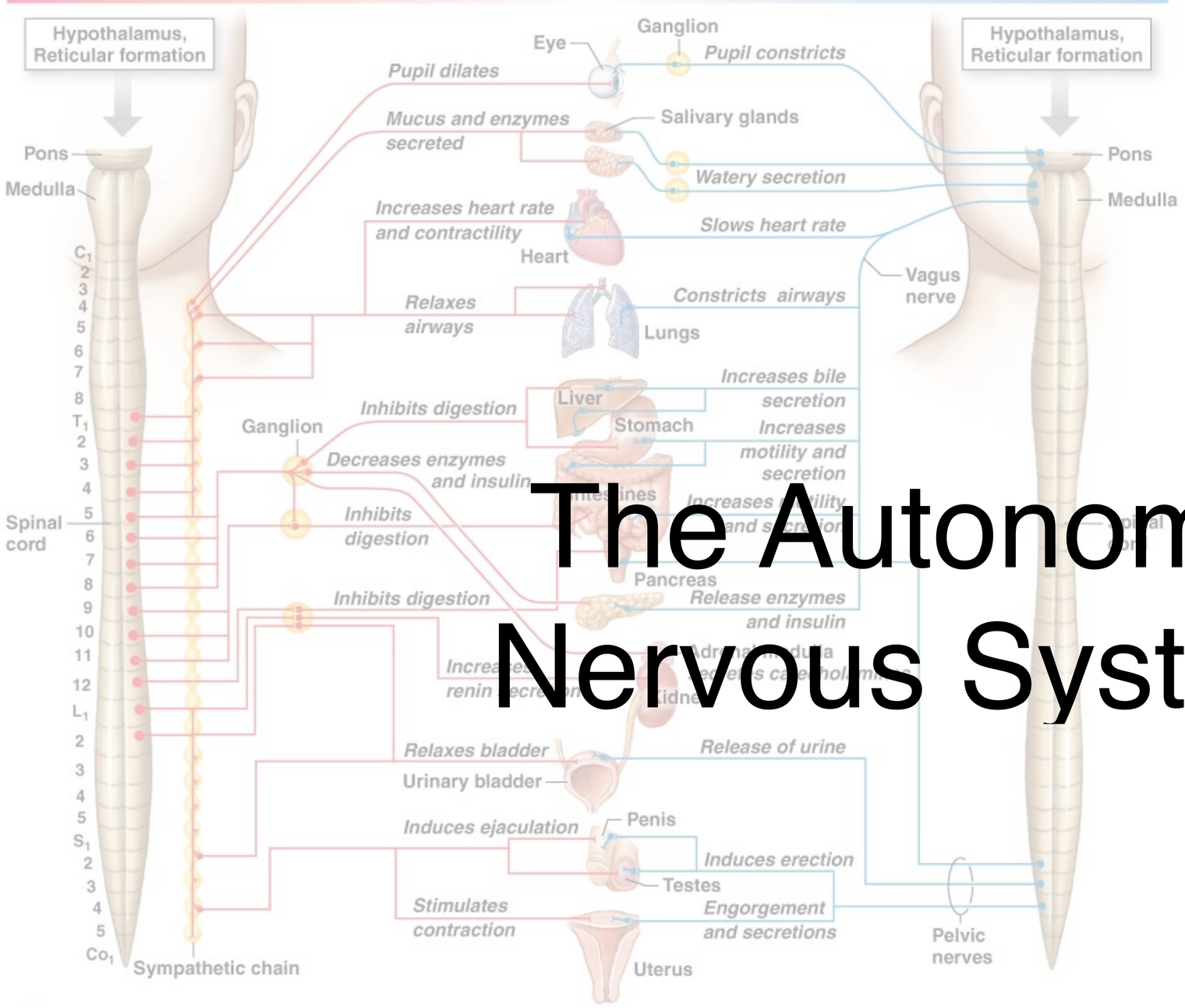
The Autonomic Nervous System



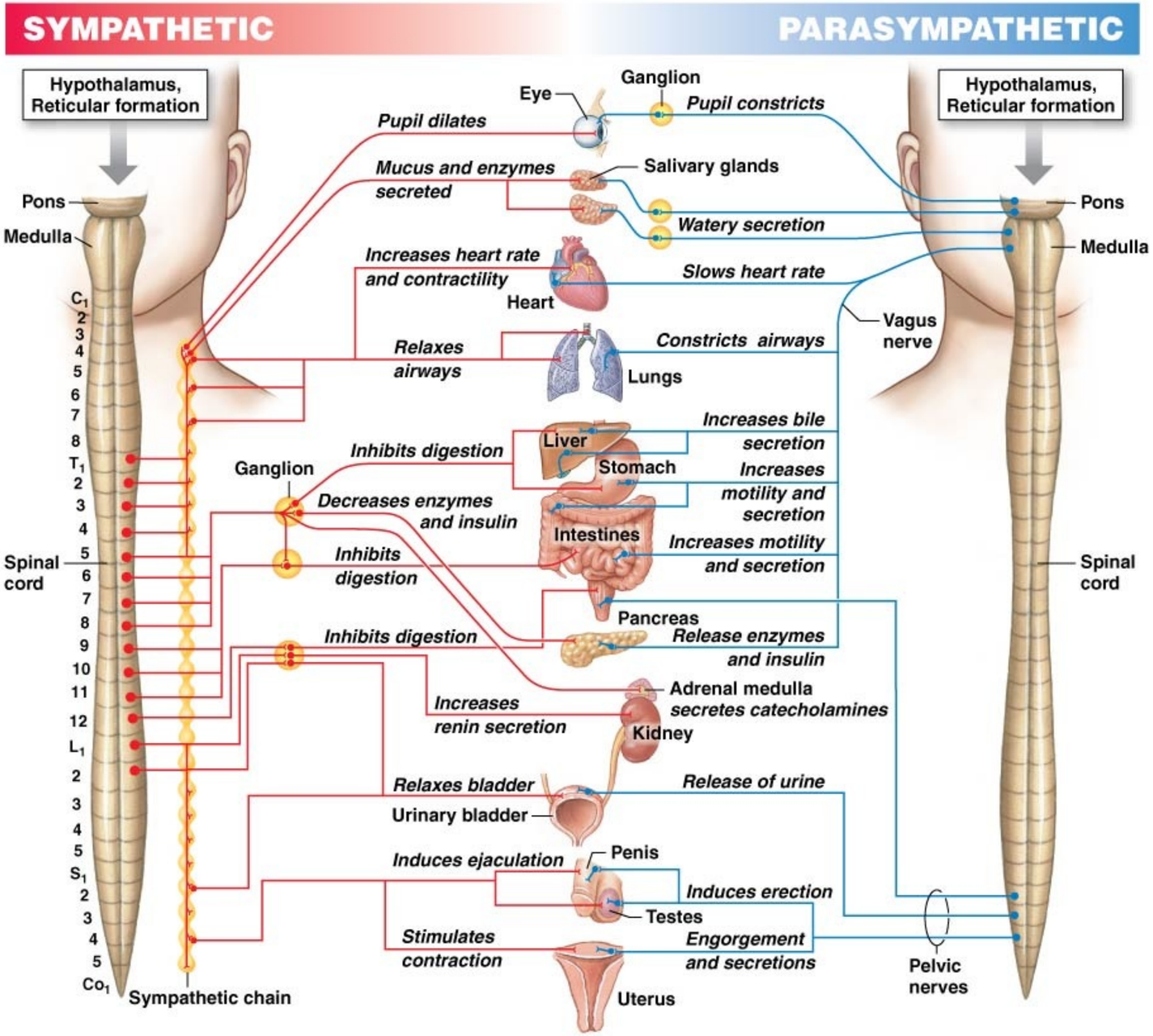
Pupil of eye	Dilates	α	Constricts
Salivary glands	Mucus, enzymes	α and β_2	Watery secretion
Heart	Increases rate and force of contraction	β_1	Slows rate
Arterioles and veins	Constricts Dilates	α β_2	—
Lungs	Bronchioles dilate	β_2*	Bronchioles constrict
Digestive tract	Decreases motility and secretion	α, β_2	Increases motility and secretion
Exocrine pancreas	Decreases enzyme secretion	α	Increases enzyme secretion
Endocrine pancreas	Inhibits insulin secretion	α	Stimulates insulin secretion
Adrenal medulla	Secretes catecholamines	—	—
Kidney	Increases renin secretion	β_1	—
Urinary bladder	Urinary retention	α, β_2	Release of urine
Adipose tissue	Fat breakdown	β	—
Male and female sex organs	Ejaculation (male)	α	Erection
Uterus	Depends on stage of cycle	α, β_2	Depends on stage of cycle
Lymphoid tissue	Generally inhibitory	α, β_2	—
	*Hormonal epinephrine only		**All parasympathetic responses are mediated by muscarinic receptors.

