

M U N I

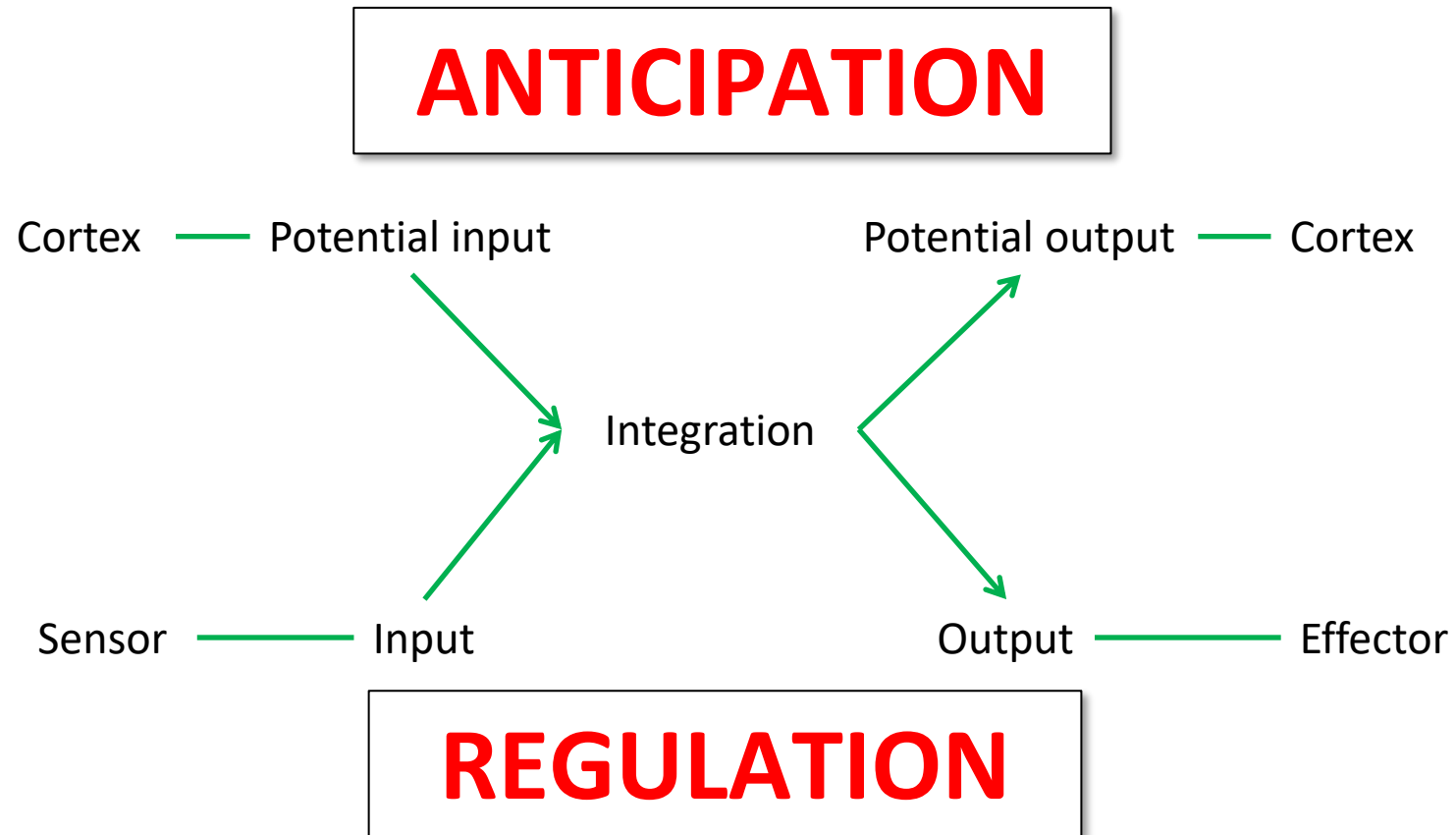
M E D

M U N I
M E D

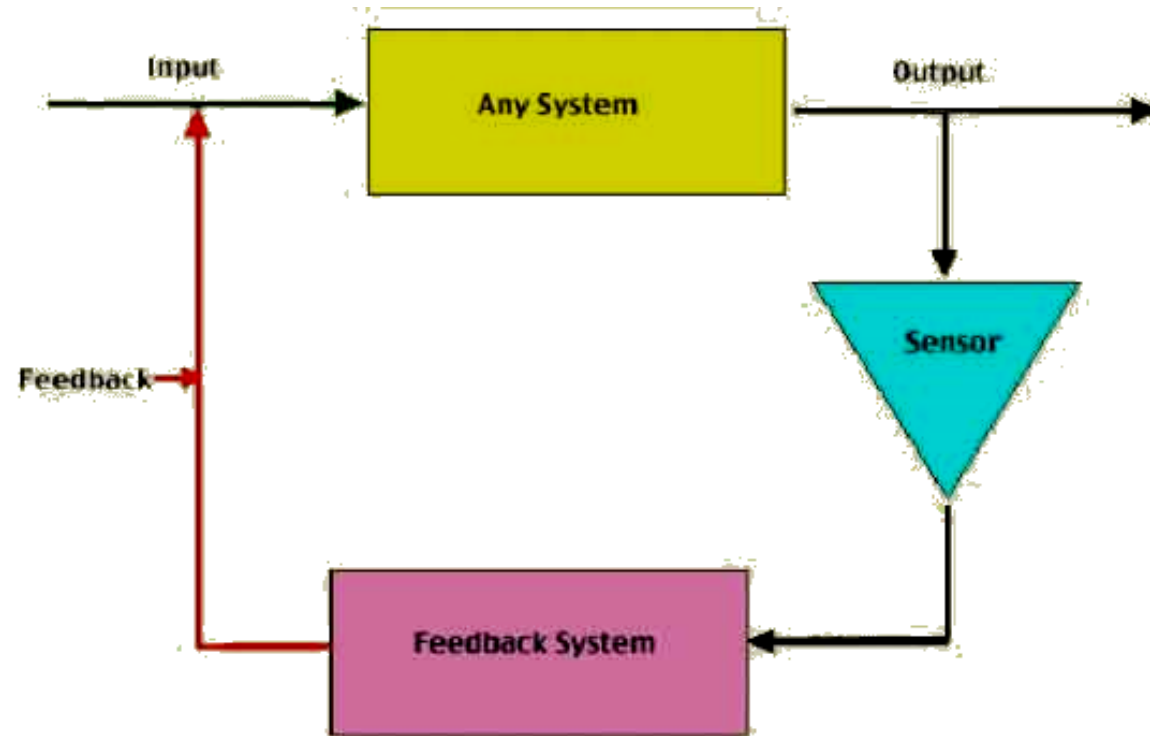
13

Autonomic nervous system

The role of nervous system

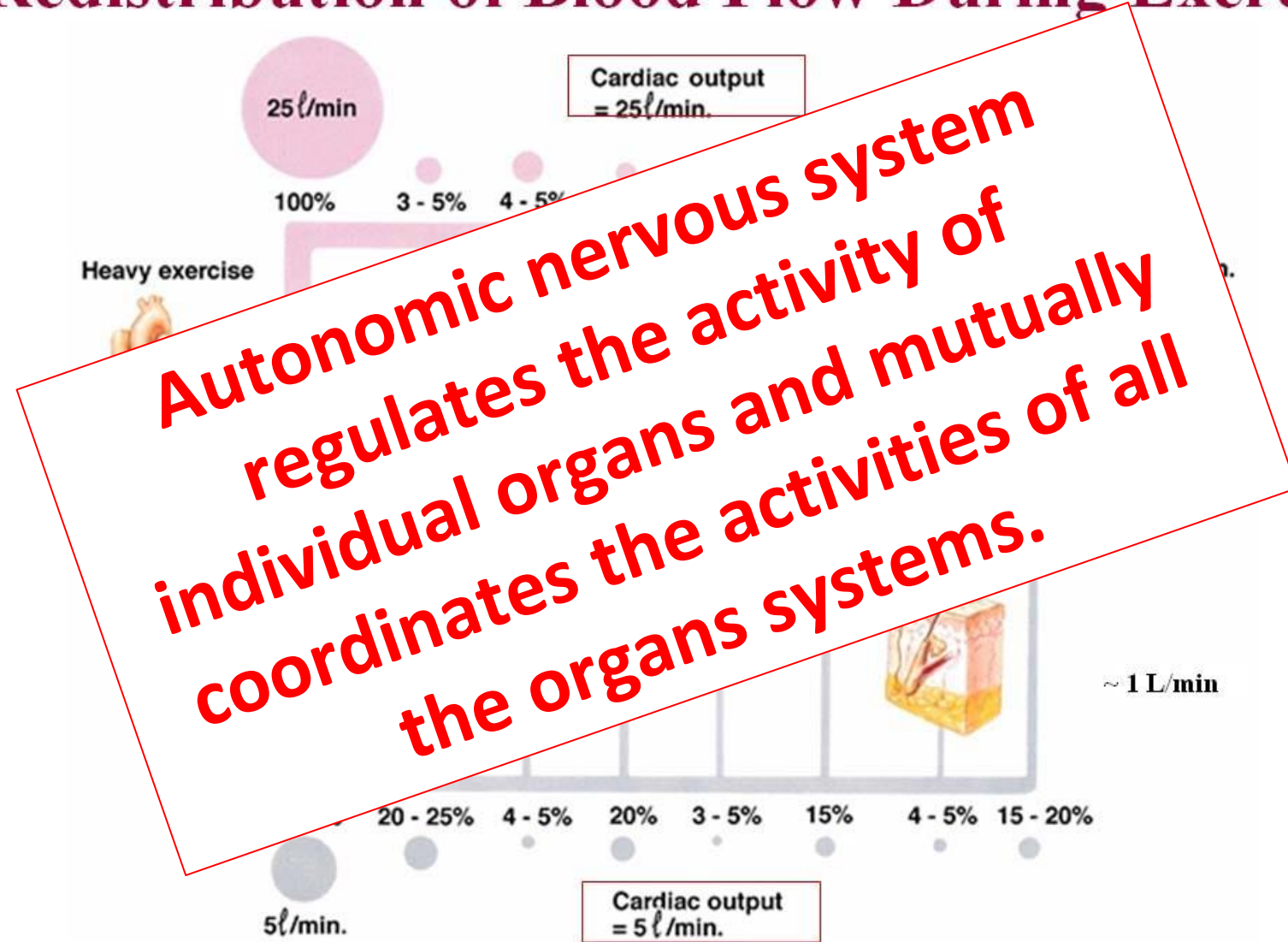


Feedback regulation

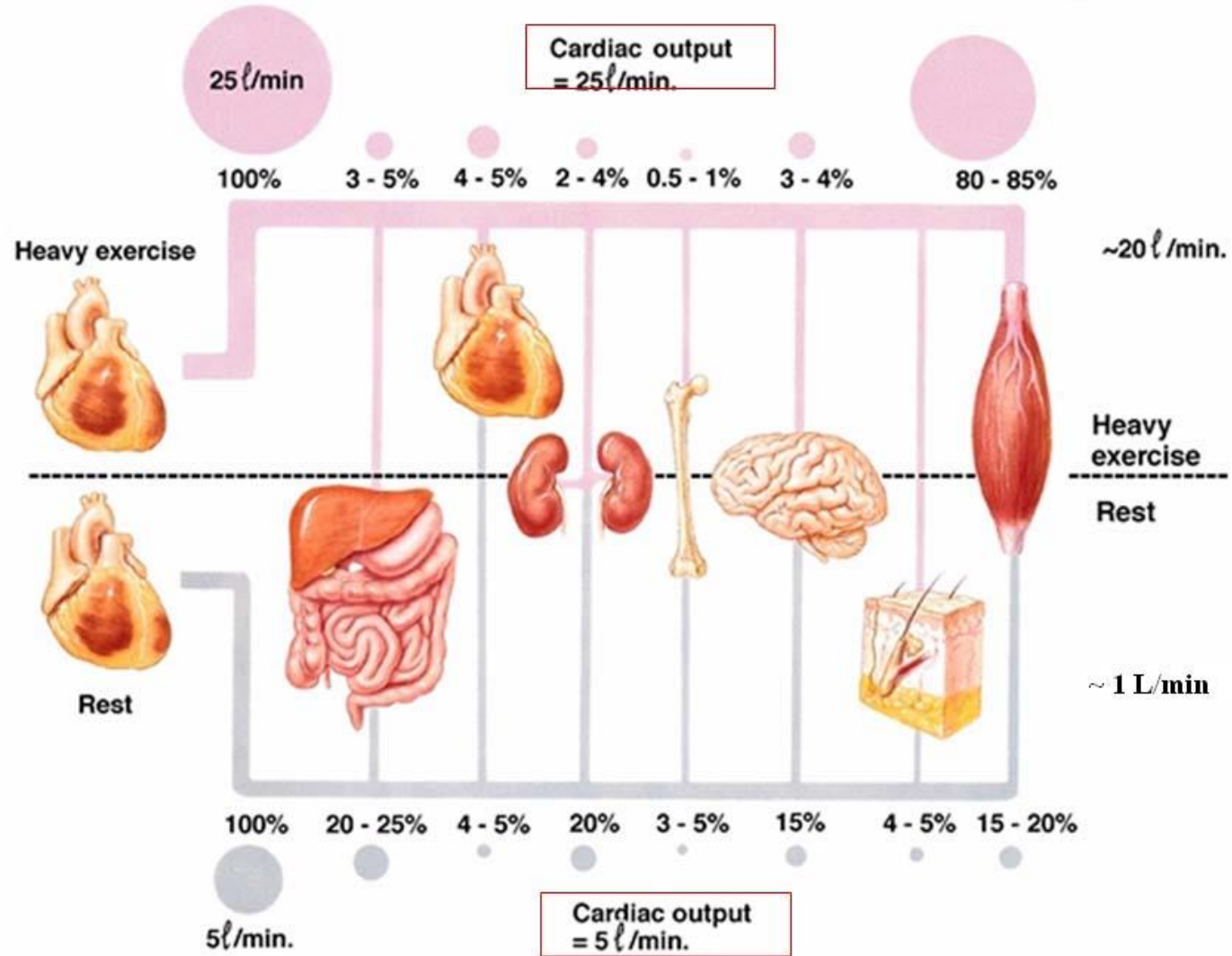


Simple Feedback Loop

Redistribution of Blood Flow During Exercise



Redistribution of Blood Flow During Exercise



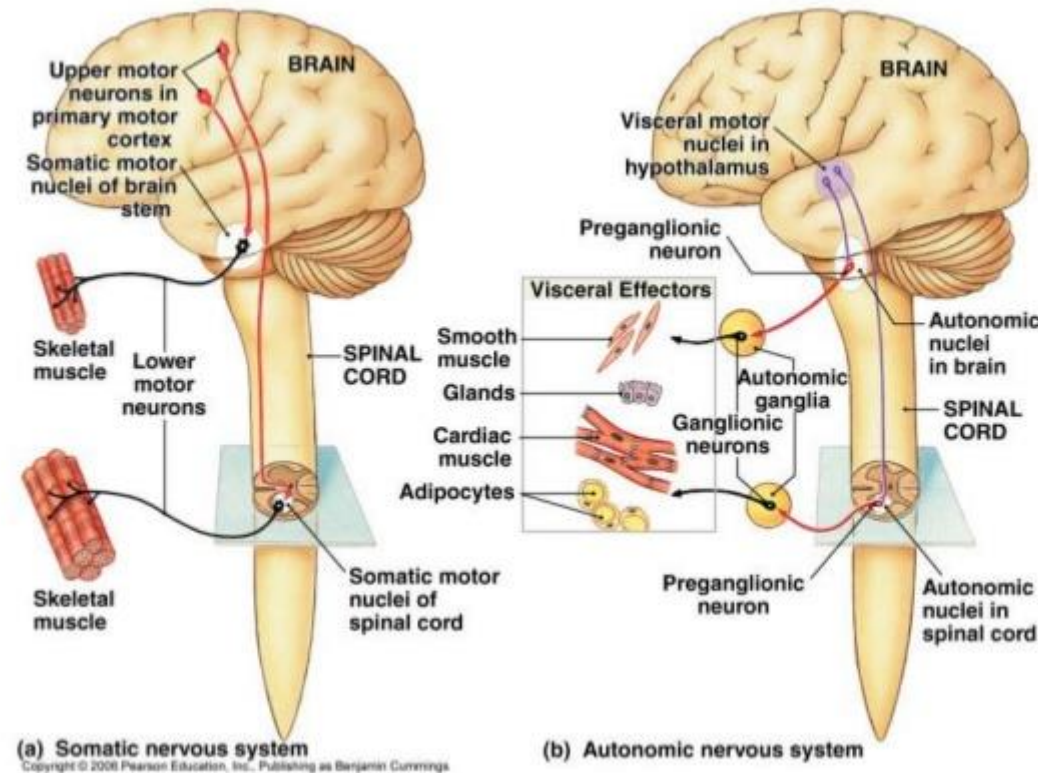
Somatic a autonomic nervous system

➤ „Voluntary“

✓ Skeletal muscle

■ Direct connection between CNS and effector

Somatic vs. Autonomic



➤ „Involuntary“

✓ Cardiomyocyte
✓ Visceral muscle
✓ Gland

■ Autonomic ganglion inserted between CNS and effector

Somatic a autonomic nervous system

