AUTONOMIC NERVOUS SYSTEM

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Learning Objectives

- Organization of the Autonomic Nervous System
- Terminology
- Sympathetic Nervous System (SNS)
- Neurotransmitters and Types of Receptors
- Parasympathetic Nervous System
- Autonomic Receptors: Adrenoreceptors, Cholinorecptors
- Prototypes of Agonists and Antagonists to Autonomic Receptors
- Sympathetic and Parasympathetic Tone
- Function of Adrenal Gland
- Examples of The Effects of Sympathetic and Parasympathetic

SOMATIC AND AUTONOMIC NERVOUS SYSTEM

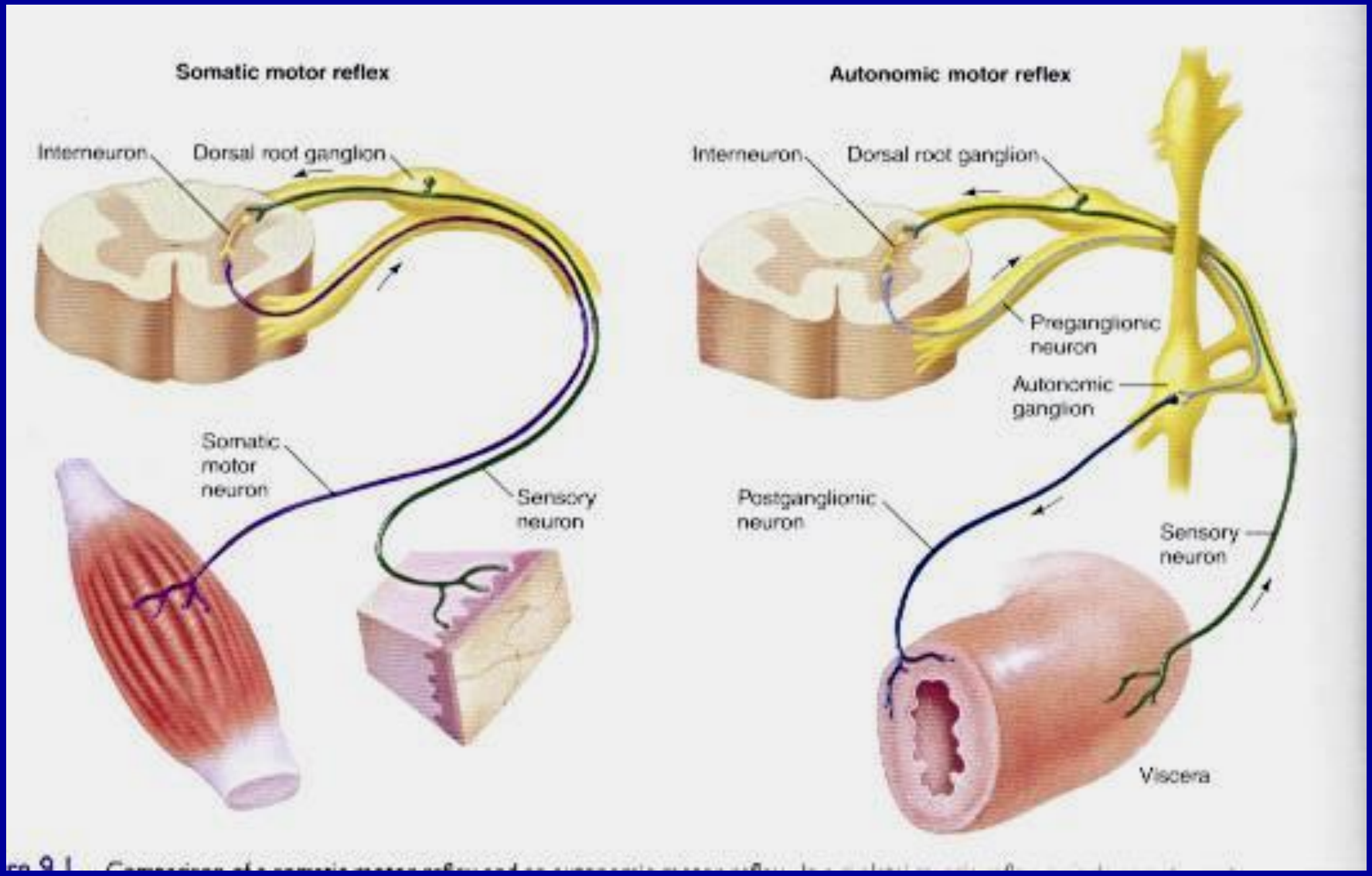
- The motor efferent nervous system has two components:
  - Somatic
  - Autonomic

