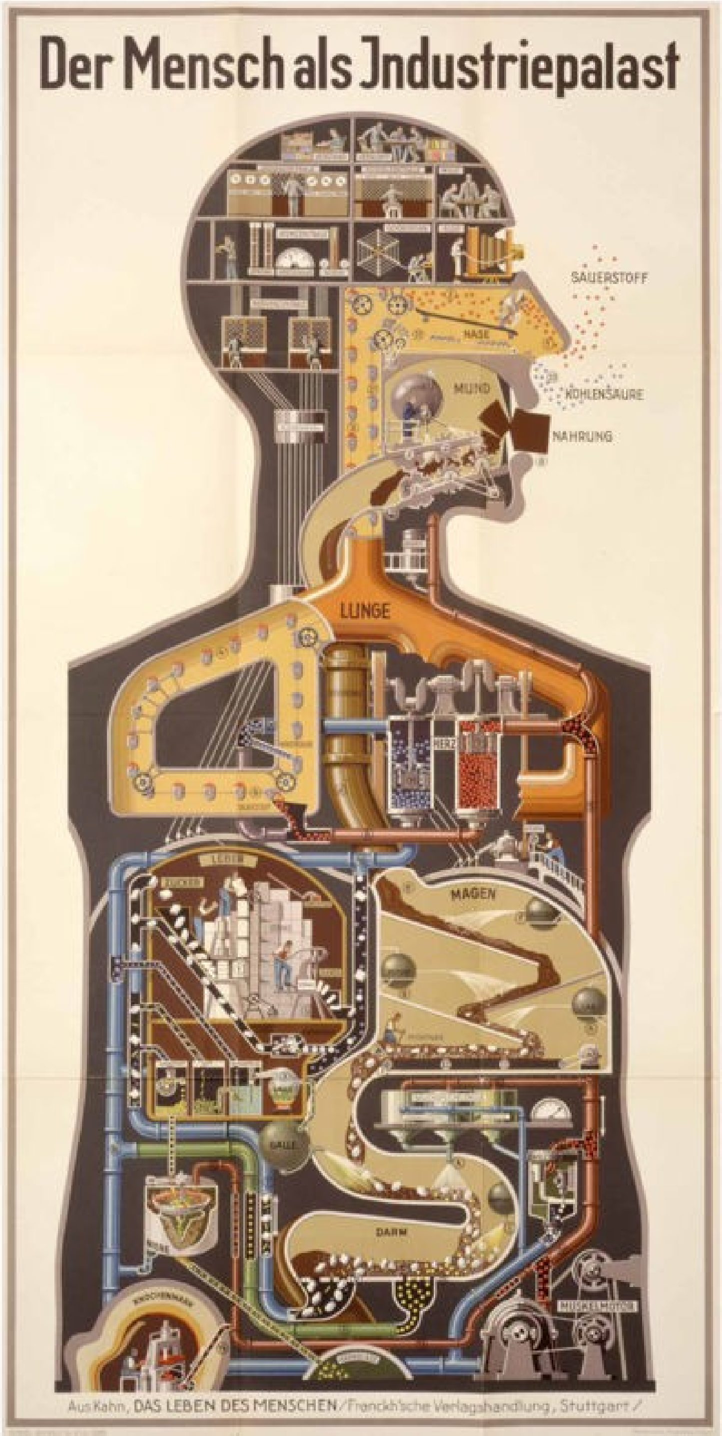
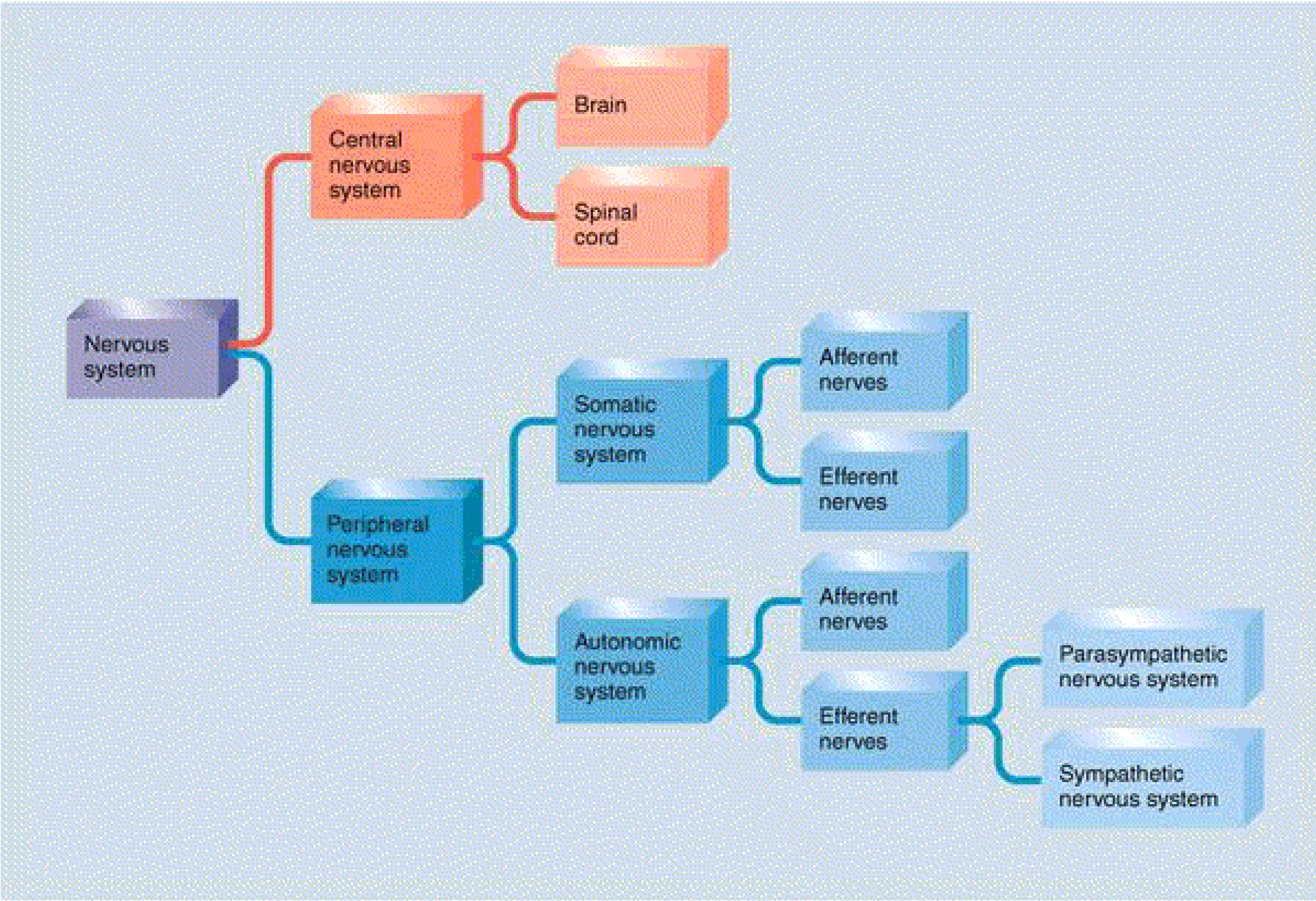
PHYSIOLOGY OF AUTONOMIC NERVOUS SYSTEM

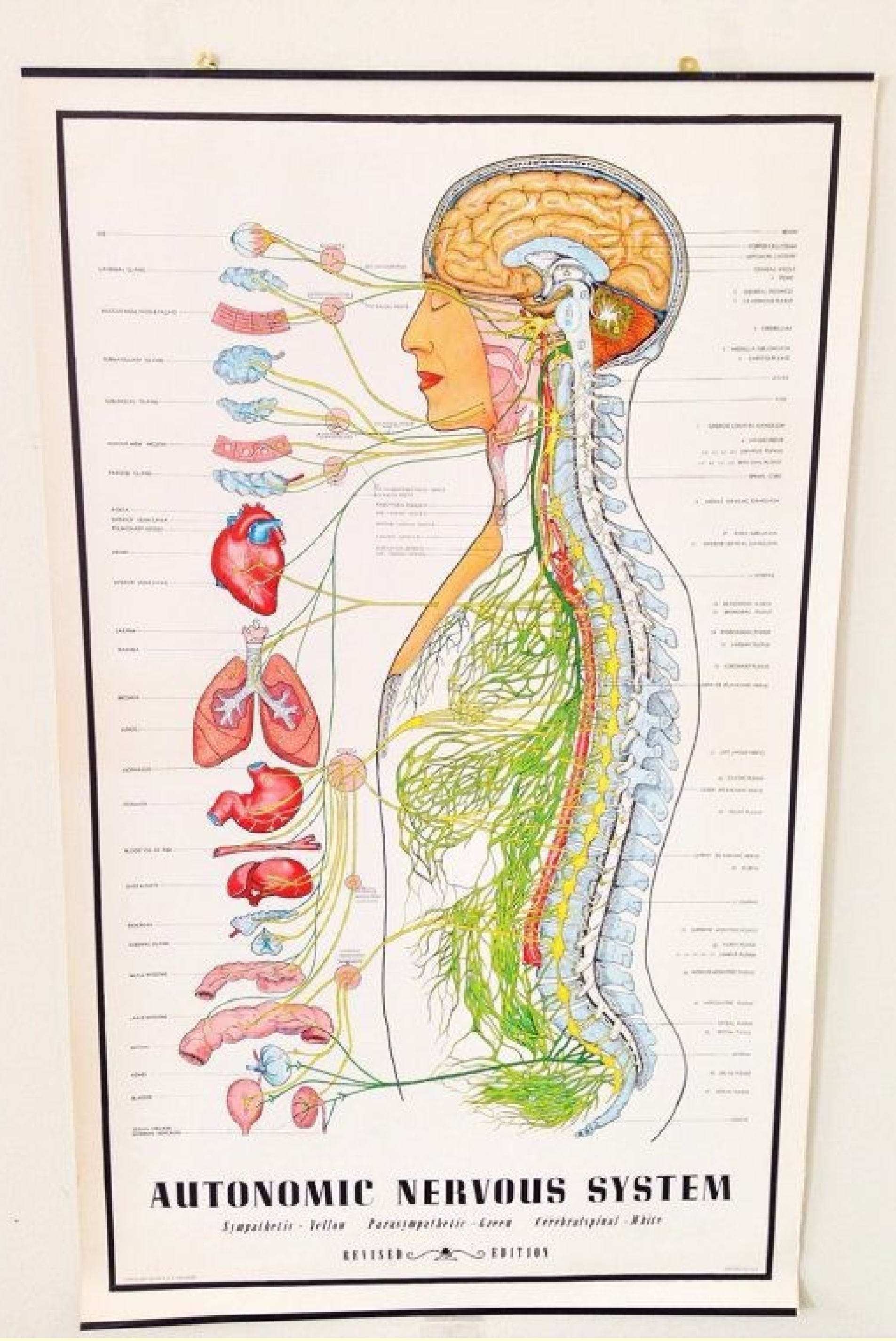


► Major Divisions of the Nervous System



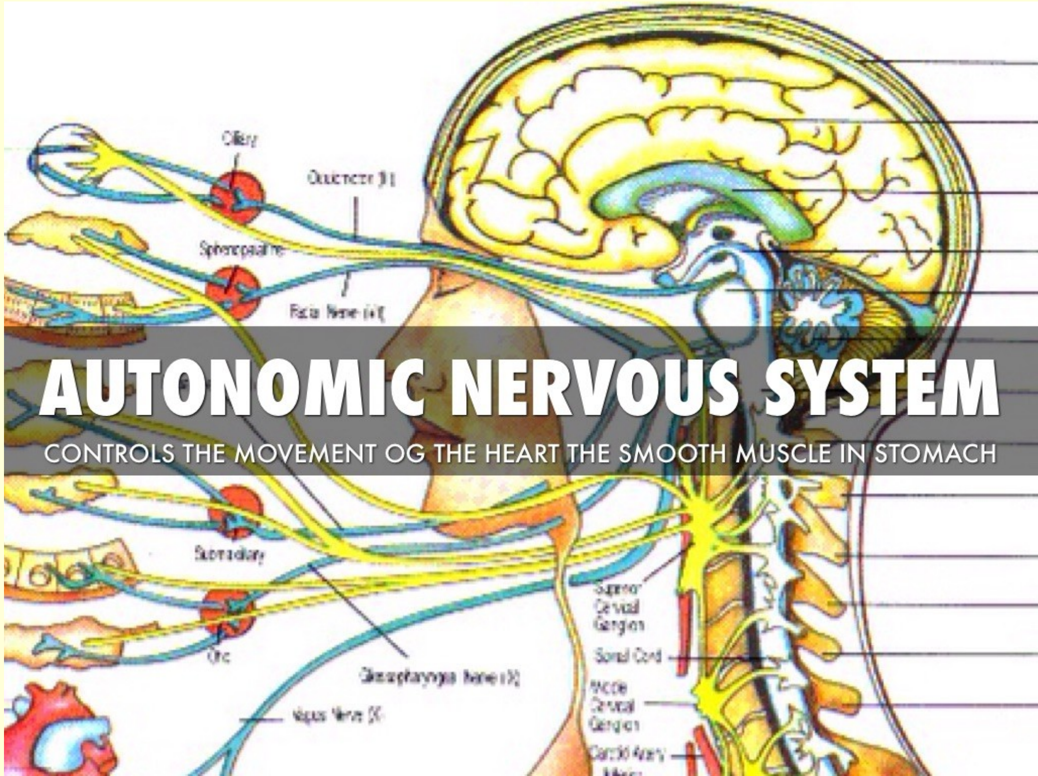
ANS

- The autonomic nervous system consists of peripheral afferent and efferent neurons, and other neurons constituting a widespread CNS representation.



ANS

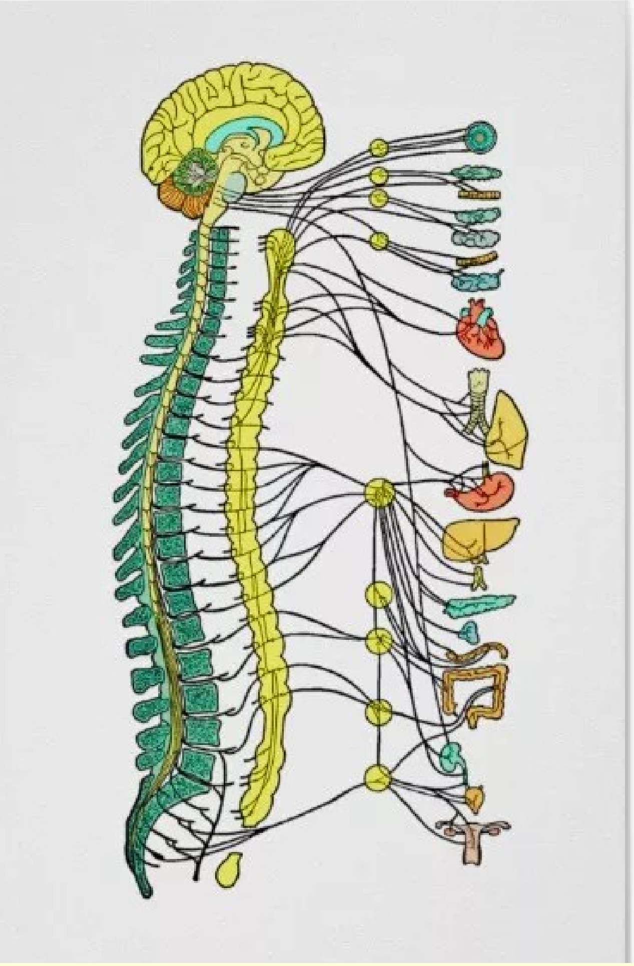
- ANS regulates the organism's internal environment and controls physical exchanges between the organism and the external environment.
- Together with the endocrine system, the ANS provides for homeostasis.



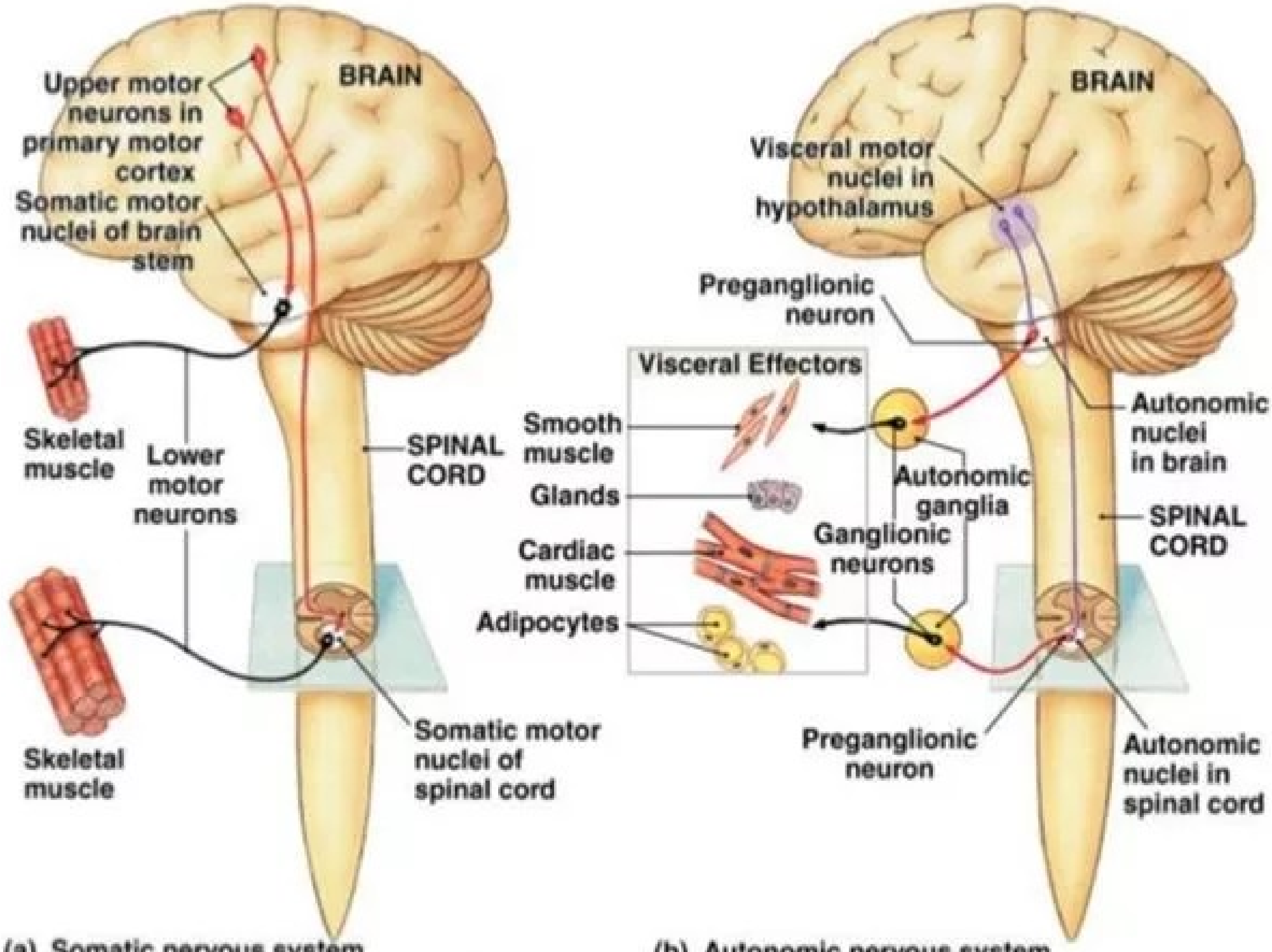
HISTORY

The term **"autonomic nervous system"** being originally proposed by the Cambridge based Professor **James Langley**, is also called the **"vegetative nervous system"**, a term coined by **Reil** in 1807.

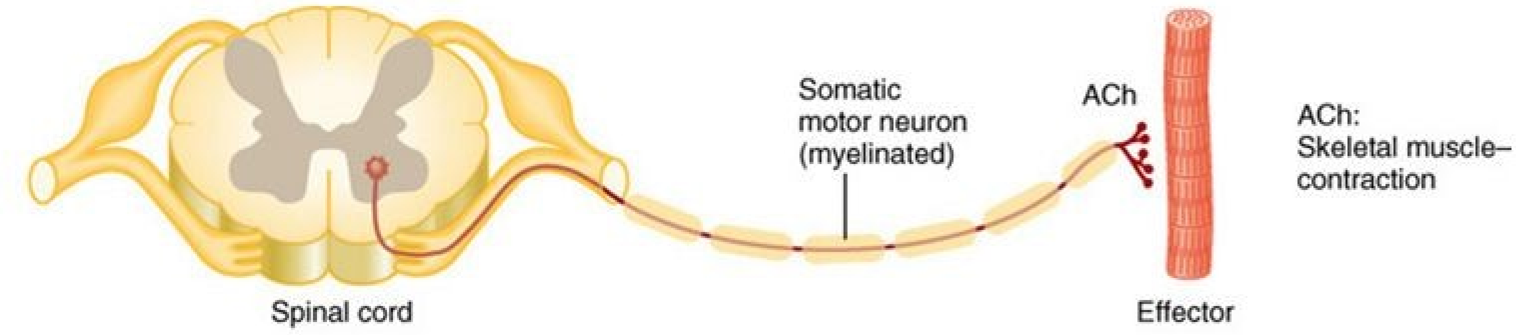
Gaskell (a London based Professor and the first editor of the Journal of Physiology) christened ANS as **"involuntary nervous system"** (involuntary, because, it is not under volition).



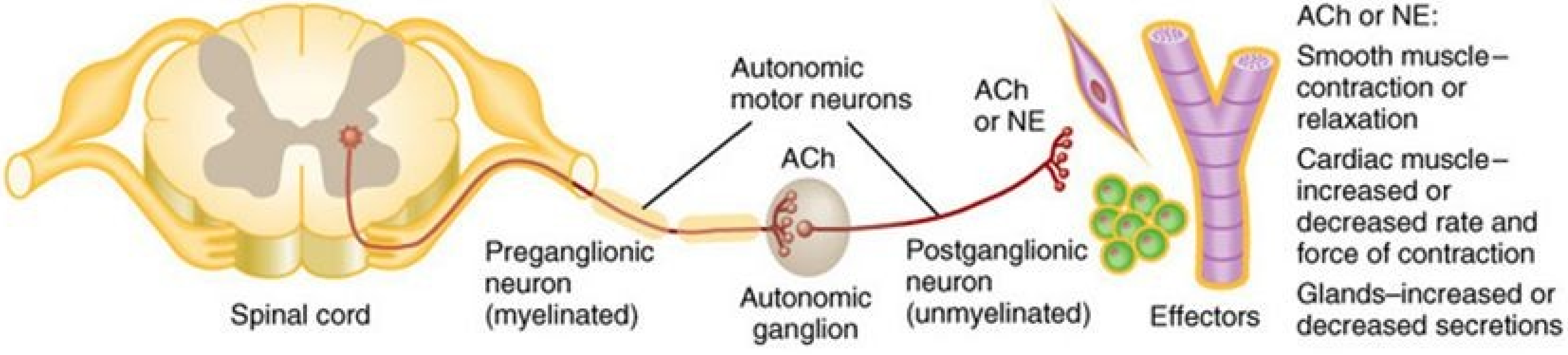
Somatic vs. Autonomic



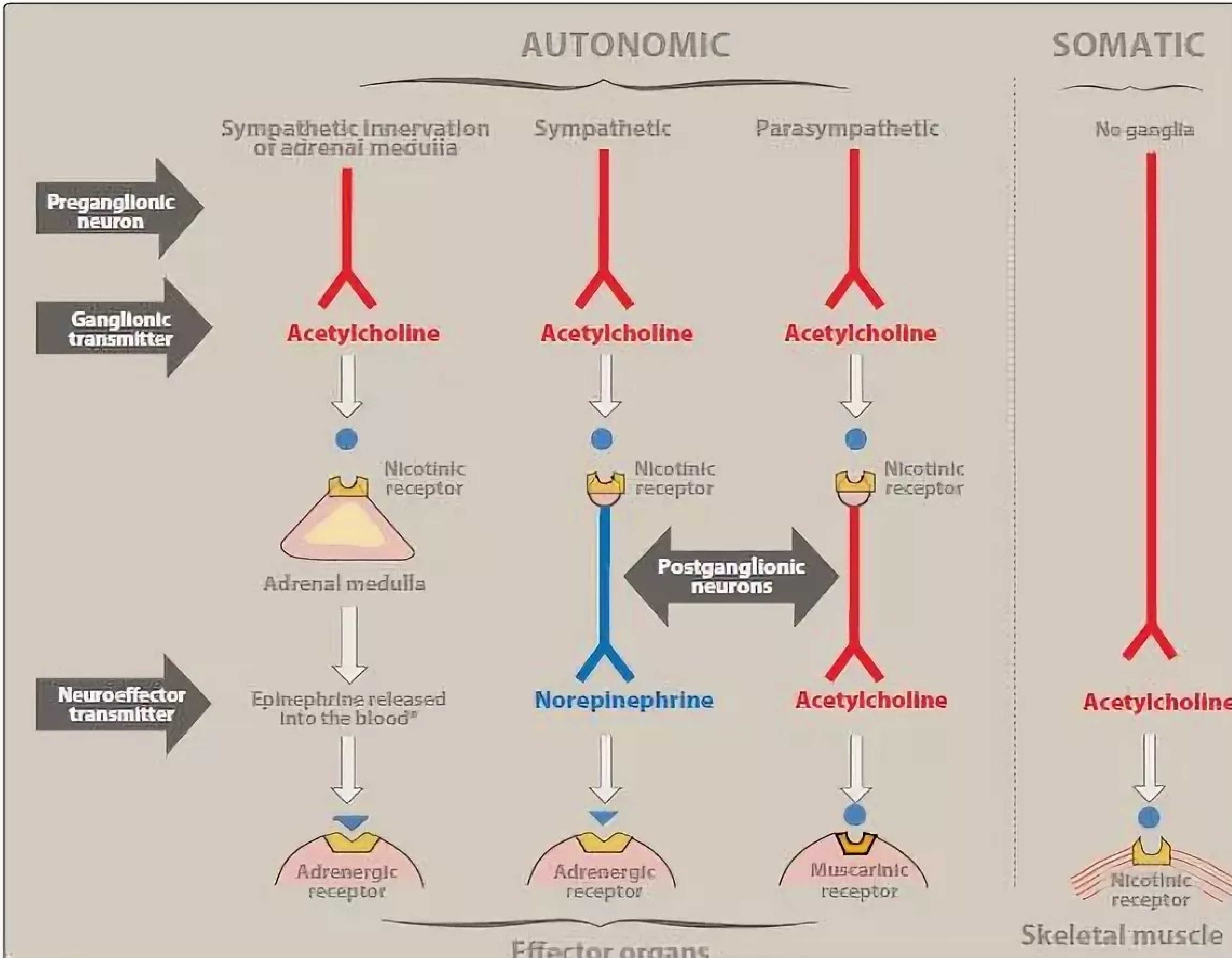
Comparison of Somatic and Autonomic Nervous Systems