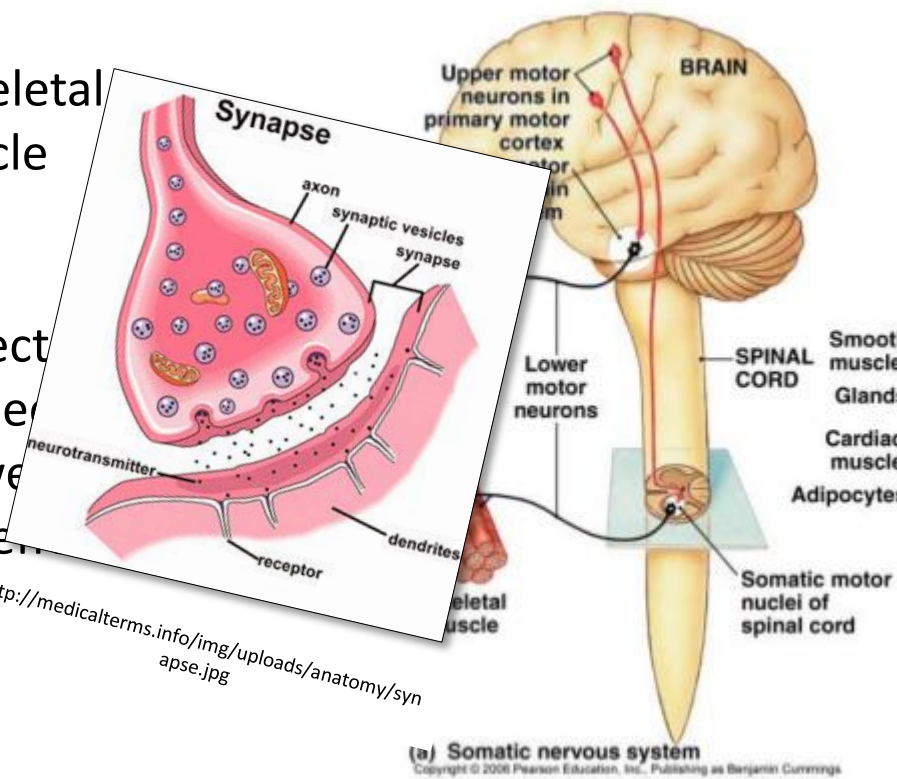
➤ „Voluntary“

Somatic vs. Autonomic

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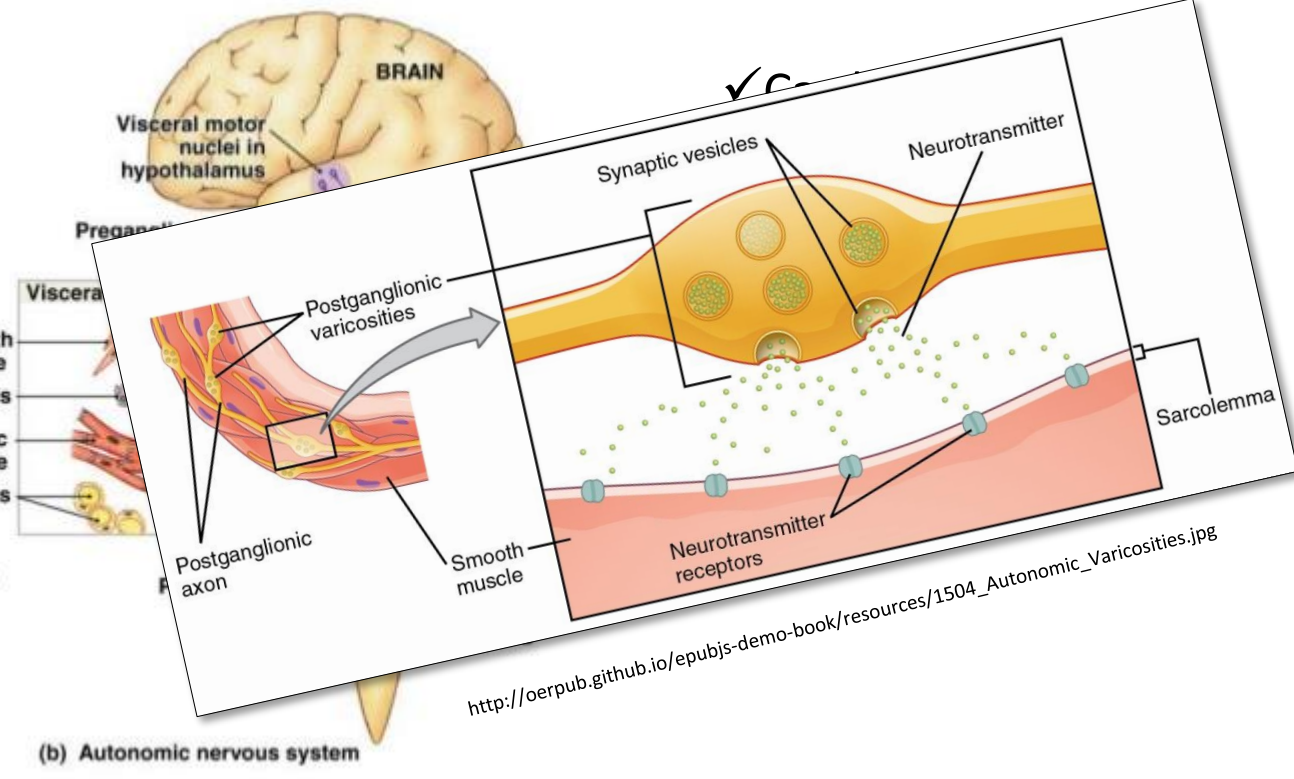
✓ Skeletal muscle

▪ Direct connection between brain and effector



<http://medicalterms.info/img/uploads/anatomy/synapse.jpg>

(a) Somatic nervous system
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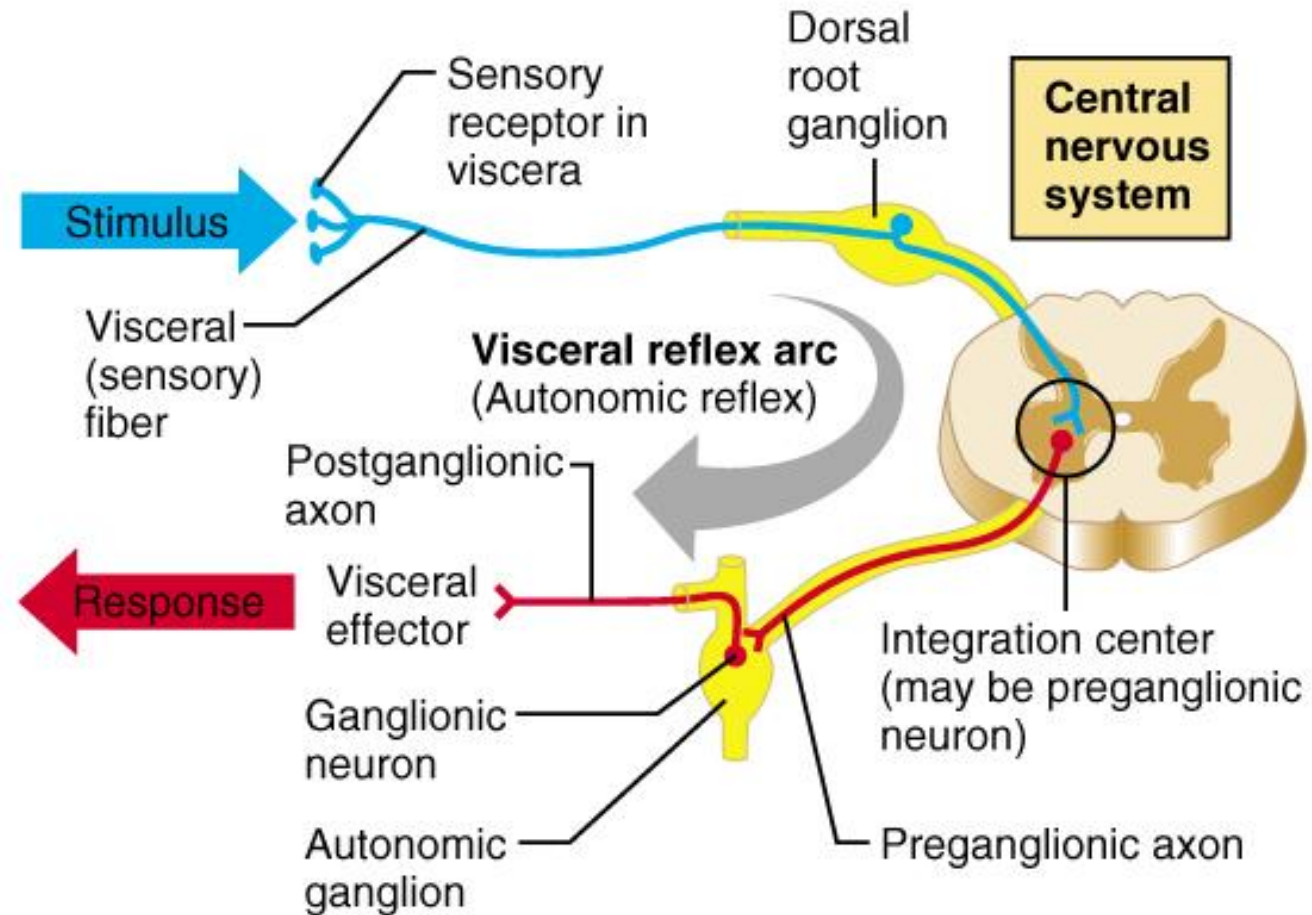


http://oerpub.github.io/epubjs-demo-book/resources/1504_Autonomic_Varicosities.jpg

(b) Autonomic nervous system

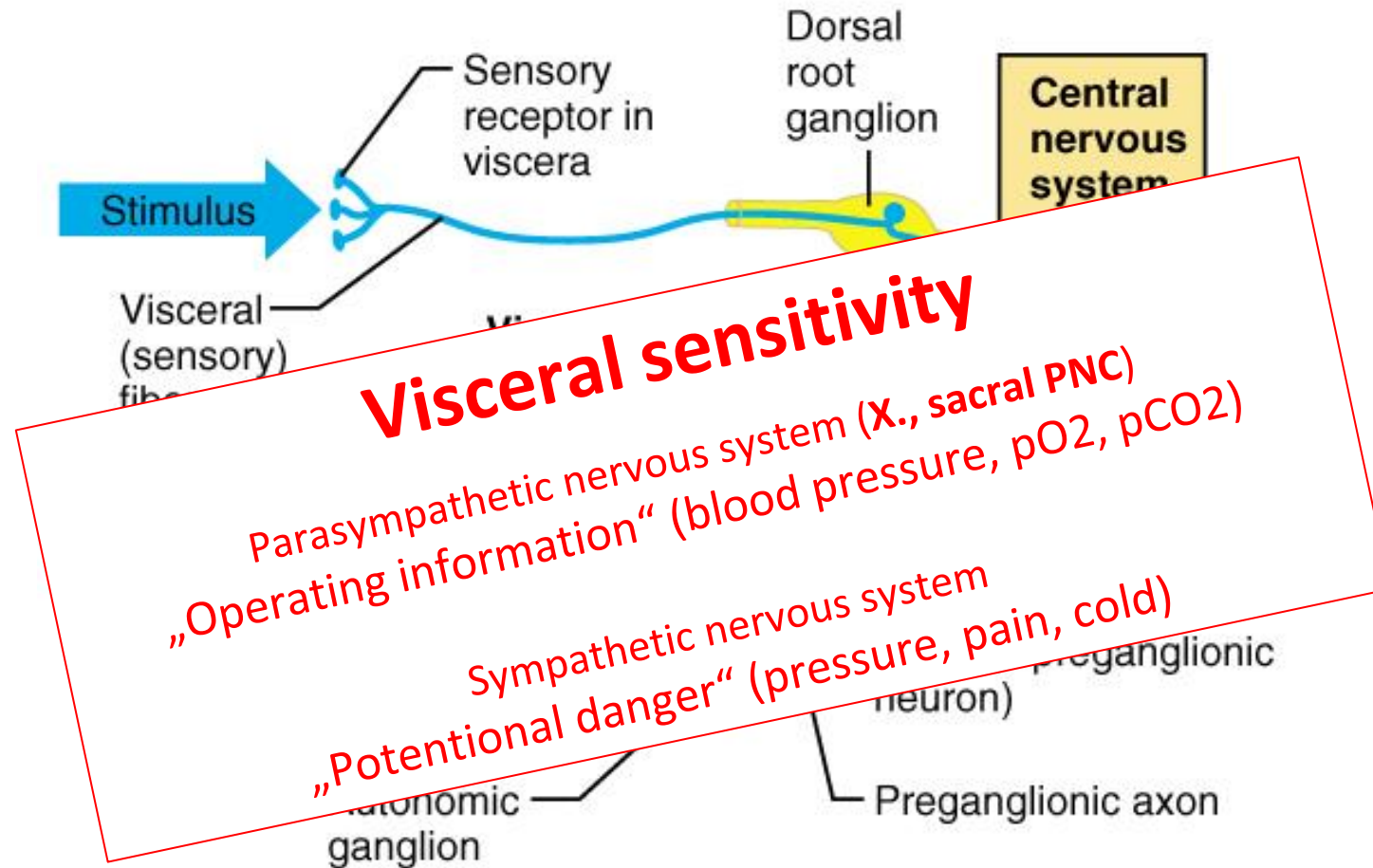
<http://image.slidesharecdn.com/ans-130217134747-phpp01/95/central-nervous-system-the-autonomic-nervous-system-7-638.jpg?cb=1361108947>