FIGURE QUESTIONS

1. Name the regions of the CNS where the two branches originate.

KEY

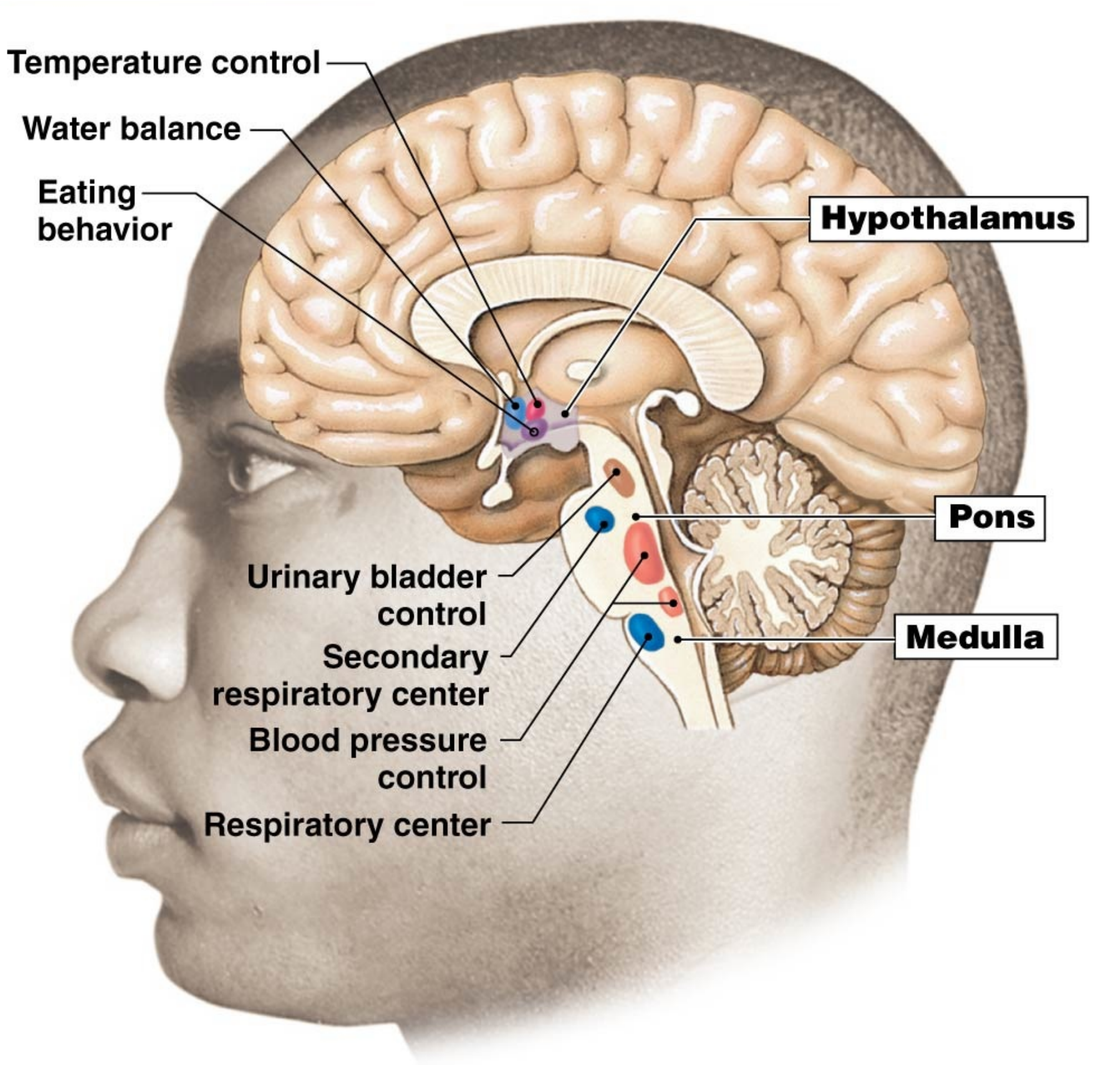
- Sympathetic
- Parasympathetic

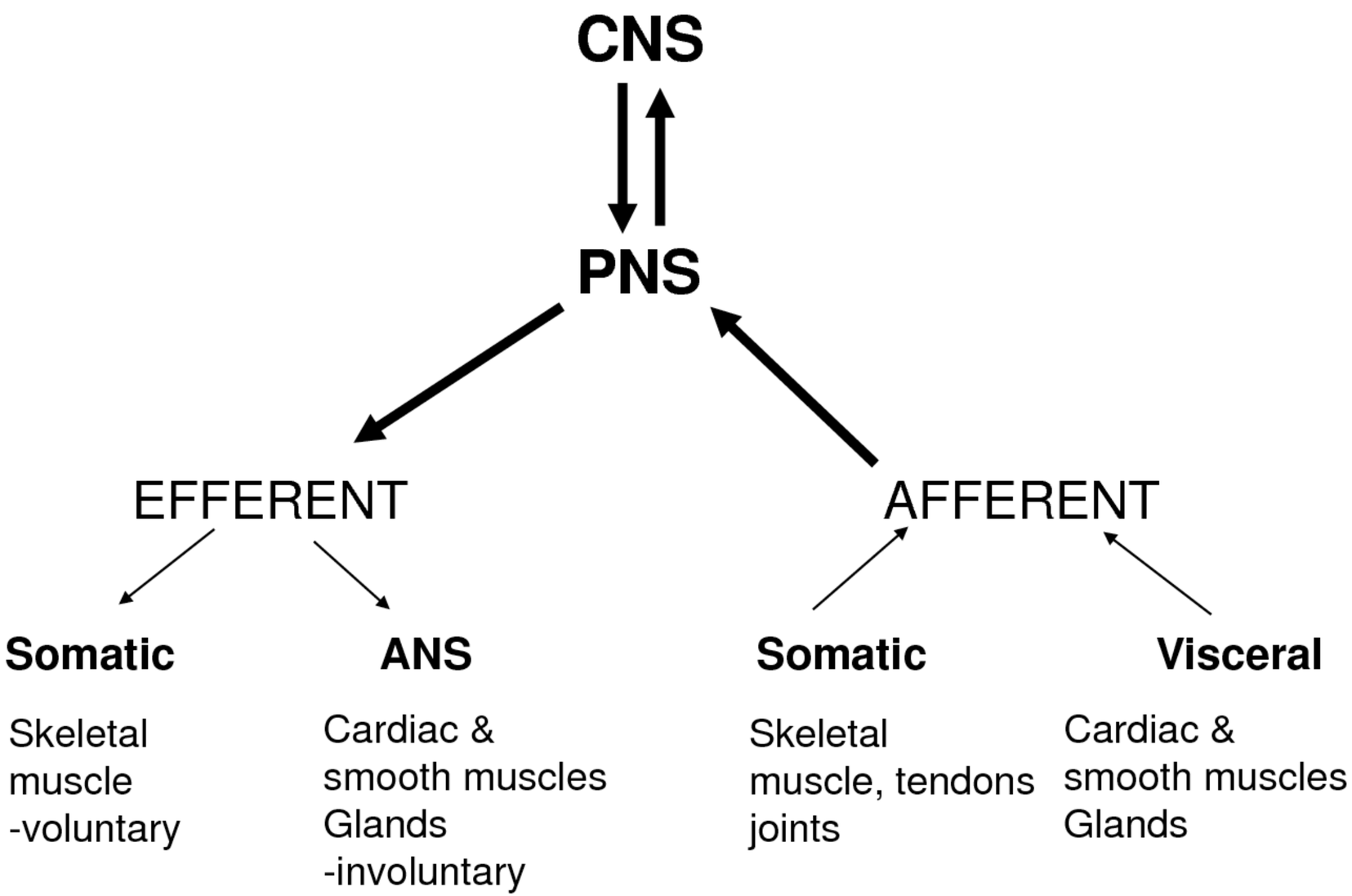


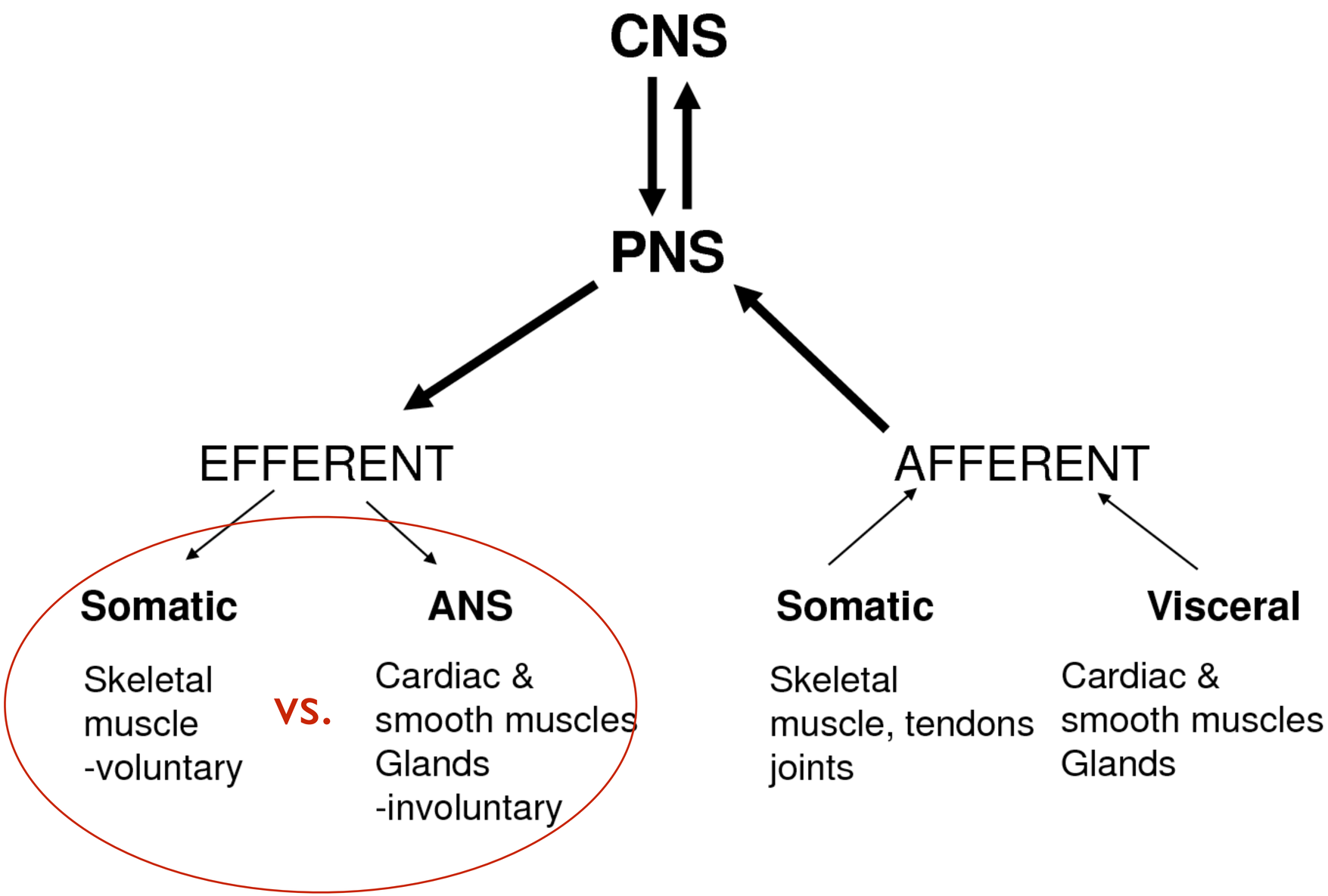
EFFECTOR ORGAN	SYMPATHETIC RESPONSE	ADRENERGIC RECEPTOR	PARASYMPATHETIC RESPONSE **
Pupil of eye	Dilates	α	Constricts
Salivary glands	Mucus, enzymes	α and β_2	Watery secretion
Heart	Increases rate and force of contraction	β_1	Slows rate
Arterioles and veins	Constricts Dilates	α β_2	—
Lungs	Bronchioles dilate	β_2*	Bronchioles constrict
Digestive tract	Decreases motility and secretion	α, β_2	Increases motility and secretion
Exocrine pancreas	Decreases enzyme secretion	α	Increases enzyme secretion
Endocrine pancreas	Inhibits insulin secretion	α	Stimulates insulin secretion
Adrenal medulla	Secretes catecholamines	—	—
Kidney	Increases renin secretion	β_1	—
Urinary bladder	Urinary retention	α, β_2	Release of urine
Adipose tissue	Fat breakdown	β	—
Male and female sex organs	Ejaculation (male)	α	Erection
Uterus	Depends on stage of cycle	α, β_2	Depends on stage of cycle
Lymphoid tissue	Generally inhibitory	α, β_2	—
	*Hormonal epinephrine only		**All parasympathetic responses are mediated by muscarinic receptors.