(a) Somatic nervous system



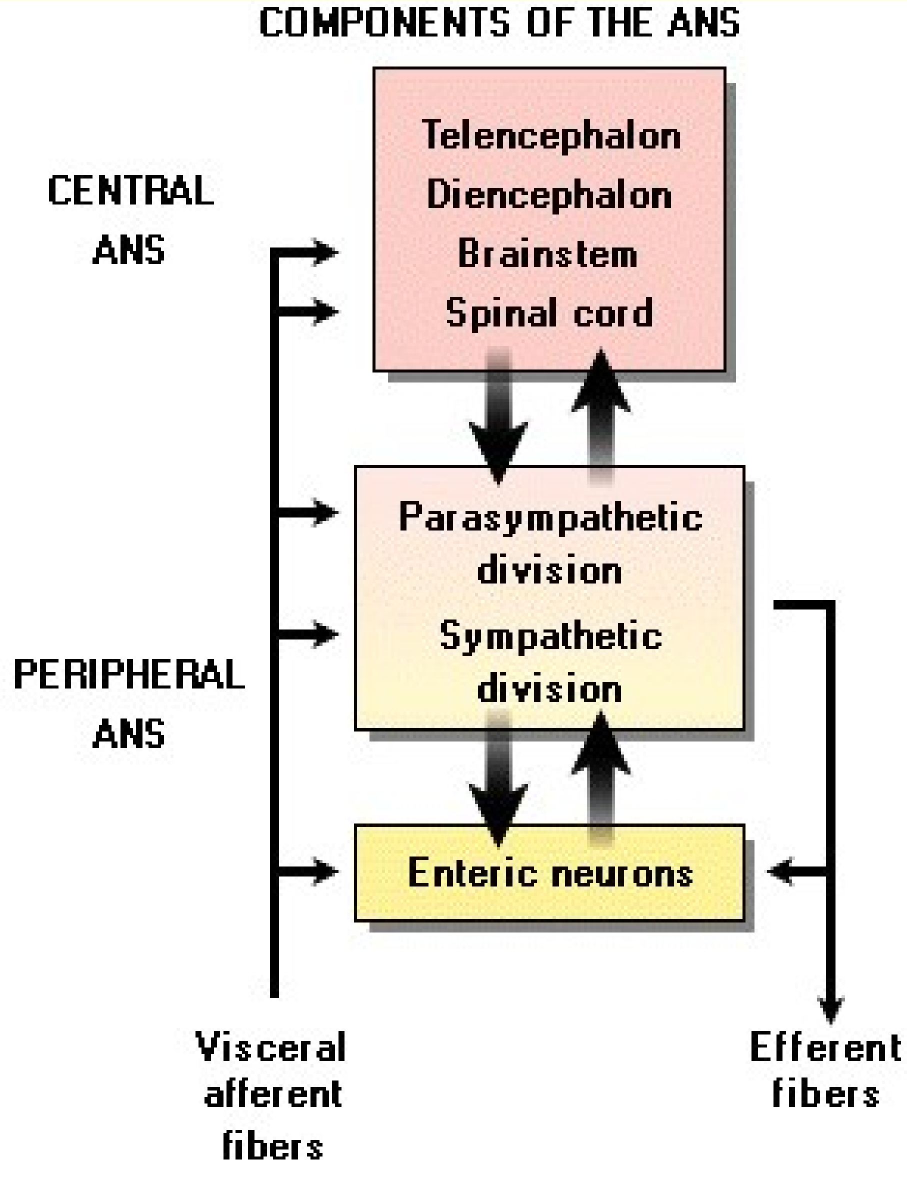
(b) Autonomic nervous system



AUTONOMIC
SOMATIC
Sympathetic innervation of adrenal medulla
Sympathetic
Parasympathetic
No ganglia
Preganglionic neuron
Ganglionic transmitter
Acetylcholine
Acetylcholine
Acetylcholine
Nicotinic receptor
Nicotinic receptor
Nicotinic receptor
Adrenal medulla
Postganglionic neurons
Neuroeffector transmitter
Epinephrine released into the blood*
Norepinephrine
Acetylcholine
Acetylcholine
Adrenergic receptor
Adrenergic receptor
Muscarinic receptor
Nicotinic receptor
Effector organs
Skeletal muscle

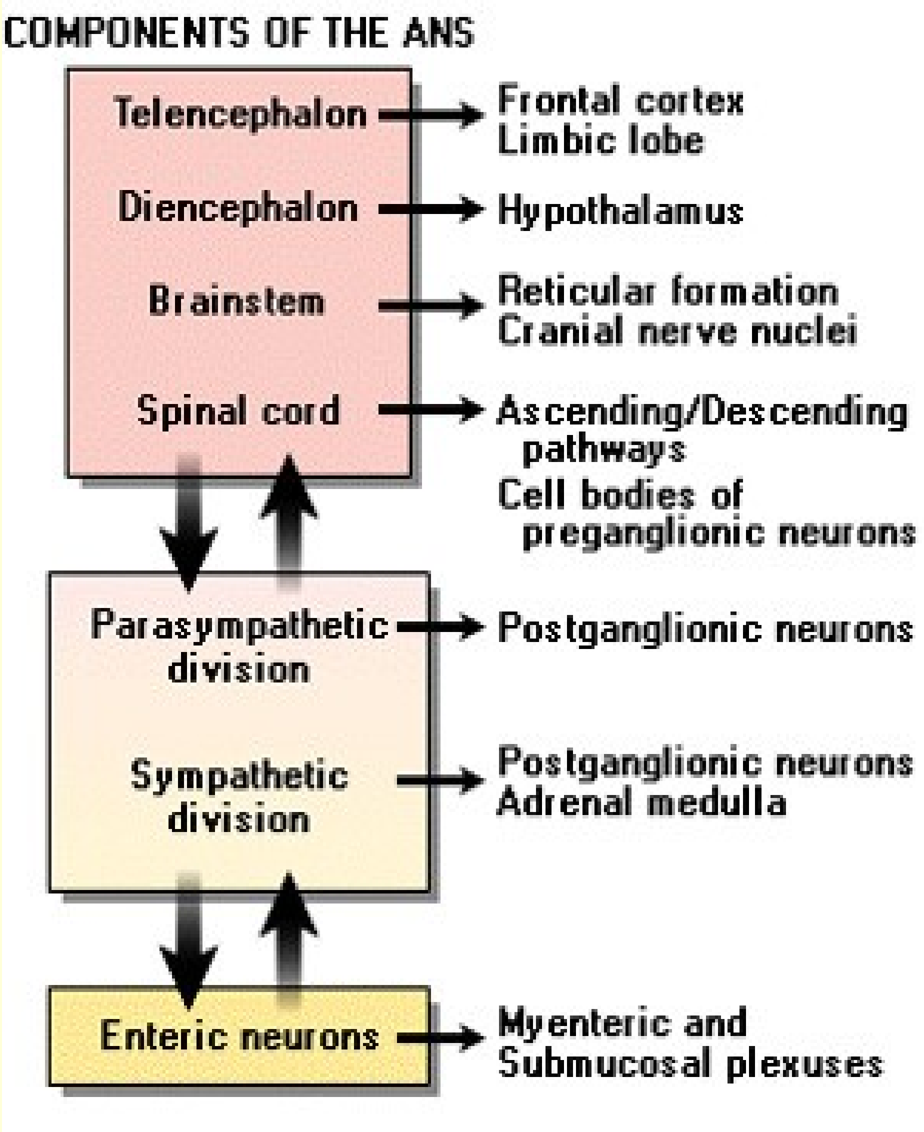
Central & peripheral ANS

- *The central ANS* is quite diffuse, consisting of tracts and regions of gray matter in the spinal cord, brainstem, diencephalon, and telencephalon.
- *The peripheral ANS* includes the neurons of the parasympathetic and sympathetic divisions, the enteric neurons of the gut, and visceral afferent fibers.

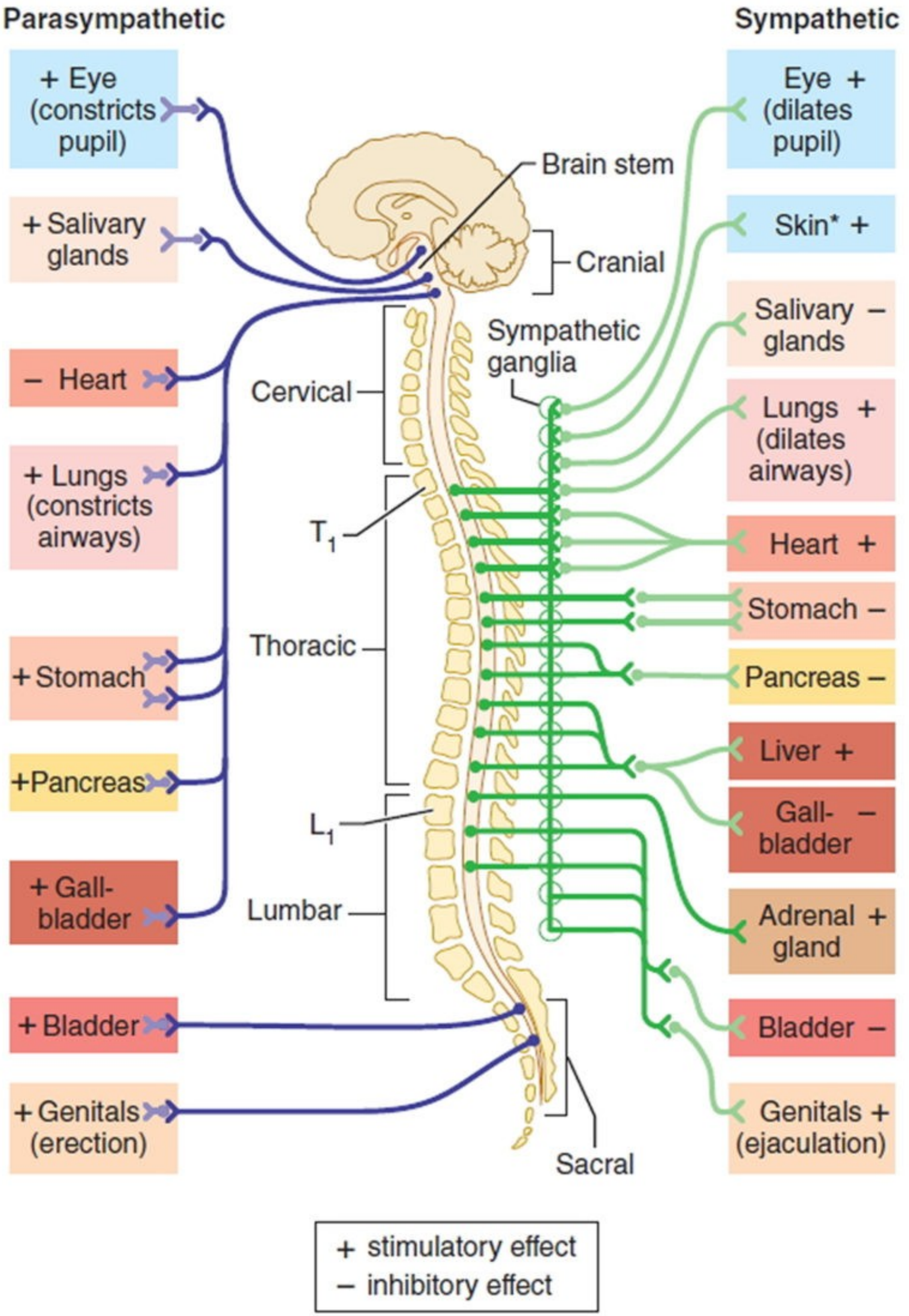


Two divisions of ANS

- “Parasympalhetic” nervous system – “craniosacral” (arises from the brain and sacral part of the spinal cord – L5-S5).
- “Sympathetic” nervous system – “thoracolumbar” (arises from the thoracic and upper lumbar segments of the cord – C8-L4).

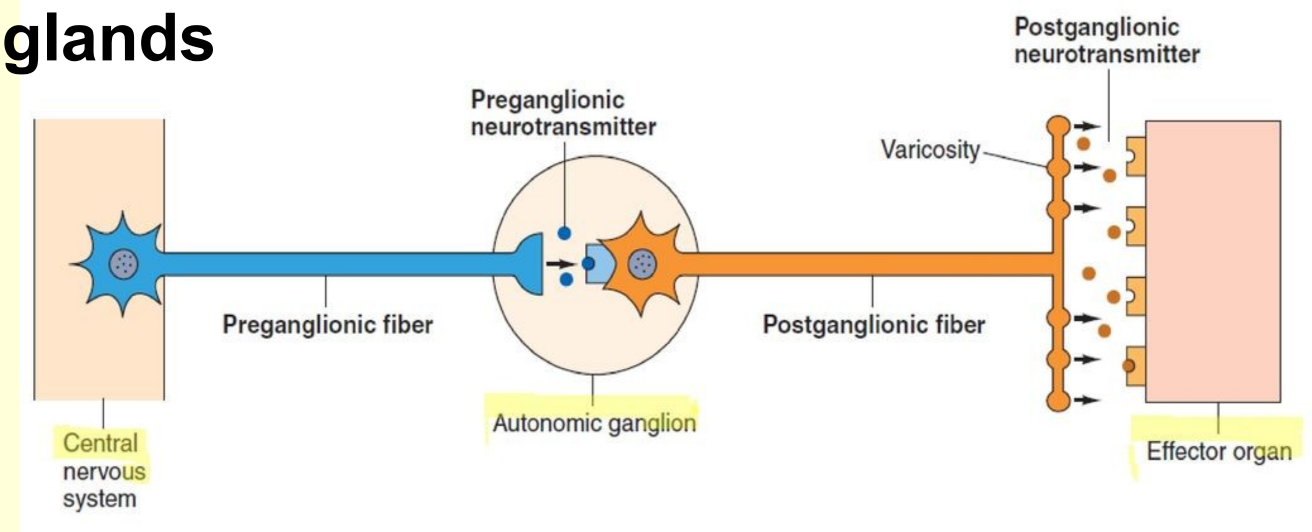


Two divisions of ANS



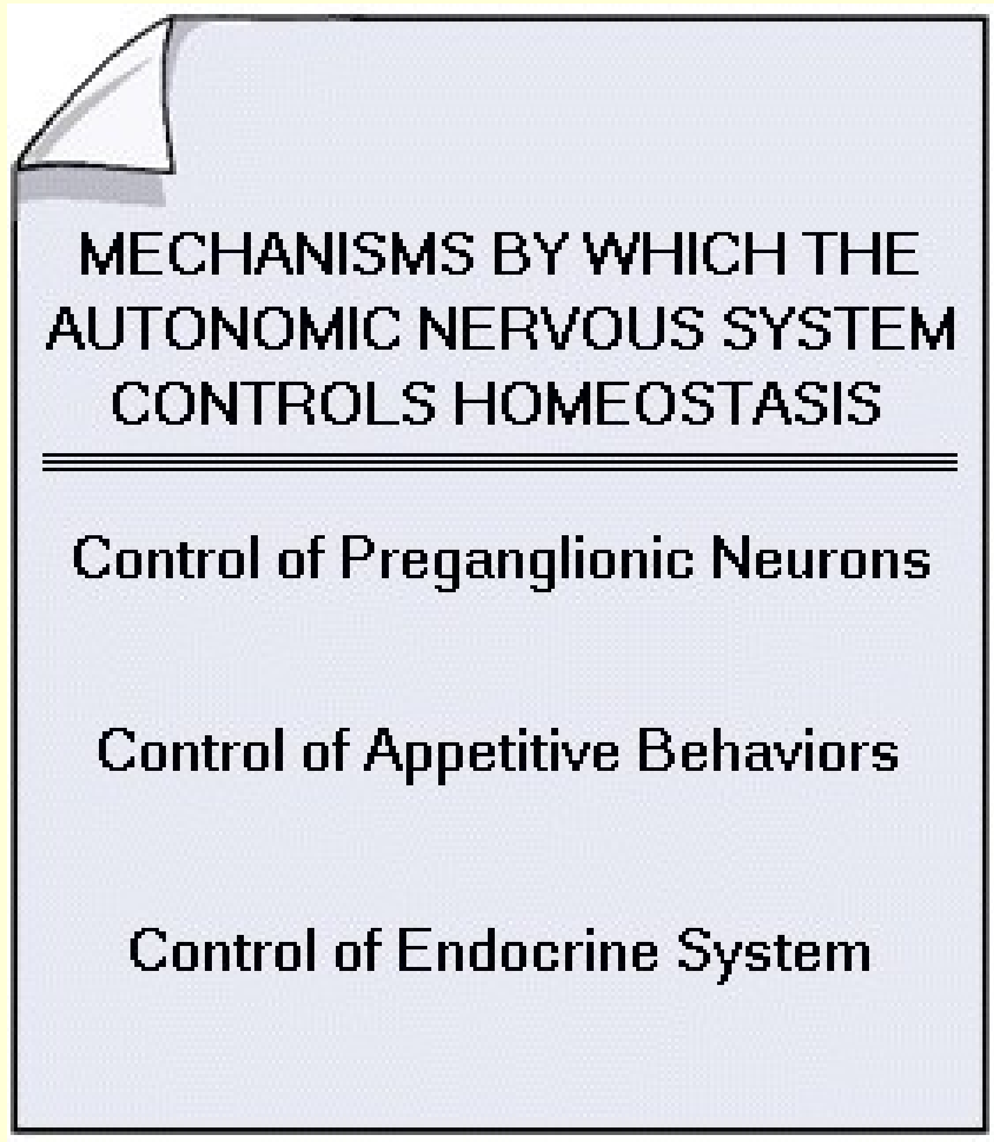
Afferent & efferent ANS fibers

- The *afferent* of autonomic fibers bring information from the viscera (visceral pain sensation).
- The *efferent* (motor) fibers of autonomic system supply:
  - smooth muscles
  - cardiac muscles
  - exocrine glands



The Central ANS (first)

The central ANS provides for homeostasis by three main routes. First, it controls the viscera via its connections to preganglionic neurons that control the heart, smooth muscle, and glands of the body through parasympathetic and sympathetic neurons.


MECHANISMS BY WHICH THE AUTONOMIC NERVOUS SYSTEM CONTROLS HOMEOSTASIS

Control of Preganglionic Neurons

Control of Appetitive Behaviors

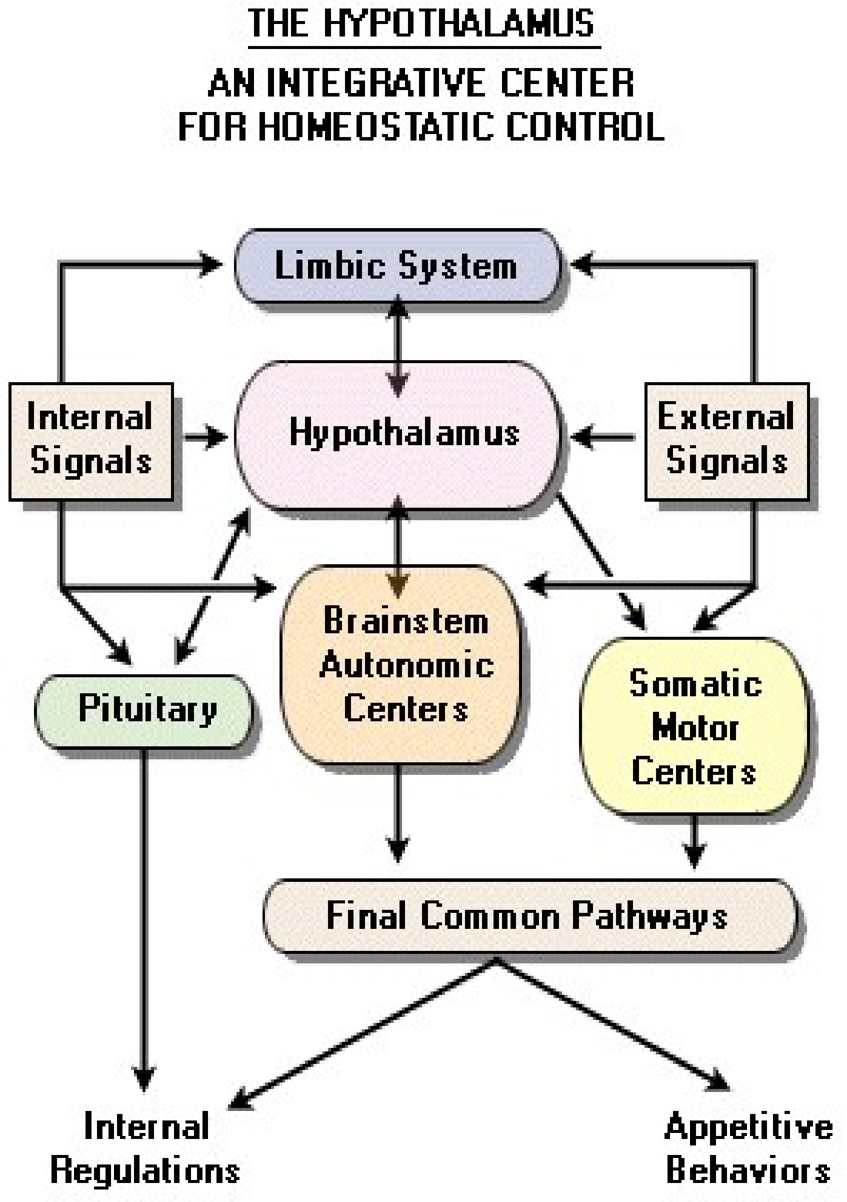
Control of Endocrine System

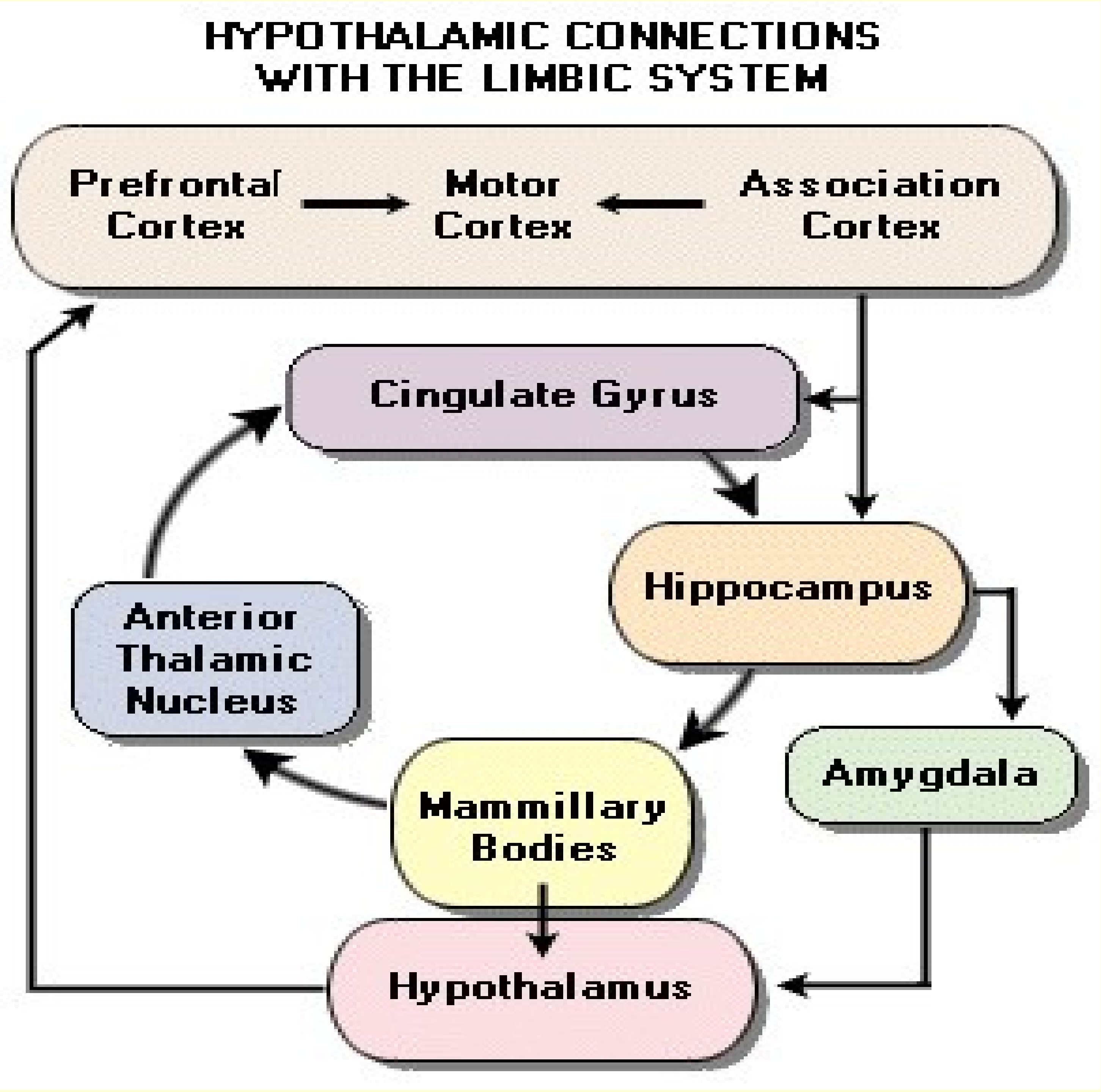
The Central ANS (second)

- It controls behaviors responsible for physical exchanges between the organism and its environment via its connections to motivational and somatic motor pathways.
- Such behaviors are called "appetitive", meaning "appetite satisfying", and include ingestive (eating and drinking), excretory (micturition and defecation), and reproductive (mating and parturition) behaviors.
- Its control of the endocrine system contributes to both of the foregoing control mechanisms.