Visceral reflex loop



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Visceral reflex loop

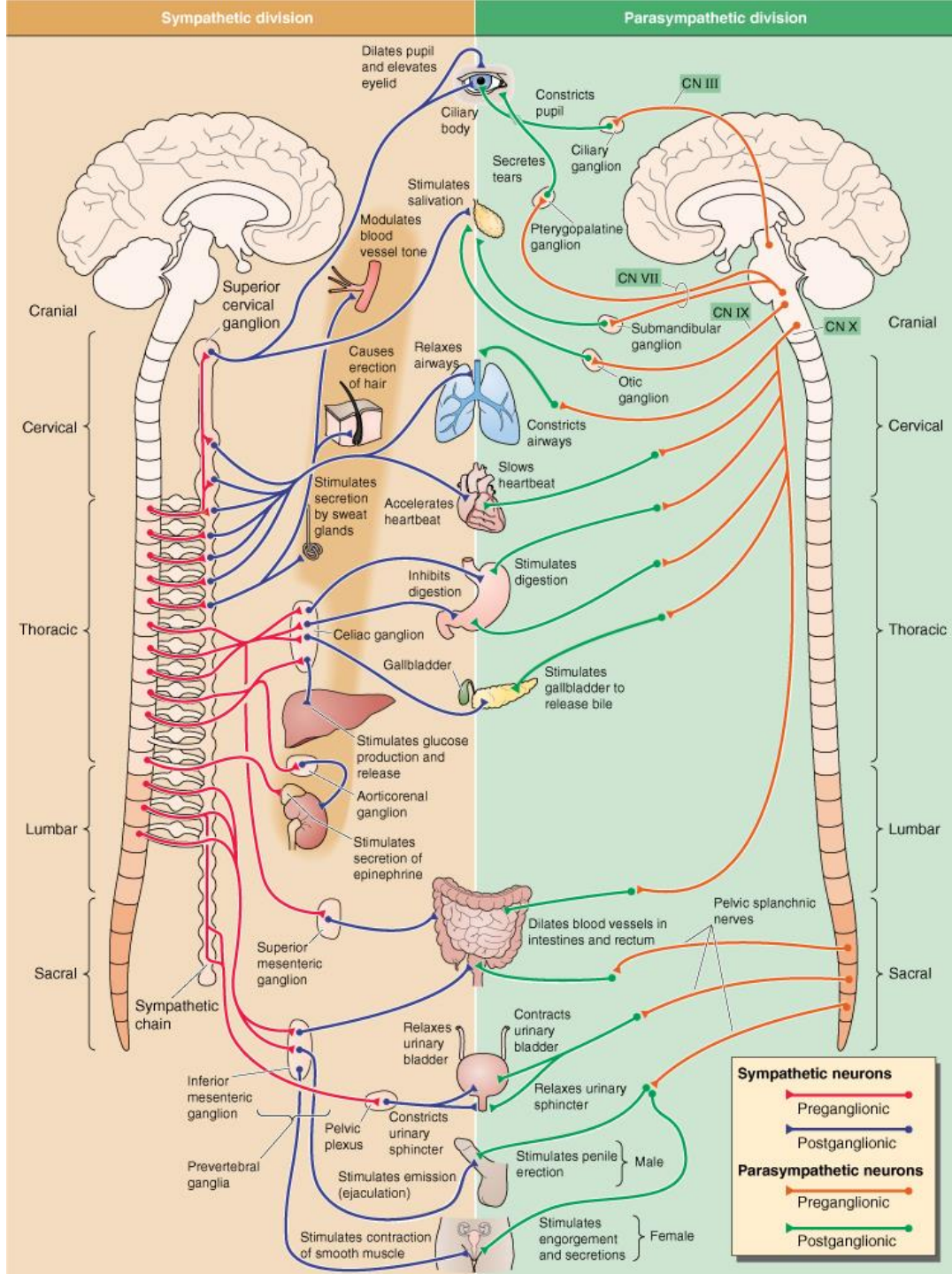


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Sympathetic nervous system

Fight or flight response

Energy/store consumption



Parasympathetic nervous system

Rest and digest response

Energy conservation/energy store production

Sympathetic nervous system

Fight or flight response

Energy/store consumption

Preganglionic neuron

– Spinal cord

-Thoraco - lumbar system

Ganglia Paravertebral

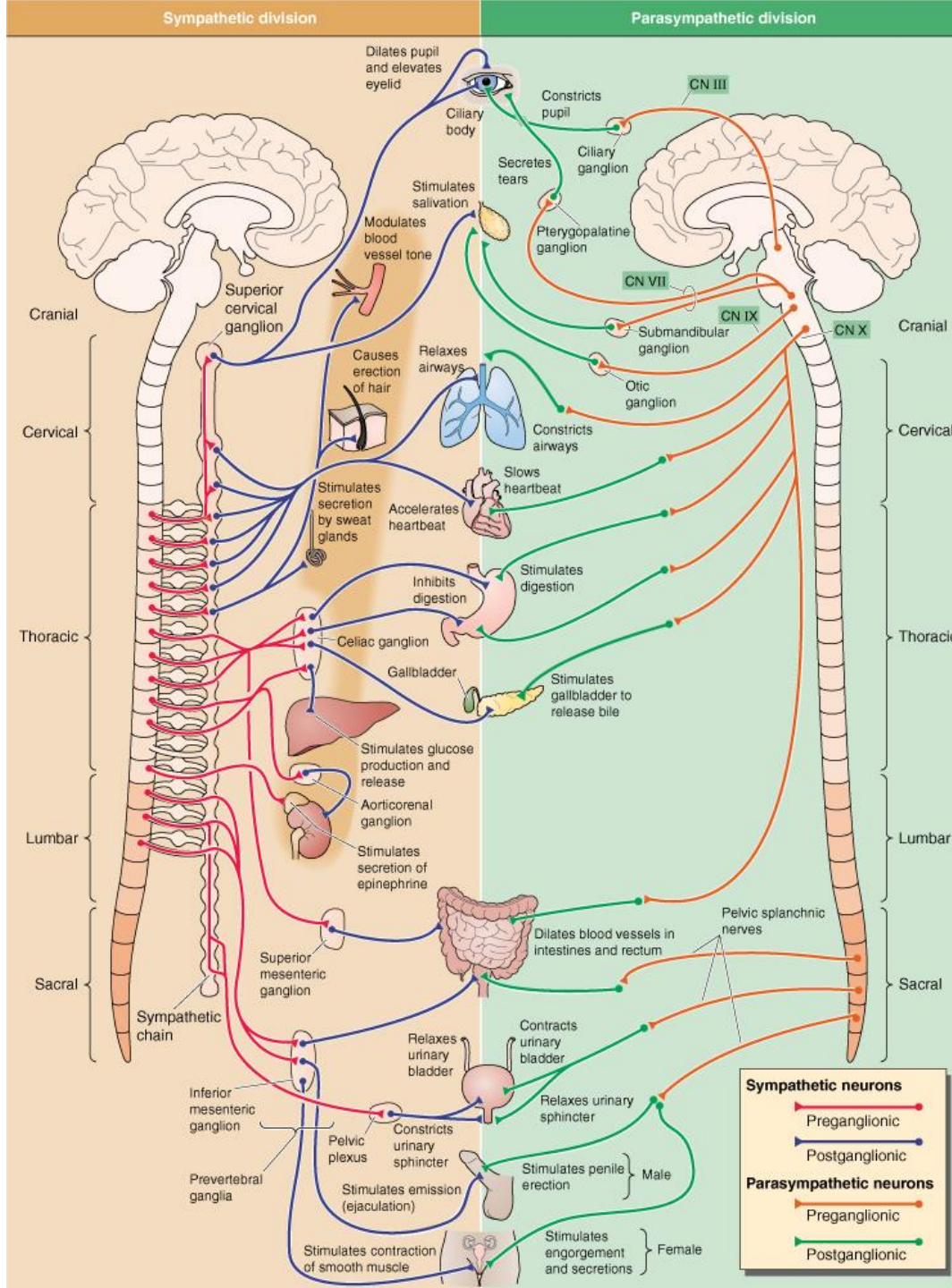
-Truncus sympathicus

- Majority

Prevertebral

-Plexus aorticus

Mostly diffuse effect



Parasympathetic nervous system

Rest and digest response

Energy conservation/energy store production

Preganglionic neuron

– Brain stem and spinal cord

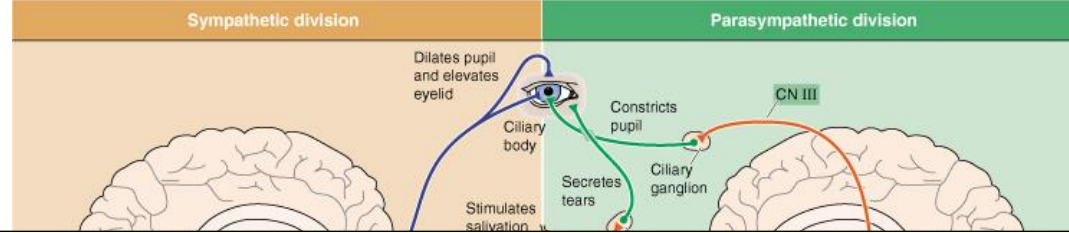
– cranio-sacral system

Ganglia

Close to target organs or intramurally

Mostly local effect

Sympathetic nervous system



Parasympathetic nervous system

Fight or flight response

Energy/store conservation

Preganglionic neuron
- Spinal cord
- Thoraco - lumbar system

Ganglia *Paravertebral*
- Truncus sympathicus
- 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

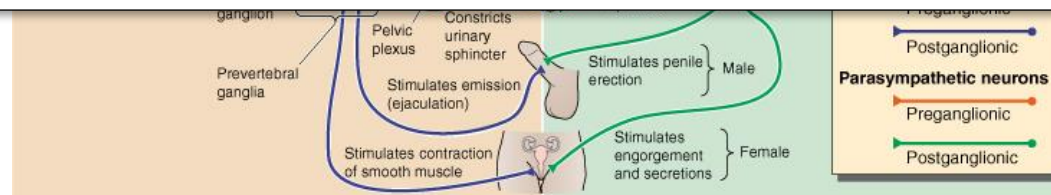
and digest response

conservation/energy store production

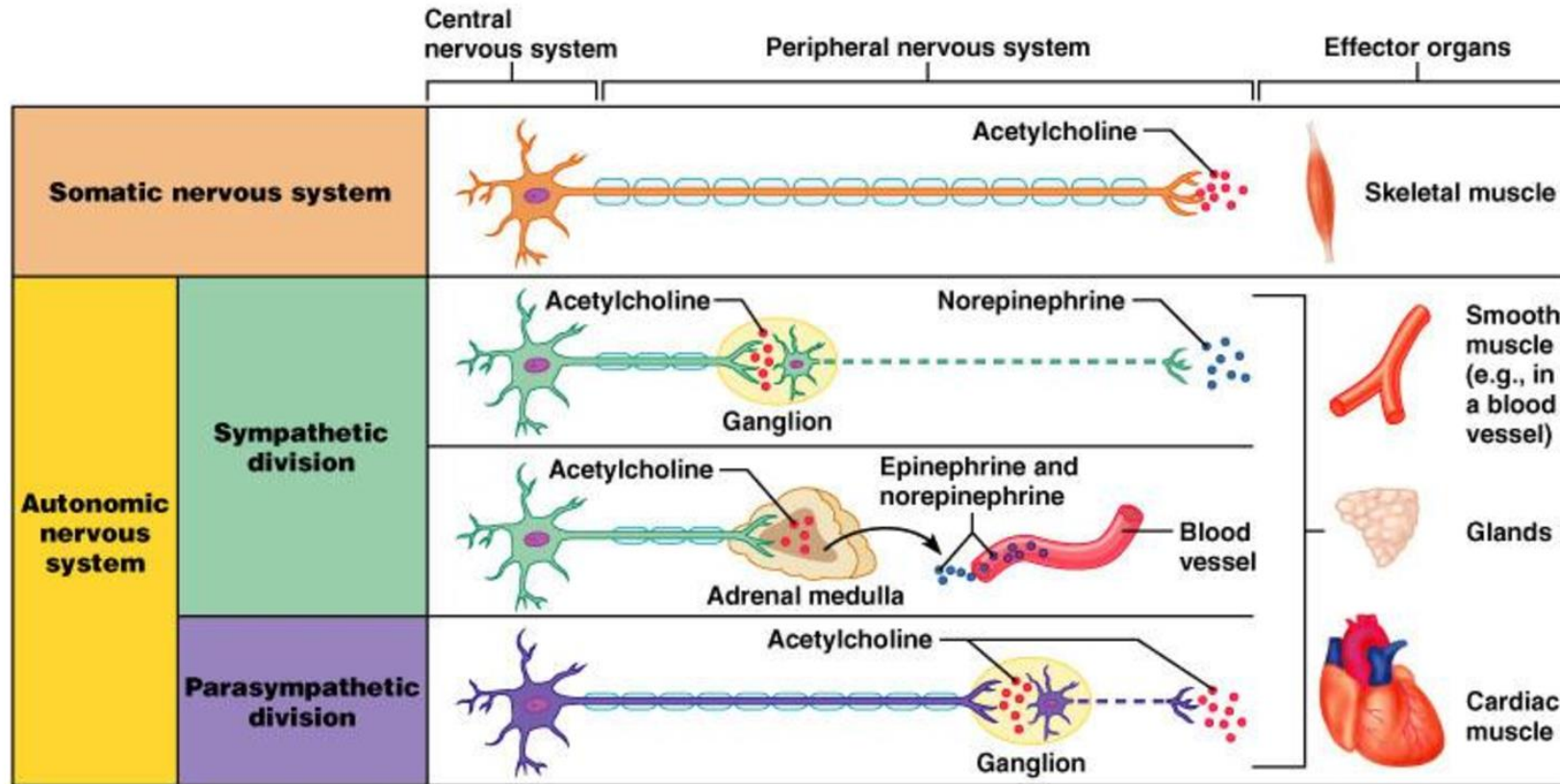
preganglionic neuron
main stem and spinal cord
- cranio-sacral system

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close to target organs or intramurally

Mostly local effect

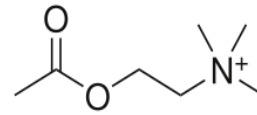


Mediators of somatic and autonomic nervous system



Key:

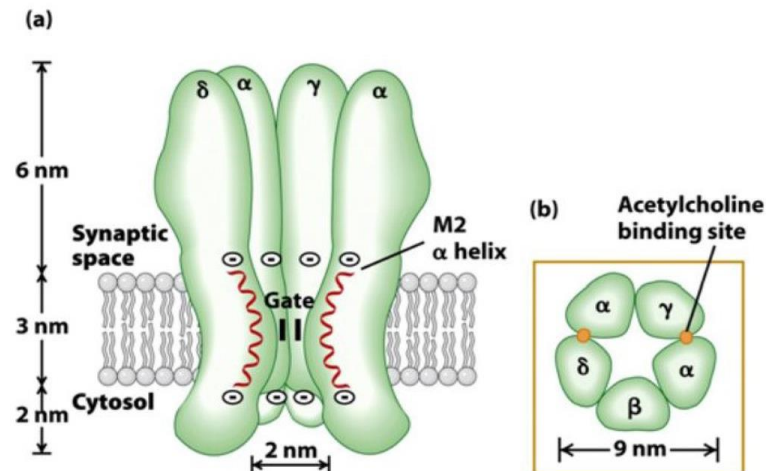
— = Preganglionic axons (sympathetic)
 - - - = Postganglionic axons (sympathetic)
 = Myelination
— = Preganglionic axons (parasympathetic)
- - - = Postganglionic axons (parasympathetic)