❖ Somatic Nervous System

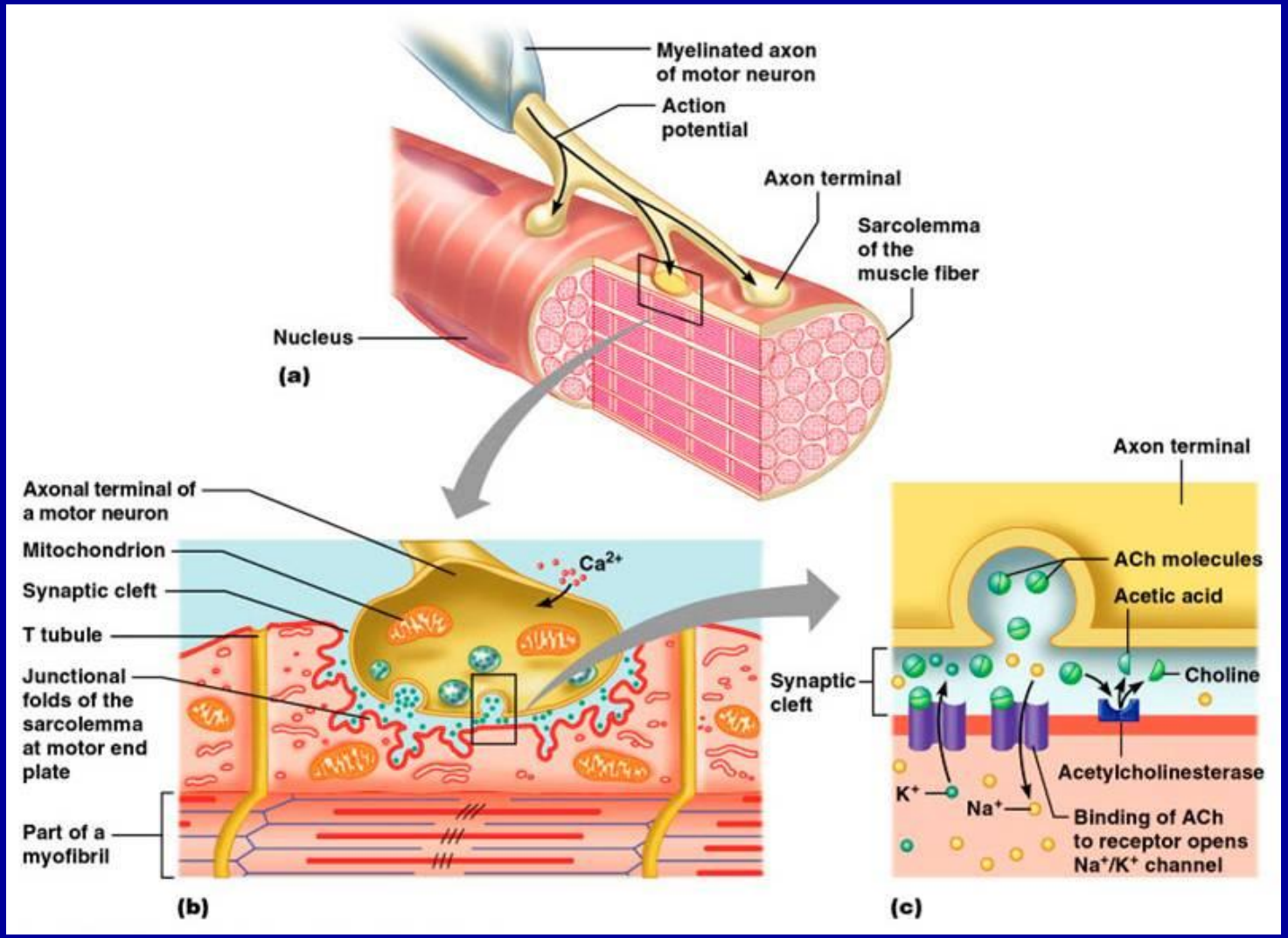
➢ a voluntary nervous system under conscious control