The Central ANS (third)

- Within the central ANS, the hypothalamus is the major integrative center for homeostatic control.
- Technically, the hypothalamus is part of the limbic system, that provides for mood and affect, the appreciation of our emotional state.



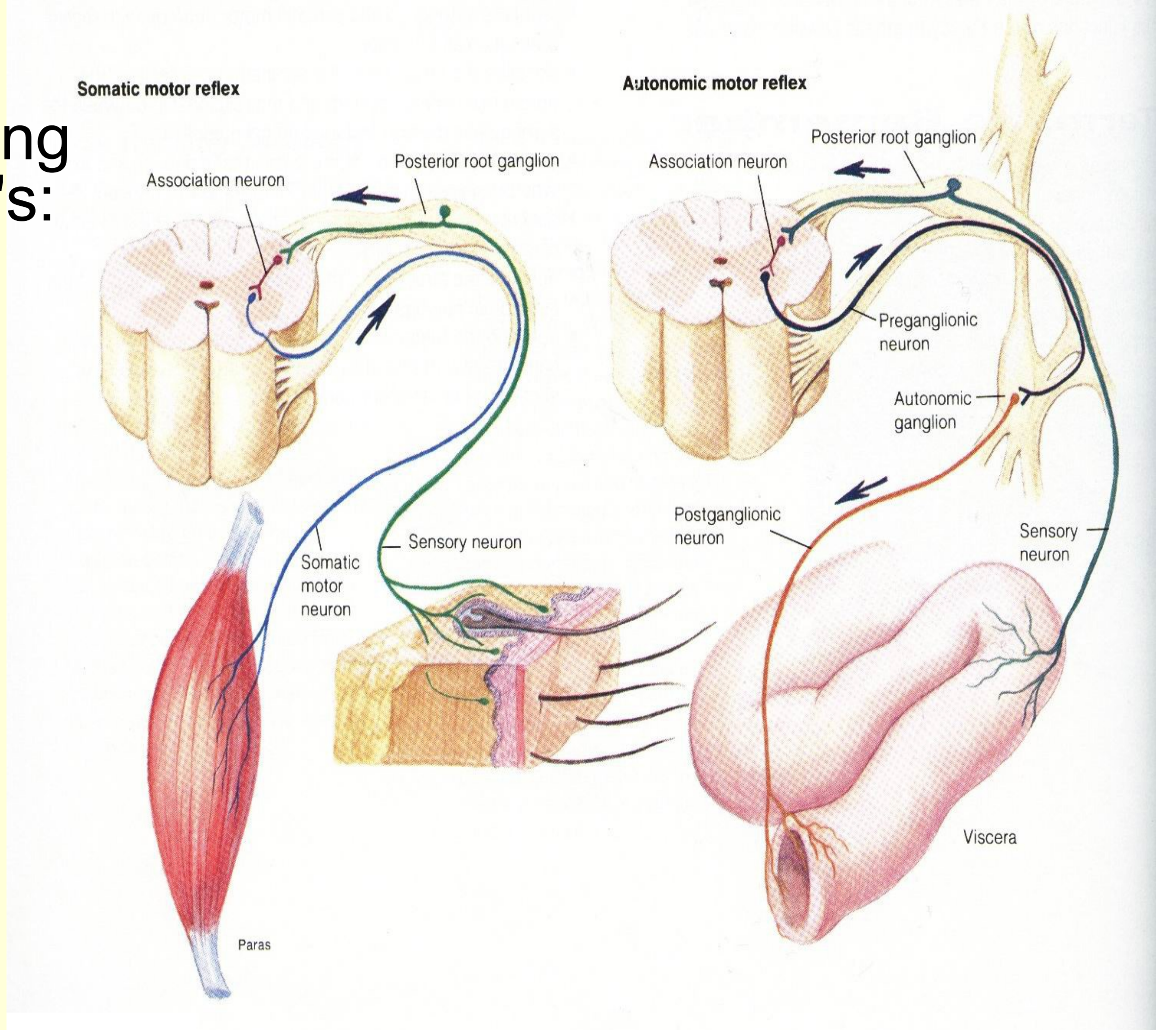

HYPOTHALAMIC CONNECTIONS WITH THE LIMBIC SYSTEM
Prefrontal Cortex
Motor Cortex
Association Cortex
Cingulate Gyrus
Hippocampus
Anterior Thalamic Nucleus
Amygdala
Mammillary Bodies
Hypothalamus

The Peripheral ANS

The ANS is said to be responsible for preparing the body for the four F's:

- fighting
- fleeing
- feeding
- fooling around

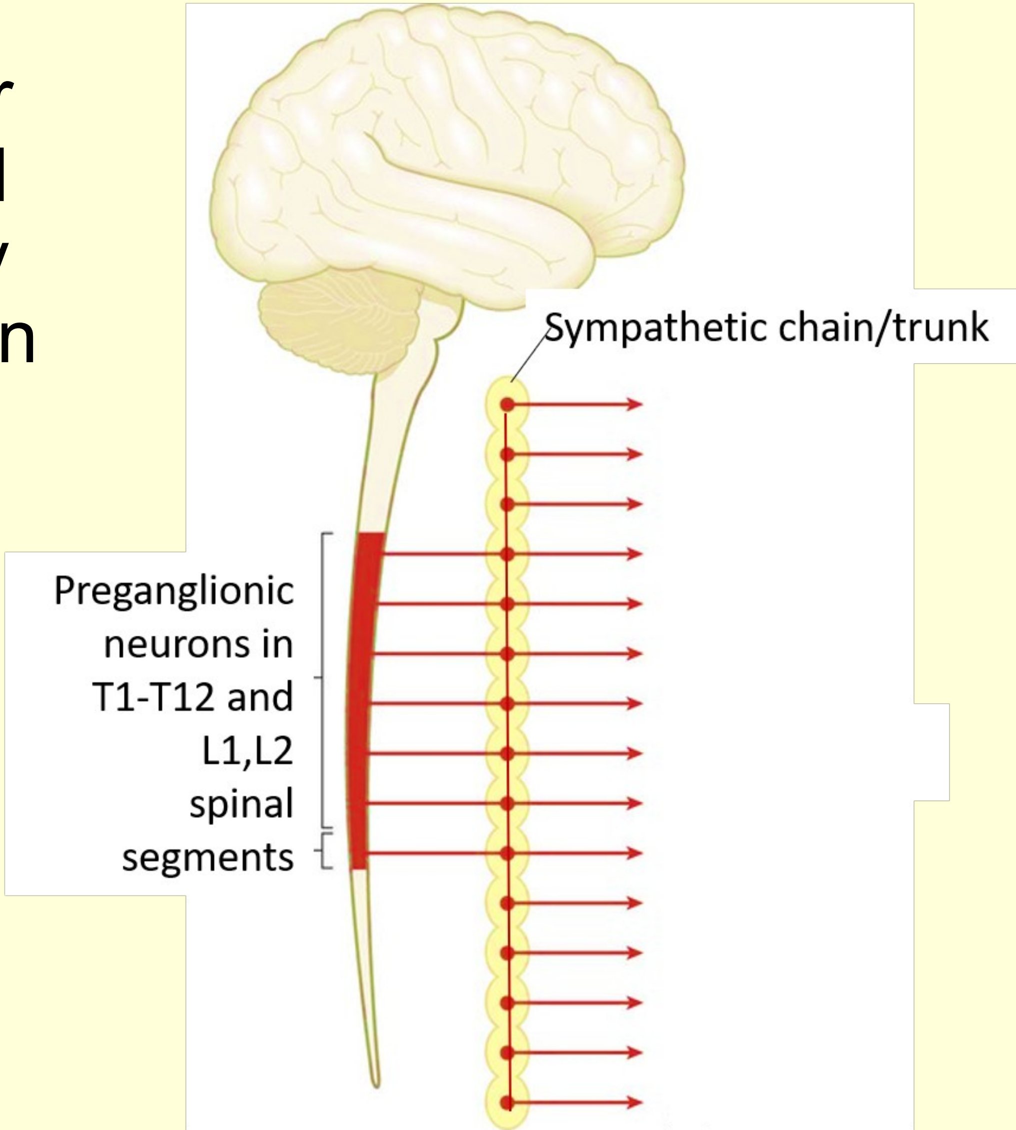
- The *sympathetic* division establishes conditions appropriate for *fight or flight*.
- The *parasympathetic* division for *feeding or fooling around*.



A comparison between a somatic motor reflex and an autonomic motor reflex.

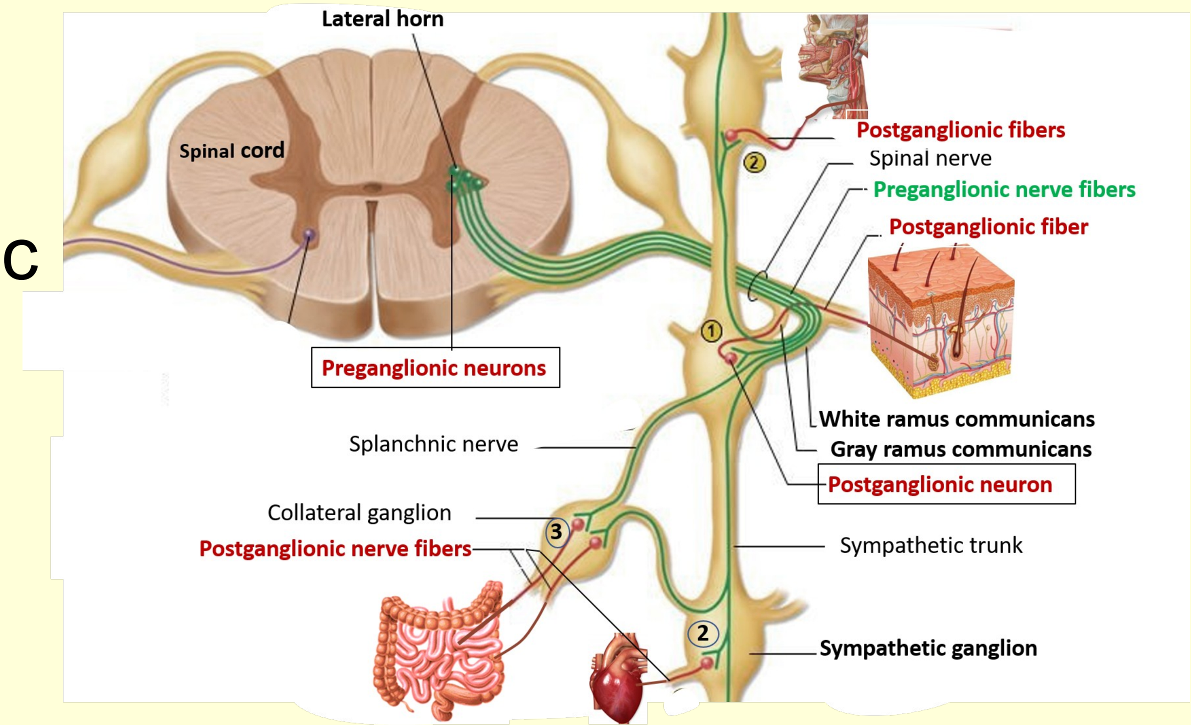
THE SYMPATHETIC SYSTEM

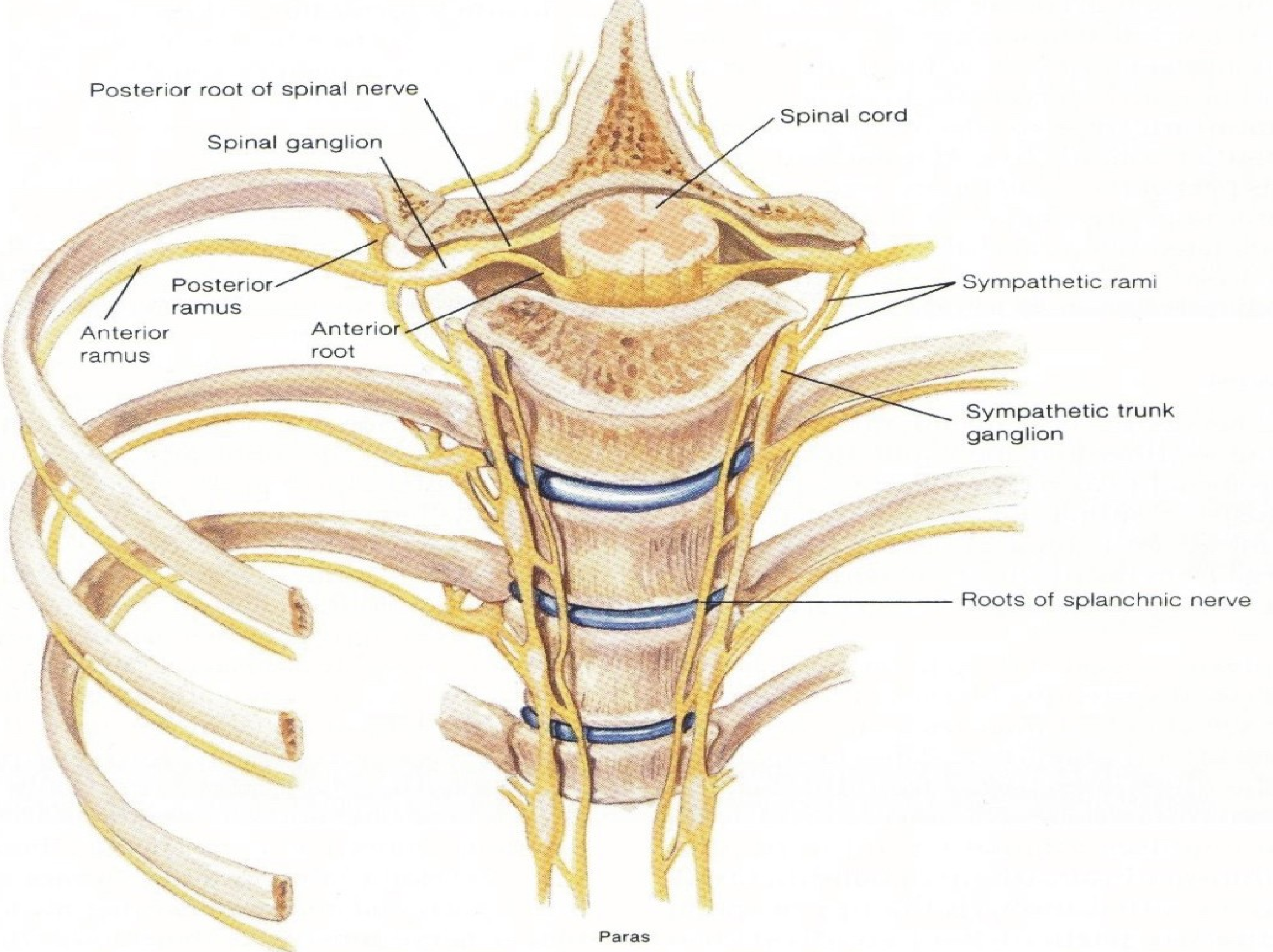
- The preganglionic fiber moves up or down and then synapses, usually with several neurons, in the trunk. From these synapses
  the postganglionic nerve fibers emerge and proceed to their destination.



THE SYMPATHETIC SYSTEM

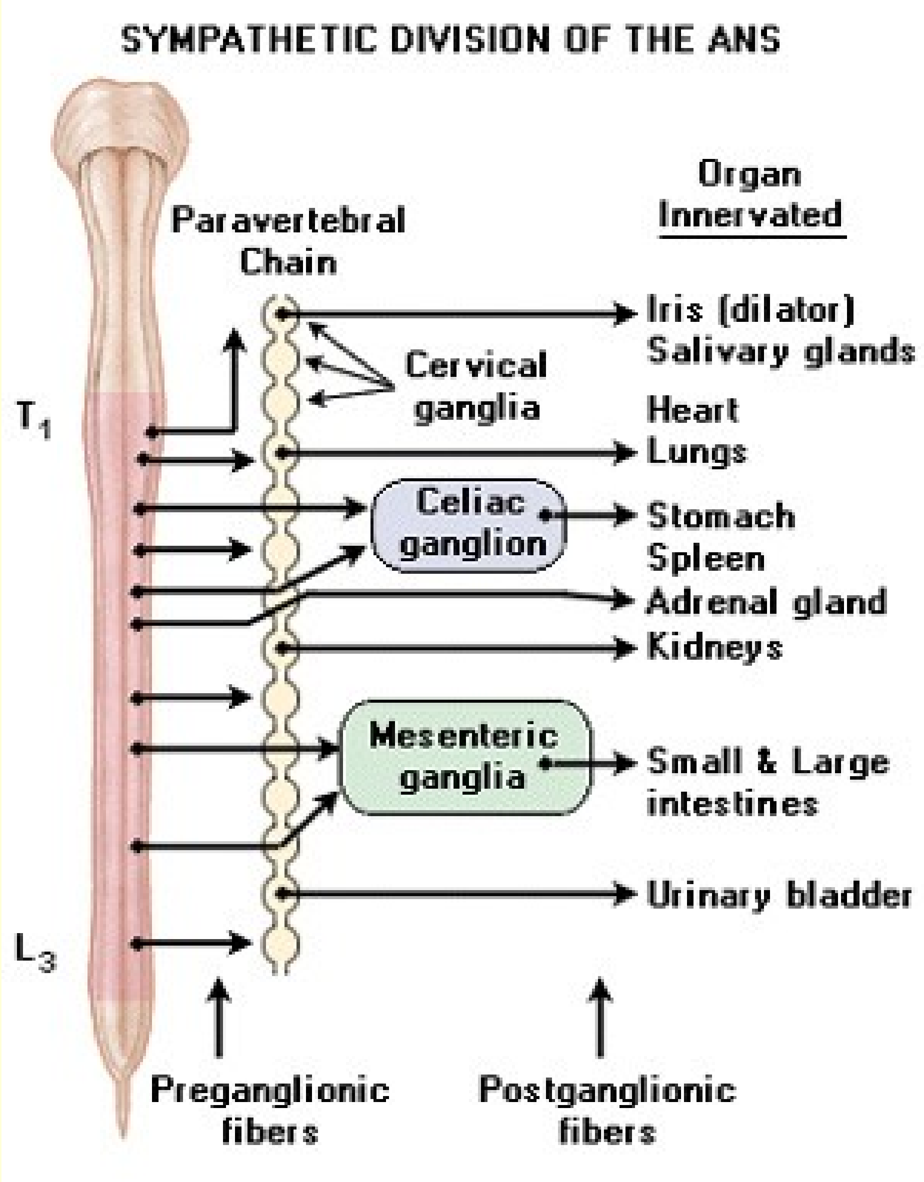
- Some preganglionic fibers leave the sympathetic trunk, still as preganglionic fibers, (i.e. without synapsing) and enter in another ganglion outside the sympathetic trunk (e.g. collateral ganglion) to synapse with the next order neuron (the postganglionic fiber).

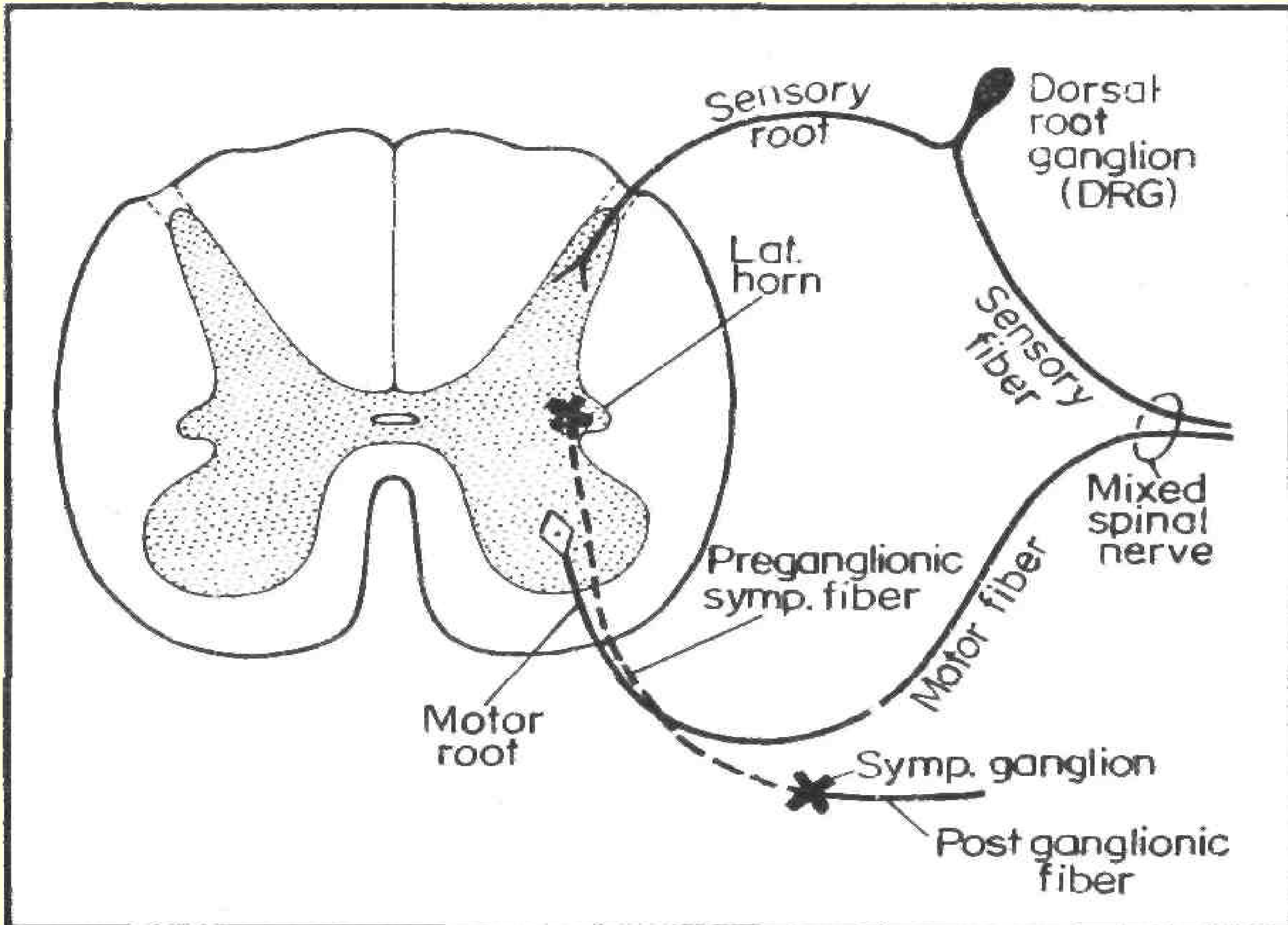



Posterior root of spinal nerve
Spinal cord
Spinal ganglion
Posterior ramus
Anterior ramus
Anterior root
Sympathetic rami
Sympathetic trunk ganglion
Roots of splanchnic nerve
Paras

THE SYMPATHETIC SYSTEM

- The post ganglionic fibers, which emerge from the sympathetic trunk (chain) to join a spinal nerve, do so as gray rami communicantes (because these post ganglionic fibers are non medullaled, they look grayish).