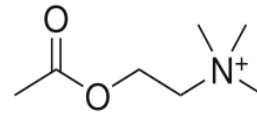


Acetylcholine

Preganglionic fibers

- Sympathetic
- Parasympathetic
- ✓ Nicotinic receptor
 - Ligand-gated ion channels
 - Na⁺, K⁺, Ca²⁺
 - Neuronal (N_N) and muscle (N_M) type
 - Excitatory





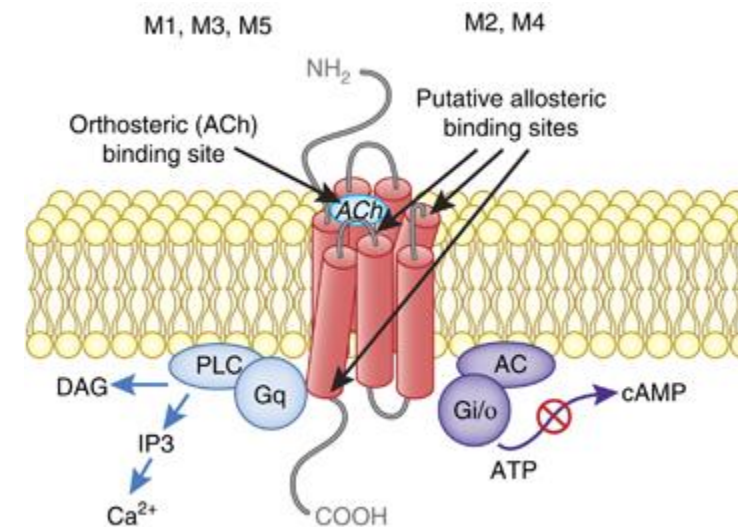
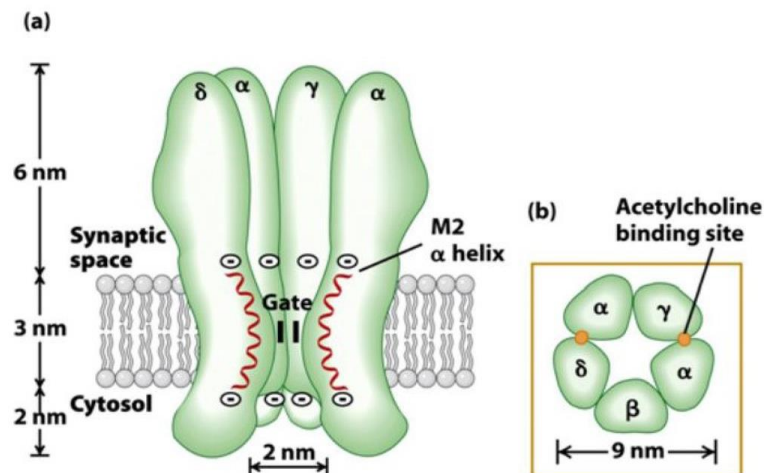
Acetylcholine

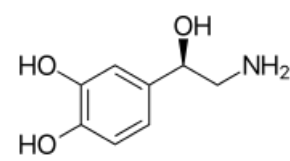
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Postganglionic fibers

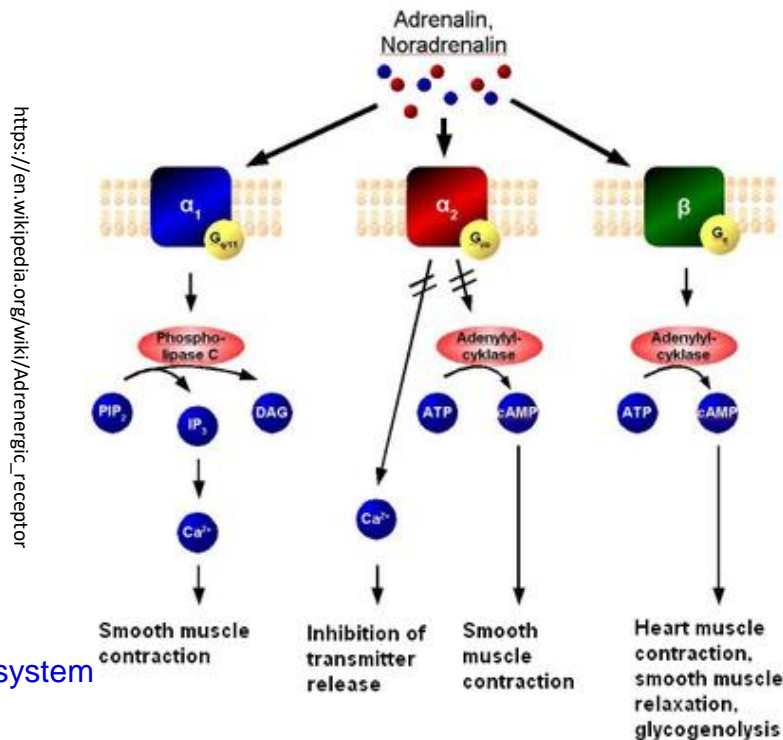
- Parasympathetic
- ✓ Muscarinic receptor
 - G-coupled
 - Excitatory
 - M1, M3, M5
 - Inhibitory
 - M2, M4

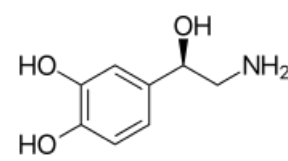




Norepinephrine

- Postganglionic sympathetic fibers
- Adrenergic receptor
 - G-coupled
 - α type – generally excitatory (contraction) with an exception of GIT
 - β type – generally inhibitory (relaxation) with an exception of !!! heart !!!

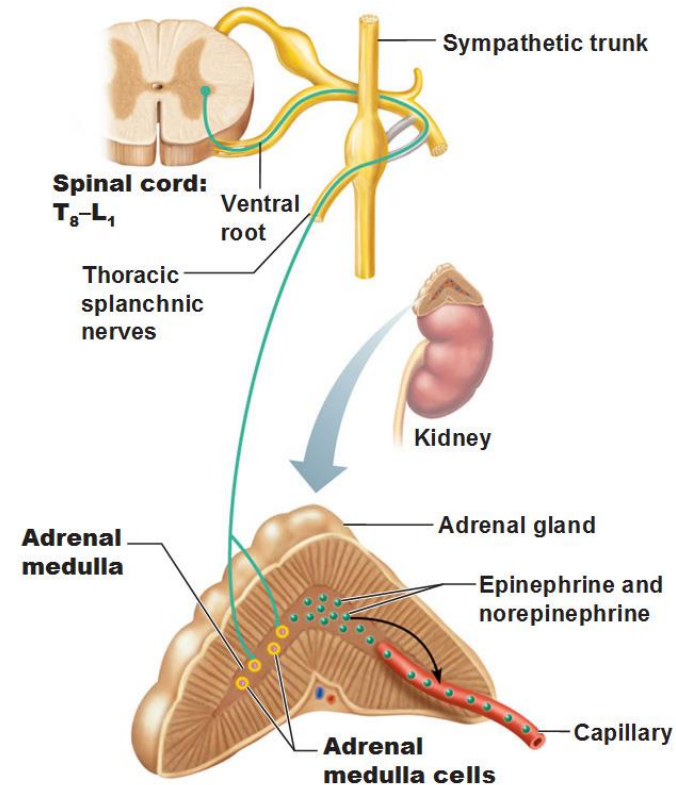
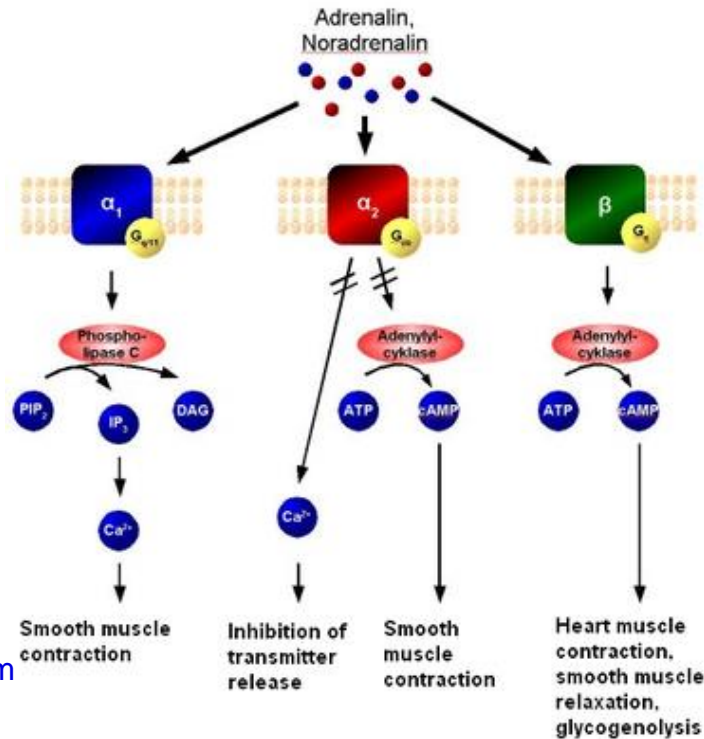




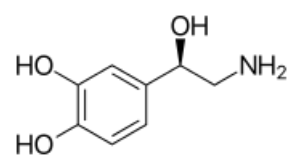
Norepinephrine

- Postganglionic sympathetic fibers
- Adrenergic receptor
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 - α type – generally excitatory (contraction) with an exception of GIT
 - β type – generally inhibitory (relaxation) with an exception of !!! heart !!!
- Adrenal medulla
 - Modified sympathetic ganglion
 - „Transmitters“ (stress hormones) secreted into the blood stream
 - Norepinephrine
 - Epinephrine

https://en.wikipedia.org/wiki/Adrenergic_receptor



<http://antranik.org/wp-content/uploads/2011/11/the-adrenal-medulla-of-the-adrenal-gland-epinephrine-norepinephrine-splanchnic-nerves.jpg>

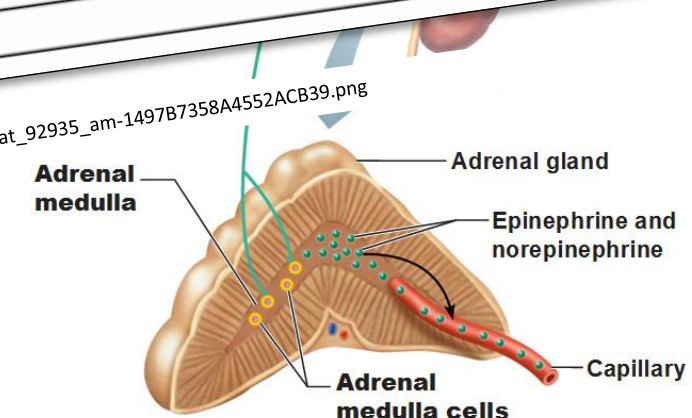
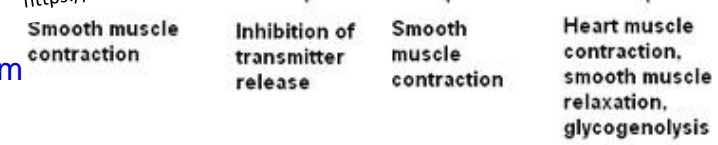


Norepinephrine

- Postganglionic sympathetic fibers
- Adrenal medulla
- Adrenergic receptor
 - G-coupled

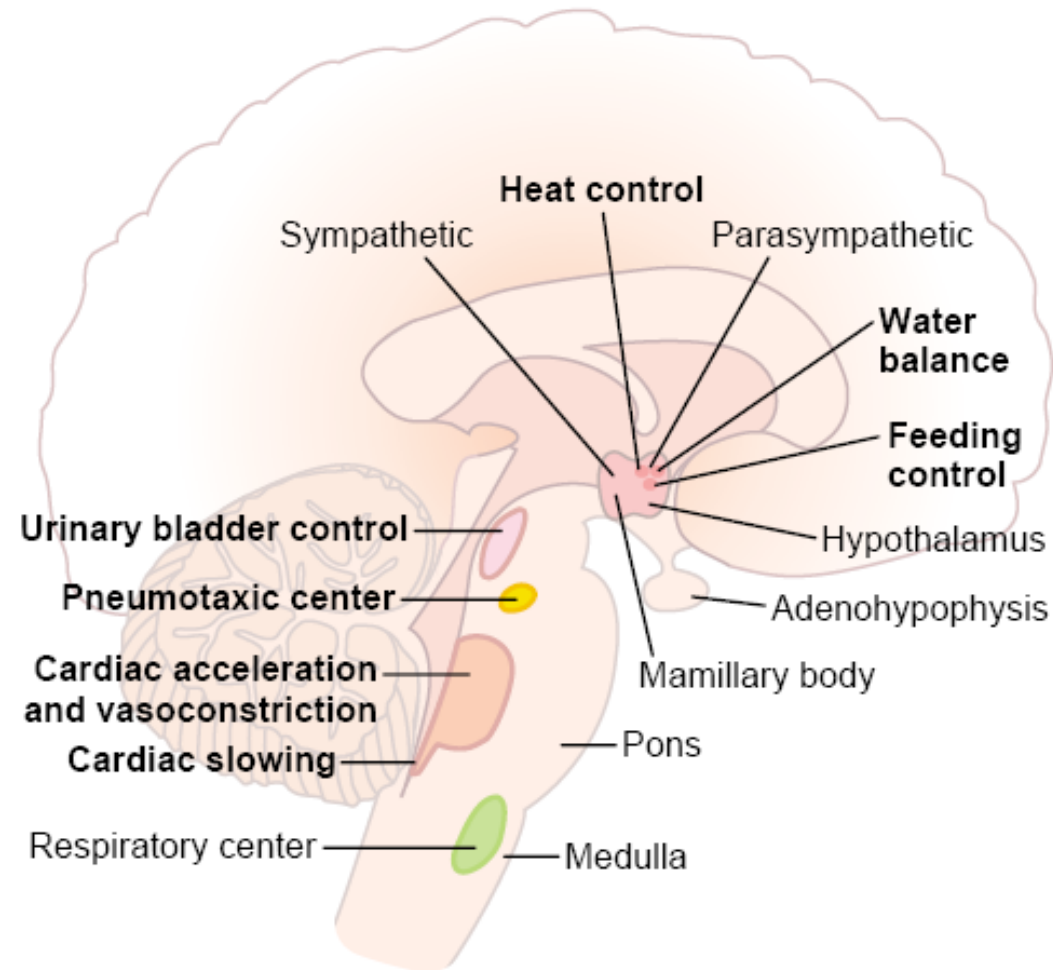
Receptor	G protein and effectors	Agonists	Tissue	Responses
Alpha ₁	Gq ↑phospholipase C, IP3 and DAG, intracellular Ca ²⁺	Epi ≥ NE >> Iso Phenylephrine	Vascular, GU smooth muscle Liver Intestinal smooth muscle Heart	Contraction Glycogenolysis; gluconeogenesis Hyperpolarization and relaxation Increased contractile force; arrhythmias
Alpha ₂	Gi, Go ↓adenylyl cyclase ↓cAMP	Epi ≥ NE >> Iso Clonidine	Pancreatic islets (β cells) Platelets Nerve terminals Vascular smooth muscle	Decreased insulin secretion Aggregation Decreased release of NE Contraction
Beta ₁	Gs ↑adenylyl cyclase, cAMP, L- type Ca ²⁺ channel opening	Iso > Epi = NE Dobutamine	Juxtaglomerular cells Heart	Increased renin secretion Increased force and rate of contraction and AV nodal conduction velocity
Beta ₂	Gs ↑adenylyl cyclase	Iso > Epi >> NE Terbutamine	Smooth muscle (vascular, bronchial, GI, GU) Skeletal muscle	Relaxation Glycogenolysis; uptake of K ⁺
Beta ₃	Gs ↑adenylyl cyclase	Iso = NE > Epi	Adipose tissue	Lipolysis