The Autonomic Division

Controlled by the limbic system and the medulla oblongata, which is in turn controlled by the hypothalamus

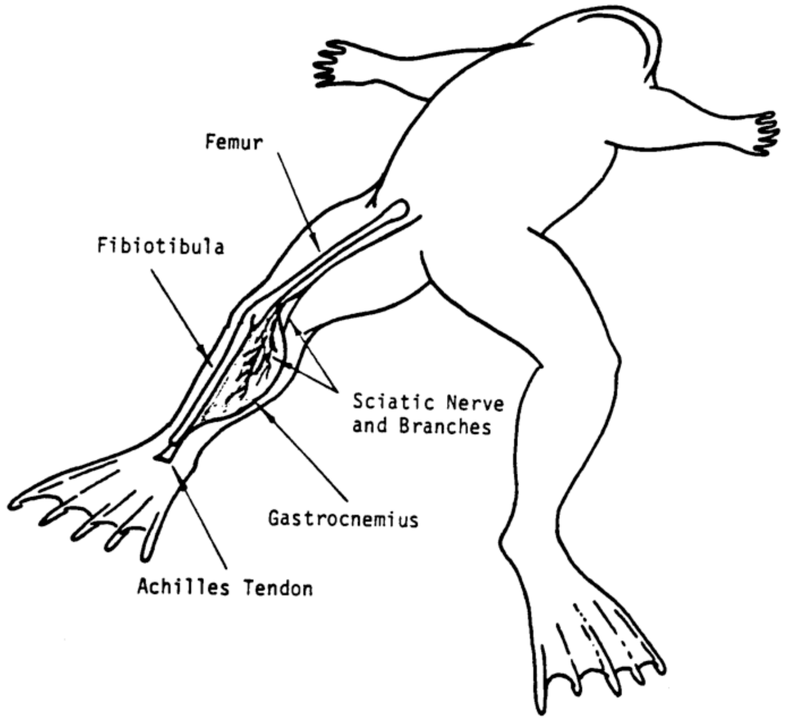


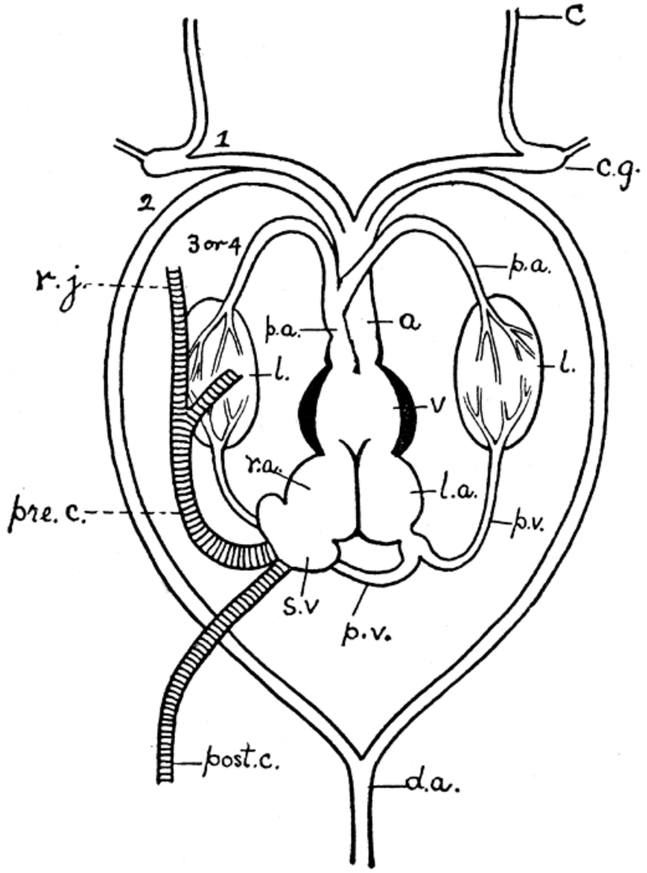

CNS
PNS
EFFERENT
AFFERENT
Somatic
Skeletal muscle -voluntary
ANS
Cardiac & smooth muscles Glands -involuntary
Somatic
Skeletal muscle, tendons joints
Visceral
Cardiac & smooth muscles Glands


CNS
PNS
EFFERENT
AFFERENT
Somatic
ANS
Skeletal muscle -voluntary
vs.
Cardiac & smooth muscles Glands -involuntary
Somatic
Visceral
Skeletal muscle, tendons joints
Cardiac & smooth muscles Glands

Somatic vs. Autonomic

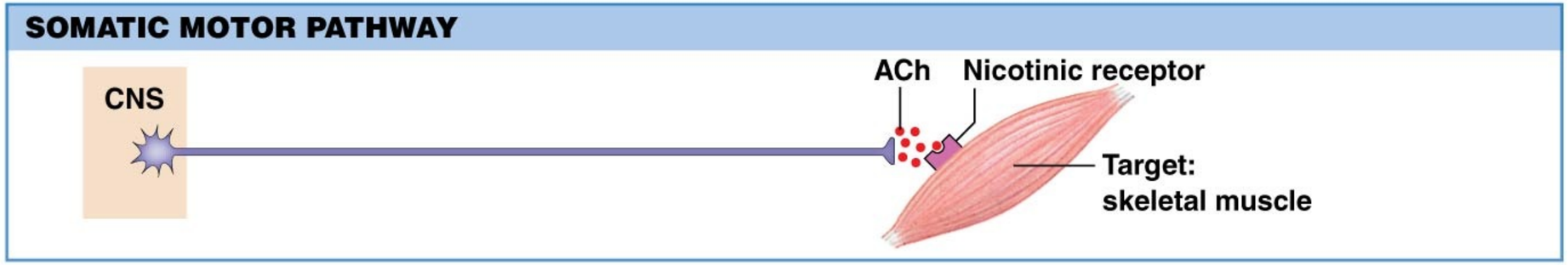
What happens if innervation is absent?

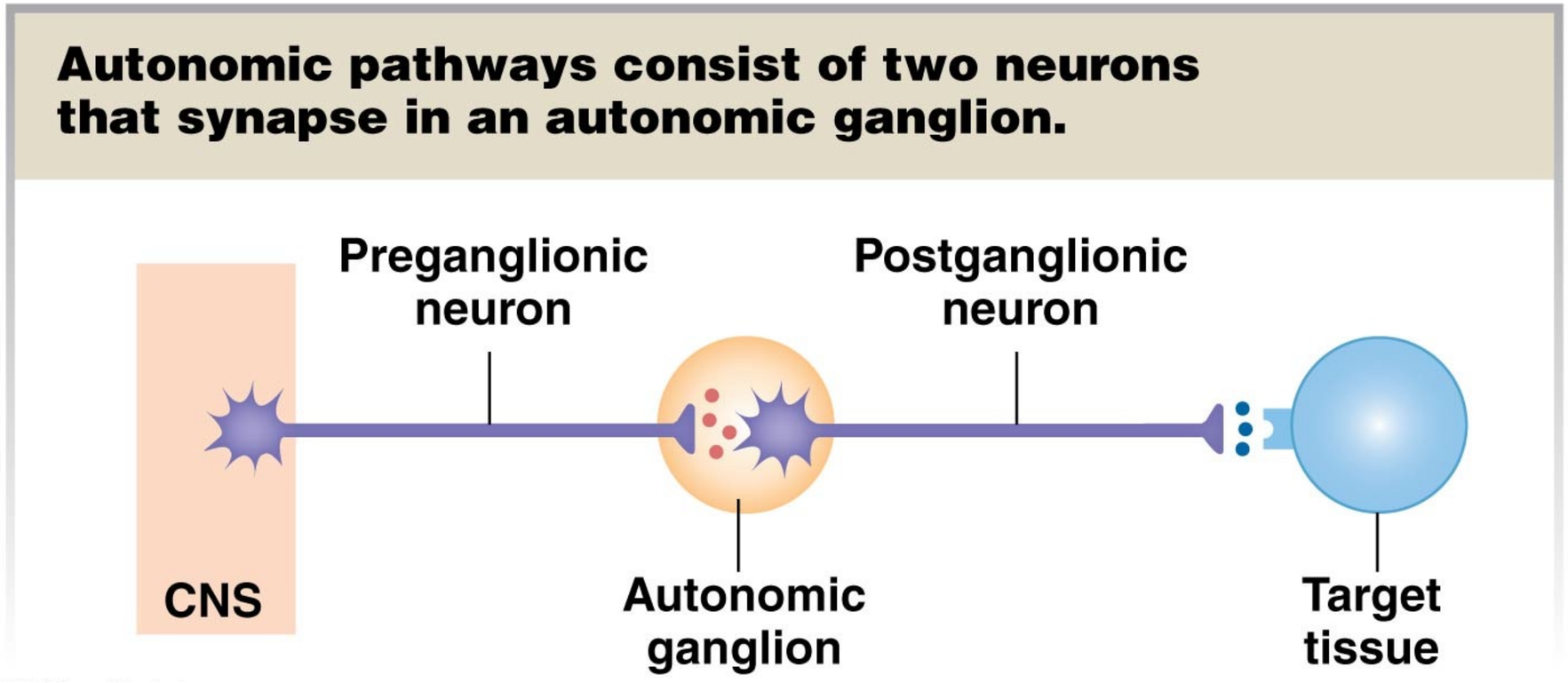




Somatic vs. Autonomic

- Somatic has 1 neuron in the efferent pathway
- Autonomic division has 2
  - Preganglionic neuron has it's cell body in the gray matter of brain or spinal cord
  - Postganglionic neuron has it's cell body in an autonomic ganglion

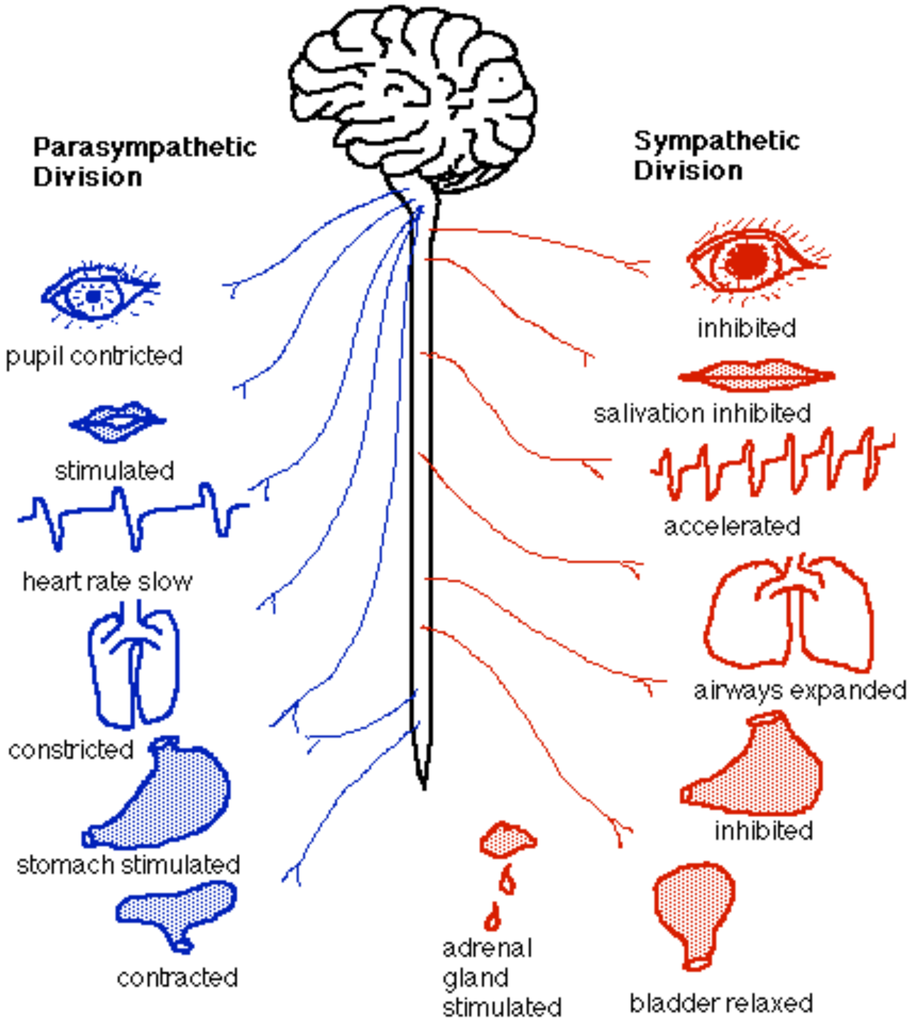




why have 2 neurons in the efferent pathway?