Sensory root
Dorsal root ganglion (DRG)
Lat. horn
Sensory fiber
Mixed spinal nerve
Preganglionic symp. fiber
Motor fiber
Motor root
Symp. ganglion
Post ganglionic fiber

The structures innervated by the postganglionic nerve fibers

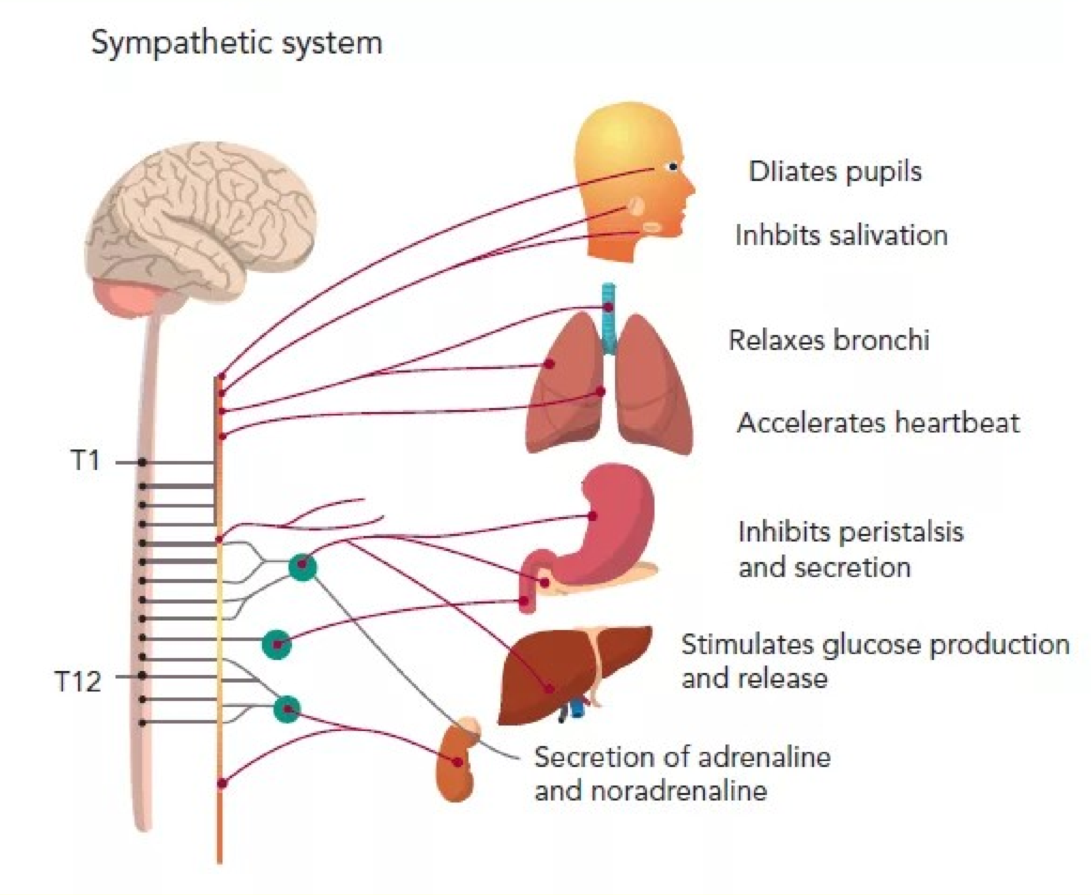
1) the smooth muscles (respiratory tract, vascular tree, gastrointestinal tract);

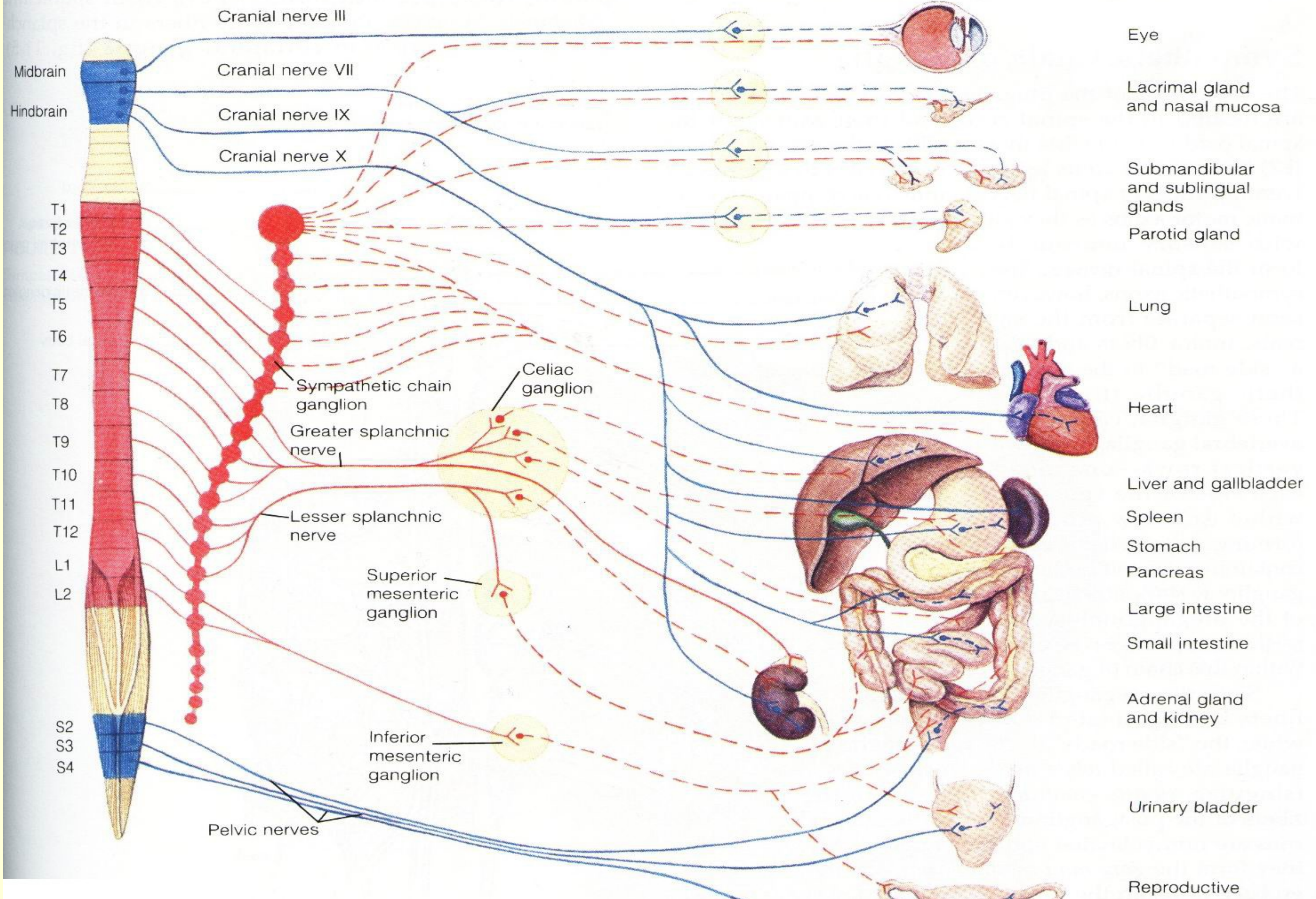
2) the heart muscles;

3) the sweat glands;

4) the arrector pili muscles of the skin;

5) exocrine glands (salivary, pancreas, gastric glands).



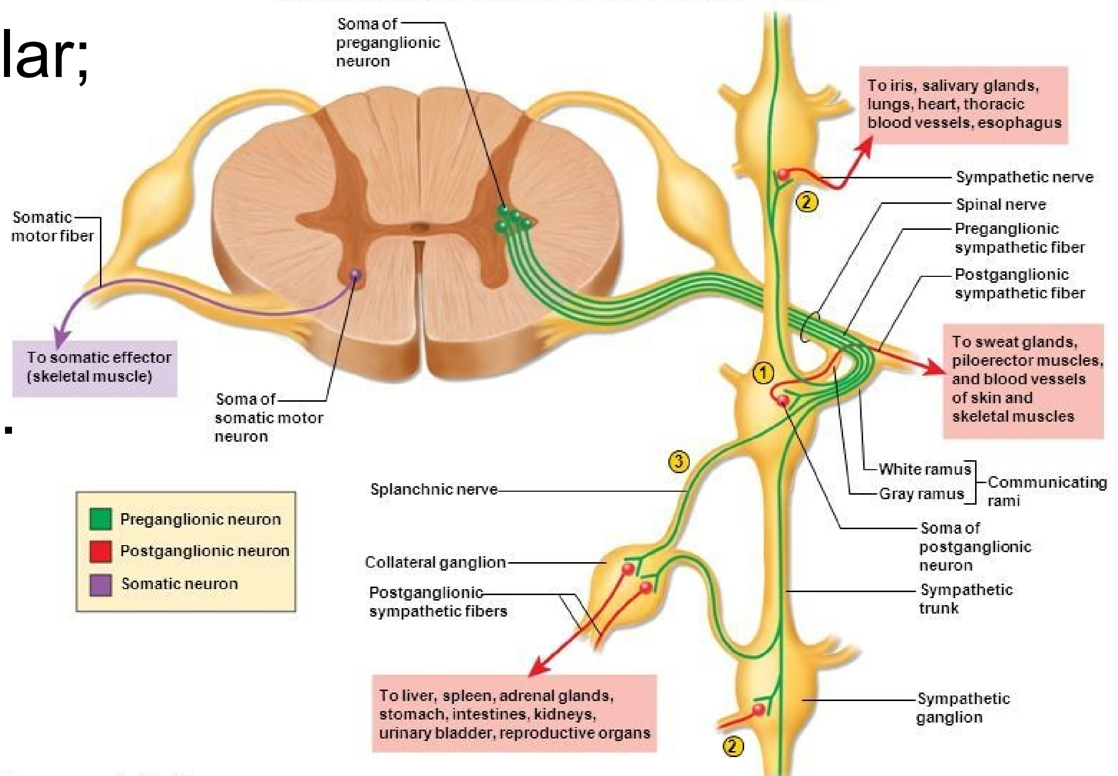


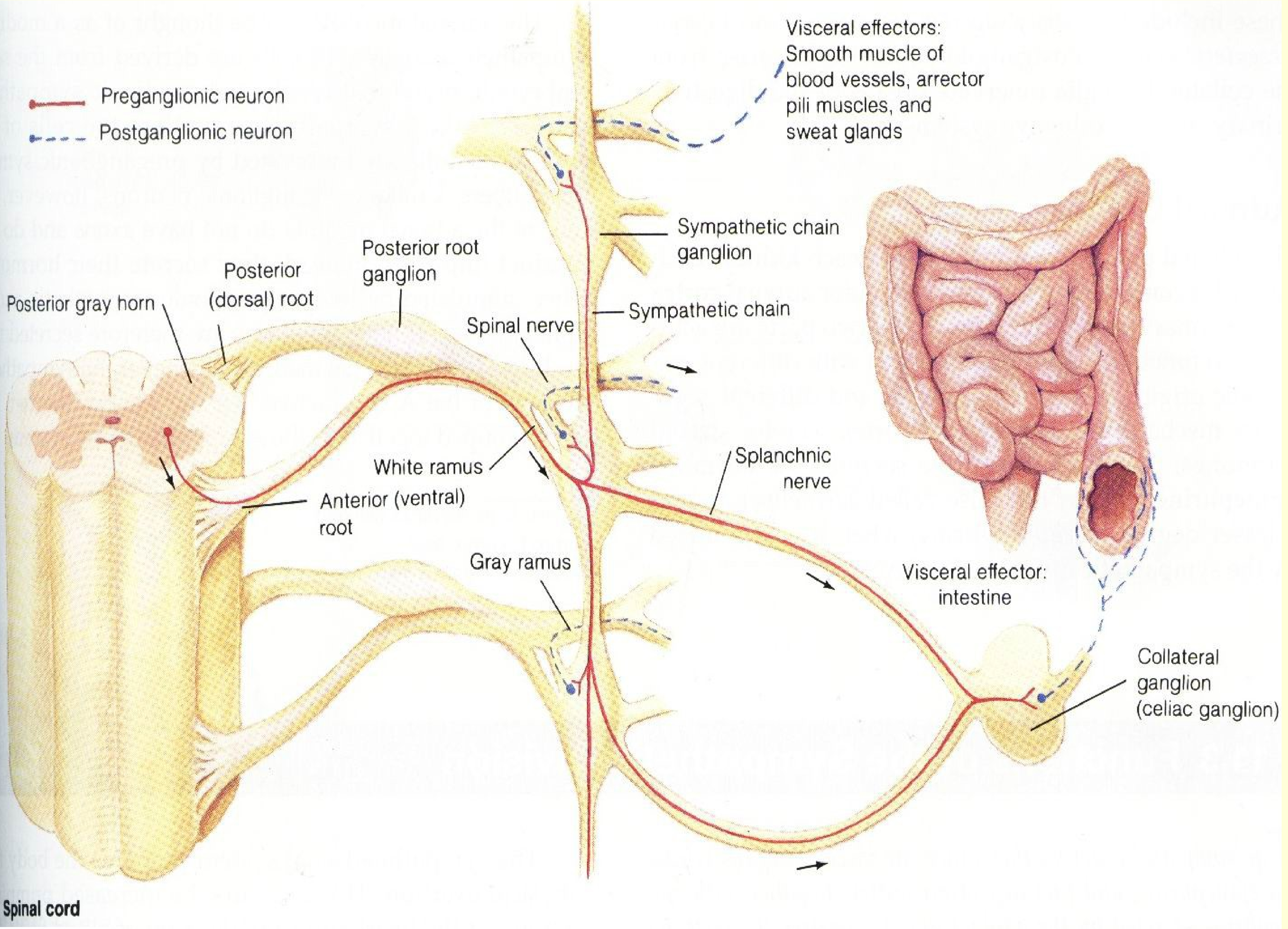
The autonomic nervous system. The sympathetic division is shown in red, the parasympathetic in blue. The solid lines indicate preganglionic fibers, and the dashed lines indicate postganglionic fibers.

Paras

THE SYMPATHETIC GANGLIA
(structures where synapsing between pre- and postganglionic fibers occurs)

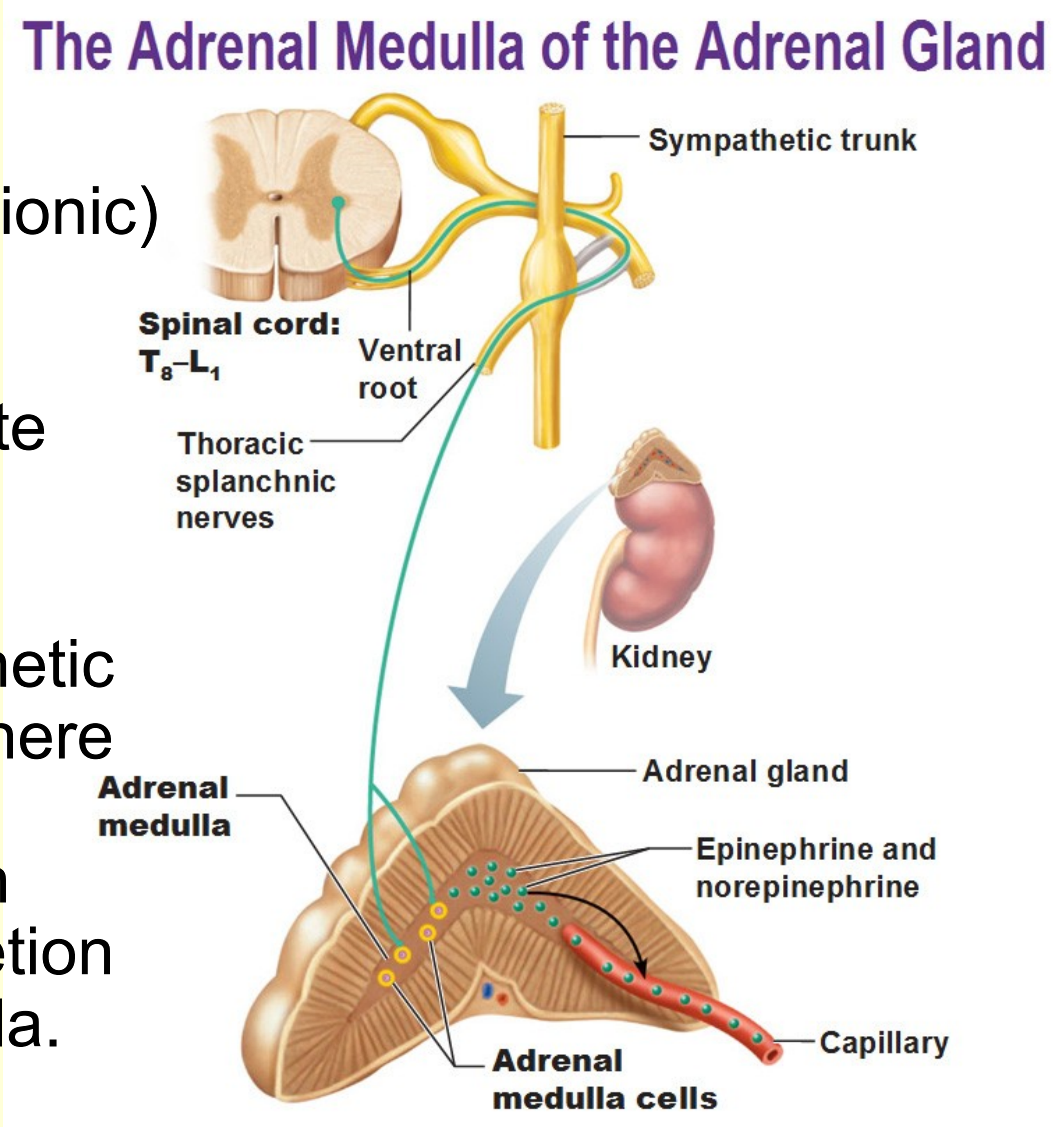
1. The sympathetic trunk: two sympathetic trunks; each consisting of 22 paravertebral ganglia.
2. Prevertebral ganglia (“collateral ganglia”):
   a) the celiac or solar;
   b) superior mesenteric;
   c) inferior mesenteric ganglion.
3. Terminal ganglia (situated near the bladder and rectum)




Preganglionic neuron
Postganglionic neuron
Visceral effectors:
Smooth muscle of
blood vessels, arrector
pili muscles, and
sweat glands
Sympathetic chain
ganglion
Posterior root
ganglion
Posterior
(dorsal) root
Posterior gray horn
Spinal nerve
Sympathetic chain
White ramus
Splanchnic
nerve
Anterior (ventral)
root
Gray ramus
Visceral effector:
intestine
Collateral
ganglion
(celiac ganglion)
Spinal cord

"SYMPATHOADRENAL AXIS"

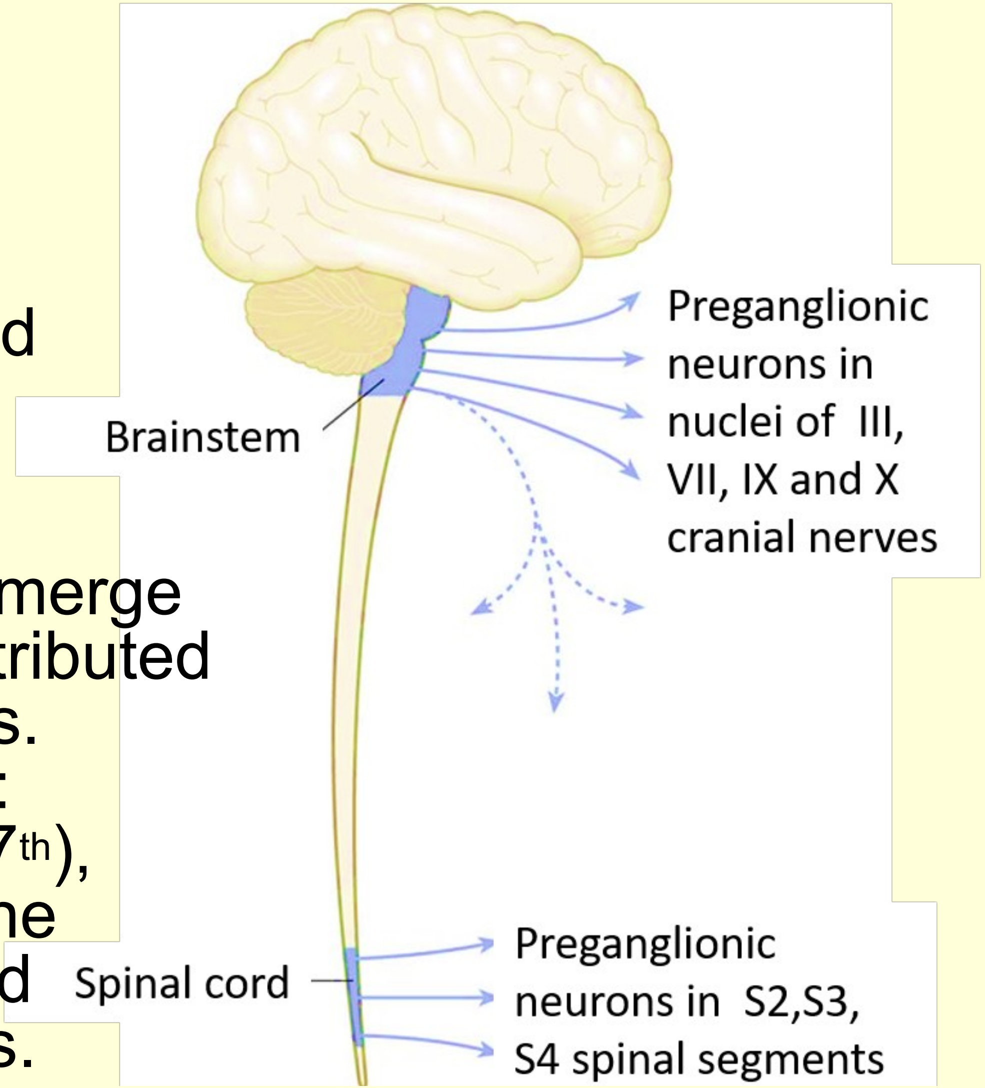
- Fibers of the greater splanchinc nerve (sympathetic, preganglionic) enter the suprarenal medulla and end in the chromaffin cells (secrete adrenalin as well as noradrenalin).
- Whenever the sympathetic system is stimulated, there is a concomitant stimulation of adrenalin and noradrenalin secretion from suprarenal medulla.



PARASYMPATHETIC SYSTEM (craniosacral outflow)

CRANIAL OUTFLOW (preganglionic)

- The 3rd (oculomotor), 7th (facial), 9th (glossopharyngeal) and the 10th (vagus) cranial nerves are the nerves via which the cranial parasympathetic nerves emerge from the brain and are distributed to the peripheral structures. They relay in their ganglia: ciliary (3rd), submaxillary (7th), otic (9th). The ganglia for the vagal efferents are situated close to their target organs.



PARASYMPATHETIC SYSTEM (craniosacral outflow)

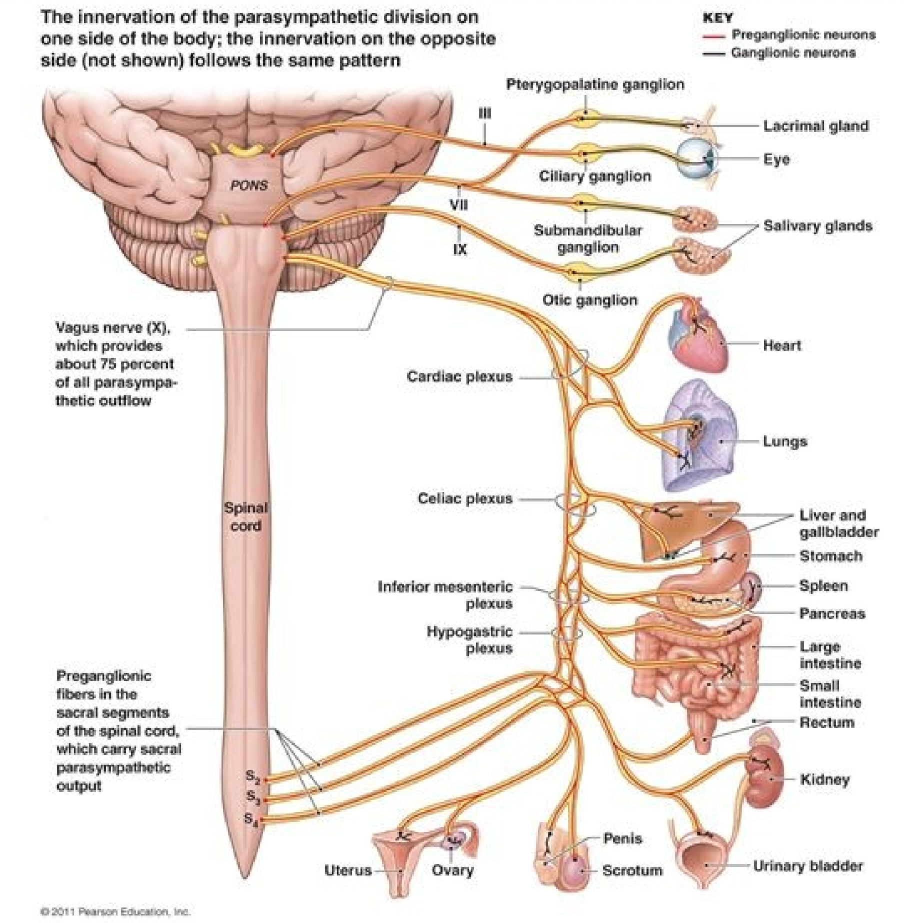
SACRAL OUTFLOW (preganglionic)

- From the lateral horns of the 2nd, 3rd and 4th segments of the sacral regions, the parasympathetic fibers come out to form pelvic splanchnic nerves. The sacral autonomic supplies:

(a) the last part of the colon and the rectum;

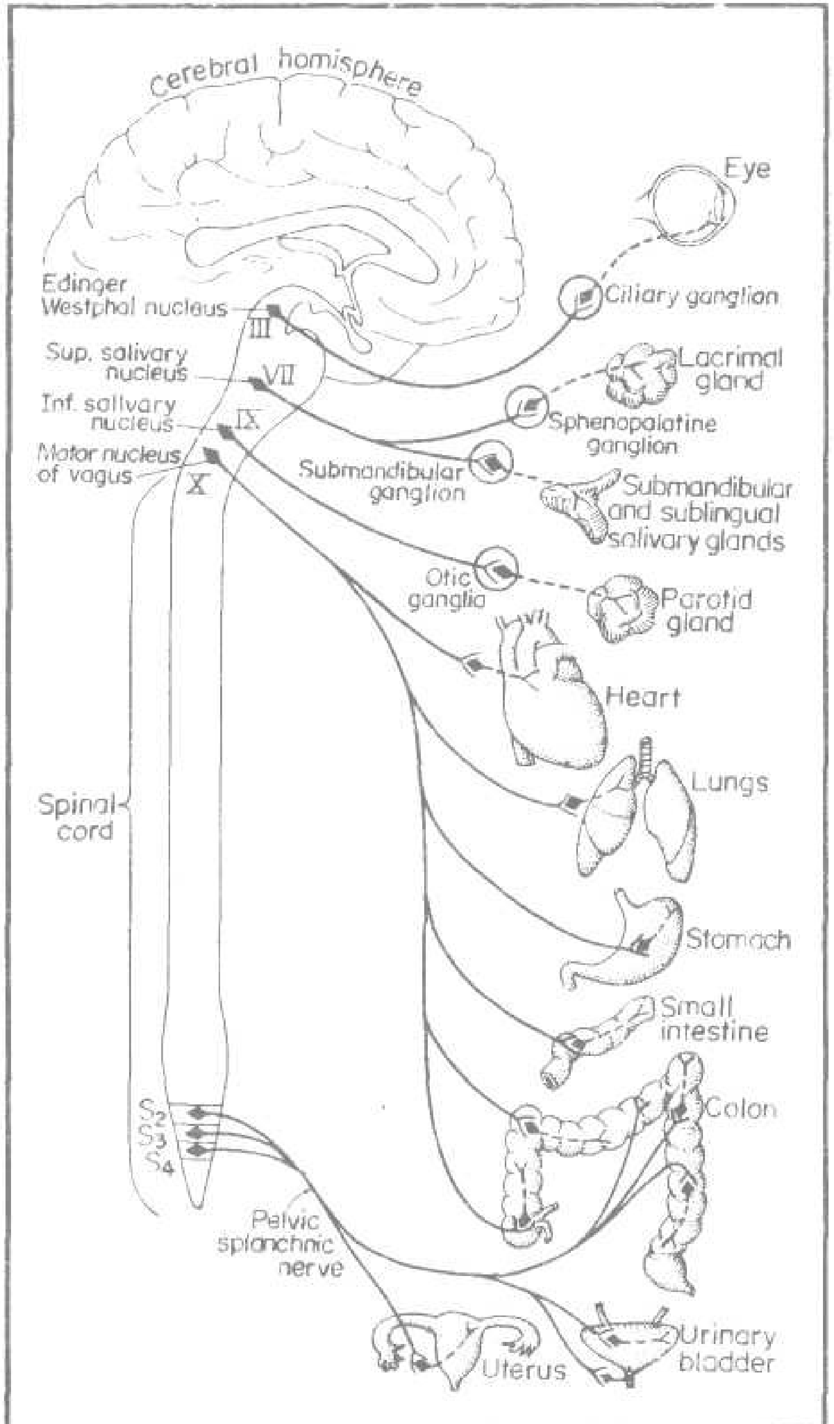
(b) urinary bladder;

(c) the uterus or the blood vessels of the penis.