Epi, epinephrine; NE, norepinephrine; Iso, isoproterenol



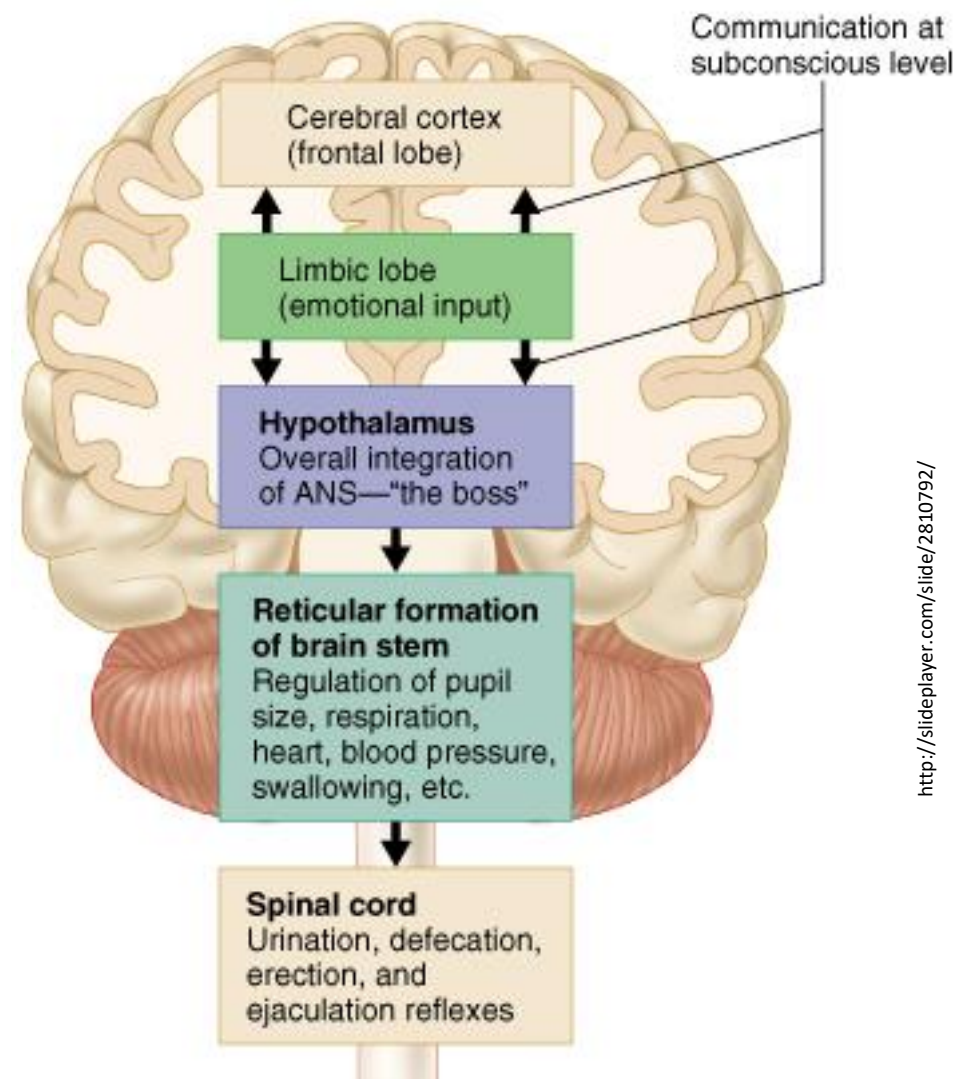
<http://antranik.org/wp-content/uploads/2014/11/adrenal-gland-epinephrine-norepinephrine-splanchnic-nerves.jpg>

Brain centers controlling autonomic nervous system



Brain centers controlling autonomic nervous system

- Most of the regulations are unconscious and originate from the hypothalamus
- Strong emotional experiences or strong emotional memories can trigger autonomic response (usually sympathetic)



Hypothalamus

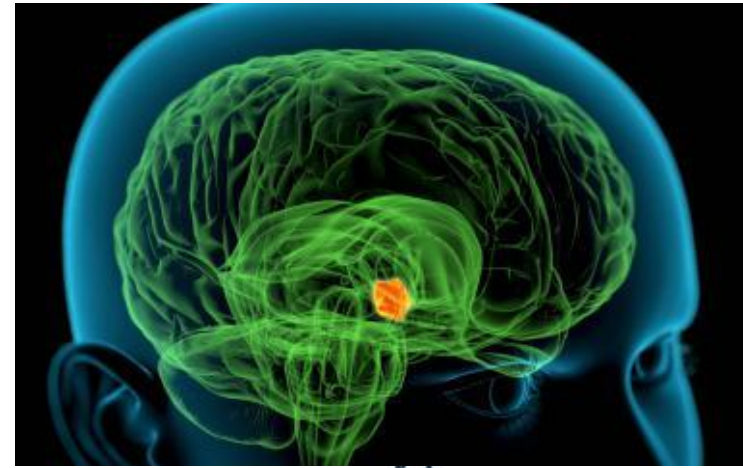
- Key center of autonomic regulations and coordination
- Integration of the information from inner and outer environment



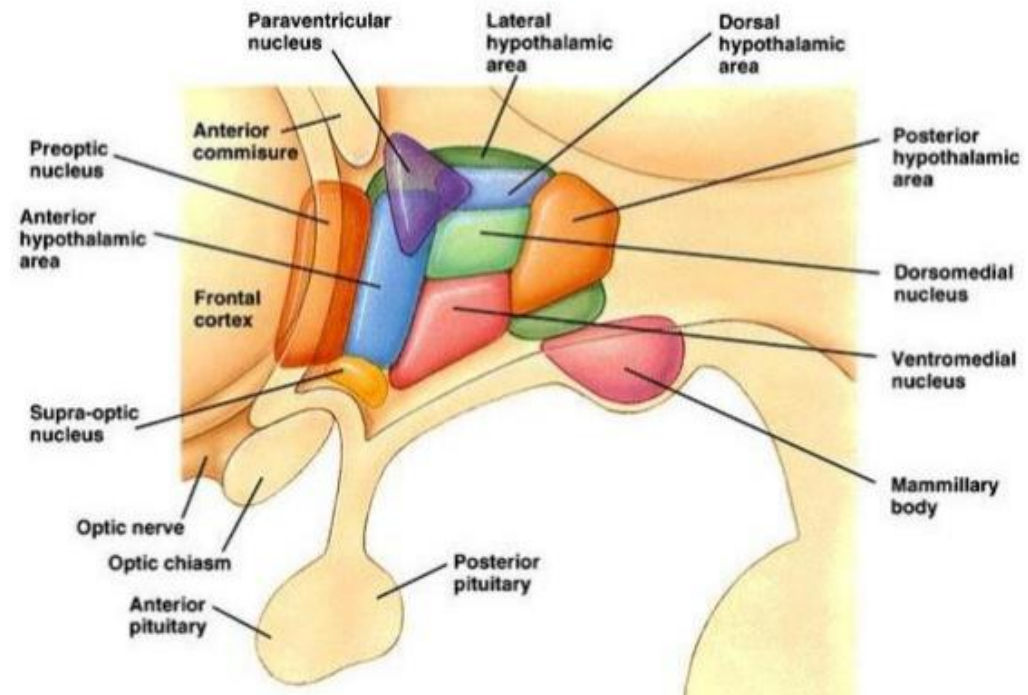
- Behavioral modulation
- Regulation of autonomic nervous system



- **Maintenance of homeostasis**



<http://biology.about.com/od/anatomy/pl/Hypothalamus.htm>



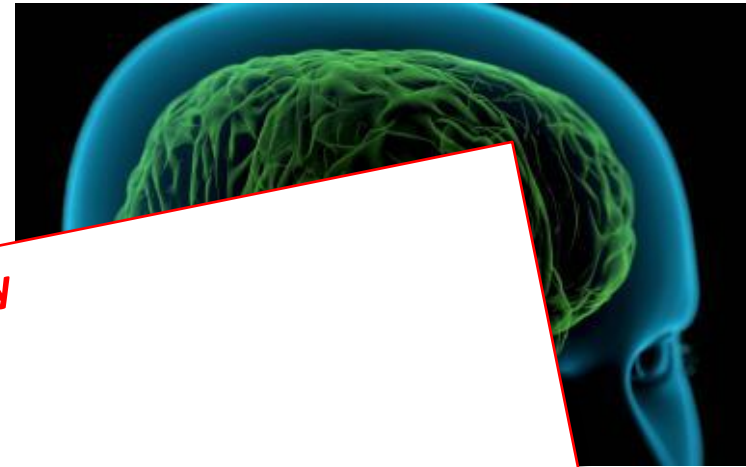
<http://www.slideshare.net/physiologymgmcri/hypothalamus-15-apr-2016>

Hypothalamus

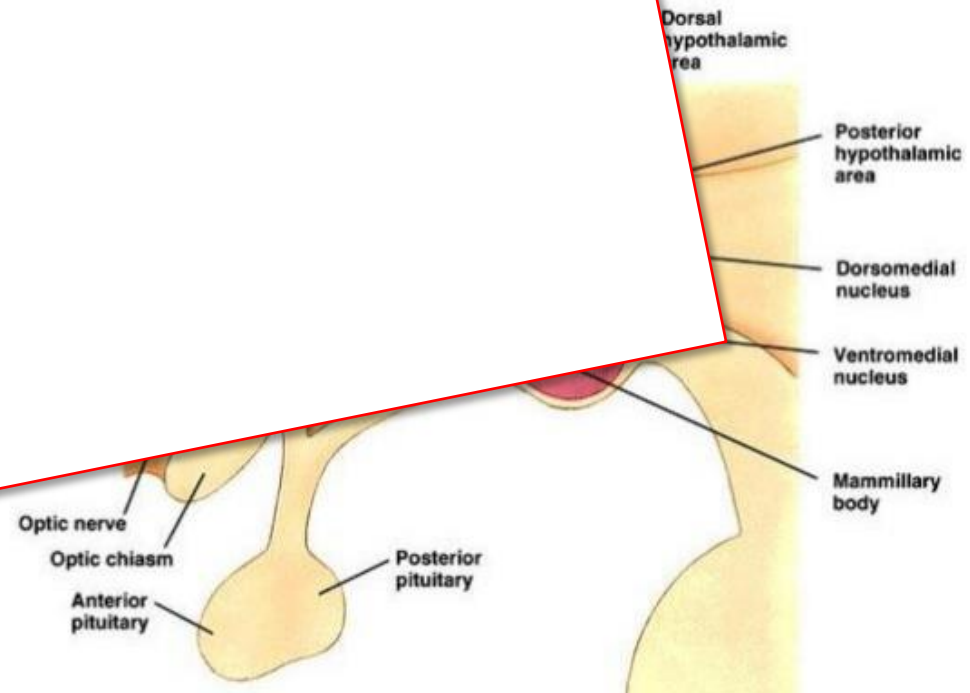
- Key center of autonomic regulations and coordination
- Integration of the information from inner and outer environment

✓ **Biological clock – circadian /seasonal activity**

- Behavior
- Regulation of nervous system
- Maintenance of body temperature



<http://biology.about.com/od/anatomy/p/Hypothalamus.htm>



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

Hypothalamus

- Key center of autonomic regulations and coordination
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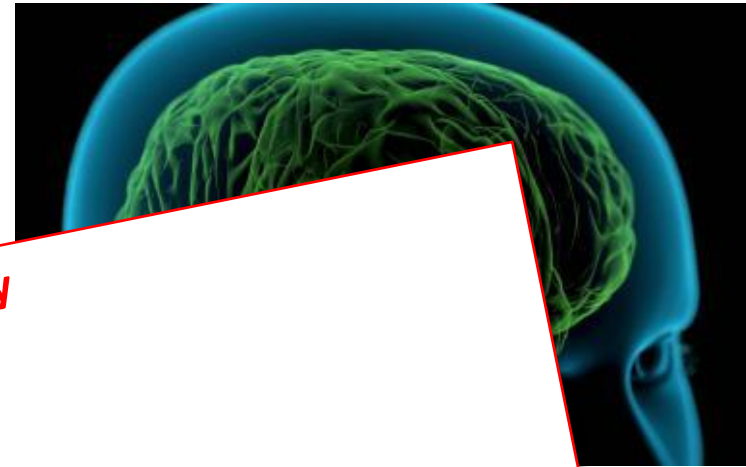
✓ **Autonomic nervous system regulation**

✓ **Endocrine system regulation**

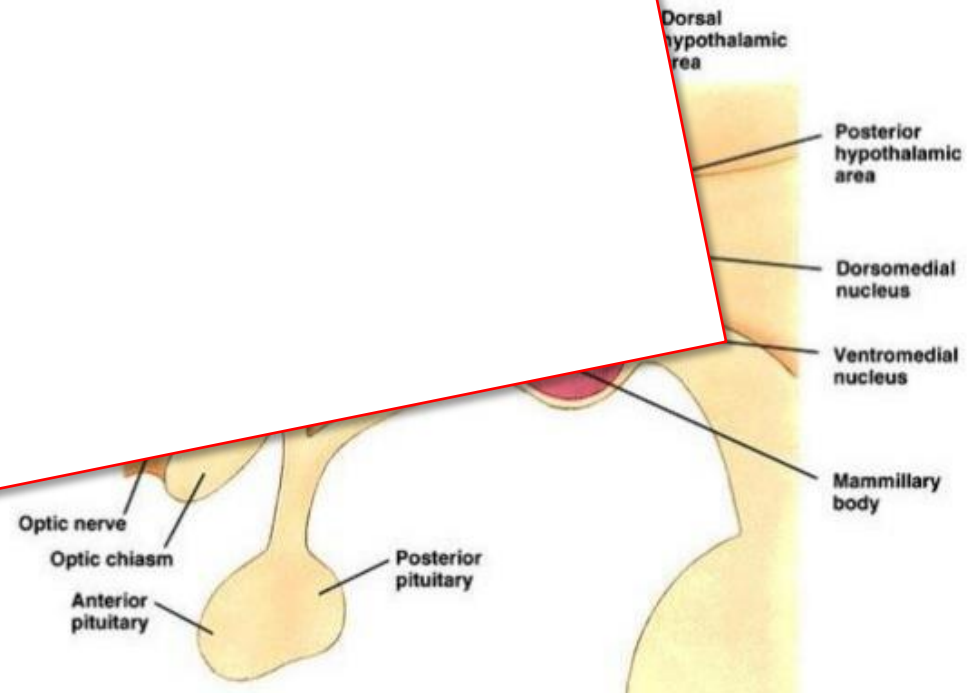
✓ **Food and water intake regulation**

✓ **Regulation of body temperature**

- Behavior
- Regulation of nervous system
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<http://biology.about.com/od/anatomy/pl/Hypothalamus.htm>



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Hypothalamus

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✓ **Food and water intake regulation**