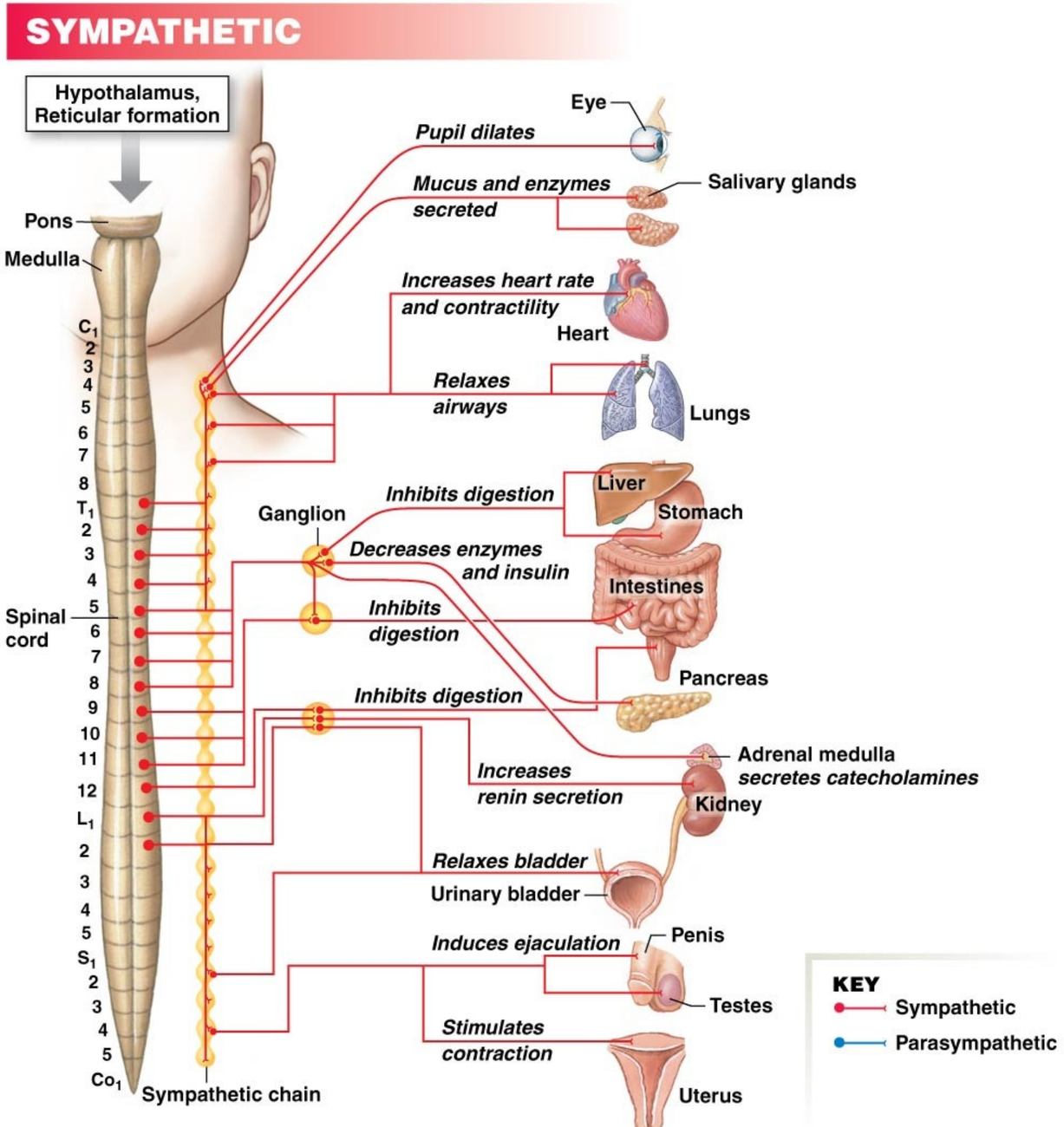
Comparison of Somatic Motor and Autonomic Divisions		
	SOMATIC MOTOR	**AUTONOMIC**
Number of neurons in efferent path	1	2
Neurotransmitter/receptor at neuron-target synapse	ACh/nicotinic	ACh/muscarinic or NE/α- or β-adrenergic
Target tissue	Skeletal muscle	Smooth and cardiac muscle; some endocrine and 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

Divisions of the Autonomic Nervous System



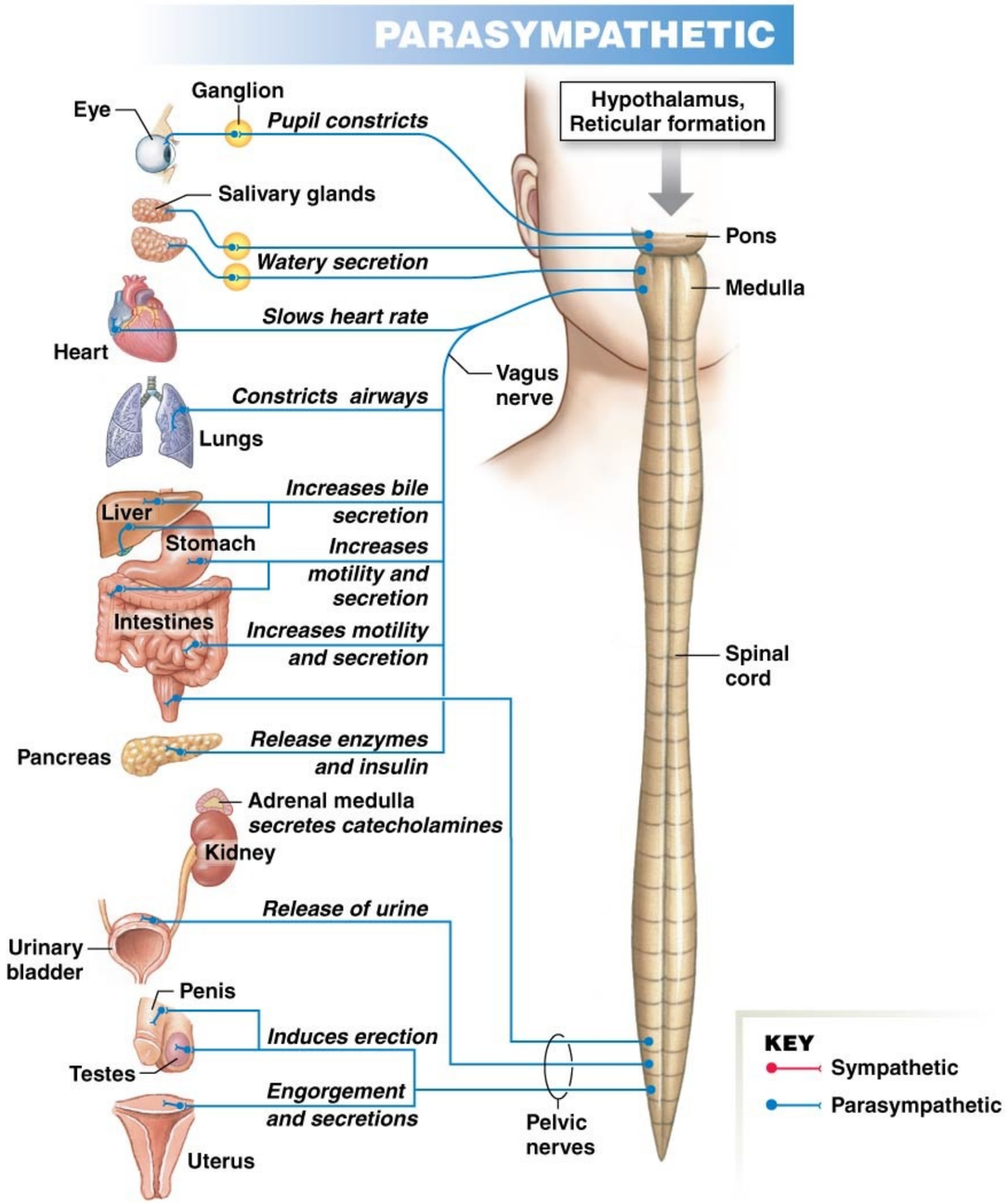
Sympathetic (Thoracolumbar) Division

- Preganglionic neurons originate in the thoracic and lumbar regions; paravertebral ganglia
- ‘Flight or Fight' system

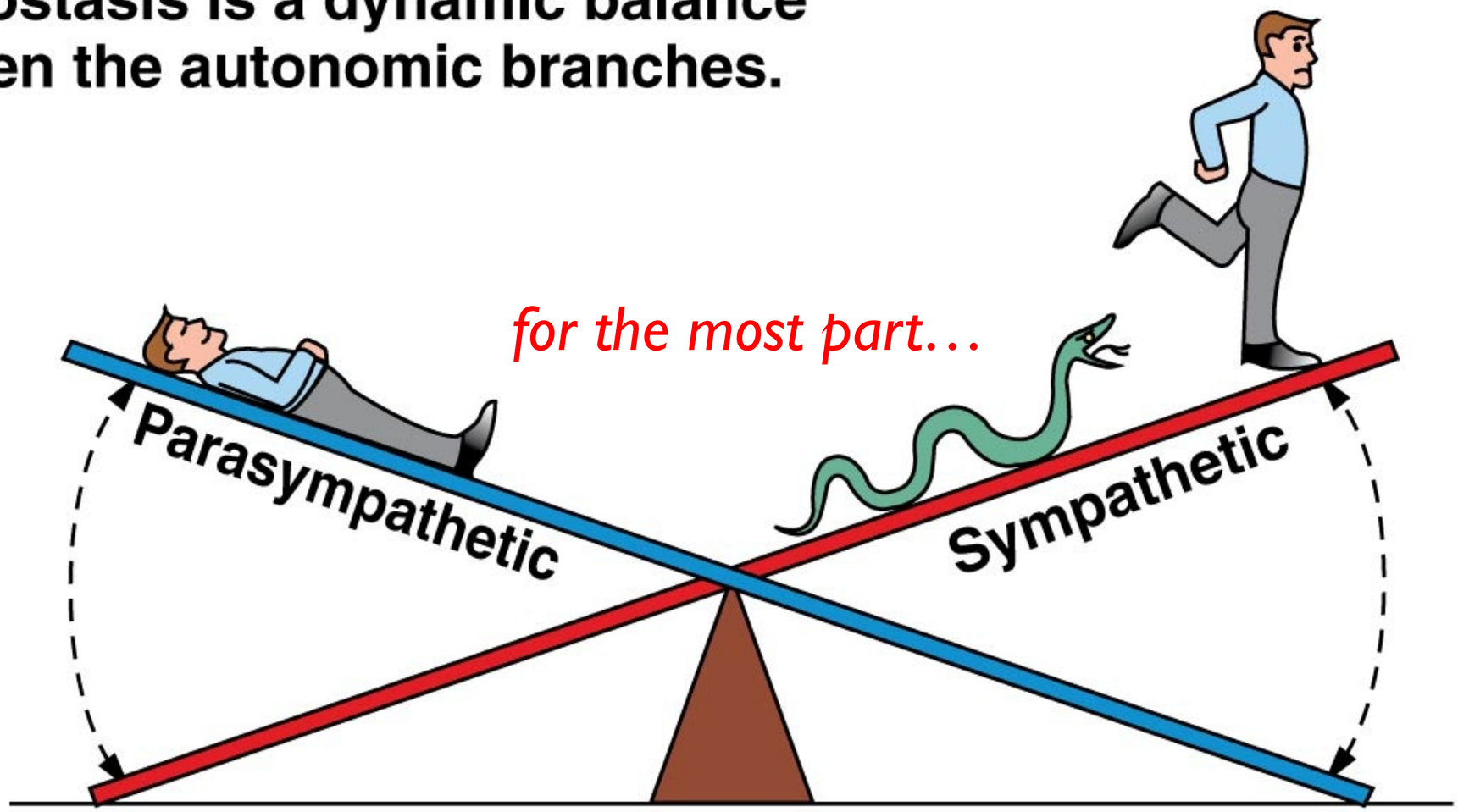


Parasympathetic (Craniosacral)

- Preganglionic neurons originate in the brain (midbrain, medulla oblongata and pons) and sacral region of the spinal cord and send axons to ganglia located at or near effector organs.
- “Rest and Digest” system



Homeostasis is a dynamic balance between the autonomic branches.