PARASYMPATHETIC DIVISION OF THE ANS

Locus of cell body	Pereipheral nerve	Ganglion	Organ Innervated
Edinger-Westphal nucleus	Oculomotor nerve (III)	Ciliary ganglion	Iris (sphincter) Ciliary muscle
Superior salivatory nucleus	Facial nerve (VII)	Pterygopalatine and Submandibular gangila	Lacrimal, submandibular, and sublingual glands
Inferior salivatory nucleus	Glossopharyngeal nerve (IX)	Otic ganglion	Parotid glands
Dorsal vagal & Nucelus ambiguous	Vagus nerve	Various terminal ganglia	Bronchial tree Lungs Heart Liver, gall bladder, pancreas Kidneys Gut (esophagus to colon)
Sacral spinal cord	Splanchnic nerve	Pelvic plexus	Descending colon Rectum Bladder Genitalia

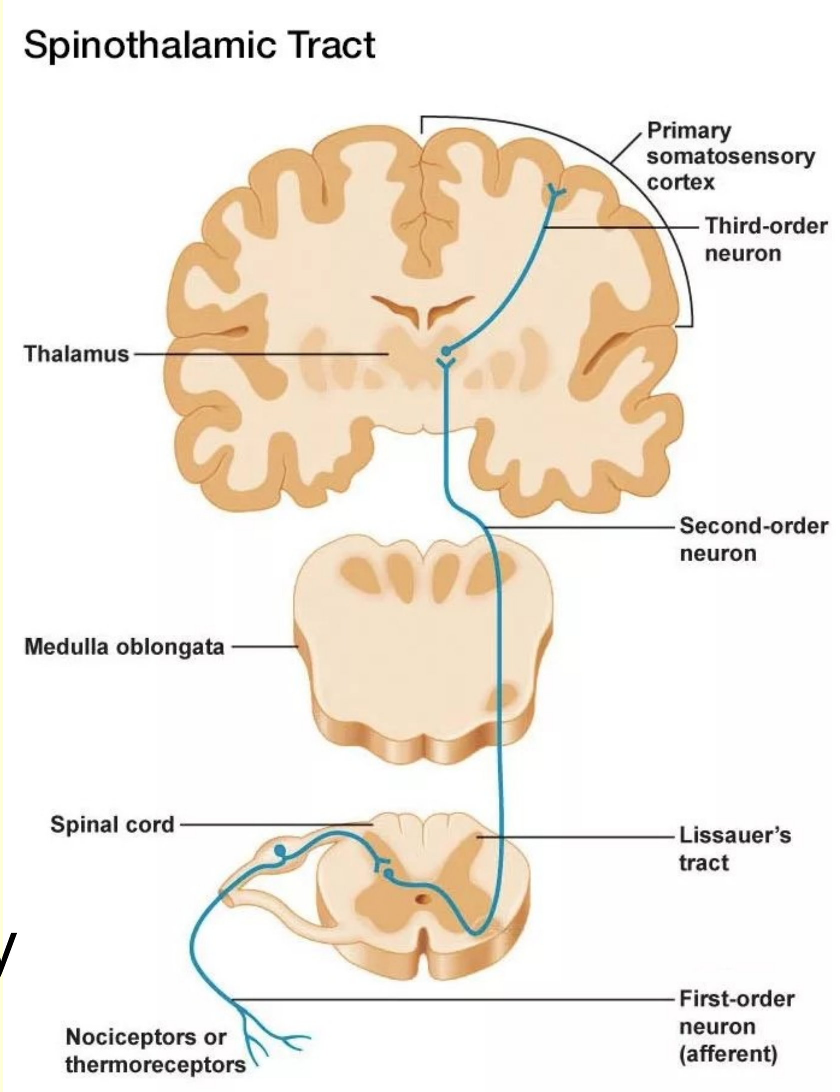


Cerebral hemisphere
Eye
Edinger Westphal nucleus
III
Ciliary ganglion
Sup. salivary nucleus
VII
Lacrimal gland
Inf. salivary nucleus
IX
Sphenopalatine ganglion
Motor nucleus of vagus
X
Submandibular ganglion
Submandibular and sublingual salivary glands
Otic ganglia
Parotid gland
Heart
Lungs
Spinal cord
Stomach
Small intestine
Colon
S_2
S_3
S_4
Pelvic splanchnic nerve
Uterus
Urinary bladder

SYMPATHETIC AFFERENTS

- Nerve cell soma of the **afferent fibers from viscera** are situated in the corresponding dorsal root ganglion. These fibers:

1) may form afferent limb of an autonomic reflex arc;
2) may be the first order neuron carrying visceral sensations (for pain sensation later order neuron travel up with the spinothalamic tract to end in the thalamus, and further relay occurs to the sensory cortex).



PARASYMPATHETIC AFFERENTS

The central processes from the ganglia (afferents from the periphery are carried via the 7th, 9th and 10th cranial nerves) end in the nucleus of tractus solitarius (NTS).

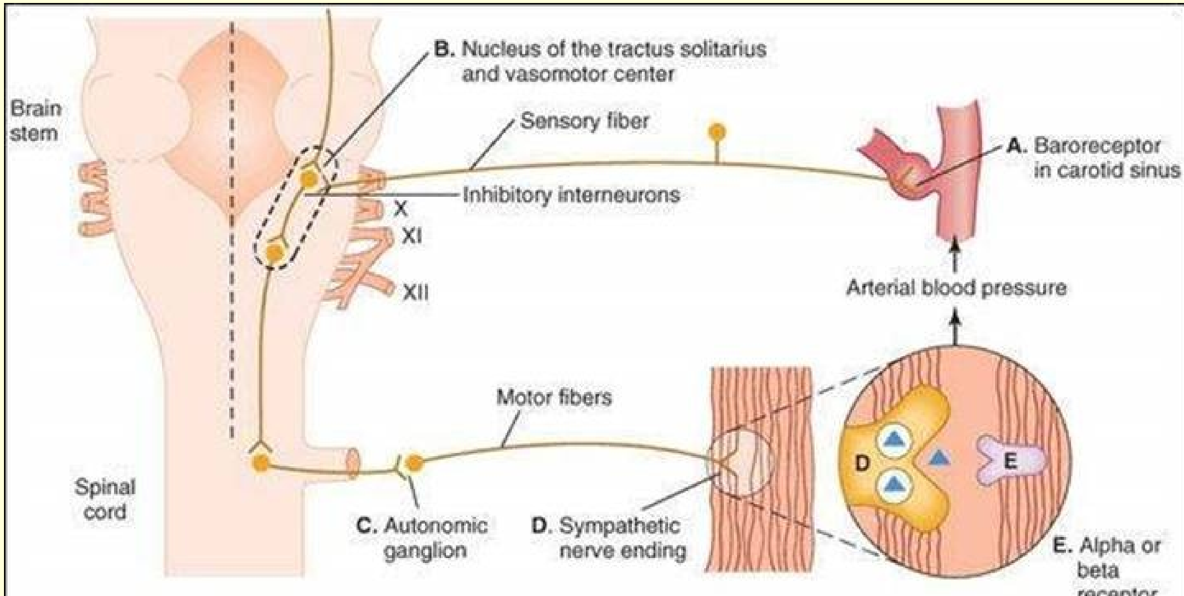
The NTS is a center where ANS is integrated.

The NTS receives inputs from:

1) carotid sinus (baroreceptors) and carotid body (chemoreceptors);

2) baroreceptors from pulmonary circulation;

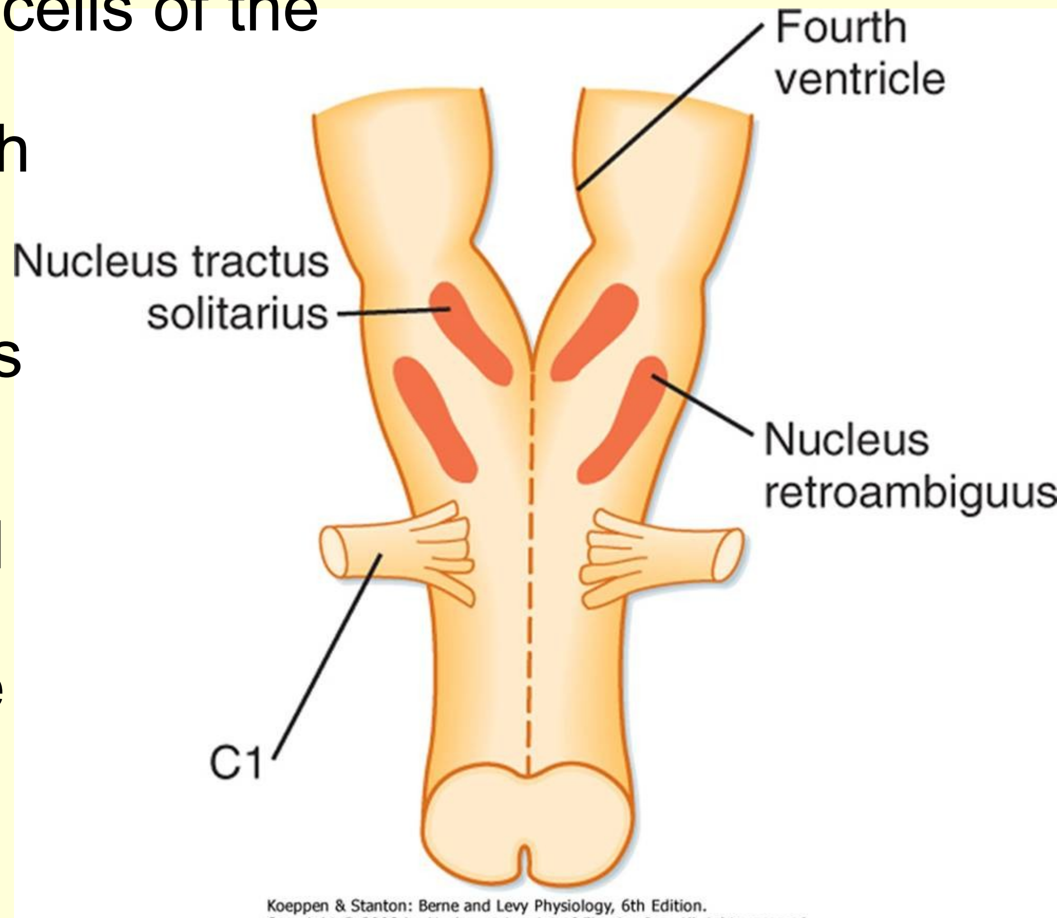
3) olfactory and taste sensations.



PARASYMPATHETIC AFFERENTS

The NTS sends fibers to:

1) higher brain centers which, in turn control the lateral horn cells of the sympathetic system;
2) to hypothalamus (which can control the endocrines);
3) to dorsal motor nucleus of the vagus (which controls the heart/ bronchi/gastrointestinal tract);
4) to selected parts of the limbic system (which control the emotion).



Koeppen & Stanton: Berne and Levy Physiology, 6th Edition.

EFFECTS OF SYMPATHETIC STIMULATION

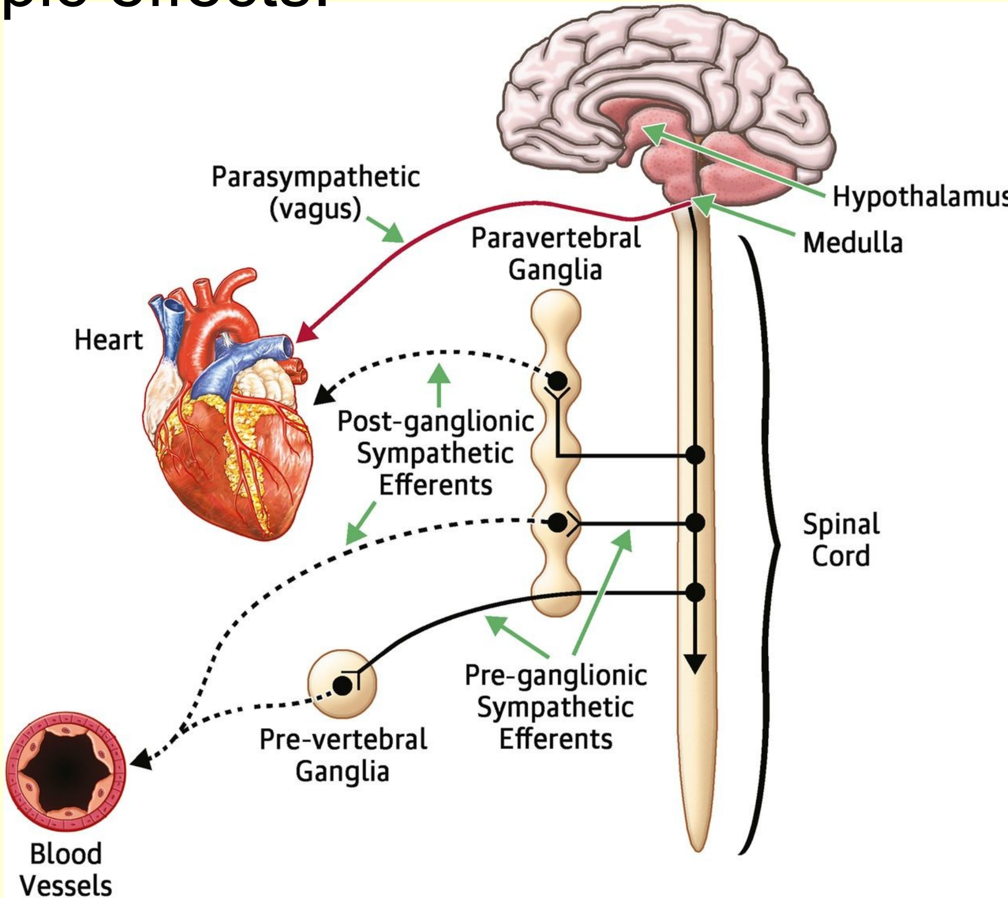
CARDIOVASCULAR SYSTEM

Heart (excitation) – positive chronotropic, dromotropic, inotropic and bathmotropic effects:

a) rate of the heart increase;

b) contractility of the heart increase (cardiac output rises);

c) coronary flow increases.



EFFECTS OF SYMPATHETIC STIMULATION

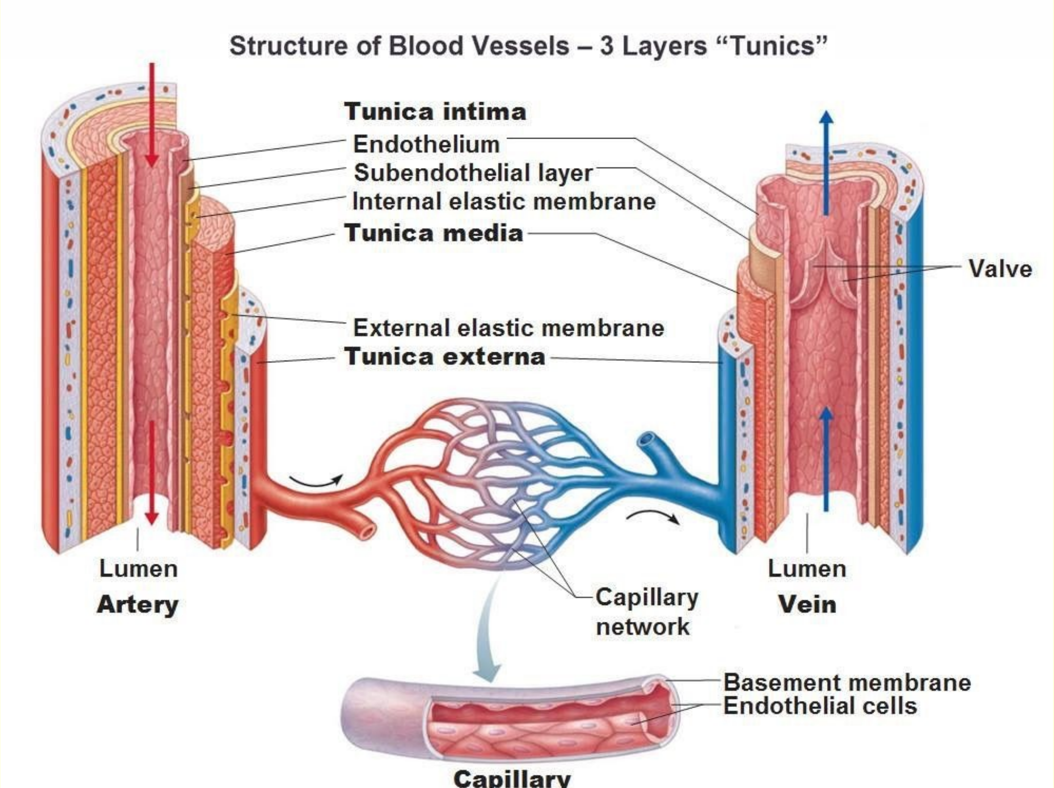
Blood vessels – target tissue is smooth muscles of the vessels.

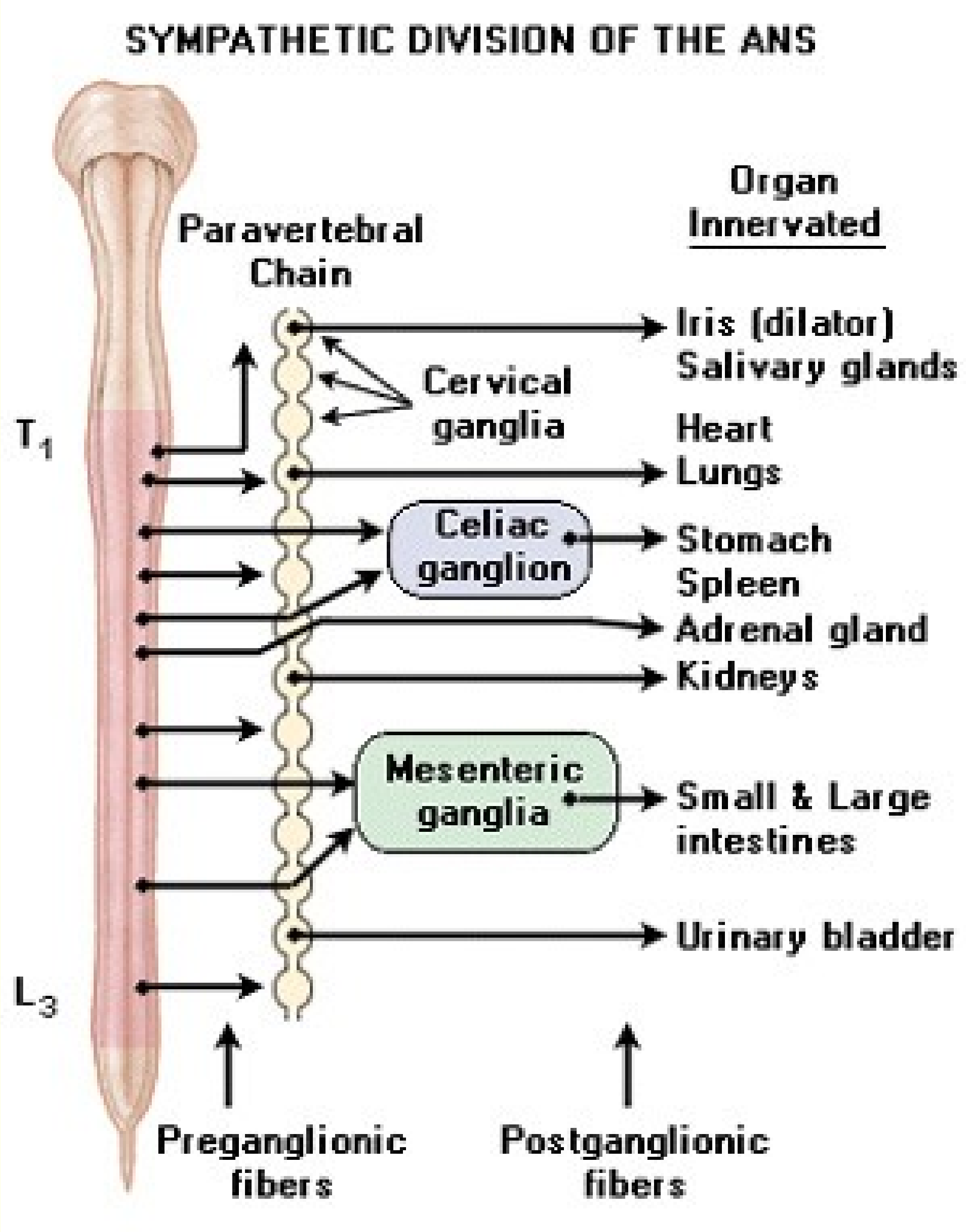
a) sharp vasoconstriction of cutaneous and splanchnic arterioles;

b) vasodilatation of coronary and skeletal arterioles;

c) vienoconstriction.

Blood pressure rises – systolic, diastolic and the mean blood pressures.




SYMPATHETIC DIVISION OF THE ANS
Organ Innervated
Paravertebral Chain
T1
L3
Iris (dilator)
Salivary glands
Cervical ganglia
Heart
Lungs
Celiac ganglion
Stomach
Spleen
Adrenal gland
Kidneys
Mesenteric ganglia
Small & Large intestines
Urinary bladder
Preganglionic fibers
Postganglionic fibers

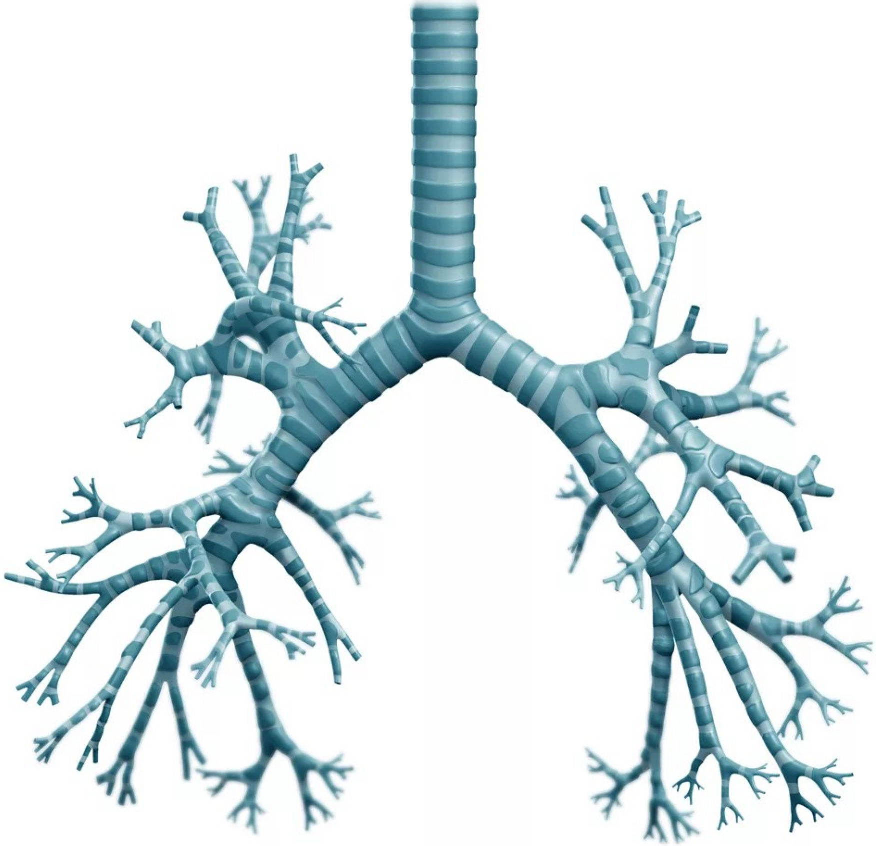
EFFECTS OF SYMPATHETIC STIMULATION

RESPIRATORY SYSTEM

Sympathetic stimulation leads to:

a) bronchodilatation (due to relaxation of the bronchial muscles);

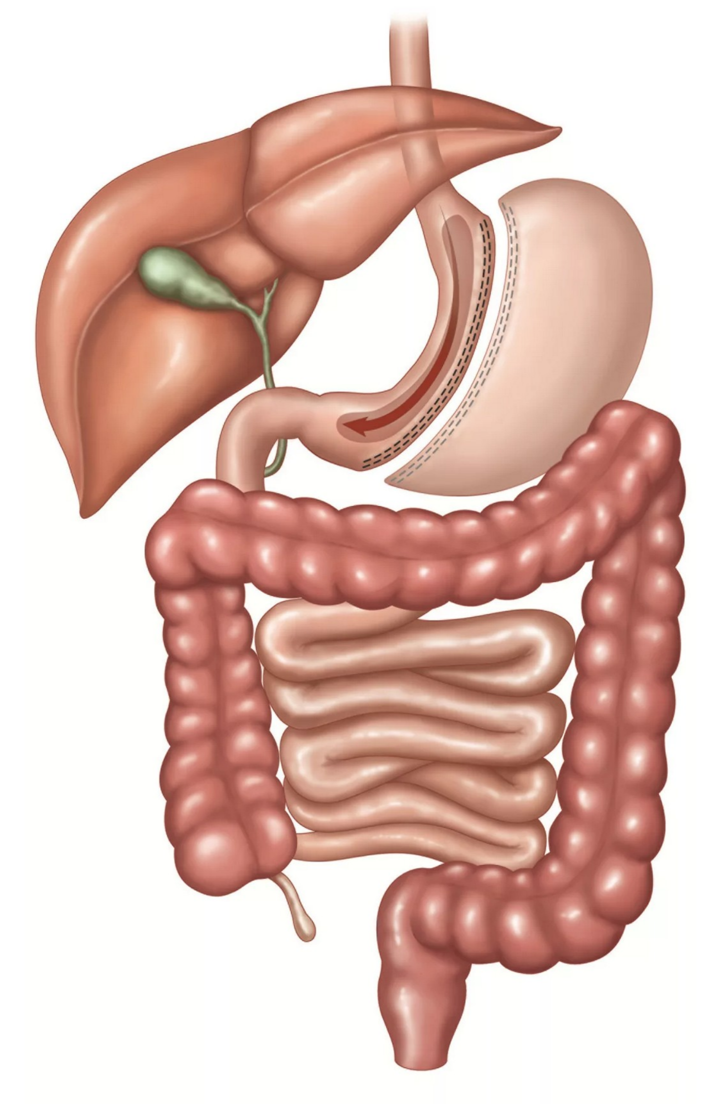
b) tachypnea (rise in the rate of ventilation volume).