➢ consists of a single motoneuron and skeletal muscle fibers

Organization of the Autonomic Nervous System



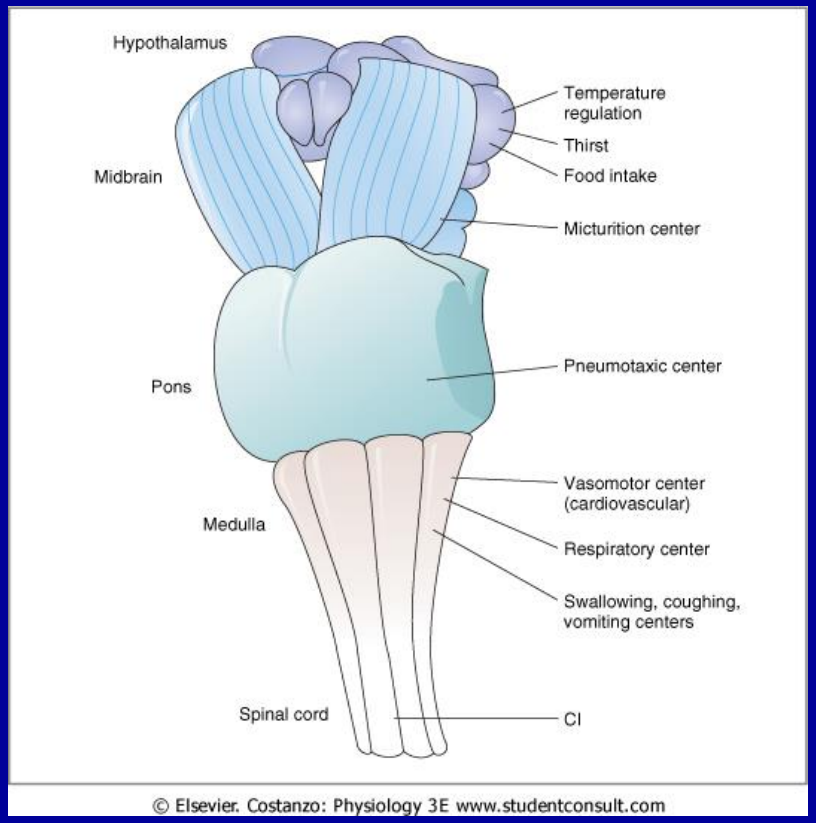
Somatic Nervous System



Organization of the Autonomic Nervous System

- An involuntary nervous system that modulates and controls the function of visceral organs
- Autonomic nervous system (ANS) consists of two major divisions:

  Sympathetic
  Parasympathetic
- ANS is activated by centers in spinal cord, brain stem and hypothalamus
- ANS is operated by visceral reflex



Autonomic Nervous System (ANS)

- Organization of autonomic nervous system motor pathway consists of two neurons:
  - Preganglionic neuron
  - Postganglionic neuron

Autonomic Nervous System (ANS)

- All preganglionic neurons release Acetylcholine (Ach)
- Post ganglionic neurons release either Ach, or norepinepherine

Terminology

- Sympathetic and parasympathetic are anatomic terms and refer to anatomic origin of preganglionic neurons in the centeral nervous system (CNS)

- Adrenergic and Cholinergic terms are used to describe neurons of either division, according to which neurotransmitter they synthesize and release.

Terminology

- Adrenergic neurons release nor-epinephrine and the receptor is adrenoreceptor

- Cholinergic neurons release Ach and the receptor is cholinergic

Sympathetic Nervous System (SNS)

Sympathetic Nervous System (SNS)