Rest-and-digest: Parasympathetic activity dominates.

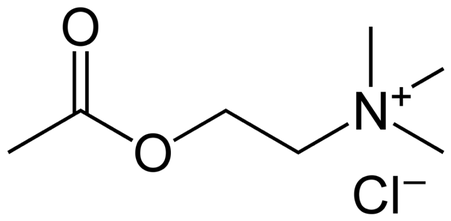
Fight-or-flight: Sympathetic activity dominates.

Functions of the Autonomic NS

What Determines the Meaning of a Message?
Oh yes, here we go again…

Neurotransmitters of the ANS

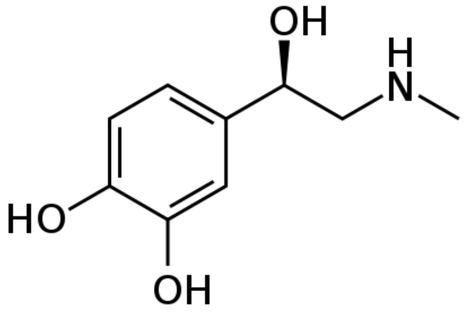
Cholinergic: Acetyolcholine

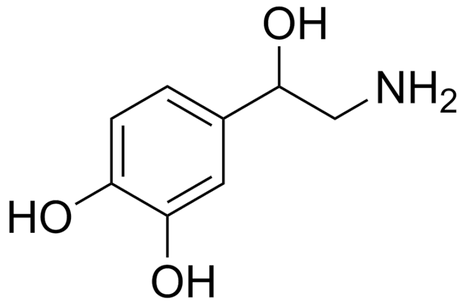


Adrenergic: Epinephrine

and

Norepinepherine





Cholinergic Neurons of the ANS

- ACh is the neurotransmitter of all preganglionic fibers of both divisions (as well as for somatic motor neurons).
- ACh is also the NT for parasympathetic postganglionic neurons

Sympathetic	Parasympathetic
Preganglionic ACh	Preganglionic ACh
Postganglionic	Postganglionic ACh

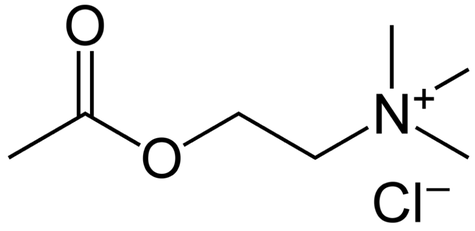
Cholinergic Stimulation Responses

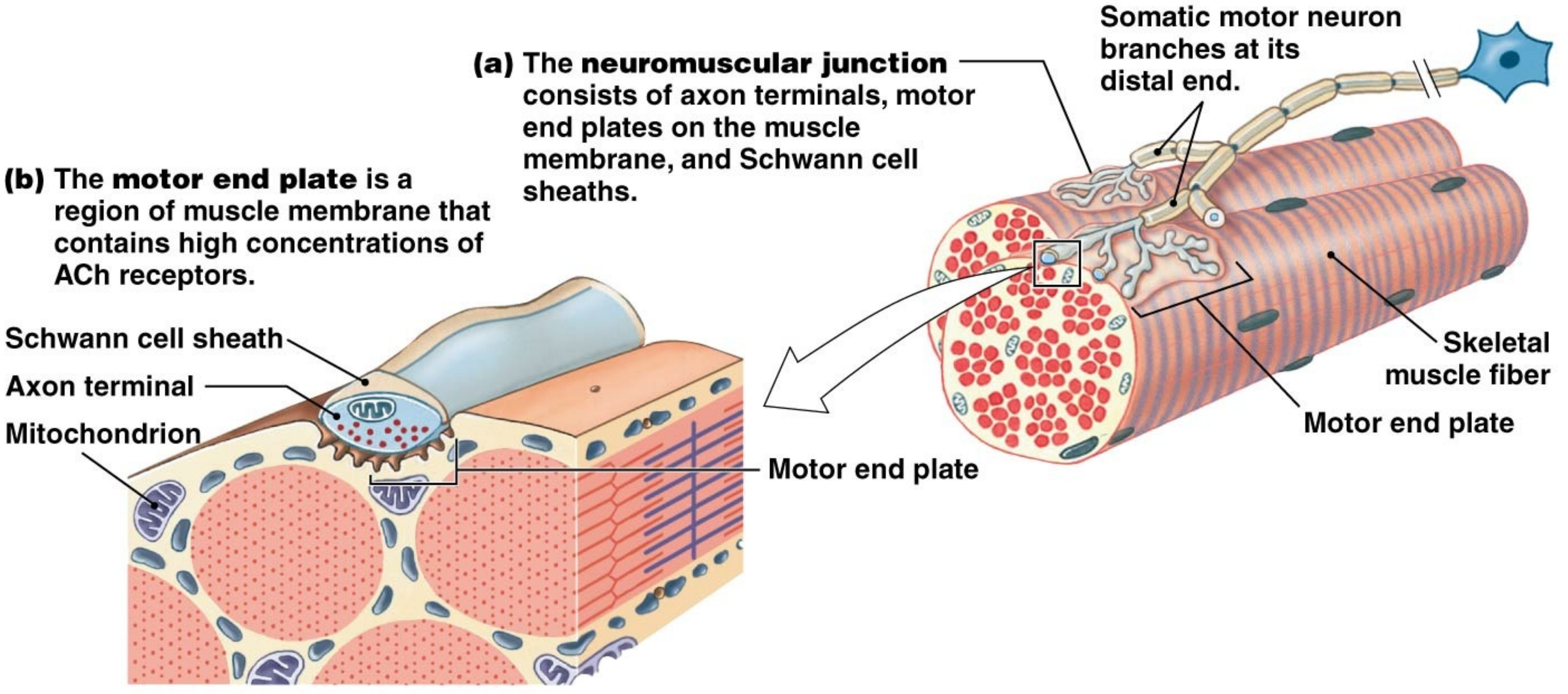
- Cholinergic effects of somatic motor neurons and of preganglionic neurons are always excitatory.
- Cholinergic effect of postganglionic parasympathetic neurons may be stimulatory or inhibitory

How is that possible?

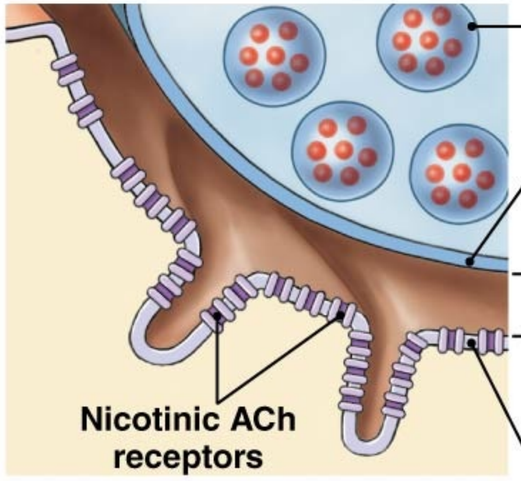
Cholinergic Receptors

- Nicotinic subtype
  - N_m found in neuromuscular junctions
  - N_n found elsewhere
- Muscarinic subtypes
  - M_1: CNS, gastric parietal cells, ANS ganglia
  - M_2: myocardium
  - M_3: smooth muscle
  - M_4, M_5: CNS

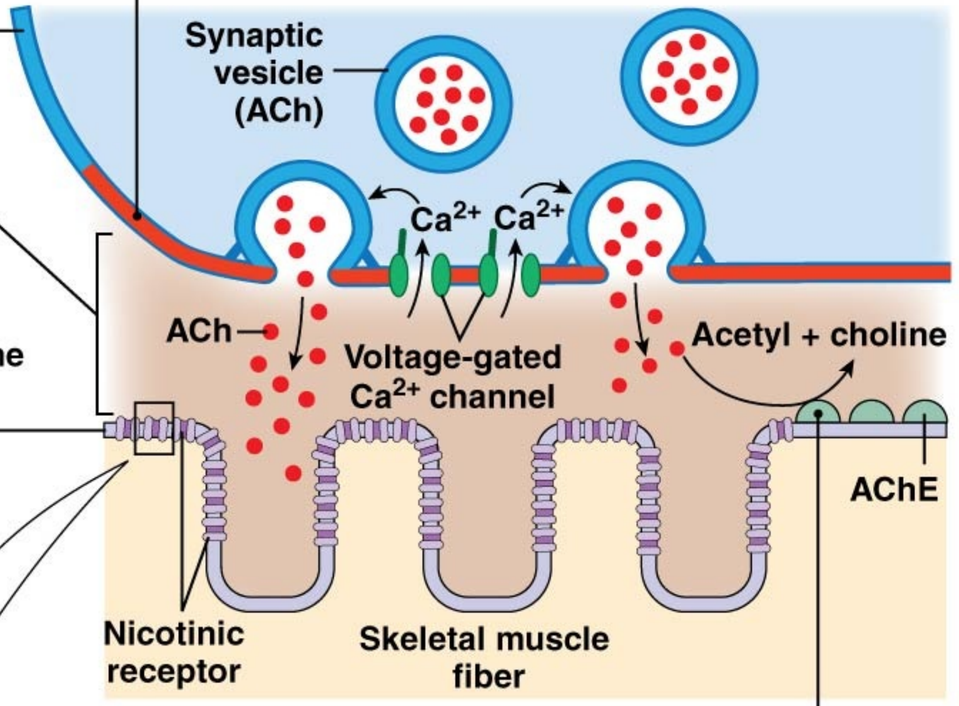



(a) The **neuromuscular junction** consists of axon terminals, motor end plates on the muscle membrane, and Schwann cell sheaths.
Somatic motor neuron branches at its distal end.
Skeletal muscle fiber
Motor end plate
(b) The **motor end plate** is a region of muscle membrane that contains high concentrations of ACh receptors.
Schwann cell sheath
Axon terminal
Mitochondrion
Motor end plate

