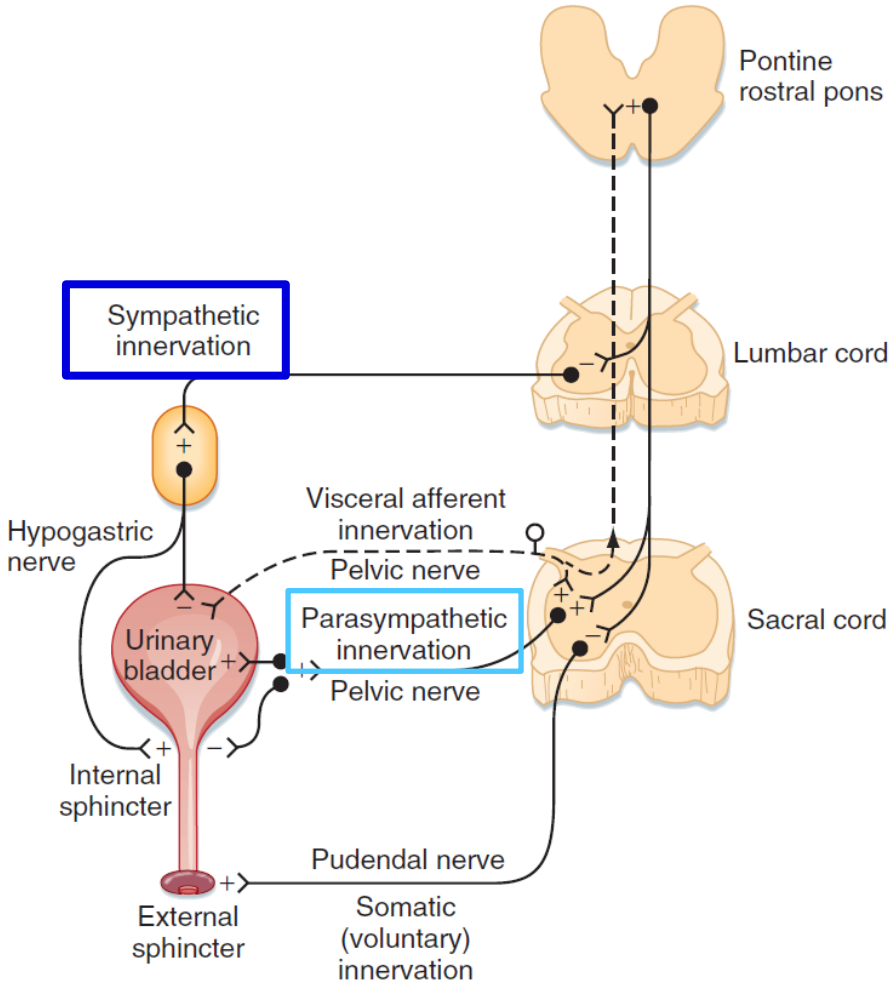
ANS and urinary bladder

SNS	
DETRUSOR	RELAXATION
SPHINCTER	CONTRACTION

PSN	
DETRUSOR	CONTRACTION
SPHINCTER	RELAXATION



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Thank you for your attention