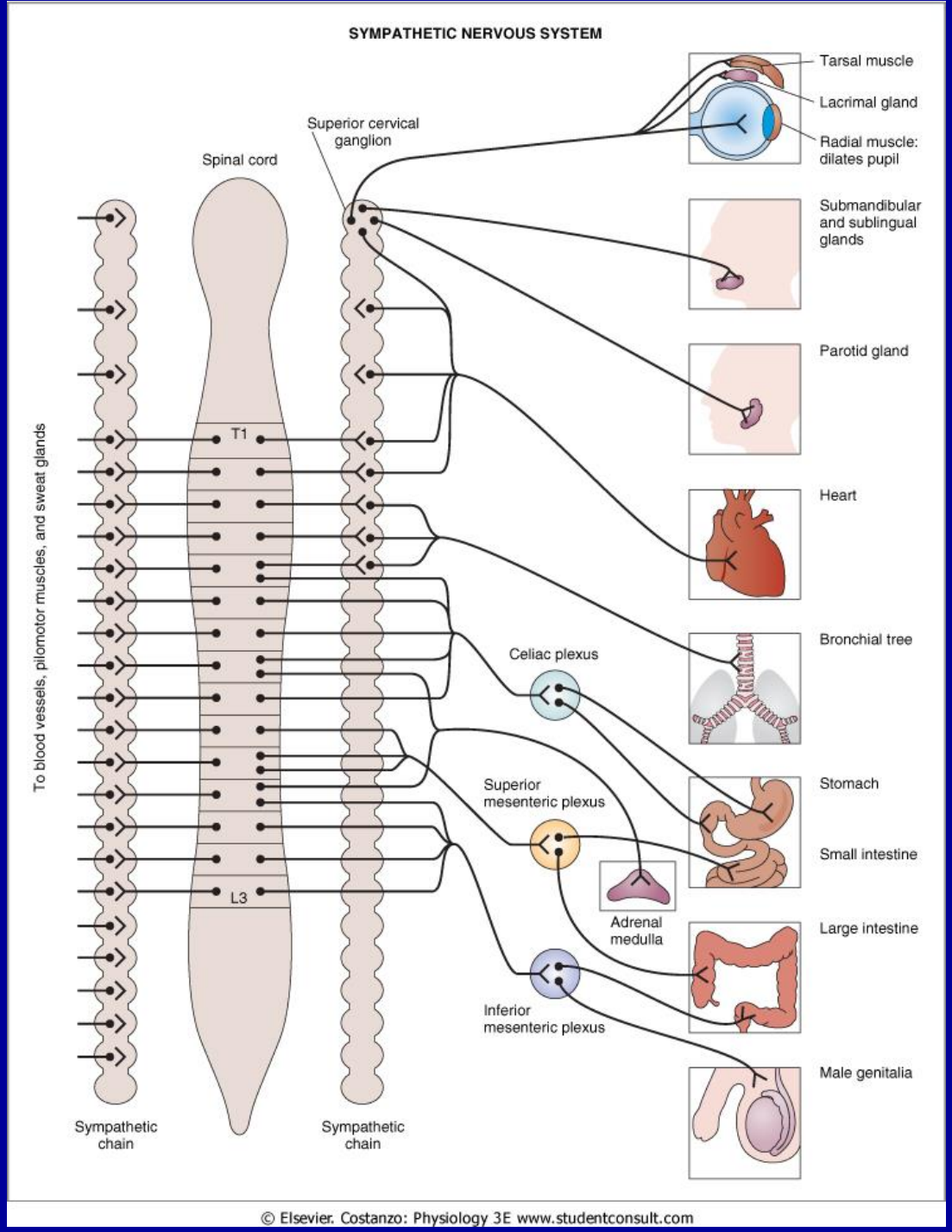
- Operates continuously to modulate the functions of many organ systems e.g; heart, blood vessels, gastrointestinal tract, bronchi and sweat glands

- Stressful stimulation activates SNS leads to a response known as "fight or flight": increased arterial pressure, blood flow, blood glucose, metabolic rate and mental activity

Sympathetic Nervous System (cont.)

- Sympathetic preganglionic neurons originate from thoracolumbar spinal cord (T1-L3)
- SNS ganglia are located near the spinal cord either in the paravertebral ganglia (sympathetic chain) or in the prevertebral ganglia
- Preganglionic neurons are short and the post ganglionic neurons are long

Sympathetic Nervous System (cont.)