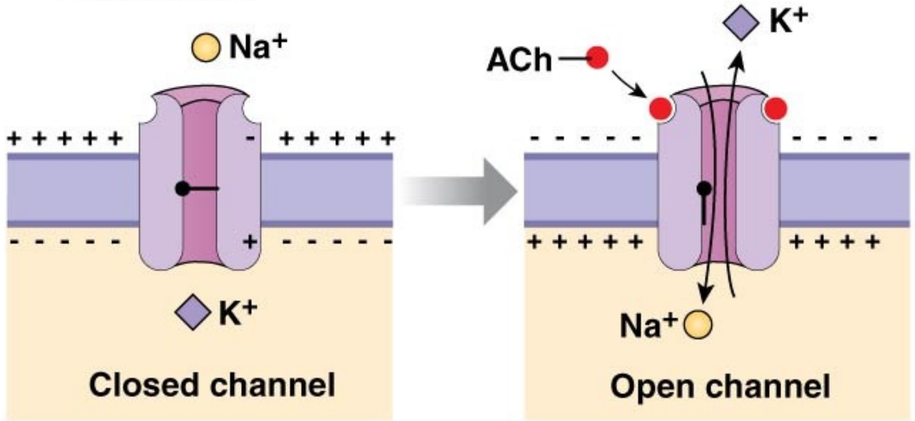
(c) The neuromuscular junction



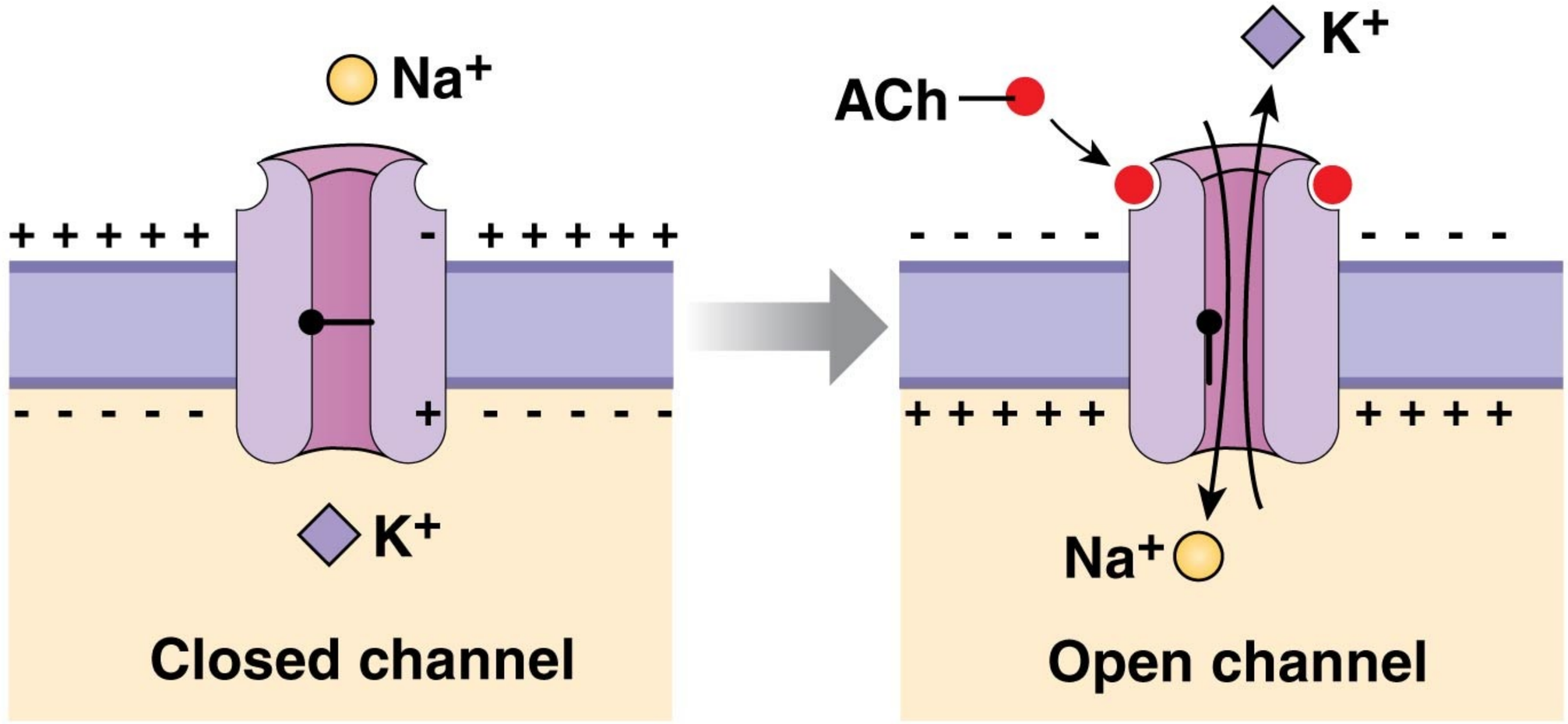
(d) An action potential arrives at the axon terminal, causing voltage-gated Ca^{2+} channels to open. Calcium entry causes synaptic vesicles to fuse with the presynaptic membrane and release ACh into the synaptic cleft.

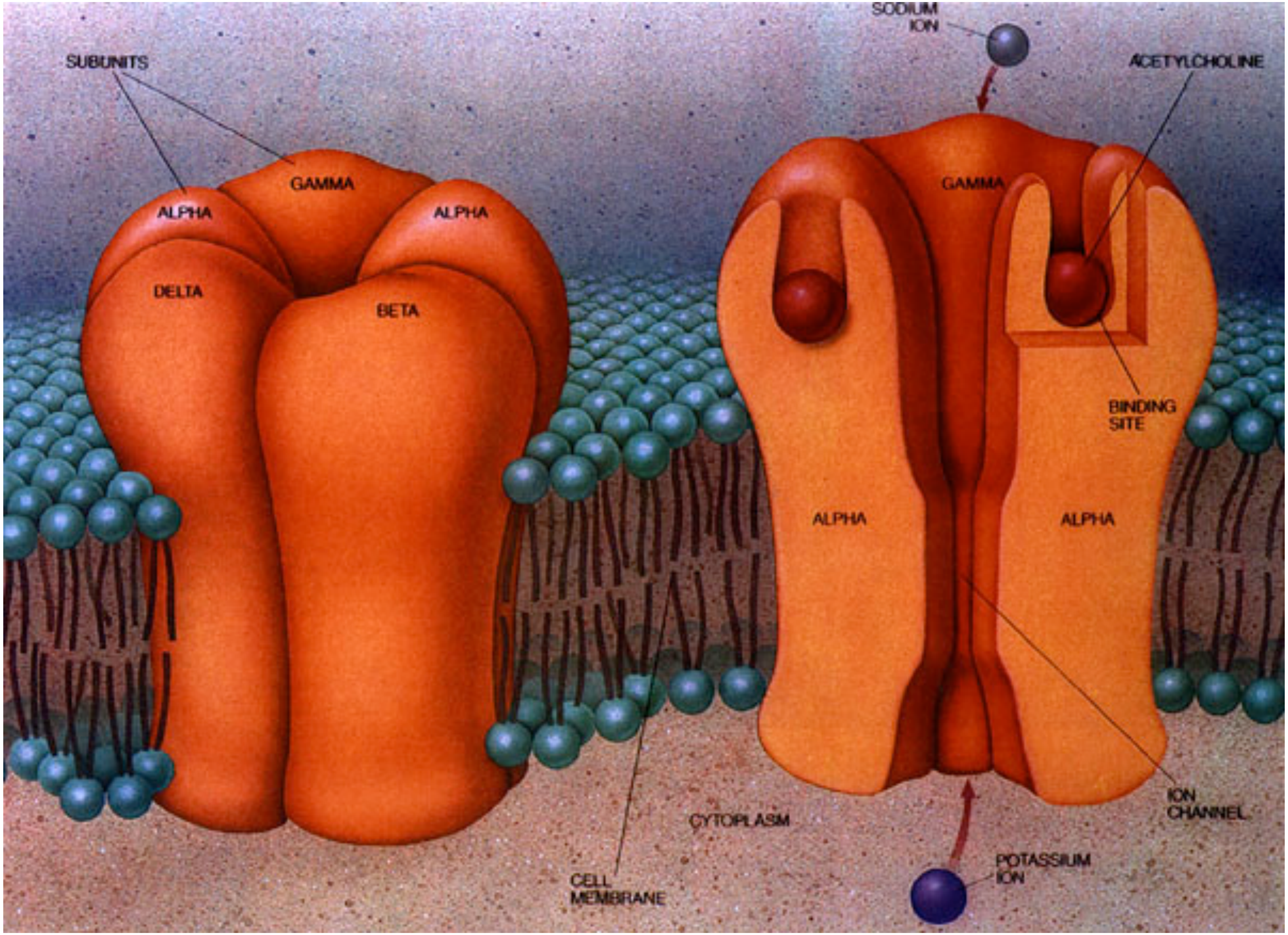


(e) The nicotinic cholinergic receptor binds two ACh molecules, opening a nonspecific monovalent cation channel. The open channel allows Na^+ and K^+ to pass. Net Na^+ influx depolarizes the muscle fiber.

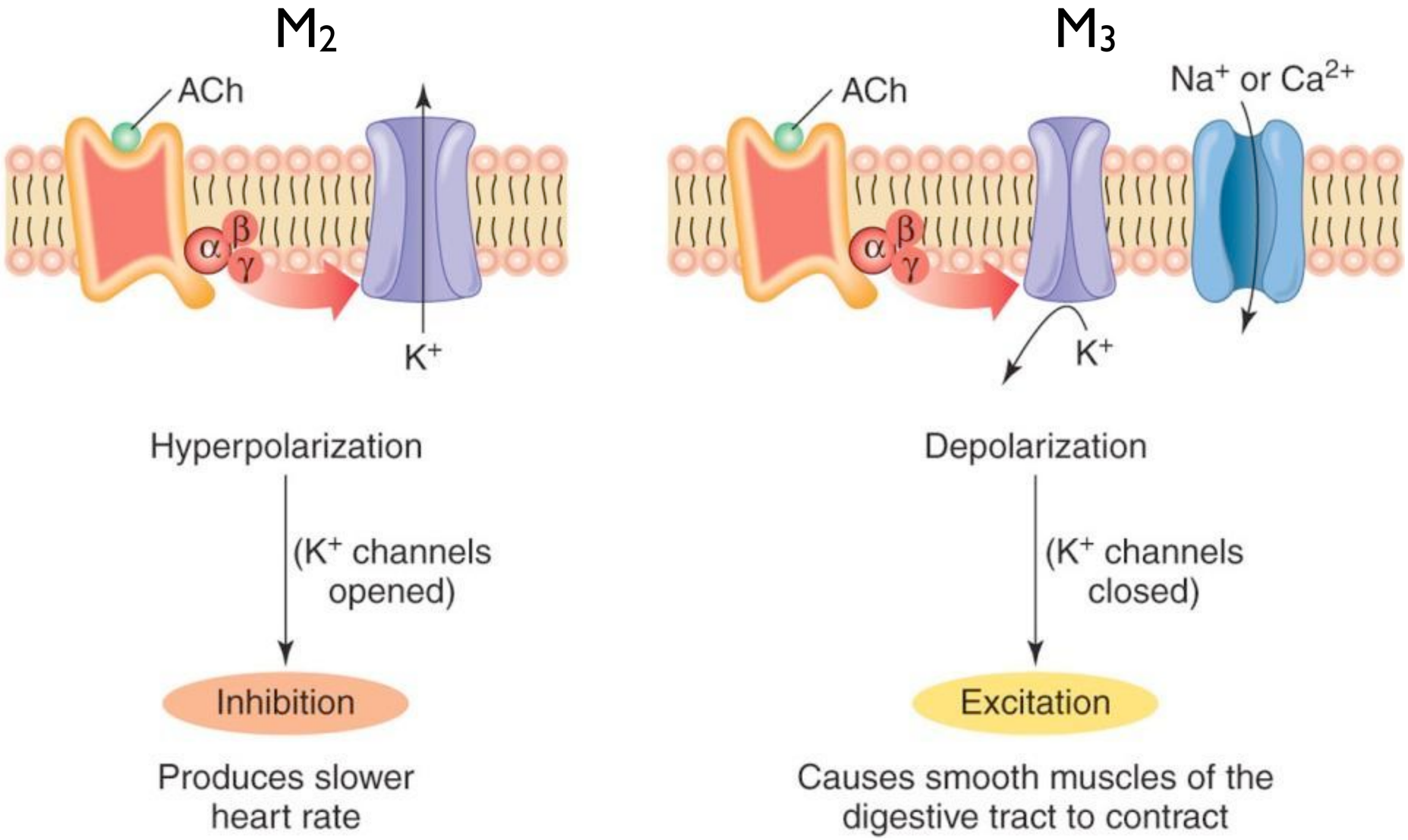


ACh Nicotinic Receptor




SODIUM ION
SUBUNITS
ACETYLCHOLINE
GAMMA
ALPHA
ALPHA
DELTA
BETA
GAMMA
BINDING SITE
ALPHA
ALPHA
ION CHANNEL
CYTOPLASM
POTASSIUM ION
CELL MEMBRANE