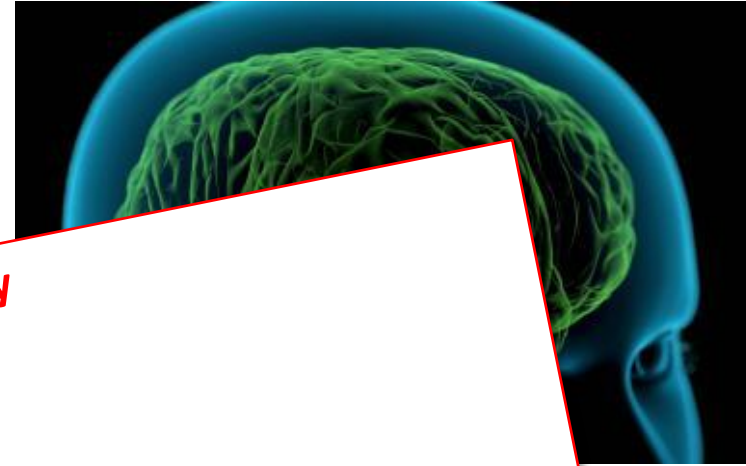
✓ **Regulation of body temperature**

✓ **„Immediate“ behavior regulation (e.g. when hunger)**

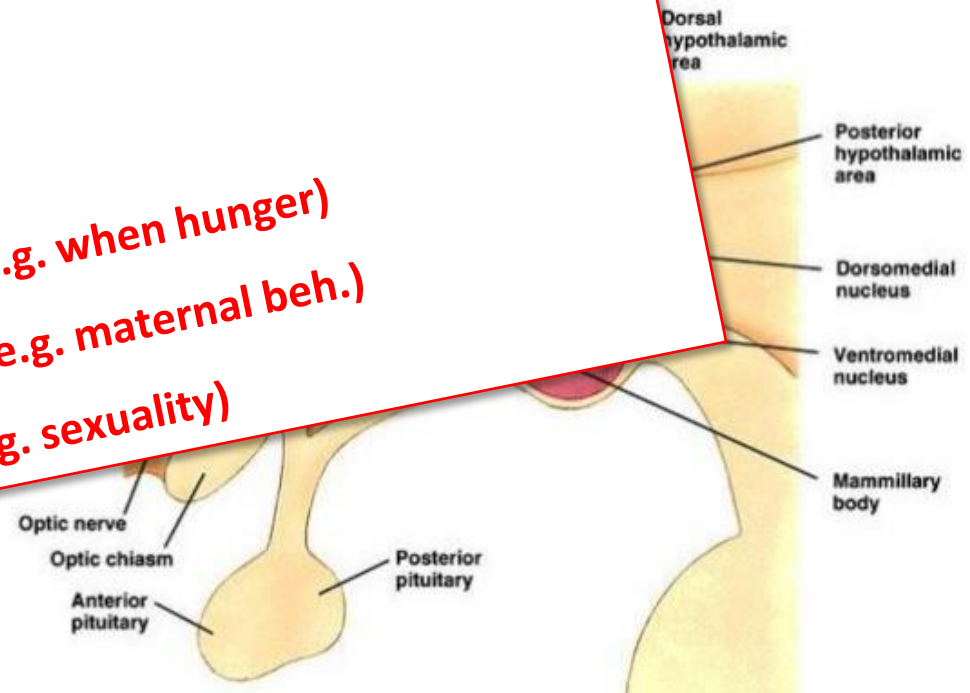
✓ **„Long-term“ behavior regulation (e.g. maternal beh.)**

✓ **Instinctive behavior regulation (e.g. sexuality)**

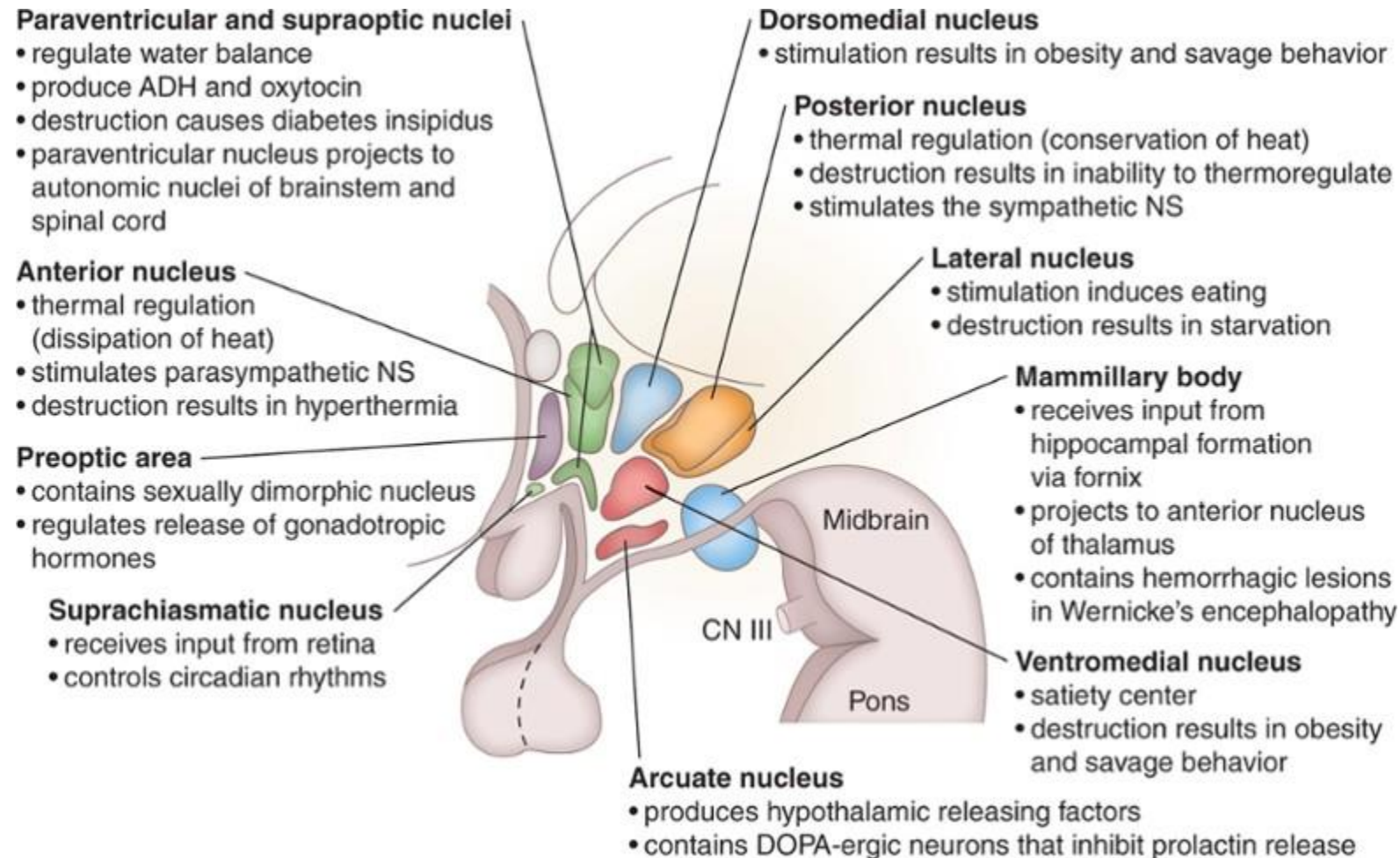
- Behavior
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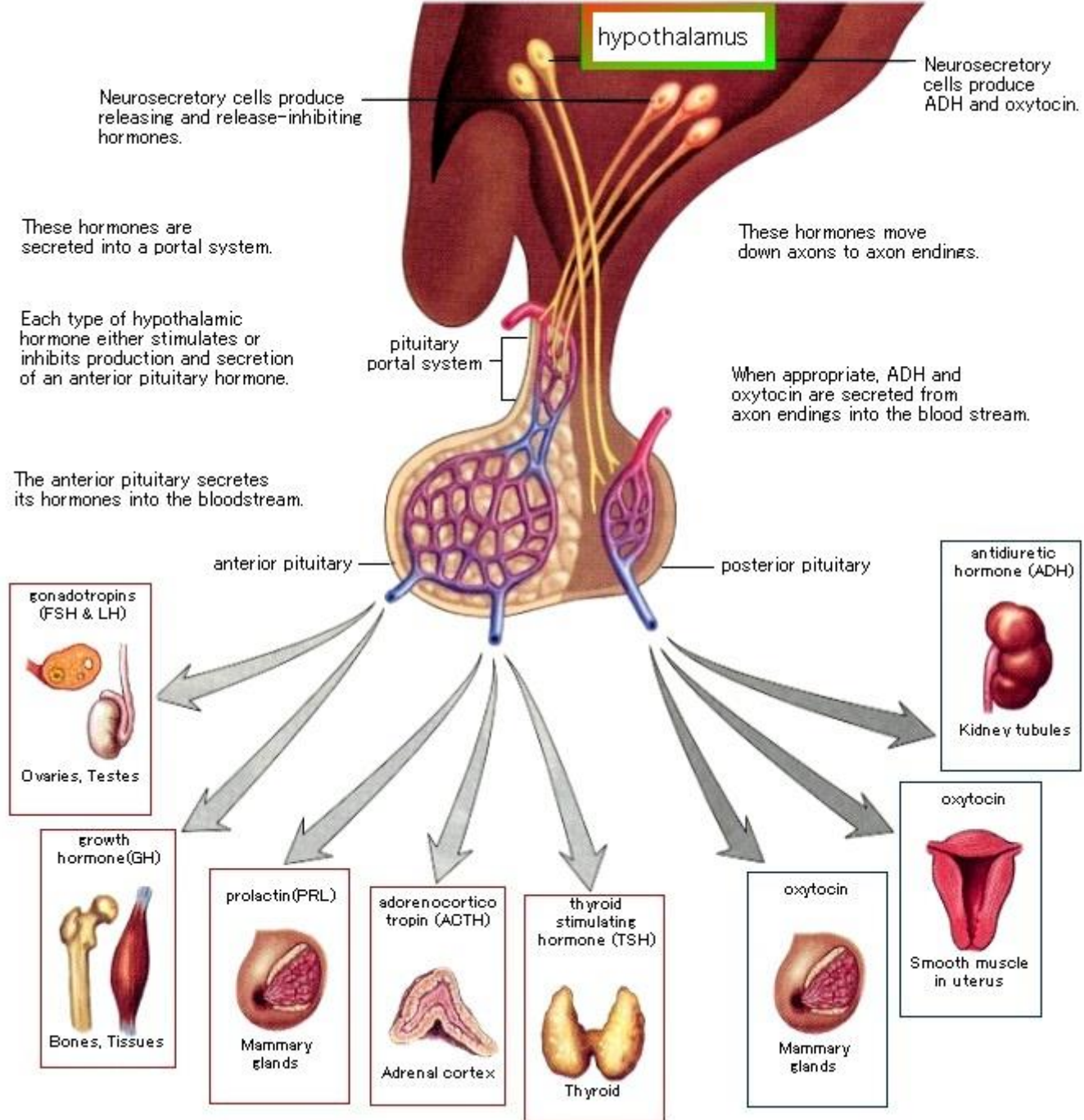
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Hypothalamus

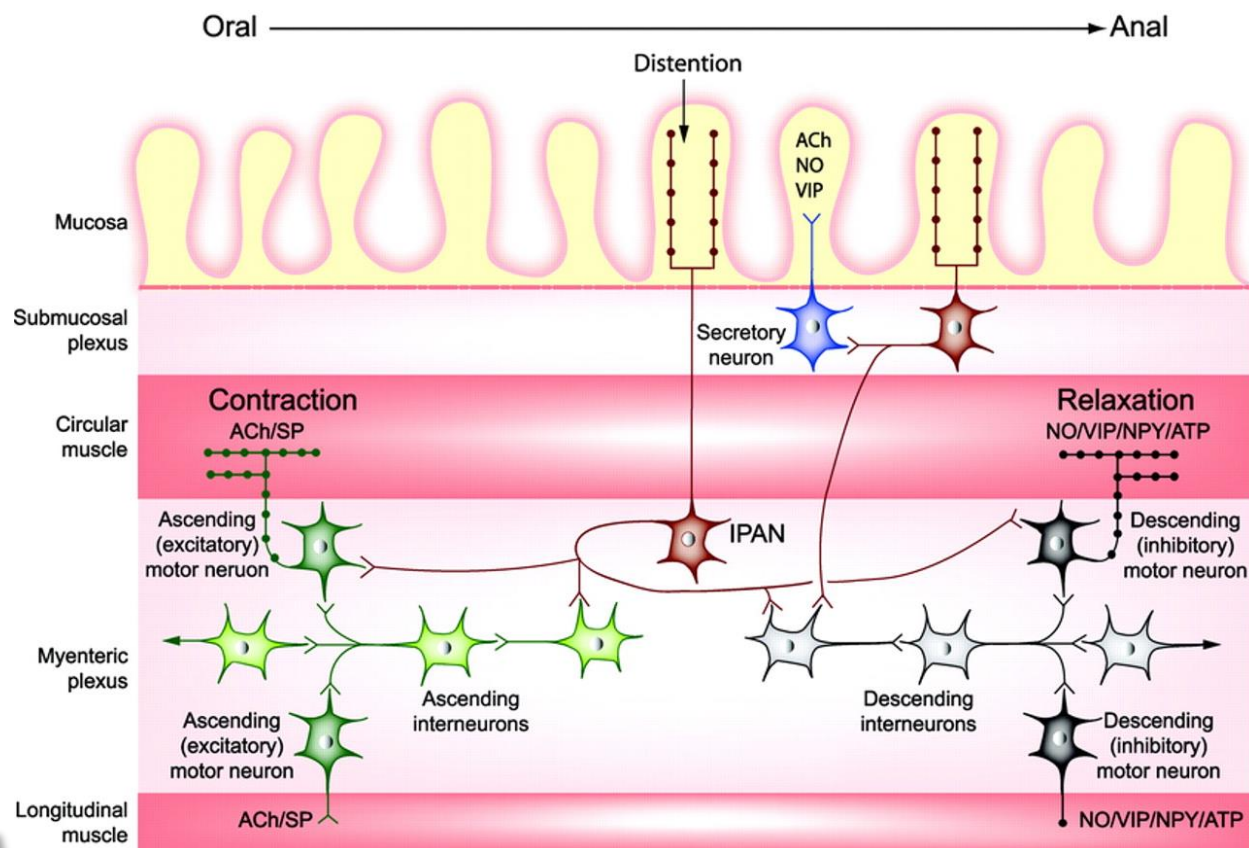


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Enteric nervous system

- aprox. 500 mil. neurons
 - (brain aprox. 100 bil.)
 - (spinal cord aprox. 100 mil.)
- Plexus myentericus
- Plexus submucosus
- Sensory component
- Executive component
- Interneurons
- High level of autonomy
 - „brain in the gut“



http://www.slideshare.net/carmencrivii/central-nervous-system-the-autonomic-nervous-system?qid=d1502190-93fe-4b05-9d92-6a42e3ca72fc&v=&b=&from_search=8

Microbiome

Enteric nervous system

- Autonomy
 - Control of motility
 - Control of secretion
 - Control of blood flow
- Autonomic nervous system
 - Whole GIT regulation
 - Coordination of all organ systems activities

The Brain in Your Gut

The gut's brain, known as the enteric nervous system, is located in sheaths of tissue lining the esophagus, stomach, small intestine and colon.