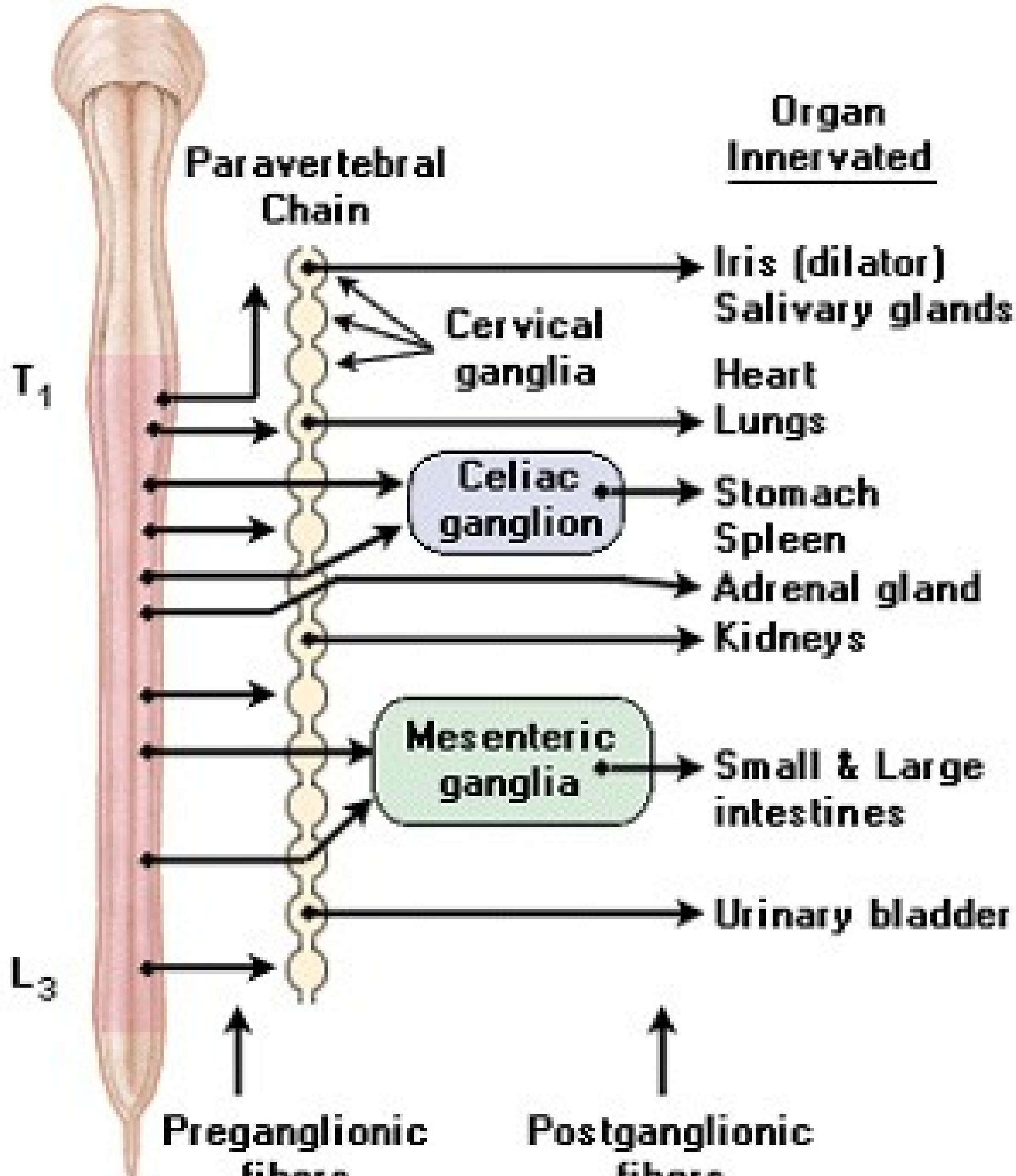
EFFECTS OF SYMPATHETIC STIMULATION

DIGESTIVE SYSTEM

- Stimulation of the sphincters (leading to their spasm) and relaxation of the general muscles of the gut (leading to inhibition of peristalsis) result.
- There is therefore, inhibition of peristalsis and holding up of the content of the gut.



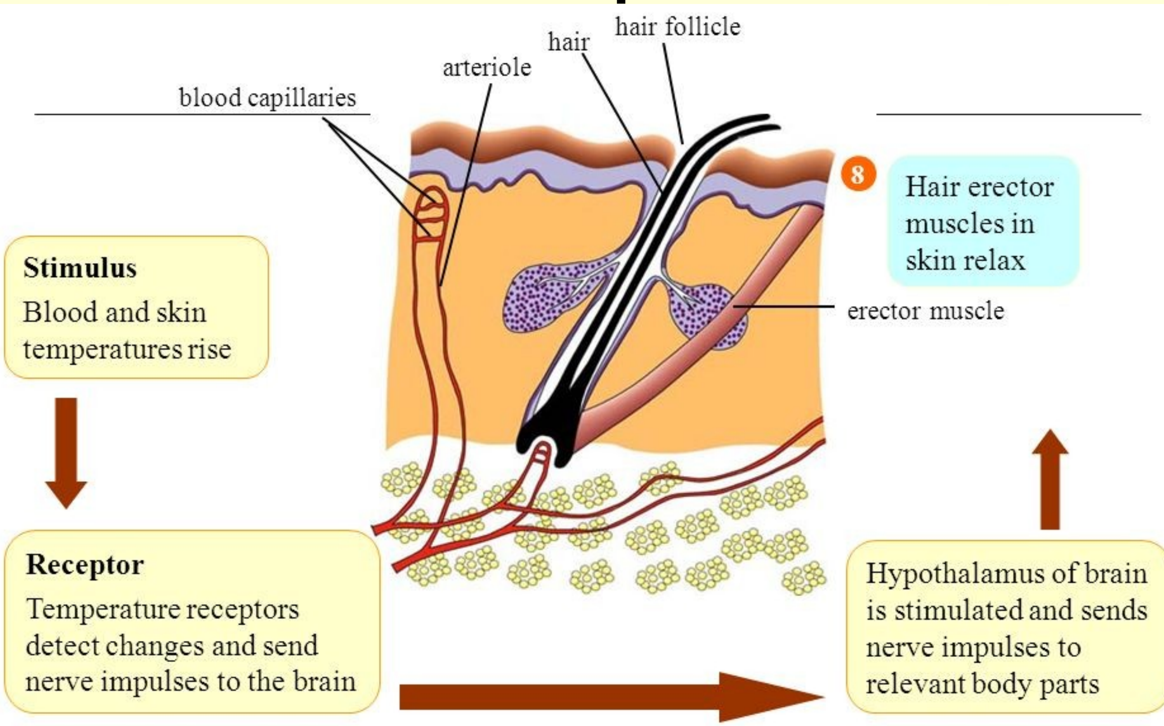
SYMPATHETIC DIVISION OF THE ANS



EFFECTS OF SYMPATHETIC STIMULATION

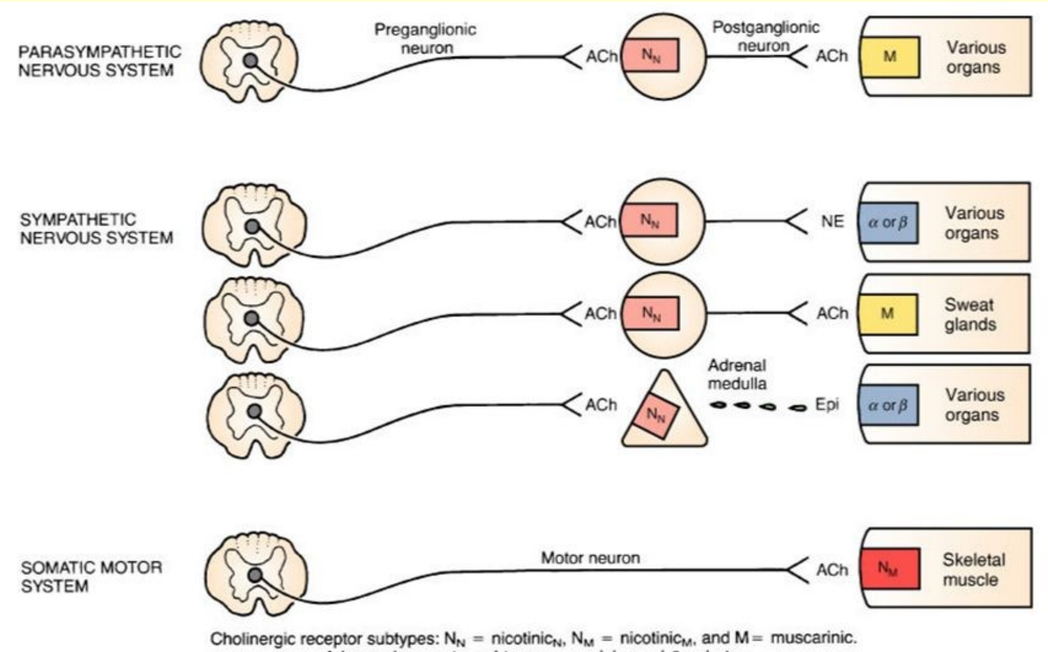
SKIN, BODY TEMPERATURE

- Cutaneous **vasoconstriction** (leading to pallor), and **piloerection** result (due to the contraction of arrectorus pilorum muscles situated at the base of hair follicle).
- Together, cause **elevation of the core temperature of the body**, and thus is useful during exposure to cold. Sympathetic stimulation can, also, lead to sweating (sympathetic nerve endings of the sweat glands are **cholinergic**).



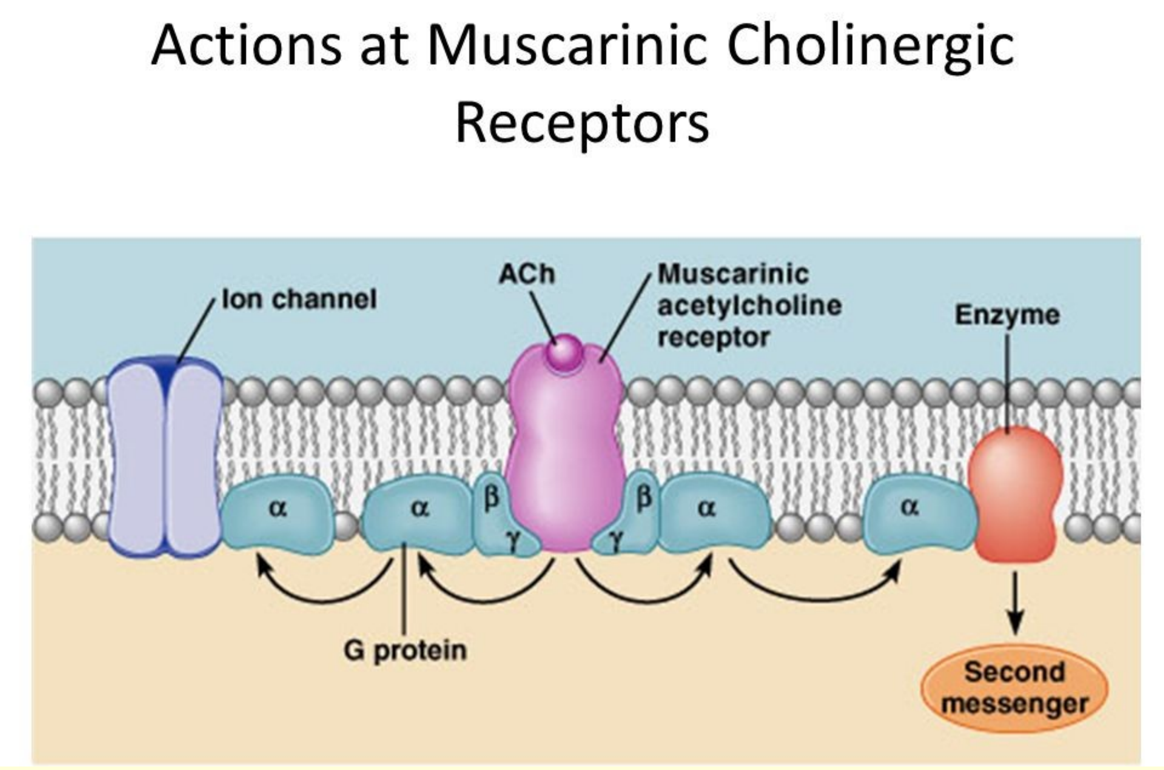
ANS receptors – ANS neurotransmitters

- The ANS uses neurotransmitters and neuromodulators, as well as a hormone, that act at ionotropic and metabotropic receptors.
- The body needs to which the ANS must respond are relatively long-lasting, so the action of postganglionic neurons is mediated by long-lasting metabotropic mechanisms initiated by neurotransmitter binding to G protein-linked receptors.



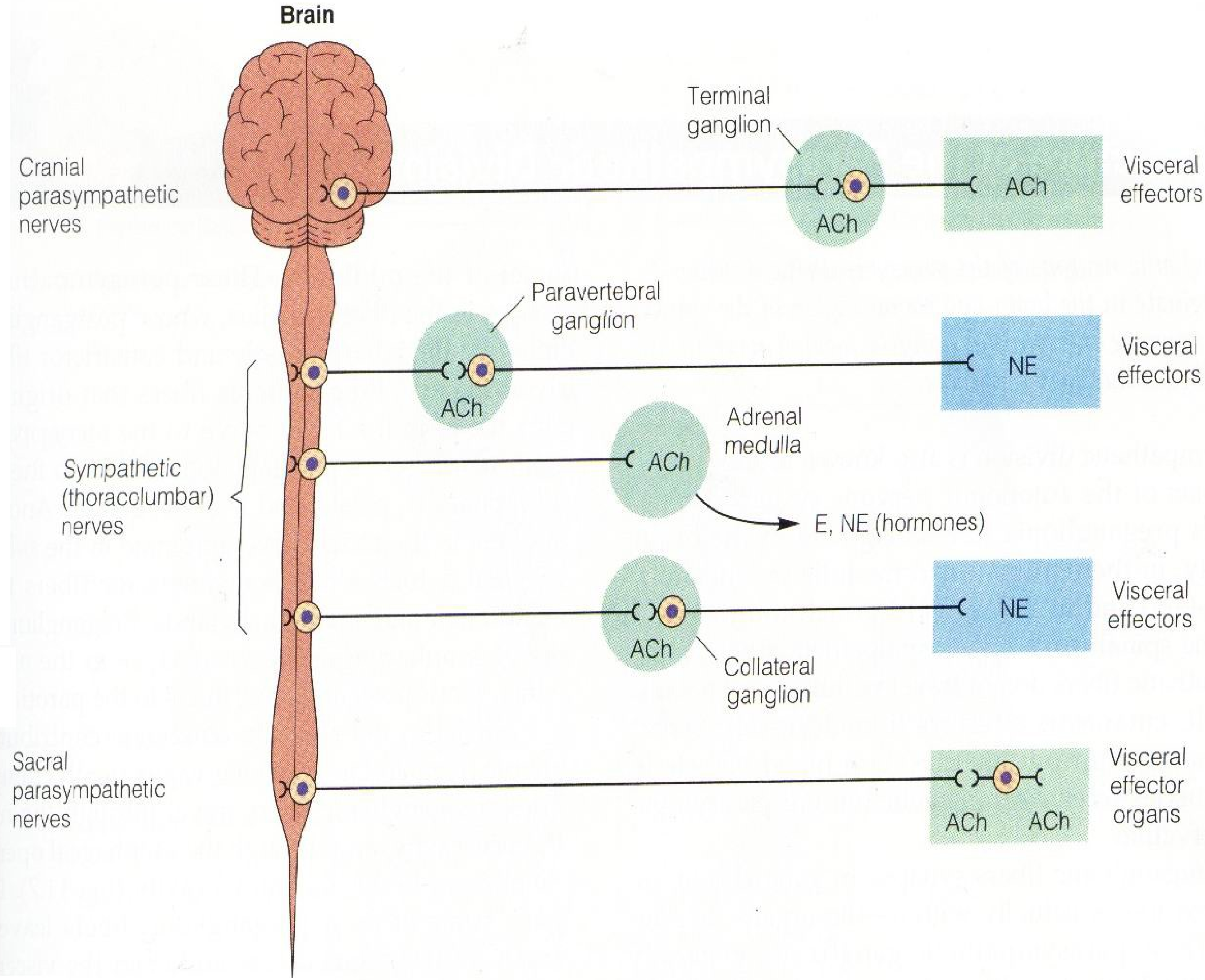
ANS receptors –
ANS neurotransmitters

- Neuroactive peptides that act as neuromodulators are very common in the neurons of the ANS. Their long, slow synaptic actions are very important to the function of the ANS. Fast, ionotropic synaptic action is limited to cholinergic transmission between pre- and postganglionic neurons.



Receptors, Signaling Mechanisms, & Neurotransmitters Important For ANS Function

M_1 M_2 M_3 M_4	Metabotropic	⇧ IP_3, DAG ⇩ cAMP; ⇧ g_K ⇧ IP_3,DAG ⇩ cAMP	Acetycholine
N_N (Neural)	Ionotropic	⇧ $g_{Na,K}$	
α_1 α_2 β_1 β_2	Metabotropic	⇧ IP_3,DAG (E > NE) ⇩ cAMP; ⇧ g_K & ⇩ g_{Ca} (E > NE) ⇧ cAMP (E = NE) ⇧ cAMP (E >> NE)	Epinephrine (E) & Norepinephrine (NE)
D_1 D_2	Metabotropic	⇧ cAMP ⇩ cAMP; ⇧ g_K & ⇩ g_{Ca}	Dopamine

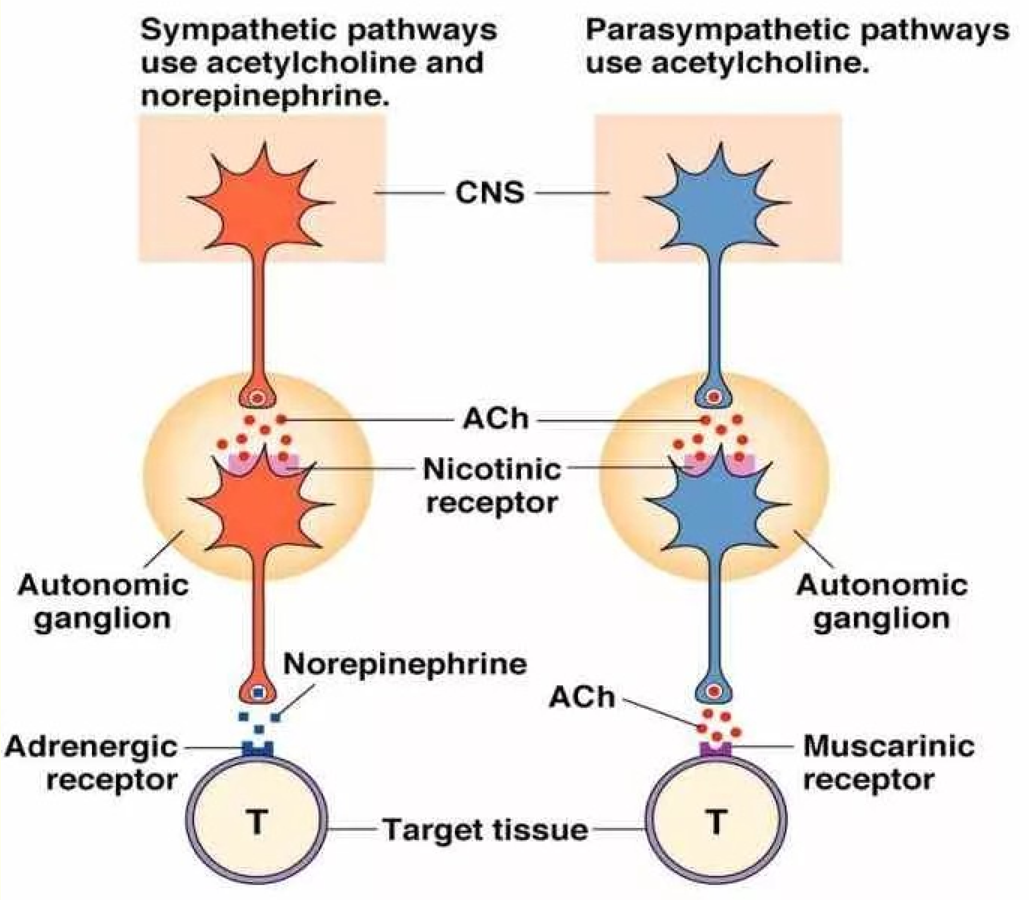


Brain
Terminal ganglion
Cranial parasympathetic nerves
ACh
ACh
Visceral effectors
Paravertebral ganglion
ACh
NE
Visceral effectors
Adrenal medulla
ACh
Sympathetic (thoracolumbar) nerves
E, NE (hormones)
ACh
NE
Visceral effectors
Collateral ganglion
Sacral parasympathetic nerves
ACh
ACh
Visceral effector organs

CHEMICAL TRANSMISSION IN ANS

ACETYLCHOLINE is liberated at:

1) the postganglionic parasympathetic nerve endings;
2) the ANS ganglia (both sympathetic and parasympathetic);
3) the postganglionic sympathetic nerve endings supplying the sweat glands and some arterioles of skeletal muscles (cholinergic sympathetic nerves);
4) the preganglionic sympathetic nerves terminating on adrenal medullary cells.



Parasympathetic Actions Mediated By Acetylcholine

Organ/Cells	Response
EYE	
Sphincter muscle, Iris	Contraction (Miosis)
Ciliary muscle	Contraction (Near Vision)
HEART	
SA node	Decreased rate
AV node	Decreased conduction velocity
LUNG	
Bronchial muscle	Contraction
Bronchial glands	Secretion
URINARY BLADDER	
Detrusor	Contraction
Trigone & sphincter	Relaxation

Organ/Cells	Response
BLOOD VESSELS	
Arteries	Dilation (by EDRF [NO])
Veins	Dilation (by EDRF [NO])
GASTROINTESTINAL TRACT	
Motility	Increase
Sphincters	Relaxation
Secretion	Stimulation
GLANDS	
Sweat, salivary, lacrimal	Secretion
REPRODUCTIVE SYSTEM	
Penus, clitoris	Erection

Sympathetic Actions Mediated by Adrenoceptors

Organ/Cells	Response	Organ/Cells	Response
EYE		BLOOD VESSELS	
Sphincter muscle, Iris	Dilation (Mydriasis)	Arterioles	Constriction, except coronary and skeletal muscle where dialation occurs
Ciliary muscle	Relaxation (Far Vision)		
HEART			
SA node	Increased rate	Veins	Constriction
AV node	Increased conduction	GASTROINTESTINAL TRACT	
Ventricles	Increased contractility	Motility	Decrease
LUNG		Sphincters	Contraction
Bronchial muscle	Relaxation	Secretion	Uncertain
URINARY BLADDER		SKIN	
Trigone & sphincter	Contraction	Pilomotor muscles	Contraction
REPRODUCTION SYSTEM		Sweat glands	Localized secretion
Male sex organ	Ejaculation	KIDNEY	Renin secretion

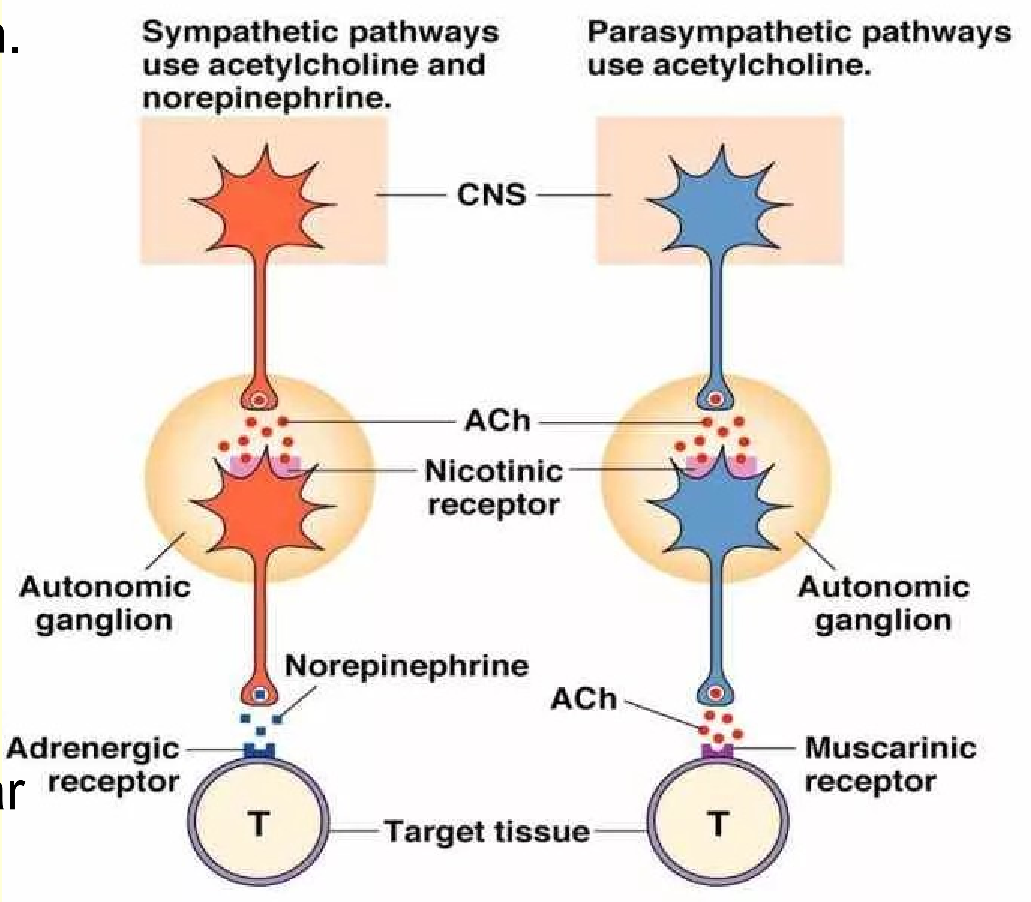
CHEMICAL TRANSMISSION IN ANS

NORADRENALIN (NOREPINEPHRINE) – acts as a transmitter at:

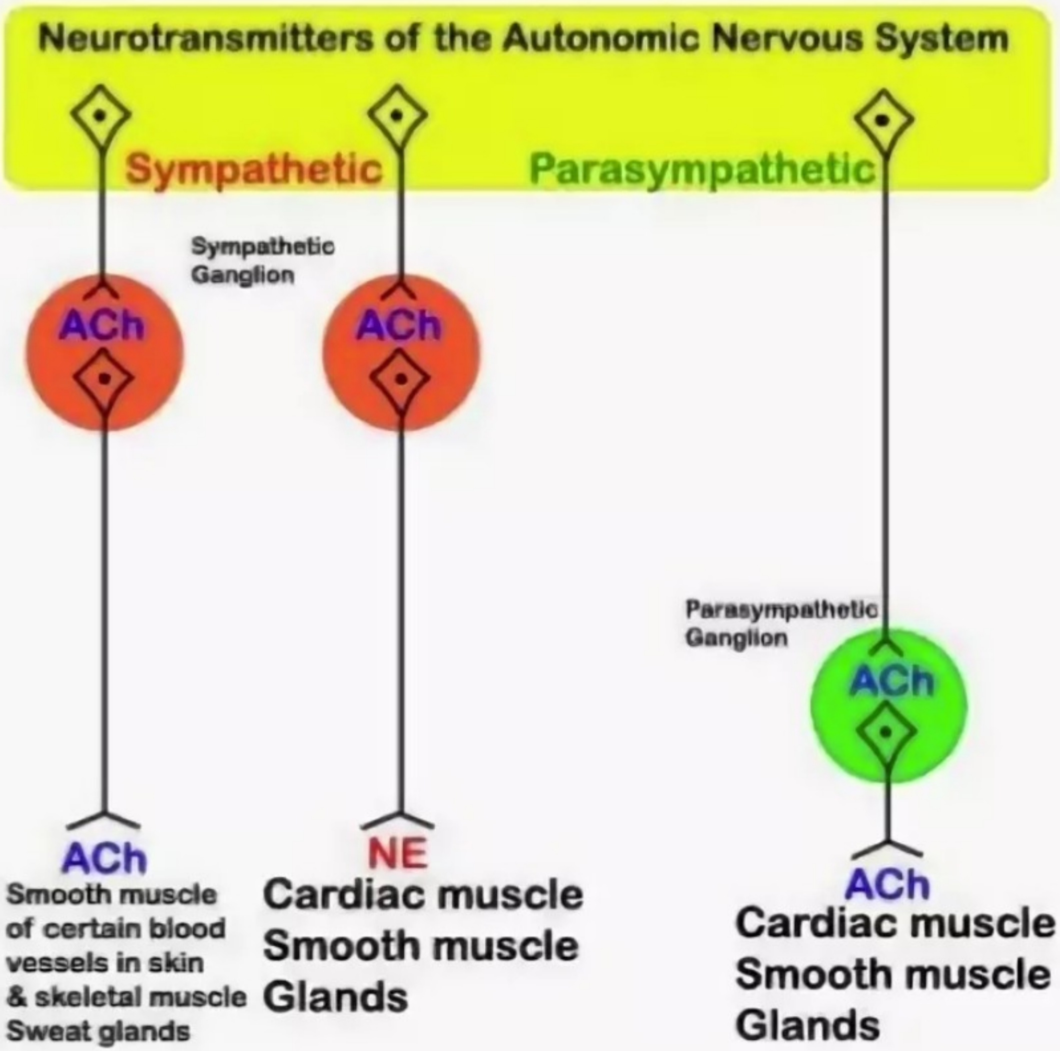
1) postganglionic sympathetic nerve terminals;
2) some regions within the brain.

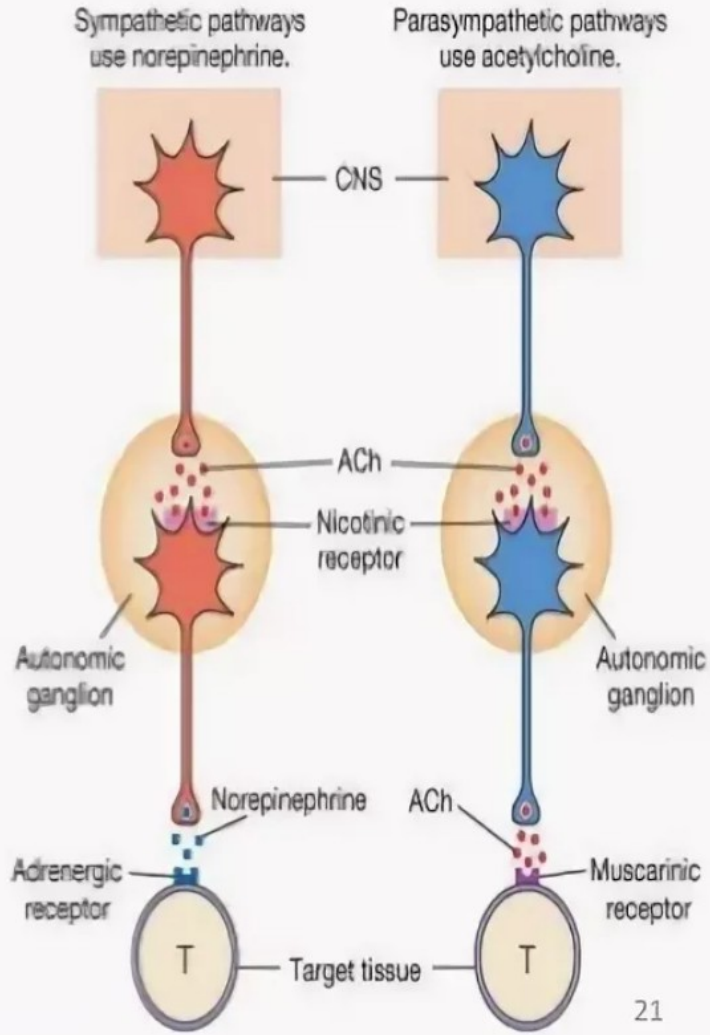
NORADRENALIN RECEPTORS – are basically two types (in sympathetic system):

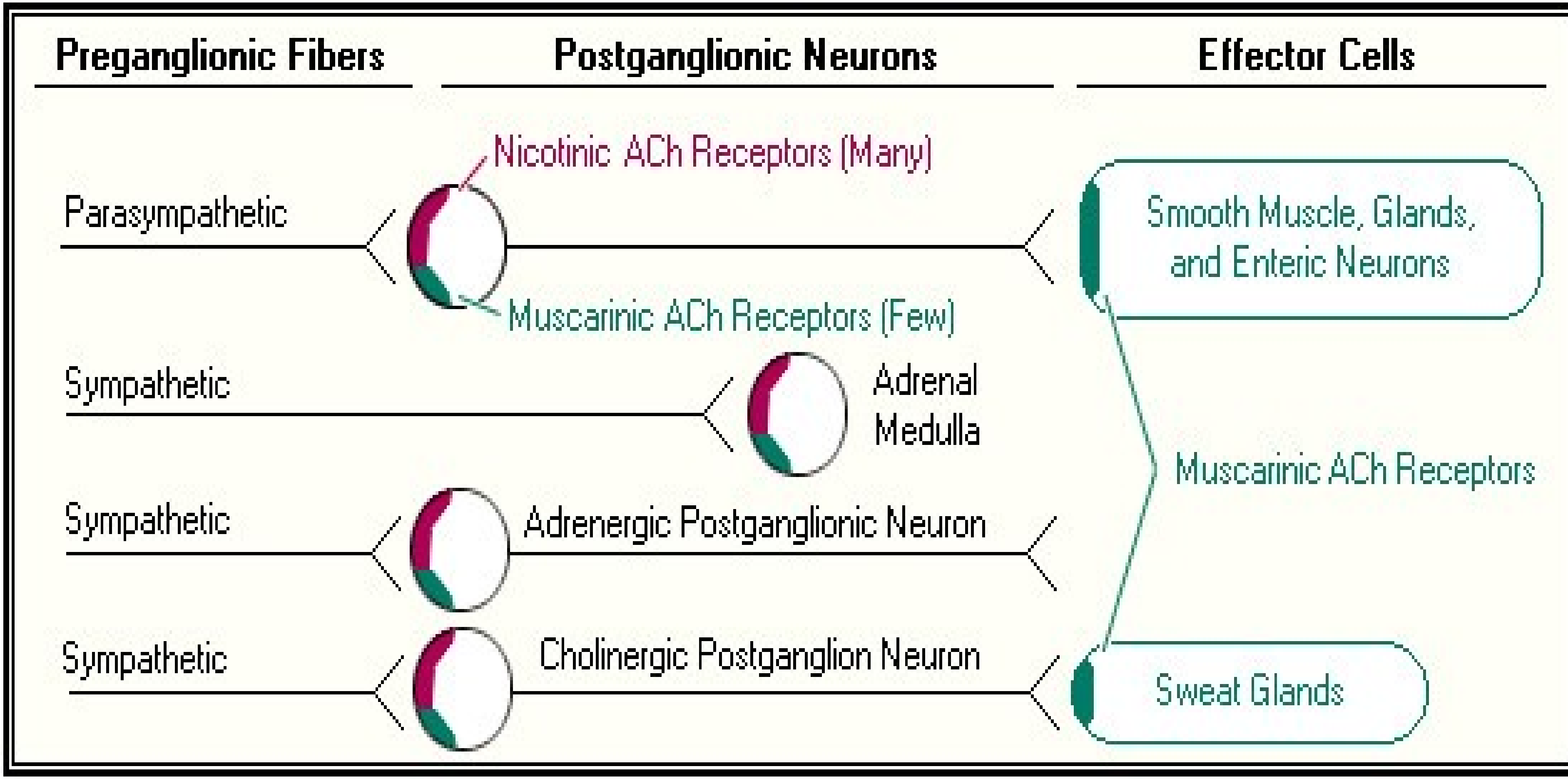
1) alfa-receptors occur both at the vascular smooth muscles in general and cardiac muscles as well as in some selective nerve terminals;
2) beta-receptors occur in the cell membrane of vascular smooth muscles (of skeletal muscles) and cardiac muscle.



Neurotransmitter in sympathetic and parasympathetic nervous system

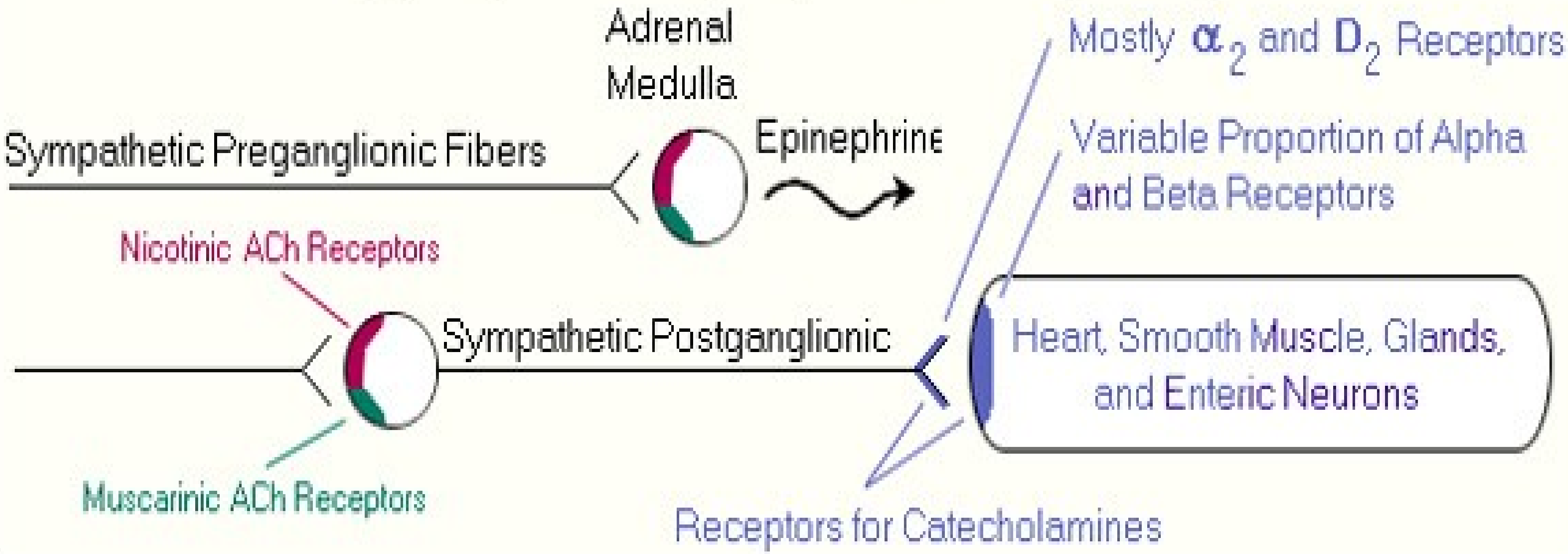






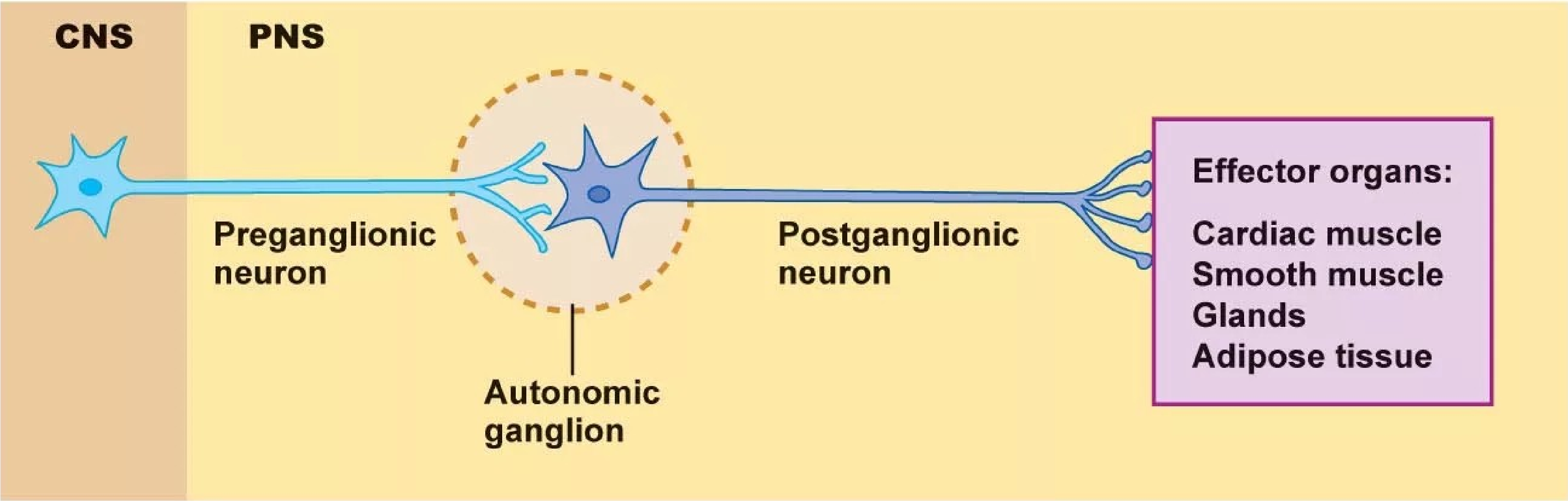
Preganglionic Fibers
Postganglionic Neurons
Effector Cells
Nicotinic ACh Receptors (Many)
Parasympathetic
Smooth Muscle, Glands,
and Enteric Neurons
Muscarinic ACh Receptors (Few)
Sympathetic
Adrenal
Medulla
Muscarinic ACh Receptors
Sympathetic
Adrenergic Postganglionic Neuron
Sympathetic
Cholinergic Postganglion Neuron
Sweat Glands

LOCATION OF RECEPTORS FOR CATECHOLAMINES
(Epinephrine, Norepinephrine, and Dopamine)



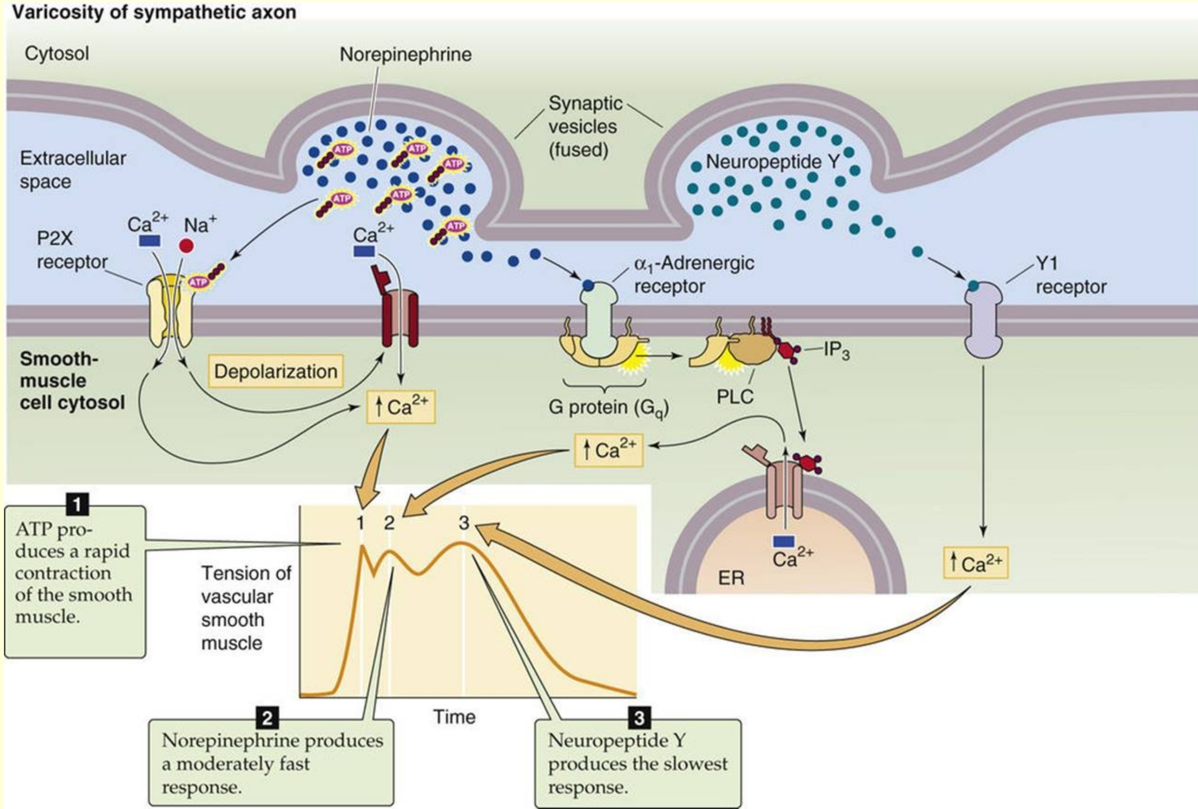
Neuromodulators in the ANS

- Neuroactive peptides are found in preganglionic and postganglionic neurons of the ANS, including the chromaffin cells of the adrenal medulla, as well as in the enteric neurons of the gut.
- Receptors for neuropeptides are present on effector cells, neuronal cell bodies, dendrites, and presynaptic terminals.



Neuromodulators in the ANS

- In many cases, neuropeptides act as neuromodulators, providing for, via G protein-mediated pathways, a long-lasting increase (or decrease) in the response of the cell to one or another of the primary neurotransmitters that act on it.

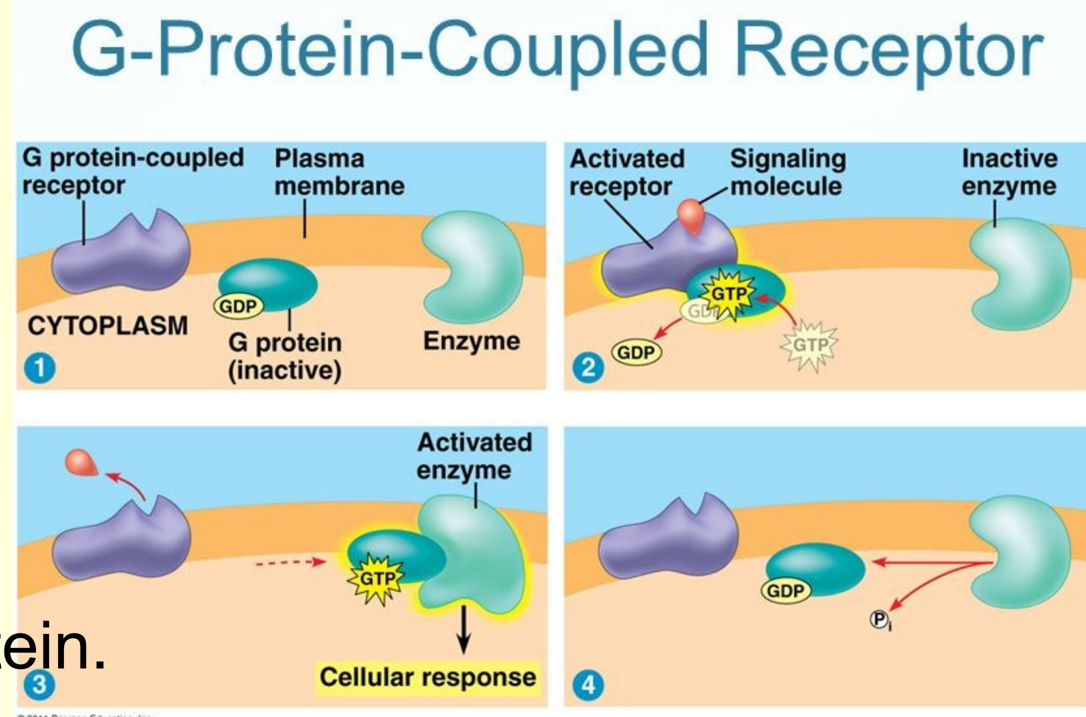


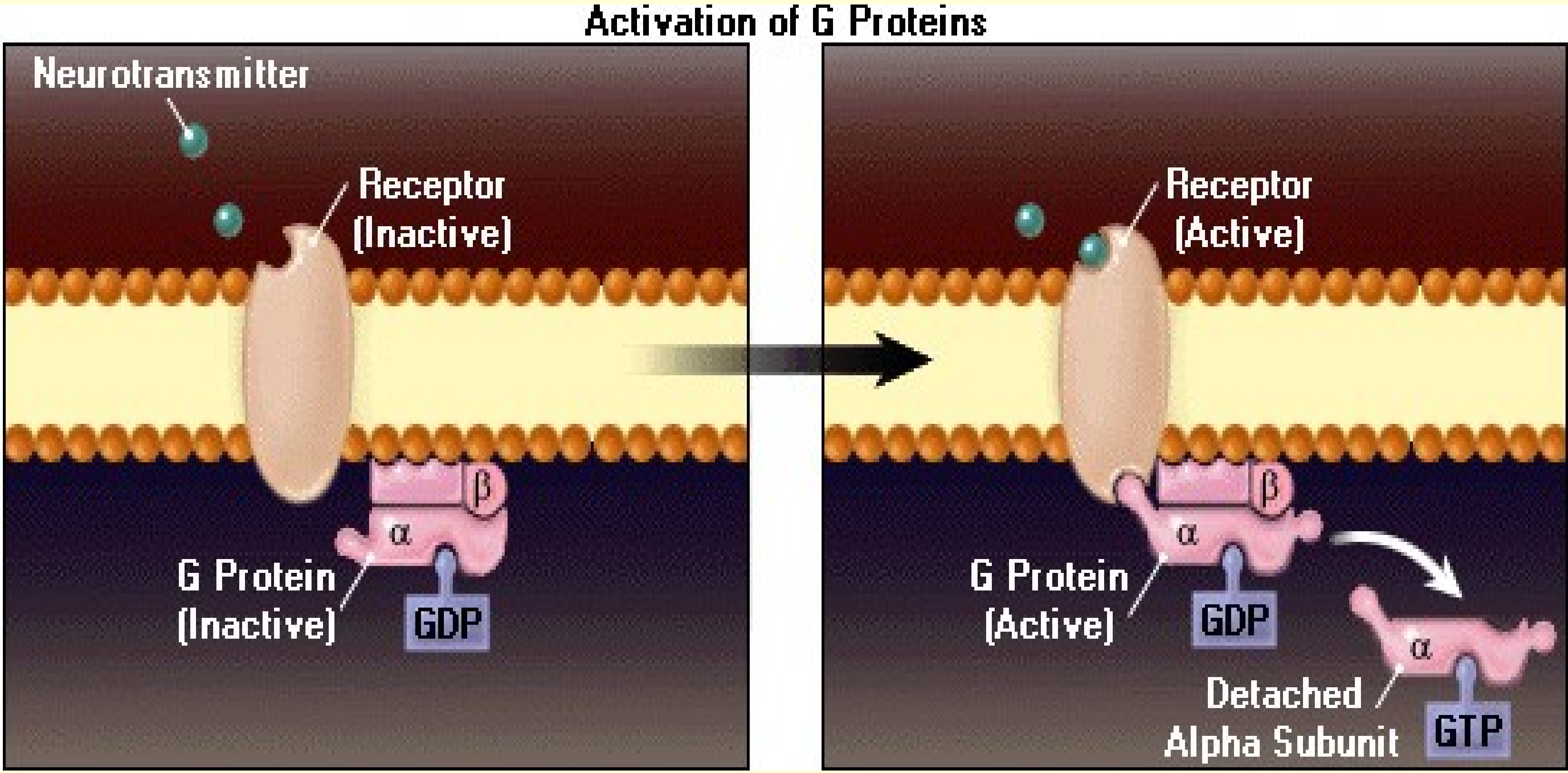
Peptides in the ANS and Its Effector Tissues	Location
Angiotensin II	D
Bombesin (Gastrin releasing peptide)	C D
Calcitonin gene-related peptide	B D
Cholecystokinin (CCK)	D
Dynorphin	C
Enkephalin	A D E
Galanin	D
Luteinizig hormone releasing hormone (LHRH)	A
Neuropeptide Y	B
Neurotensin	A
Oxytocin	D
Somatostatin	A D
Substance P	A B C
Vasoactive Intestinal Polypeptide (VIP)	B C D E

A = Preganglionic neurons
B = Postganglionic neurons
C = Enteric neurons
D = Viseral afferent fibers
E = Adrenal medulla

Cell Signaling by G Protein Activation

- G proteins are a class of proteins that control the formation of intracellular second messengers by regulating the activity of enzymes in the plasma membrane.
- When the neurotransmitter (or hormone) binds to its G protein-linked receptor, a conformation change in the receptor protein activates of the G protein.