ACh Muscarinic Receptors

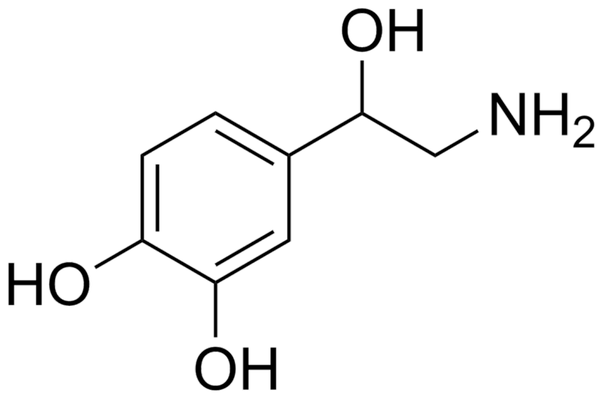


Sympathetic	Parasympathetic
Preganglionic ACh binds to Nicotinic Receptors	Preganglionic ACh binds to Nicotinic Receptors
Postganglionic	Postganglionic ACh binds to Muscarinic Receptors

Adrenergic Stimulation Responses

- Most postganglionic sympathetic nerve fibers release norepinepherine
- Effects vary

How is that possible?



Sympathetic	Parasympathetic
Preganglionic ACh binds to Nicotinic Receptors	Preganglionic ACh binds to Nicotinic Receptors
Postganglionic NE and E bind to Adrenergic Receptors	Postganglionic ACh binds to Muscarinic Receptors

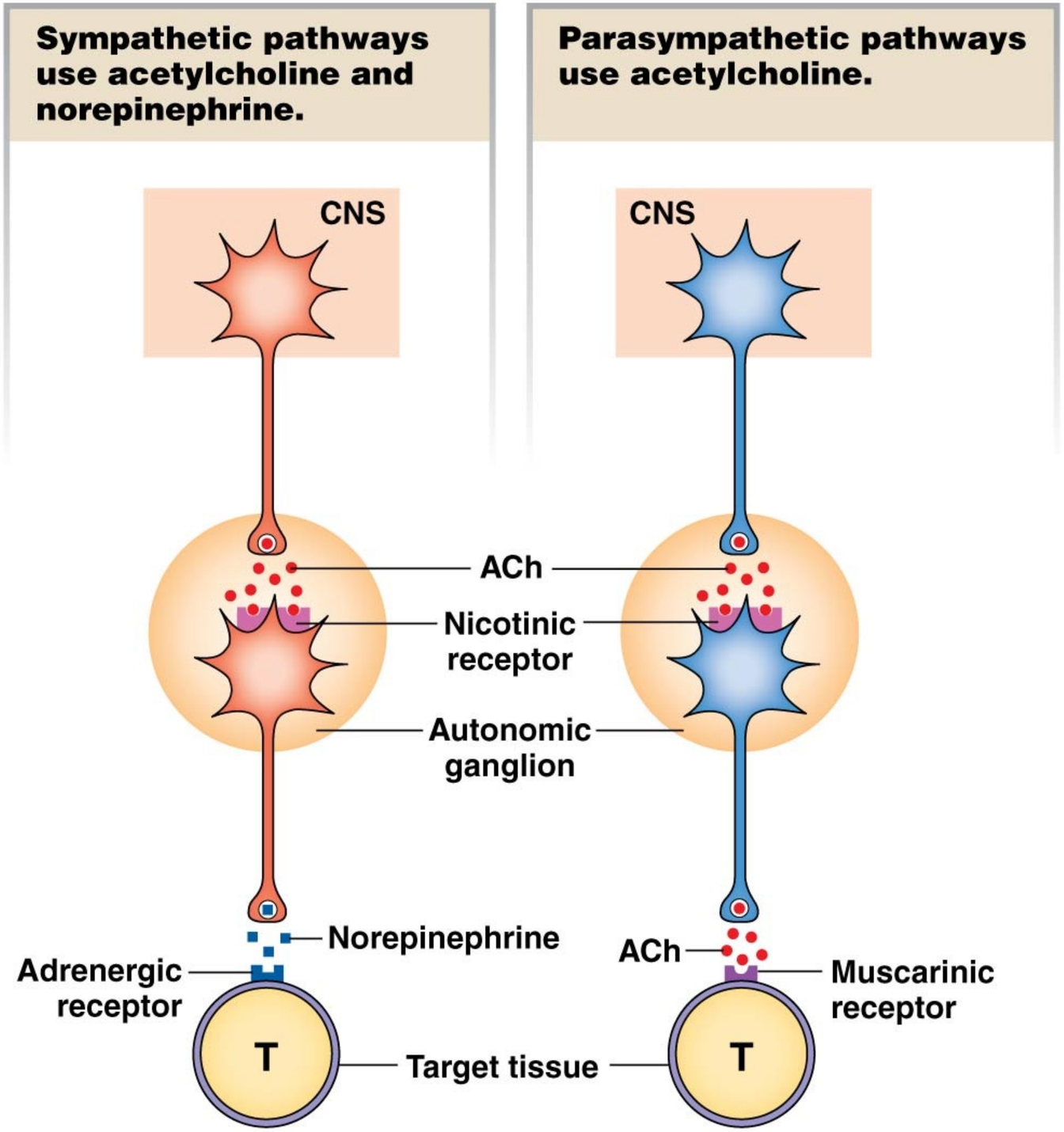
Adrenergic Receptors

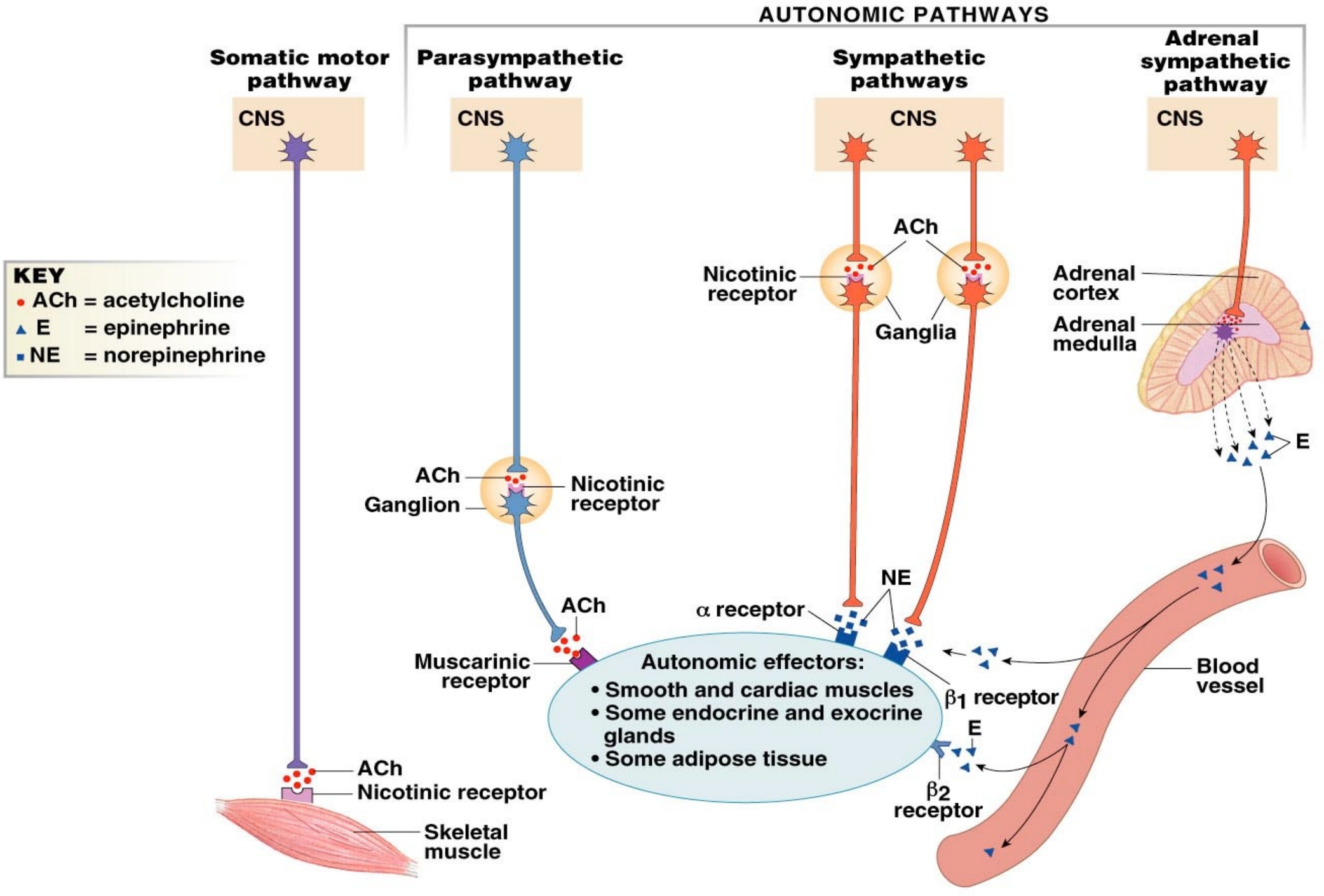
Table 11.2

Properties of Adrenergic Receptors

Receptor	Found in	Sensitivity	Effect on Second Messenger
α_1	Most sympathetic target tissues	NE > E*	Activates phospholipase C
α_2	Gastrointestinal tract and pancreas	NE > E	Decreases cAMP
β_1	Heart muscle, kidney	NE = E	Increases cAMP
β_2	Certain blood vessels and smooth muscle of some organs	E > NE	Increases cAMP
β_3	Adipose tissue	NE > E	Increases cAMP

*NE = norepinephrine, E = epinephrine.