SMALL INTESTINE CROSS SECTION

Submucosal plexus

Layer contains sensory cells that communicate with the myenteric plexus and motor fibers that stimulate the secretion of fluids into the lumen.

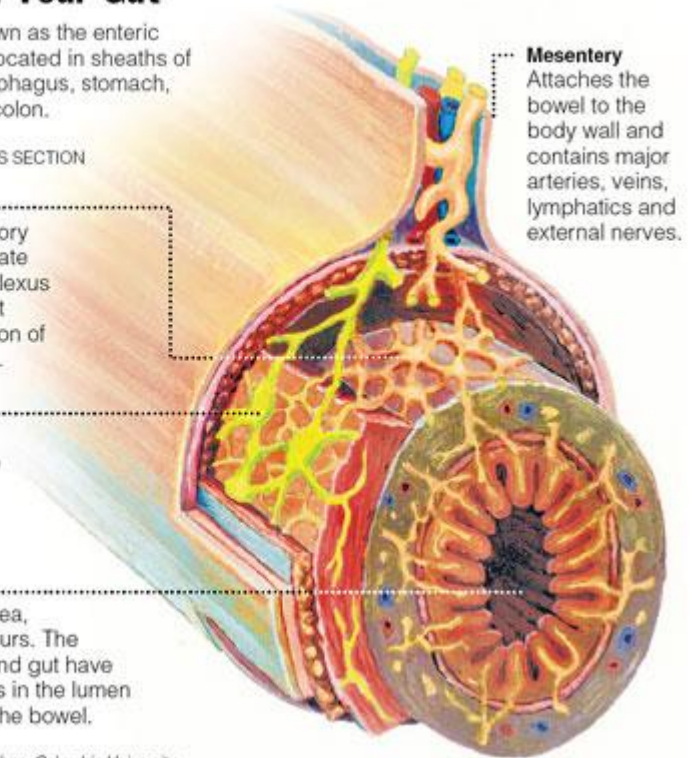
Myenteric plexus

Layer contains the neurons responsible for regulating the enzyme output of adjacent organs.

Lumen

No nerves actually enter this area, where digestion occurs. The brains in the head and gut have to monitor conditions in the lumen across the lining of the bowel.

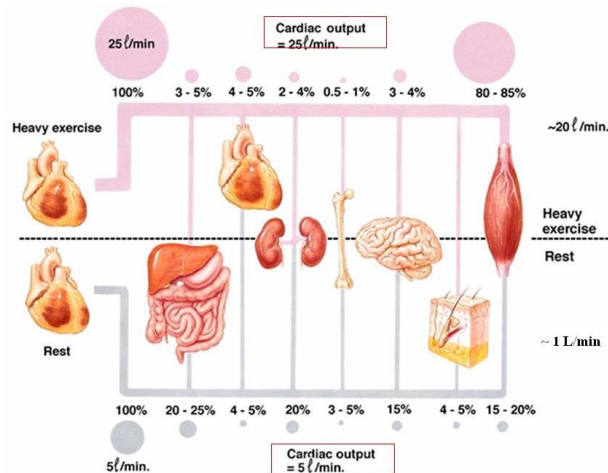
Source: Dr. Michael D. Gershon, Columbia University



<https://kin450-neurophysiology.wikispaces.com/file/view/gut.jpg/187924395/gut.jpg>

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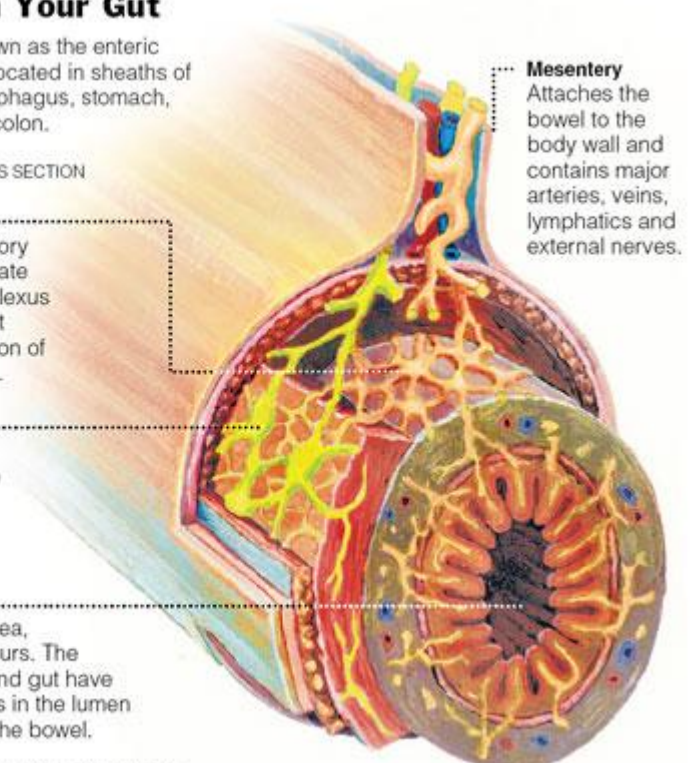
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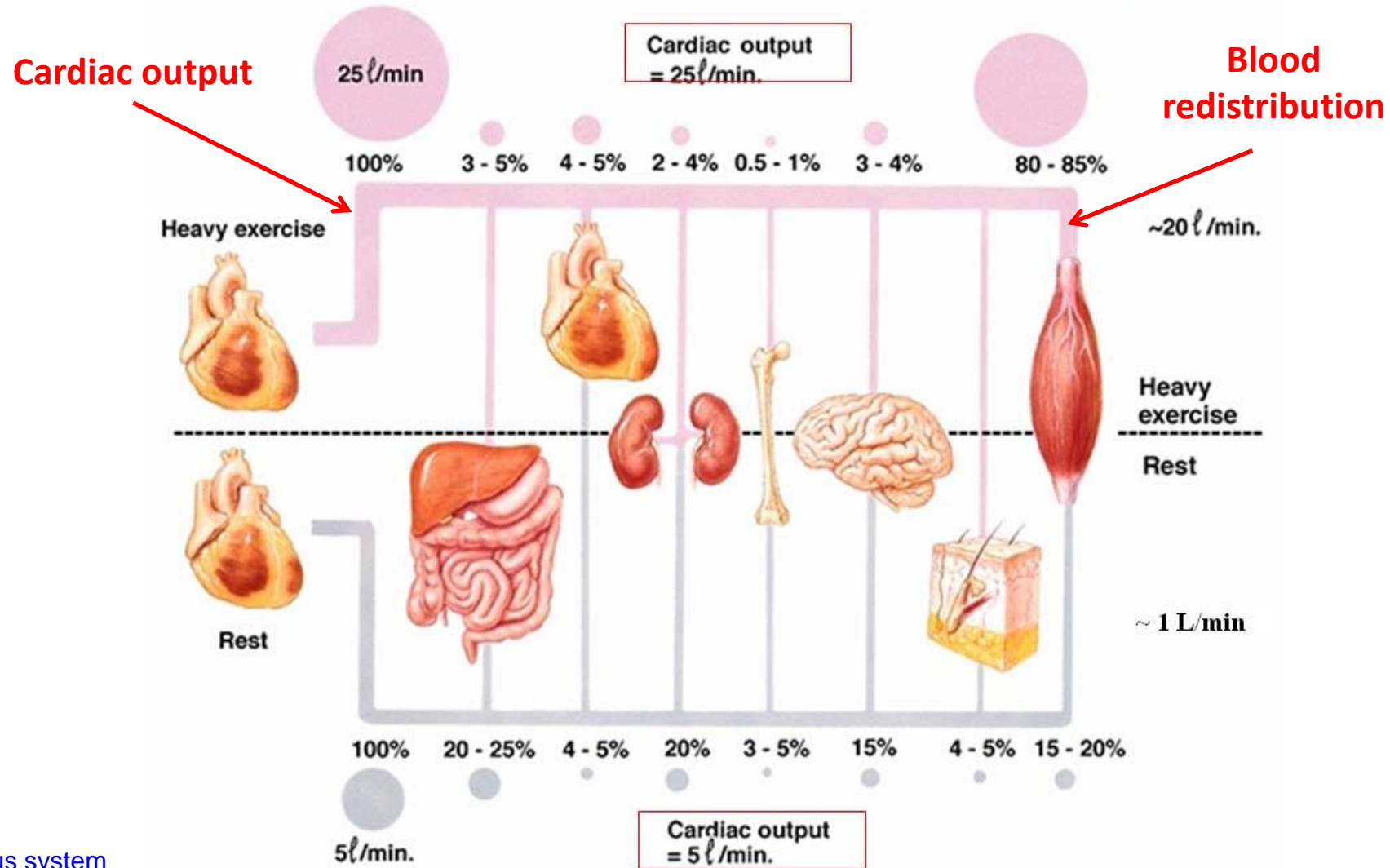
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<https://kin450-neurophysiology.wikispaces.com/file/view/gut.jpg/187924395/gut.jpg>

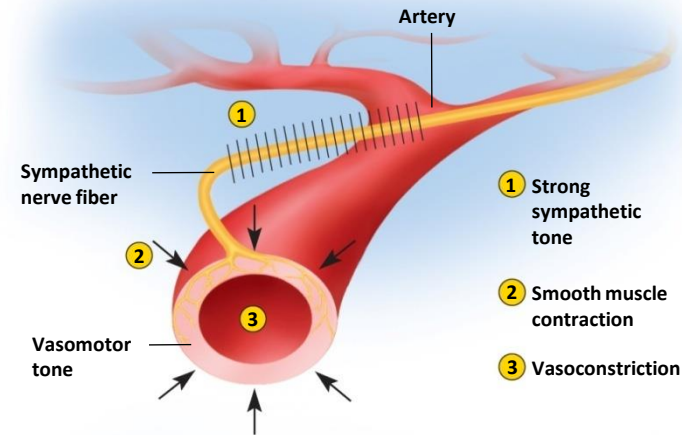
ANS and cardiovascular system



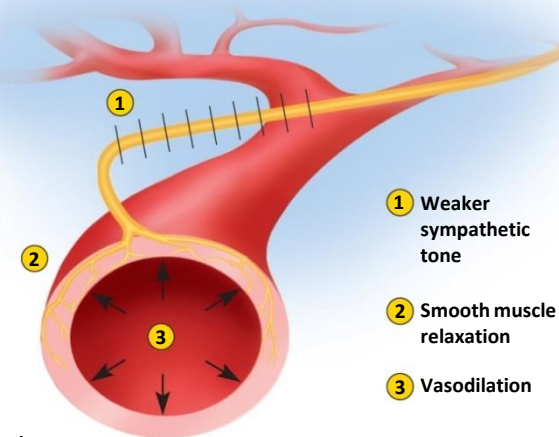
ANS and cardiovascular system

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- Local regulatory mechanisms play major role in vasoreactivity
- Sympathetic regulation
 - Skin vessels contraction
 - Muscle vessels dilatation
- Parasympathetic regulation
 - GIT vessels dilation



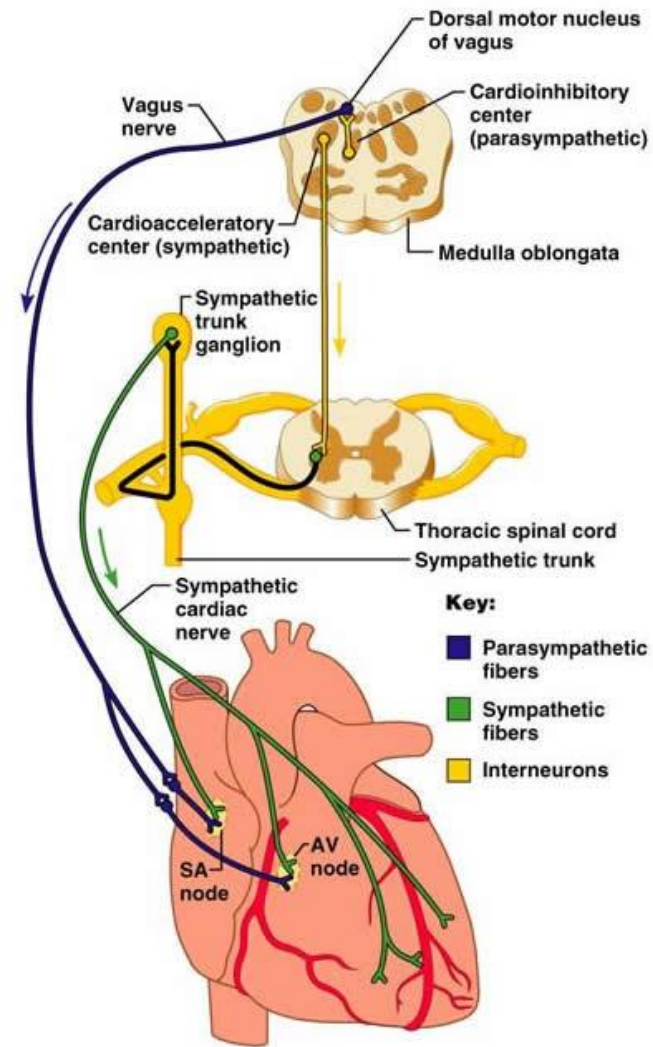
(a) Vasoconstriction



(b) Vasodilation

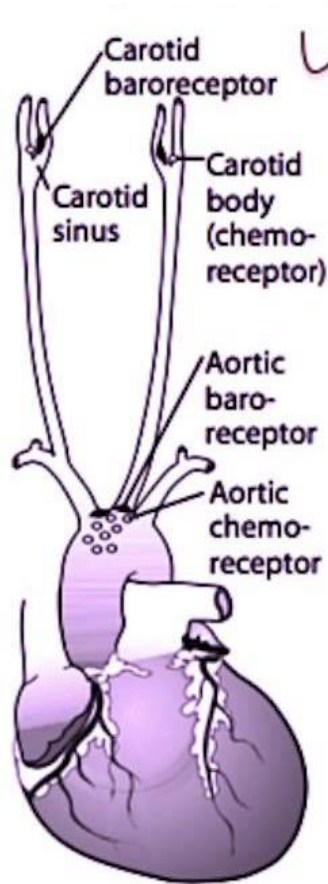
ANS and cardiovascular system

- Sympathetic regulation
 - Heart rate increase
 - Contractility increase
 - Conductivity increase
- Parasympathetic regulation
 - Heart rate decrease
 - Contractility decrease
 - Conductivity decrease



https://medwrite.biz/58603_vagus_nerve_anatomy/

Baroreceptors a chemoreceptors



Receptors:

1. Aortic arch transmits via vagus nerve to medulla (responds **only** to \uparrow BP)
2. Carotid sinus transmits via glossopharyngeal nerve to solitary nucleus of medulla (responds to \downarrow and \uparrow in BP).