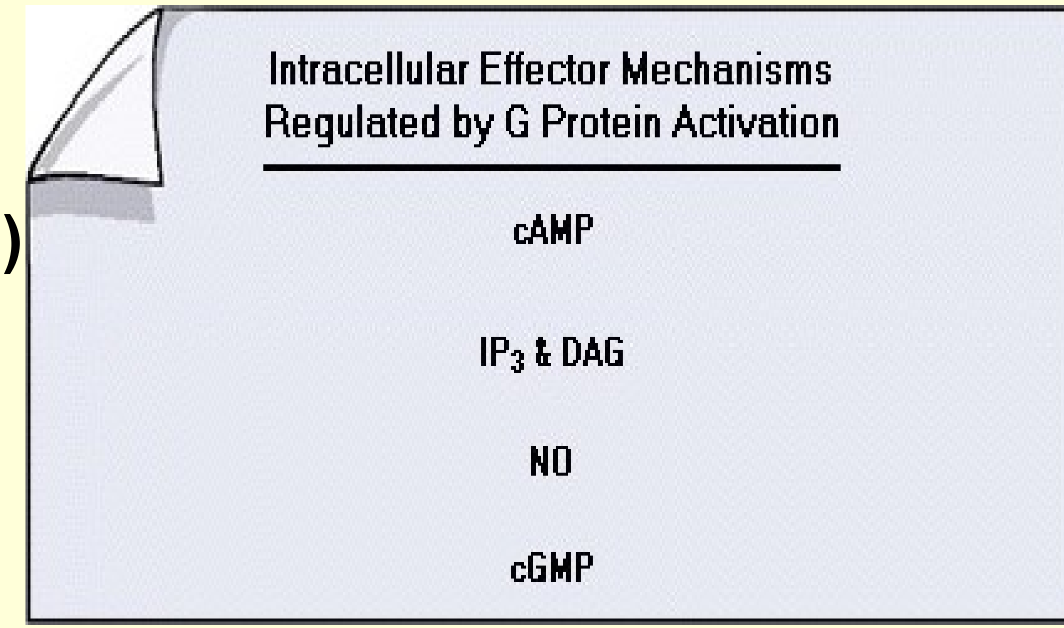



Activation of G Proteins
Neurotransmitter
Receptor
(Inactive)
G Protein
(Inactive)
β
α
GDP
Receptor
(Active)
G Protein
(Active)
β
α
GDP
α
Detached
Alpha Subunit
GTP

Cell Signaling by G Protein Activation

This can produce several effects, including:

- increase or decrease in cyclic adenosine monophosphate (cAMP)
- increase in inositol trisphosphate (IP3) and diacylglycerol (DAG),
- direct effects on ion channels, and production of nitric oxide (NO).



FACTORS REGULATING THE NUMBER OF RECEPTORS

FACTOR	TISSUE RESPONSE
Presence of agonist or endogenous ligand	⇩ Receptors & sensitivity
Presence of antagonist	⇧ Receptors & sensitivity
Denervation	⇧ Receptors & sensitivity
Aging	⇩ Receptors & sensitivity
Hormones	⇧ or ⇩ Receptors & sensitivity
Innervation (During development)	⇧ Receptors & sensitivity

HIGHER CONTROL OF SYMPATHETIC

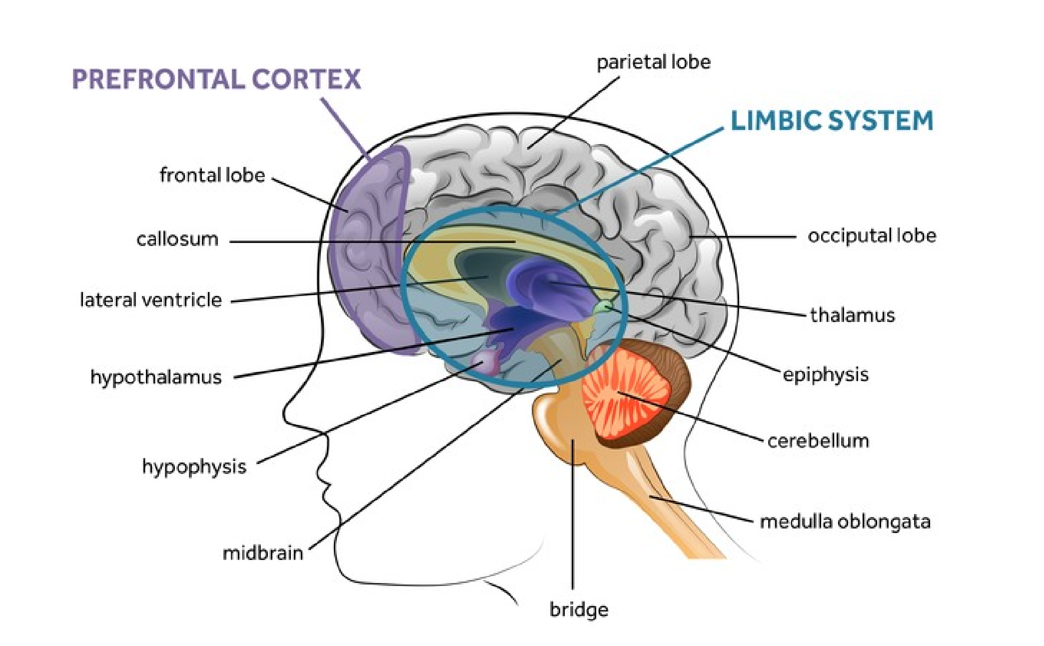
- The lateral horn cells of the spinal cord of the thoracolumbar regions are the "spinal centers" of sympathetic. These spinal centers are controlled by "higher centers".
- An immediate higher center is "vasomotor center" at medulla. The "vasomotor center", in turn is controlled and influenced by:

  a) still higher centers like hypothalamus, limbic system, cerebral cortex (prefrontal lobe) and pontine nucleus;

  b) reflexes like sinuaortic reflex;

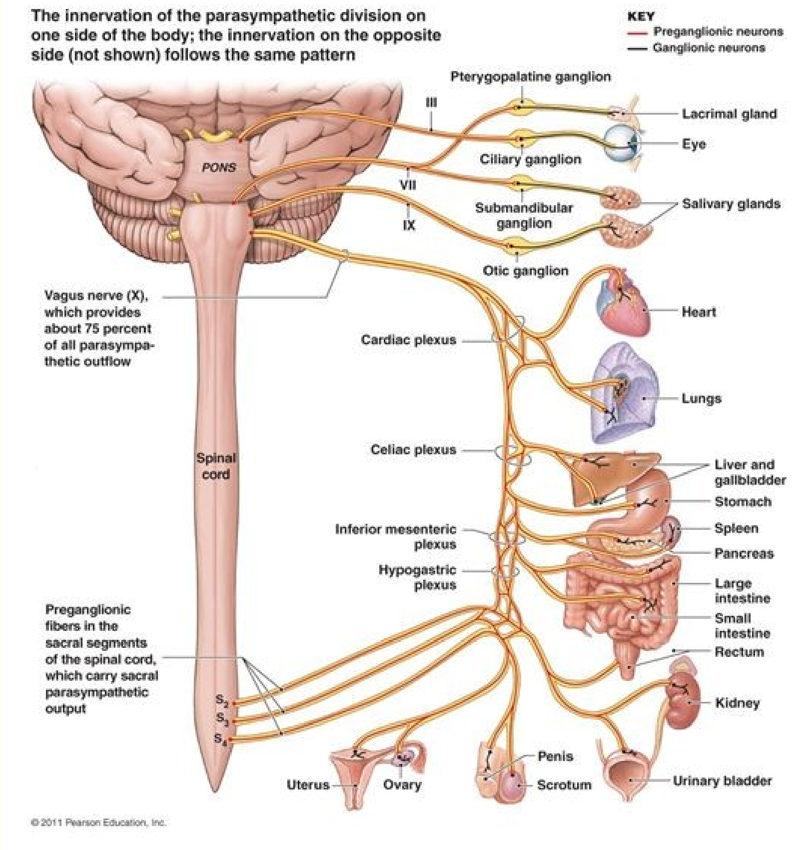
  c) blood oxygen tension and pH;

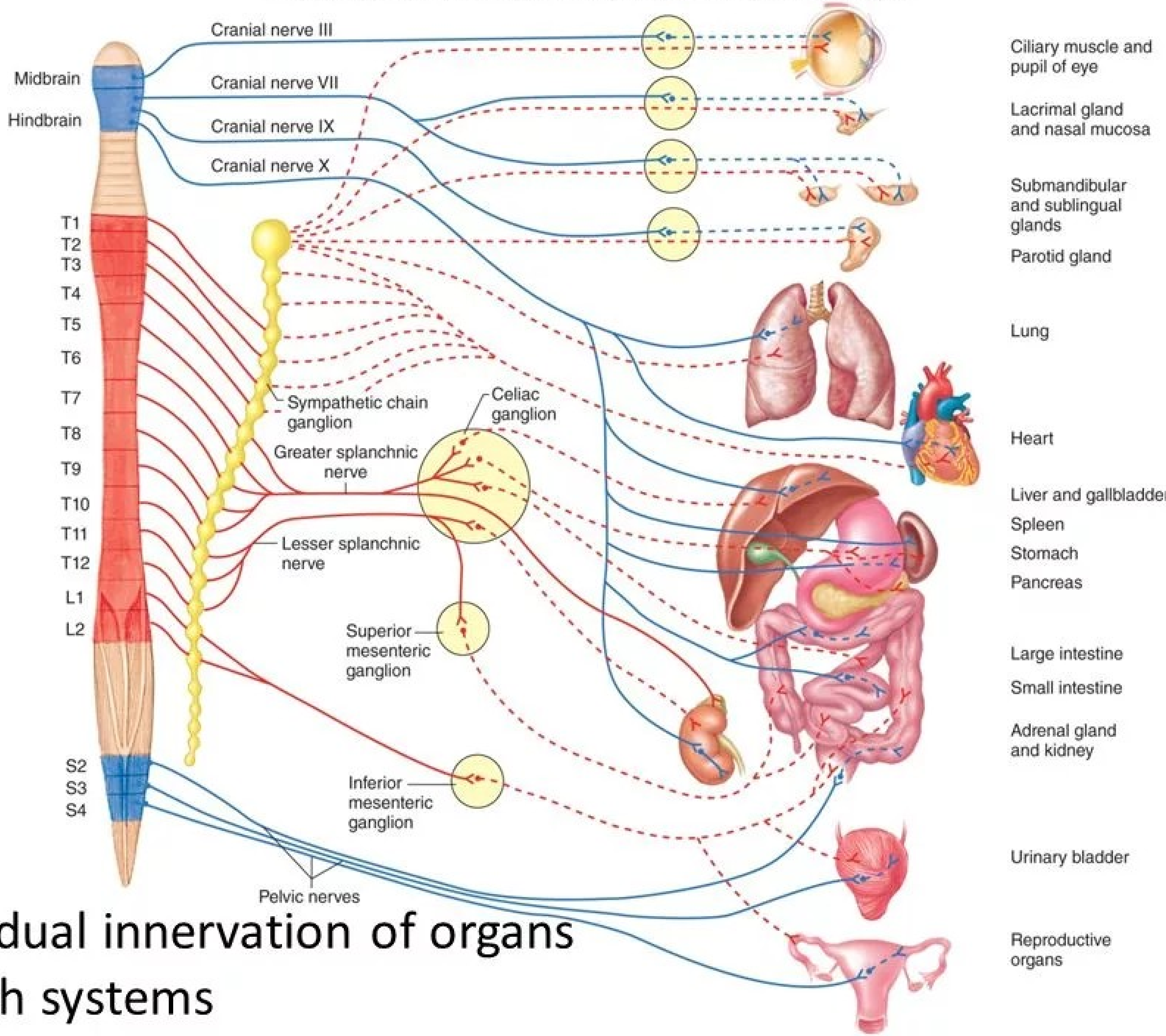
  d) drugs.



HIGHER CONTROL OF PARASYMPATHETIC

- Anterior region of hypothalamus is a higher center of parasympathetic activity.
- The dorsal nucleus of vagus is influenced by various reflexes like baroreceptor reflex.
- The superior (7th), inferior (9th) salivary nuclei and Edinger-Westphal nuclei (3rd) are influenced by various reflexes.





<u>Note</u>: dual innervation of organs by both systems

TYPICAL SIGNS OF ANS DYSFUNCTION

Postural (orthostatic) Hypotension

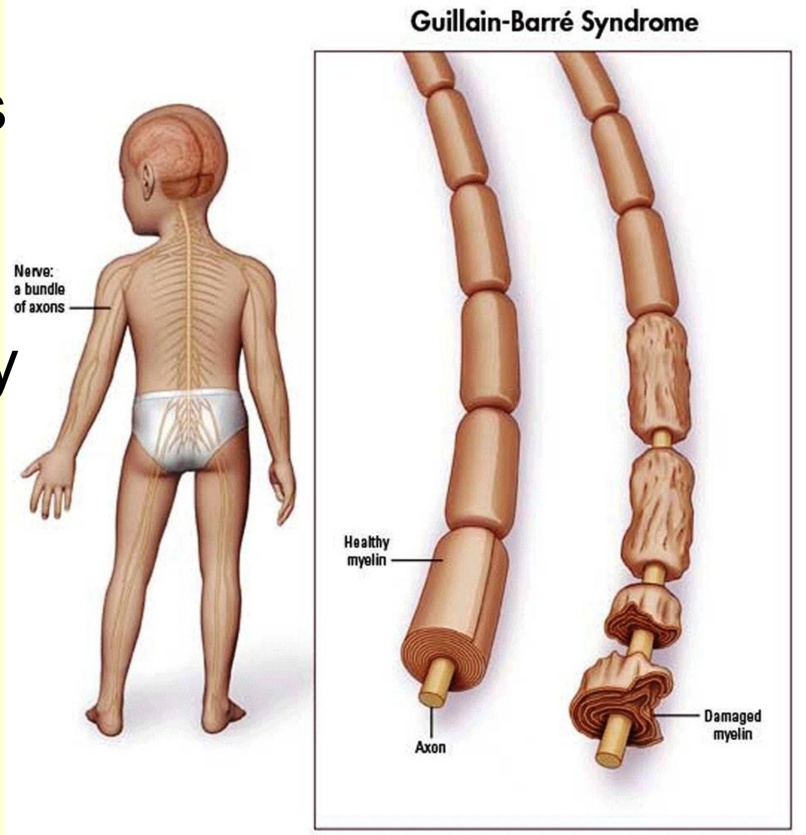
Sexual Impotence

Disturbances of Micturition

Defective Sweating

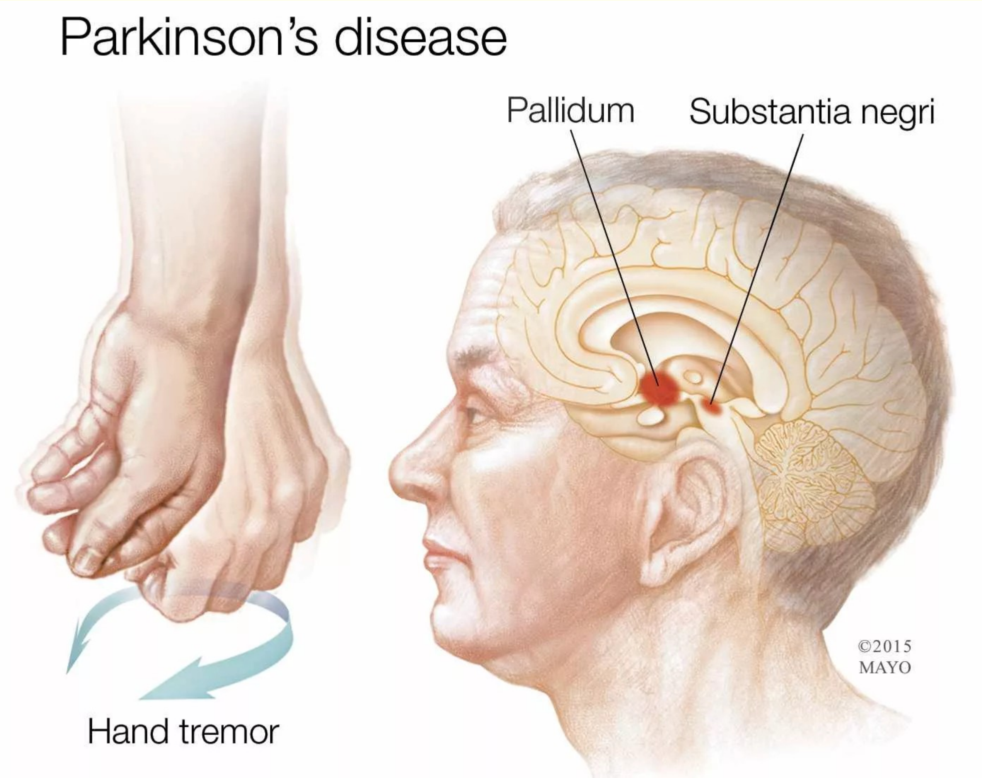
Clinical Signs of ANS Dysfunction

- Autonomic dysfunction may occur due to a disease process that is selective for the cells and fibers of the ANS. Examples are pure autonomic failure, multiple system atrophy, and familial dysautonomia (Riley-Day syndrome).
- In other cases, autonomic signs accompany other medical conditions. Examples are Parkinson's disease, diabetes, infectious peripheral neuropathy (Guillain-Barre syndrome), alcoholism, multiple sclerosis, and spinal cord damage.



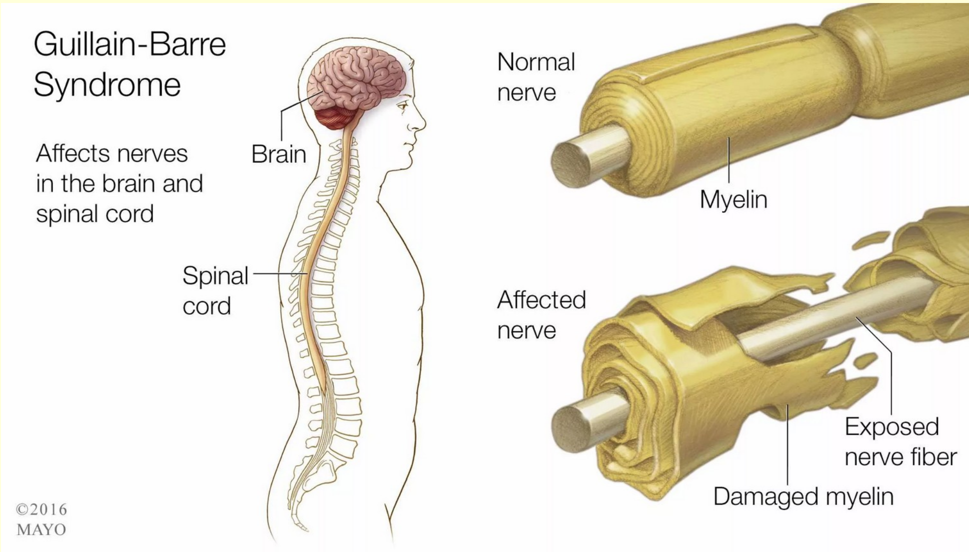
Clinical Signs of ANS Dysfunction

- Some typical signs of ANS dysfunction, especially postural hypotension, impotence, and disturbance of micturition, may be the first signs of pure autonomic failure and multiple system atrophy.
- Degeneration of pre- and postganglionic autonomic neurons occurs in these diseases. This degeneration may progress and include lower motor neurons (multiple system atrophy) or cells in the substantia nigra (Parkinson's disease).



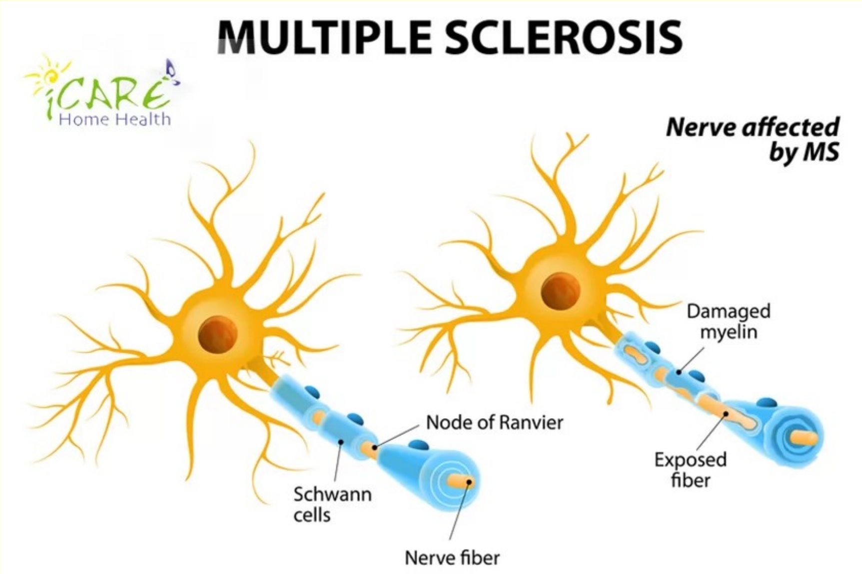
Peripheral Neuropathies

- In peripheral neuropathies, similar signs may occur, but they are usually accompanied by the distinct signs of peripheral somatic sensory and somatic motor dysfunction that are hallmarks of damage to peripheral nerves.
- For example, in acute infectious peripheral neuropathy (Guillian-Barre syndrome), initial signs are distal paresthesias, numbness, and muscle weakness, the latter accompanied by muscle wasting and decreased stretch reflexes, but no fasciculations.

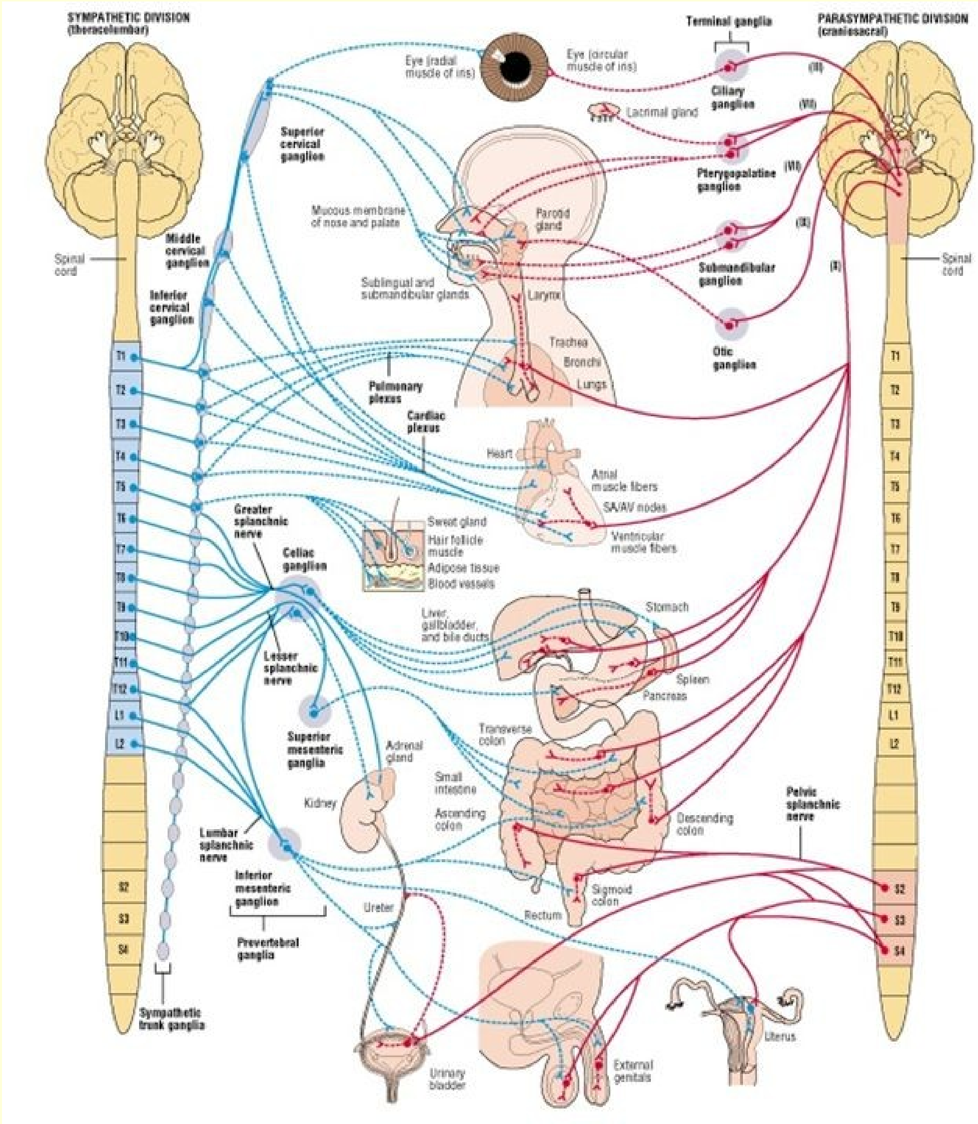


Multiple Sclerosis and Spinal Cord Lesions

- These disorders mainly influence ANS function by disconnecting the preganglionic neurons of the spinal cord, the final common path for much of the ANS, from their supraspinal control.
- The effects depend on the level and severity of the lesion.
- Complete spinal cord transection is devastating to body temperature control, blood pressure regulation, and bowel, bladder, and sexual function.



Thank You
For Your Attention!



Sympathetic
- Speeds up
- Fight or flight

Parasympathetic
- slows down
- rest & digest