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Extra information

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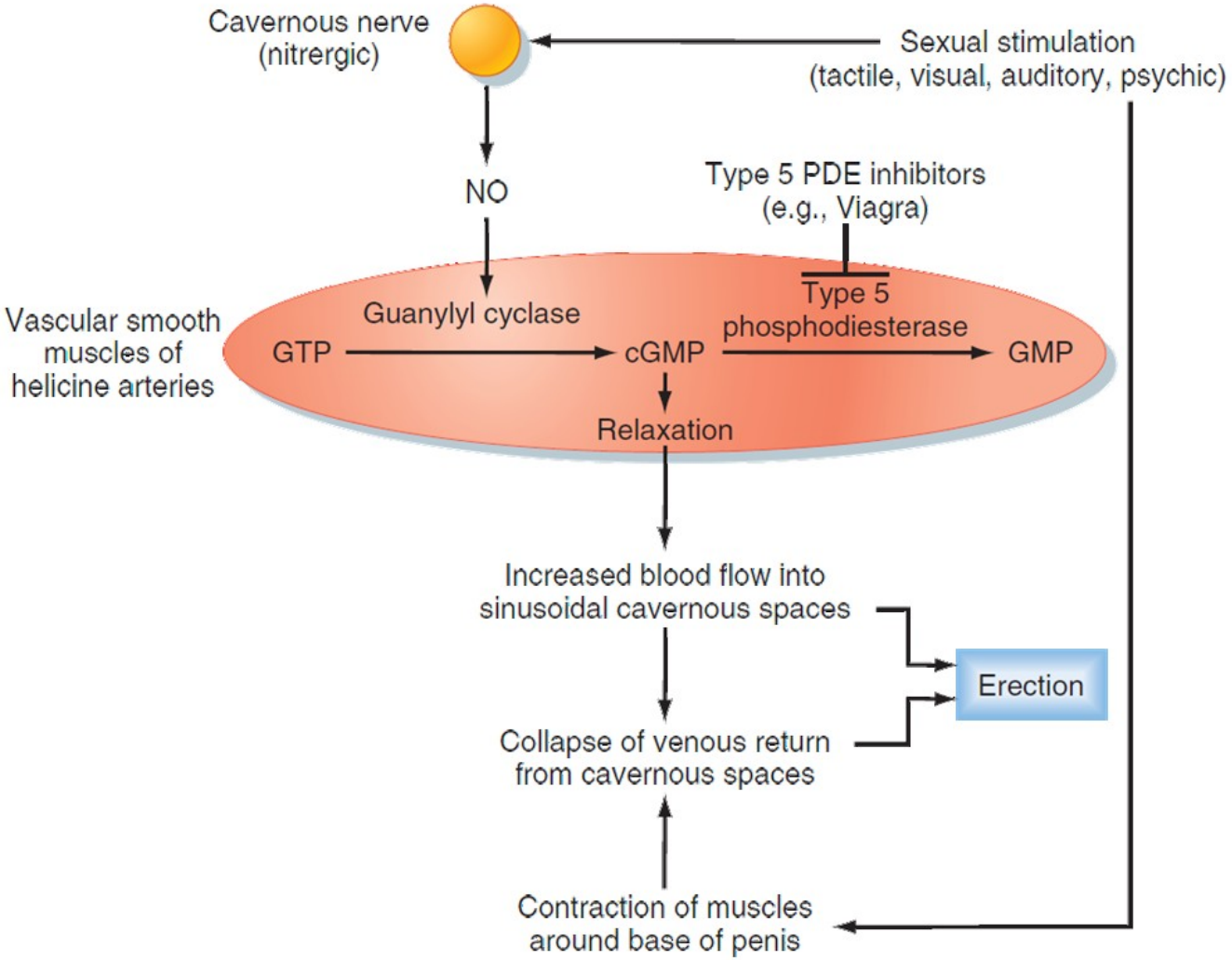
ANS and sexual function



Neurogenic bladder

NAME	COMMENTS
Uninhibited bladder	Lesion: above the pontine micturition center Signs: reduced awareness of bladder fullness, incontinence may occur
Upper motor neuron bladder (Detrusor-sphincter dyssynergia)	Lesion: between the pontine micturition center and sacral cord Signs: detrusor is usually spastic, simultaneous detrusor and urinary sphincter contractions increase pressures in the bladder, can lead to vesicoureteral reflux that and renal damage
Mixed type A bladder	Lesion: sacral cord lesion at the detrusor nucleus with sparring of the pudendal nucleus Signs: the detrusor muscle is flaccid, bladder is large, external urinary sphincter is spastic, incontinence uncommon
Mixed type B bladder	Lesion: sacral cord lesion at the pudendal nucleus with sparring of the detrusor nucleus Signs: the bladder is spastic and the external urinary sphincter is flaccid, incontinence is common
Lower motor neuron bladder	Lesion: sacral cord or sacral root while the thoracic sympathetic outflow to the lower urinary tract is preserved Signs: bladder is large and hypotonic, incontinence uncommon

ANS and sexual function