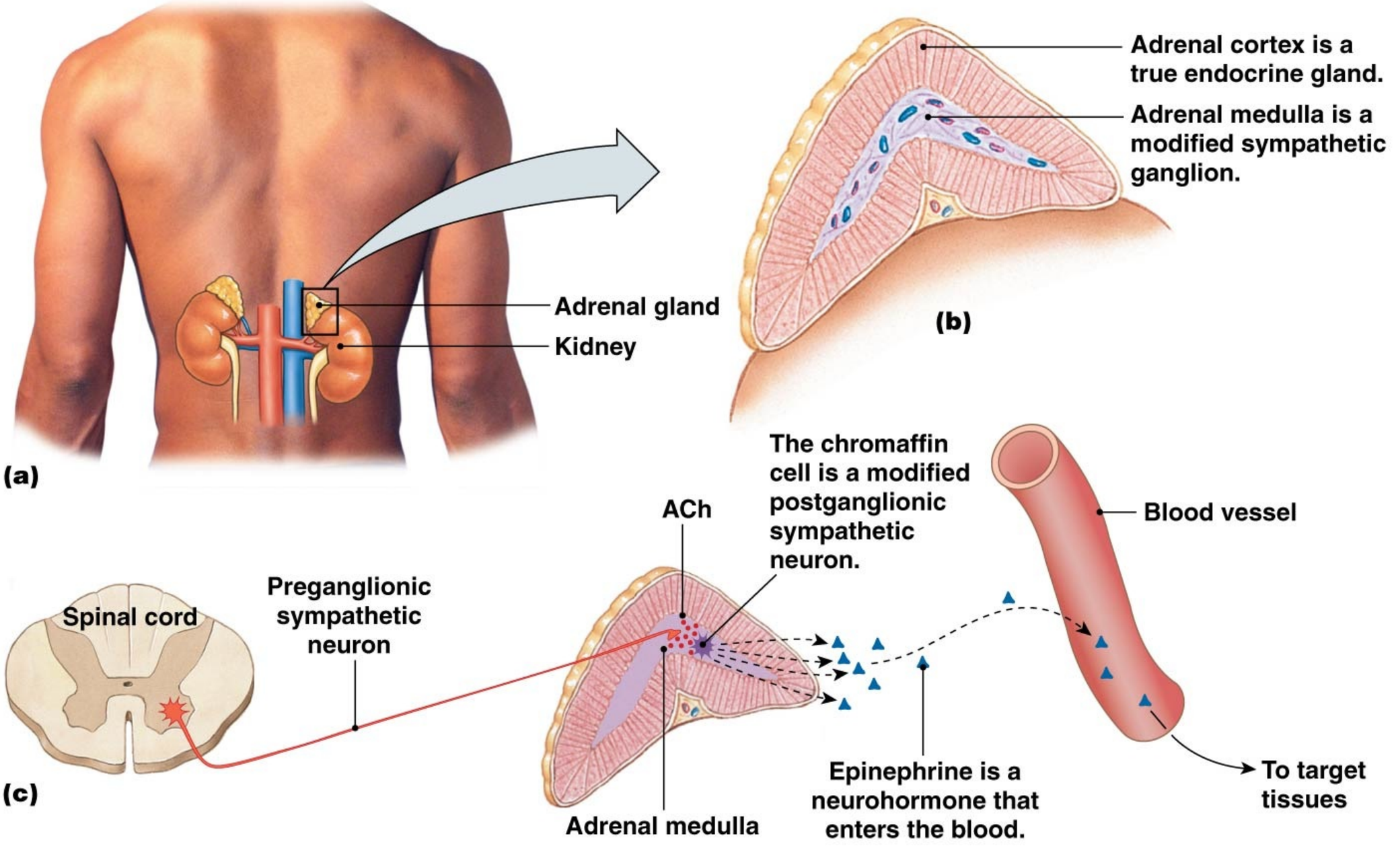

Sympathetic pathways use acetylcholine and norepinephrine.
Parasympathetic pathways use acetylcholine.
CNS
CNS
ACh
Nicotinic receptor
Autonomic ganglion
Norepinephrine
Adrenergic receptor
ACh
Muscarinic receptor
T
Target tissue
T


AUTONOMIC PATHWAYS
Somatic motor pathway
Parasympathetic pathway
Sympathetic pathways
Adrenal sympathetic pathway
CNS
CNS
CNS
CNS
KEY
ACh = acetylcholine
E = epinephrine
NE = norepinephrine
ACh
Nicotinic receptor
Ganglia
Adrenal cortex
Adrenal medulla
E
ACh
Ganglion
Nicotinic receptor
ACh
Muscarinic receptor
α receptor
NE
Autonomic effectors:
• Smooth and cardiac muscles
• Some endocrine and exocrine glands
• Some adipose tissue
β1 receptor
E
β2 receptor
Blood vessel
ACh
Nicotinic receptor
Skeletal muscle

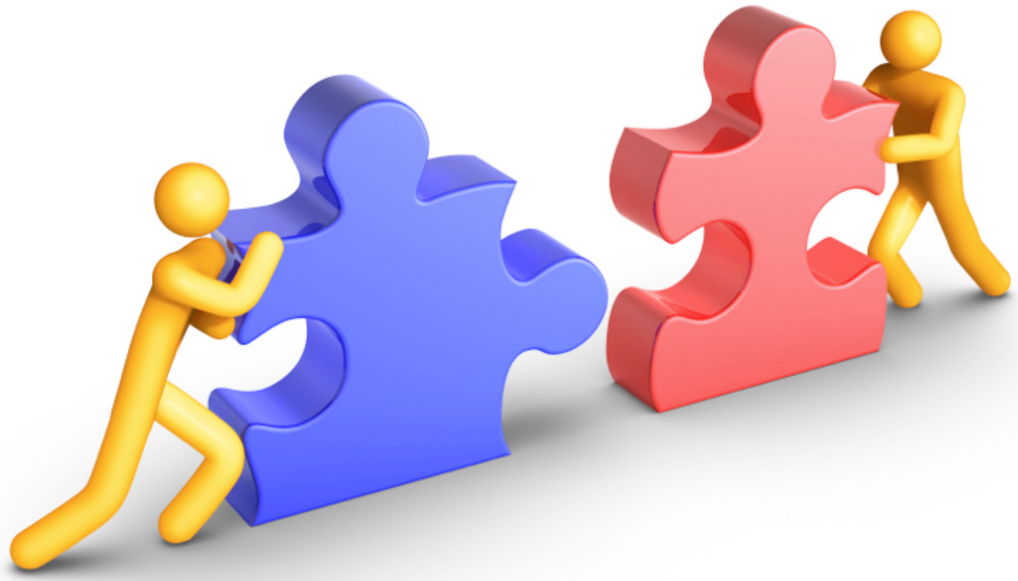
One More Thing…. The Adrenal Sympathetic Pathway

- “Postganglionic neuron” replaced by epinephrine-releasing chromaffin cells
- Epinephrine is a neurohormone, released into the blood

THE ADRENAL MEDULLA SECRETES EPINEPHRINE INTO THE BLOOD.

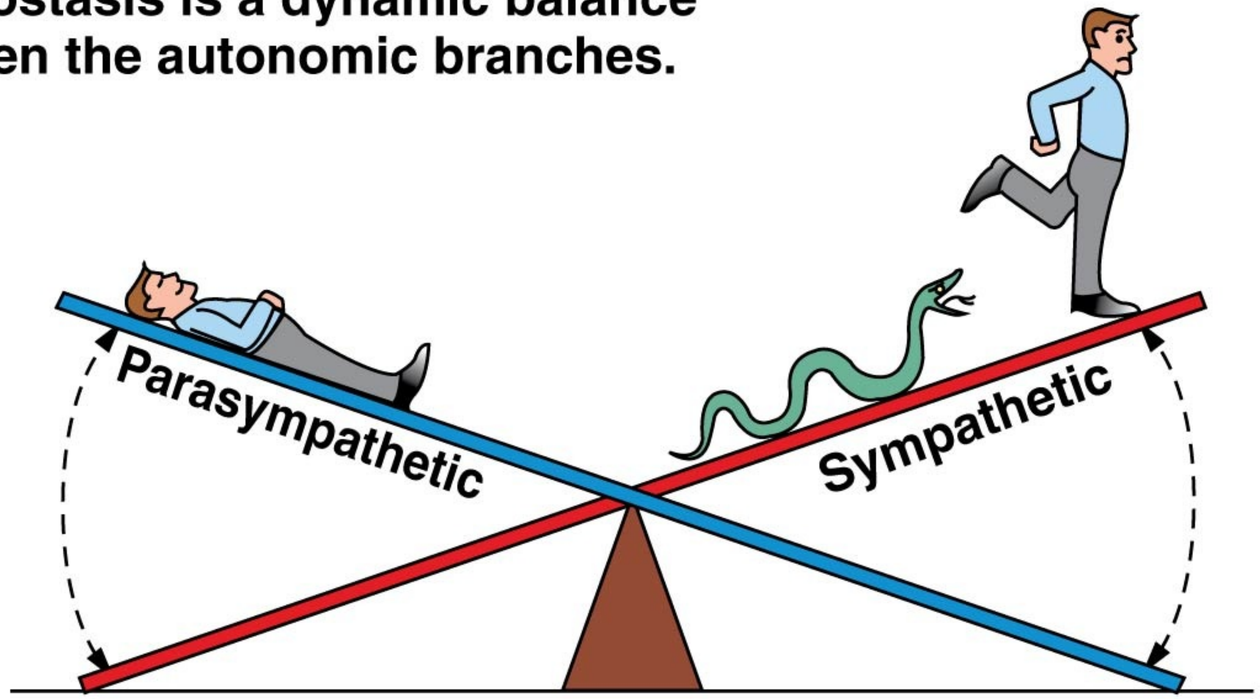


How the Divisions Work Together



Antagonistic

Homeostasis is a dynamic balance between the autonomic branches.

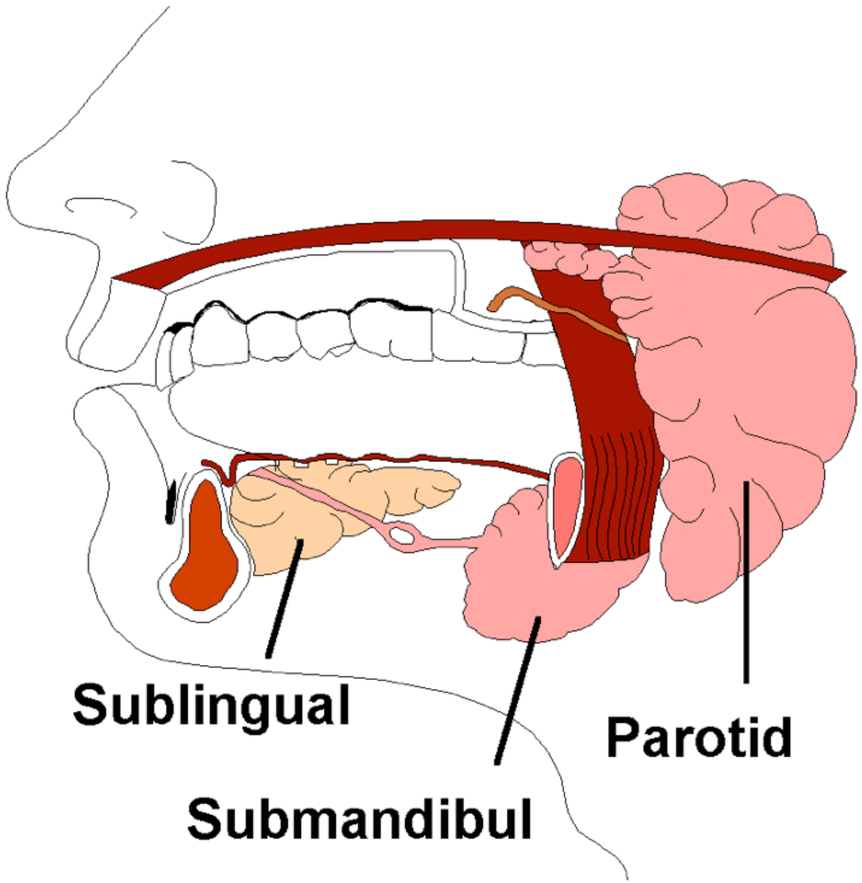


Rest-and-digest: Parasympathetic activity dominates.

Fight-or-flight: Sympathetic activity dominates.

Complementary

- Sympathetic and parasympathetic on salivary gland function



Cooperative

- Urination
- Erection / ejaculation