Neurotransmitters and Types of Receptors

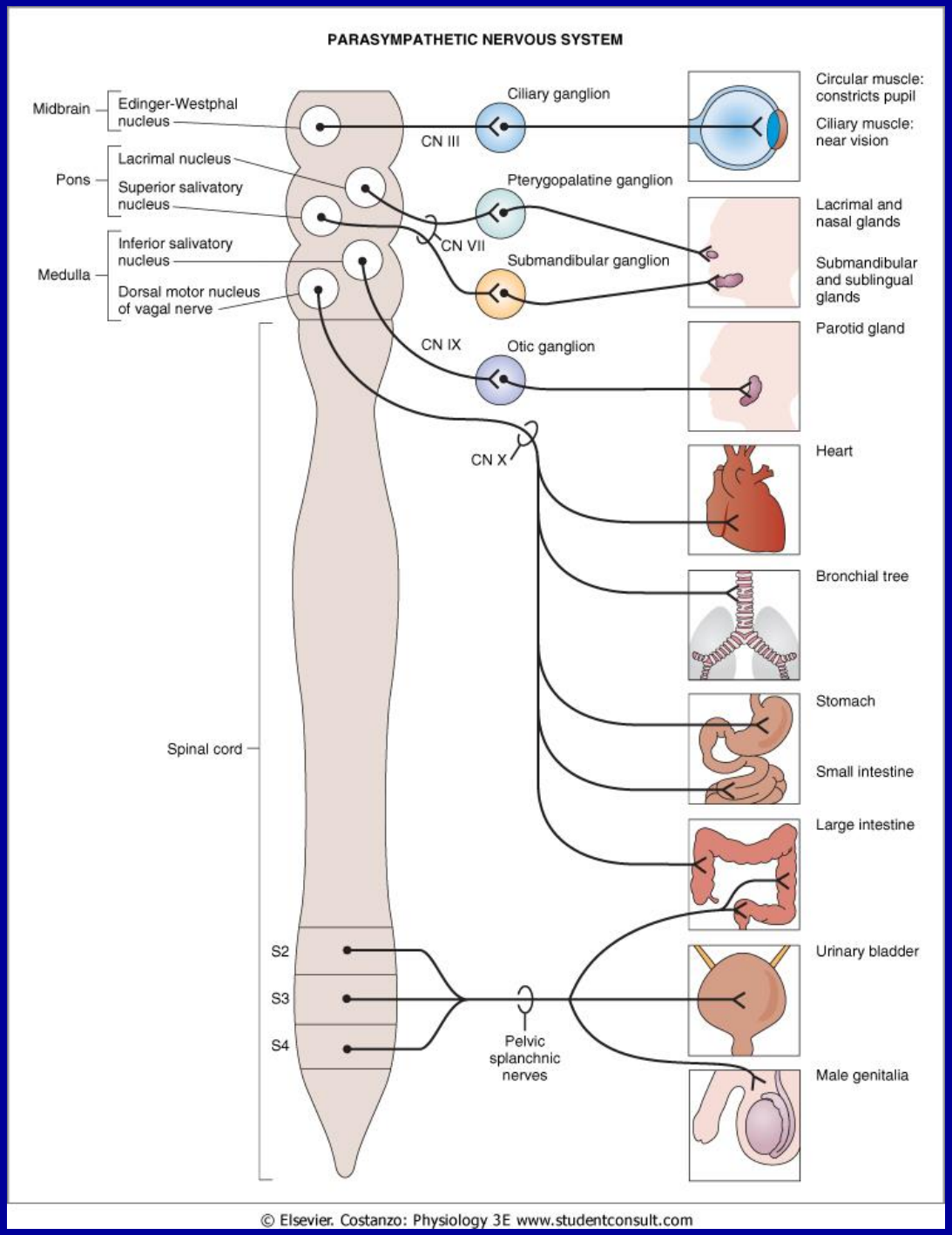
- Preganglionic neurons are always cholinergic
  - Release Ach, interacts with nicotinic receptors on the cell body of postganglionic neurons
- Postganglionic neurons are adrenergic except in thermoregulatory sweat glands (muscranic, cholinergic)
- Adrenergic neurons affect adrenorecepters: $alpha_1$, $alpha_2$, $beta_1$, $beta_2$

Parasympathetic Nervous System

Parasympathetic Nervous System

- Preganglionic fibers originate from cranial nuclei in brain stem (mid brain, pons, medulla) and in sacral segments (S_2-S_4) (Craniosacral)
- Parasympathetic ganglia are located on or in the affected organs
- Preganglionic neuron has long axon and postganglionic neuron has short axon