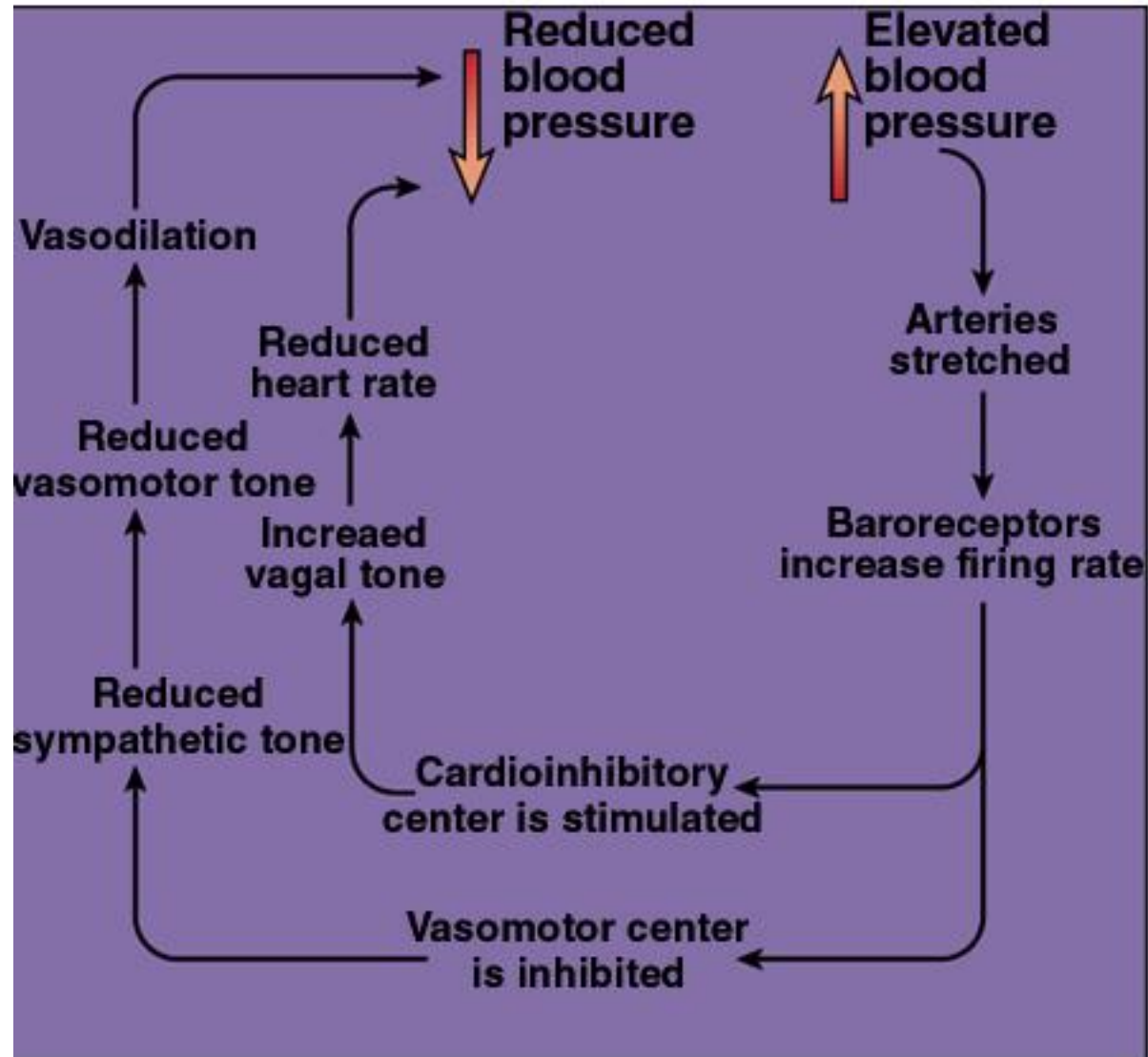
Baroreceptors:

1. Hypotension — \downarrow arterial pressure \rightarrow \downarrow stretch \rightarrow \downarrow afferent baroreceptor firing \rightarrow \uparrow efferent sympathetic firing and \downarrow efferent parasympathetic stimulation \rightarrow vasoconstriction, \uparrow HR, \uparrow contractility, \uparrow BP. Important in the response to severe hemorrhage.
2. Carotid massage — \uparrow pressure on carotid artery \rightarrow \uparrow stretch \rightarrow \uparrow afferent baroreceptor firing \rightarrow \downarrow HR.

Chemoreceptors:

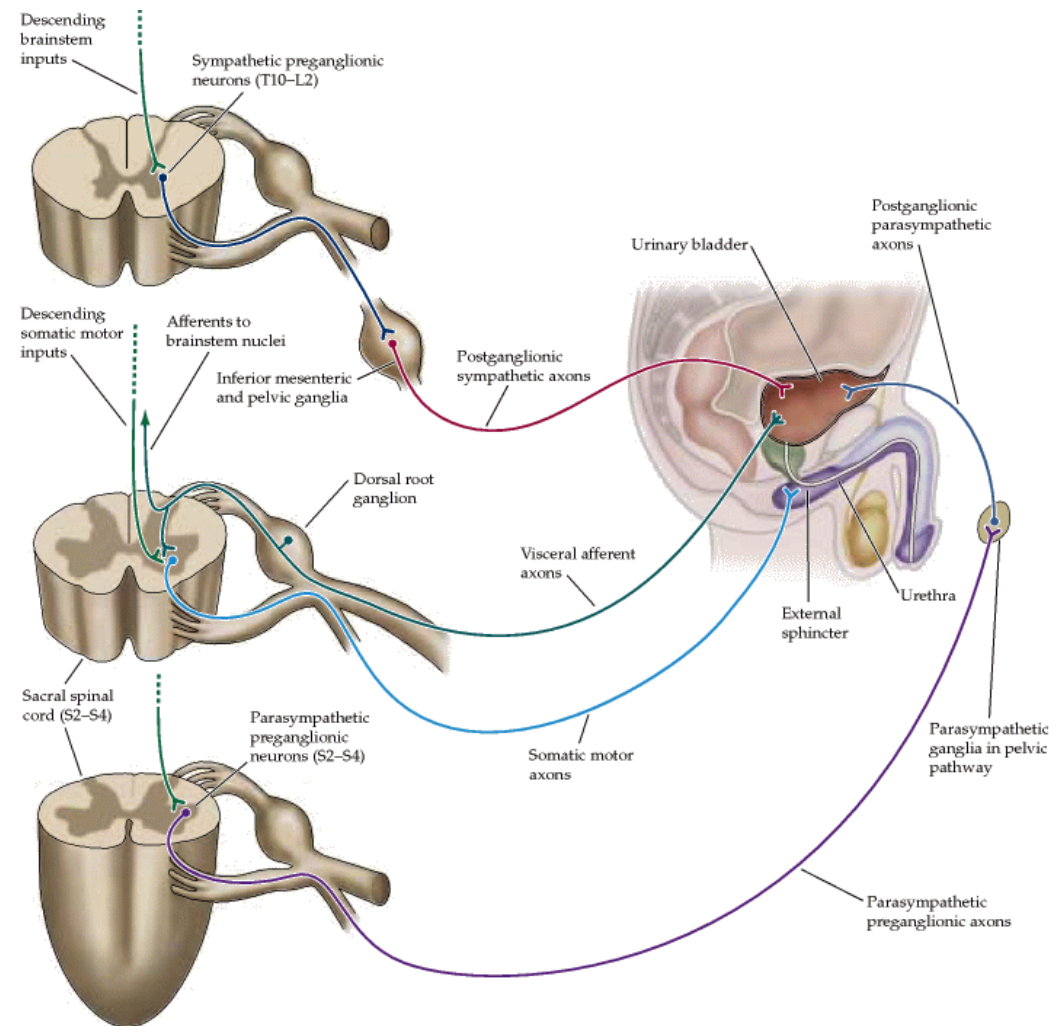
1. Peripheral — carotid and aortic bodies respond to \downarrow PO_2 (< 60 mmHg), \uparrow PCO_2 , and \downarrow pH of blood.
2. Central — respond to changes in pH and PCO_2 of brain interstitial fluid, which in turn are influenced by arterial CO_2 . Do not directly respond to PO_2 . Responsible for Cushing reaction — \uparrow intracranial pressure constricts arterioles \rightarrow cerebral ischemia \rightarrow hypertension (sympathetic response) \rightarrow reflex bradycardia. Note: Cushing triad = hypertension, bradycardia, respiratory depression.

Baroreflex



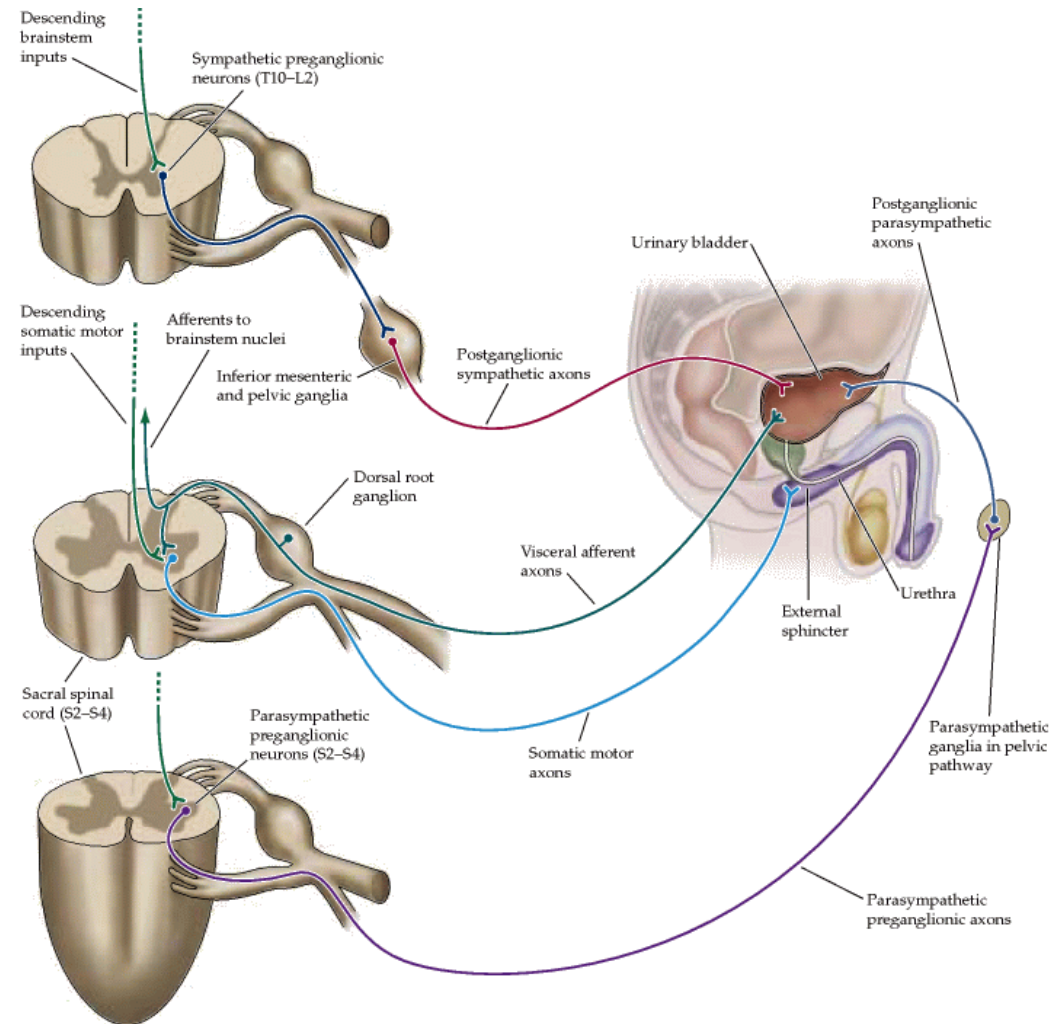
ANS and urinary bladder

- Sympathetic regulation
 - Detrusor relaxation
 - Sphincter contraction
- Parasympathetic regulation
 - Detrusor contraction
 - Sphincter relaxation



ANS and male reproductive system

- Parasympathetic reg.
 - Erection
- Sympathetic reg.
 - Ejaculation



ANS and female reproductive system

Very complicated....

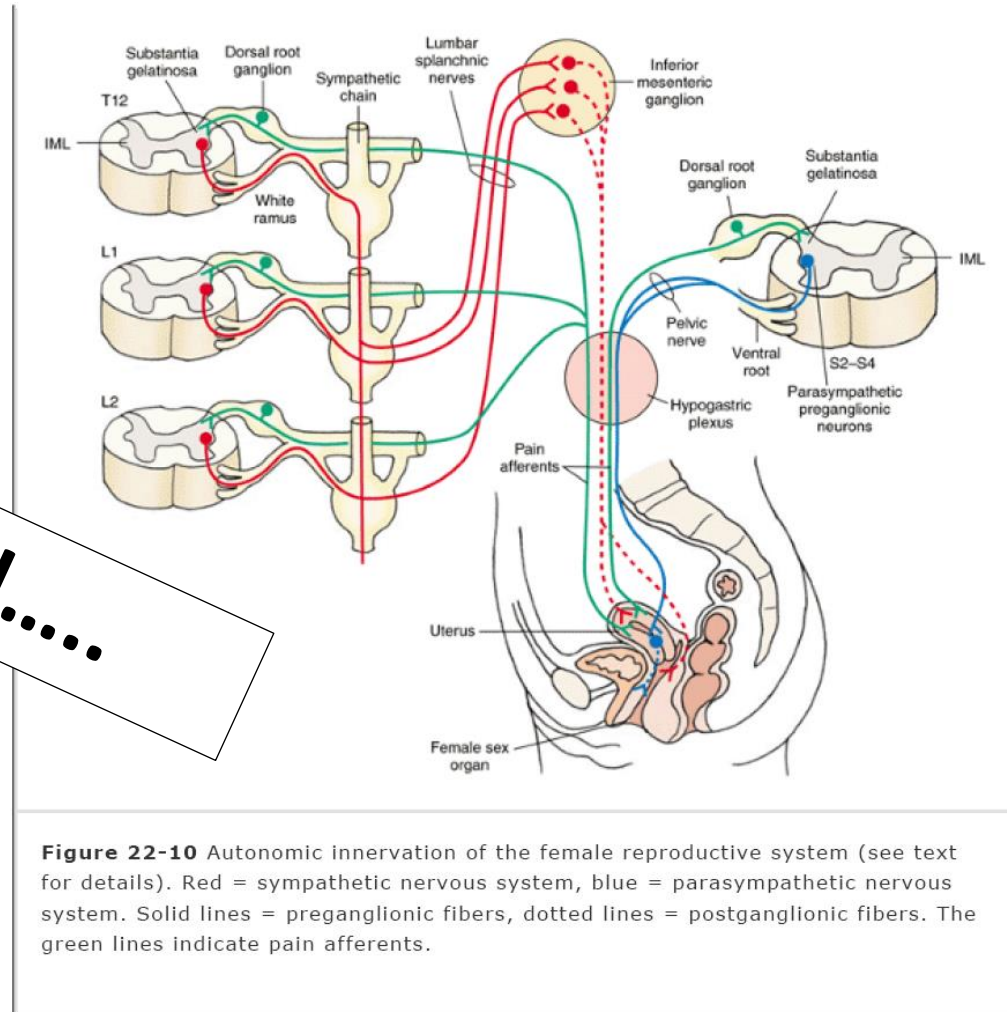


Figure 22-10 Autonomic innervation of the female reproductive system (see text for details). Red = sympathetic nervous system, blue = parasympathetic nervous system. Solid lines = preganglionic fibers, dotted lines = postganglionic fibers. The green lines indicate pain afferents.

82. The basic division and functions of autonomic nervous system

- Definition of autonomic nervous system
- Somatic and autonomic nervous system comparison (function, synapse reflex circuit...)
- Comparison of sympathetic and parasympathetic division
- Basic characteristics of neurotransmitter and receptor systems (description of autonomic innervation of particular systems is covered in each organ system separately)
- Examples of brain centers controlling the autonomic nervous system (both in hypothalamus, brain stem...)
- Pupillary light reflex
- Role of hypothalamus in essential regulations
- Brief characterization of enteric nervous system and its specifics

M U N I

M E D