Parasympathetic Nervous System

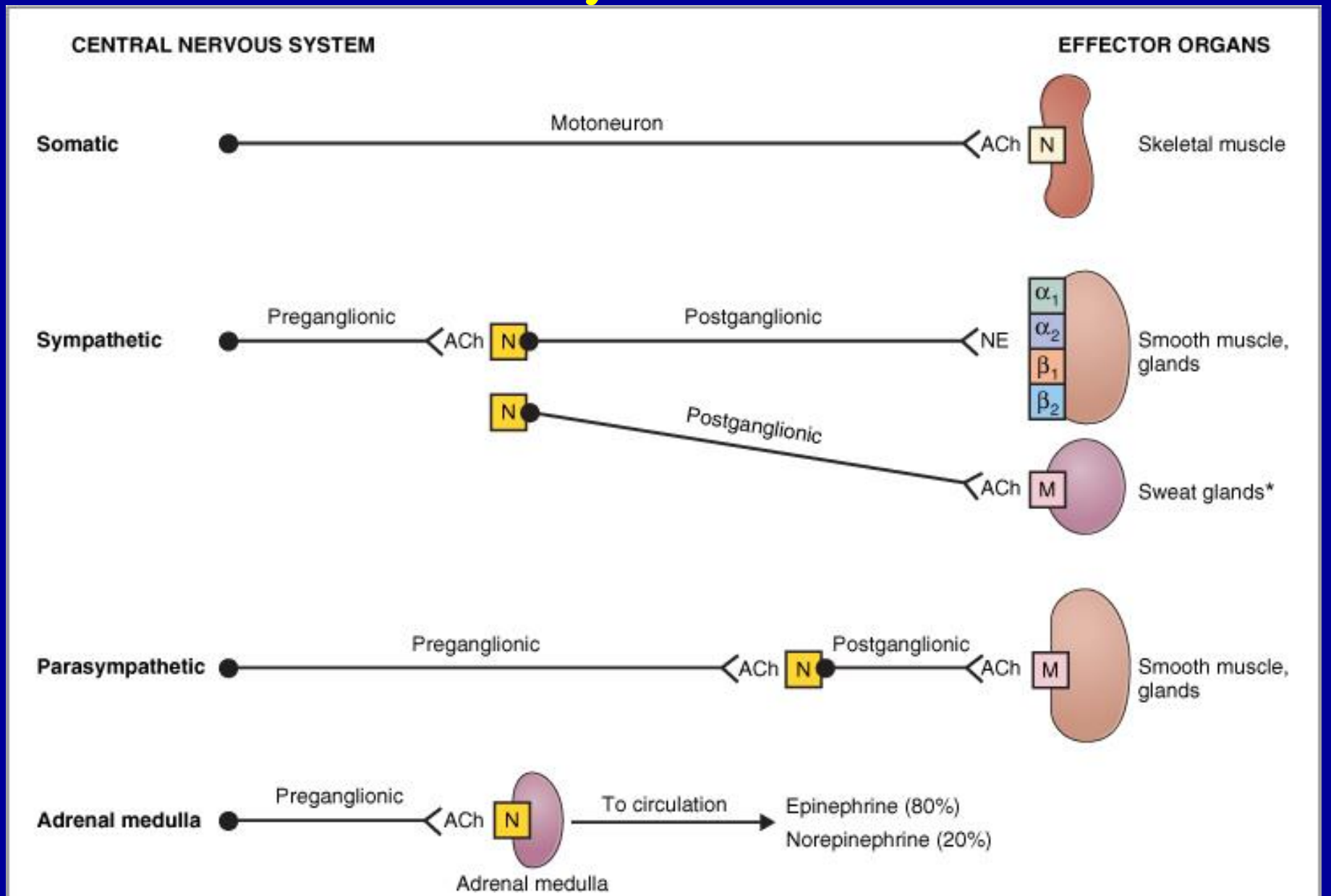


Neurotransmitters and types of receptors

- All preganglionic neurons are cholinergic, release Ach which interacts with nicotinic receptors

- Postganglionic neurons are cholinergic, release Ach which interacts with muscrinic receptors

Organization of the Autonomic Nervous System



Autonomic Receptors

- Adrenoreceptors
- Cholinoreceptors

Adrenoreceptors

α_1 receptor: found in vascular smooth muscle, gastrointestinal (GI) sphincters and bladder, radial muscle of iris:

- Activation of α_1 ⟶ ↑ contraction.

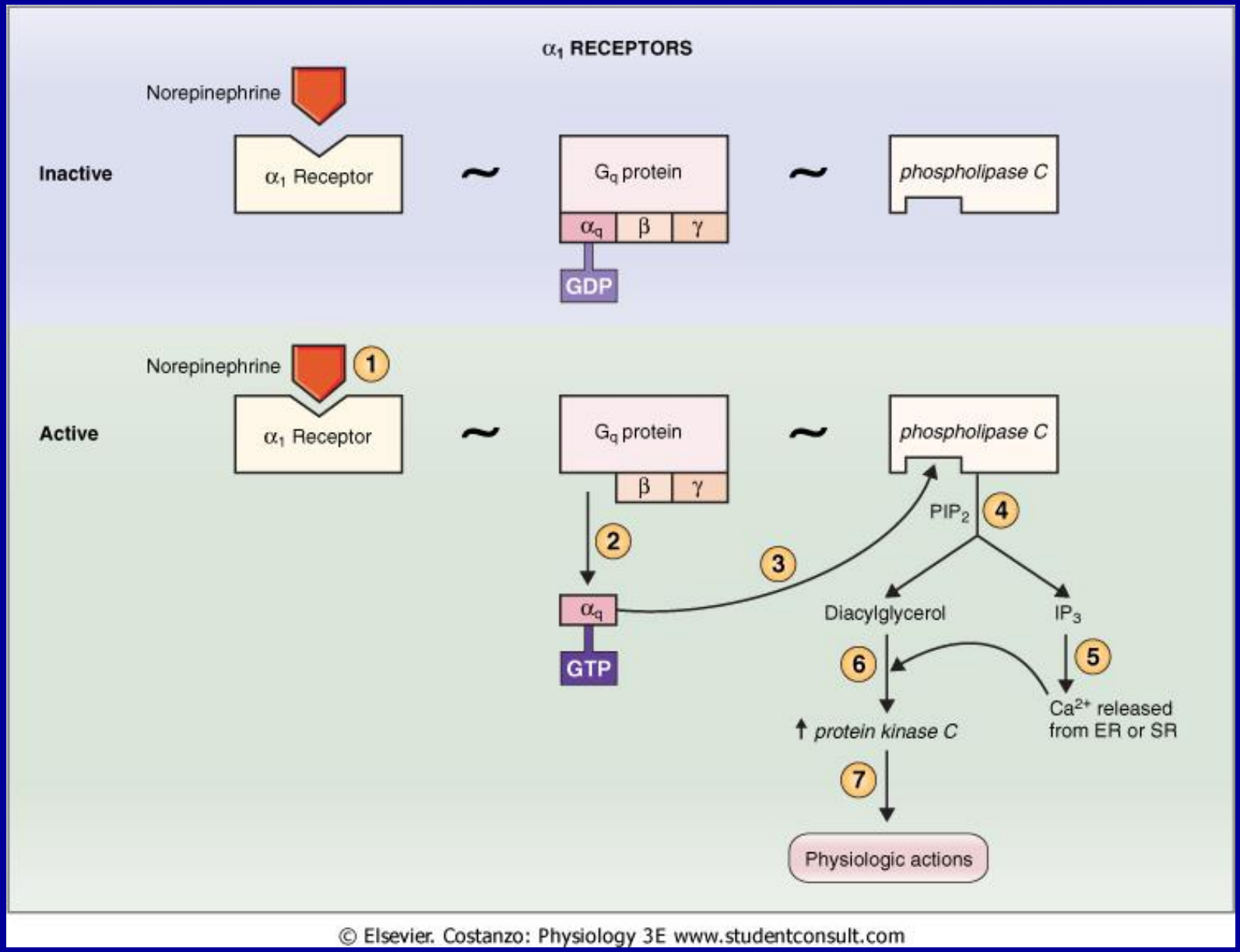
β_1 receptor: is found in the following tissues:

- S.A node ⟶ ↑ heart rate.
- AV node ⟶ ↑ conduction velocity.
- Ventricular muscle ⟶ ↑ contractility.
- Salivary gland ⟶ ↑ salivary secretions, (enzymes only)

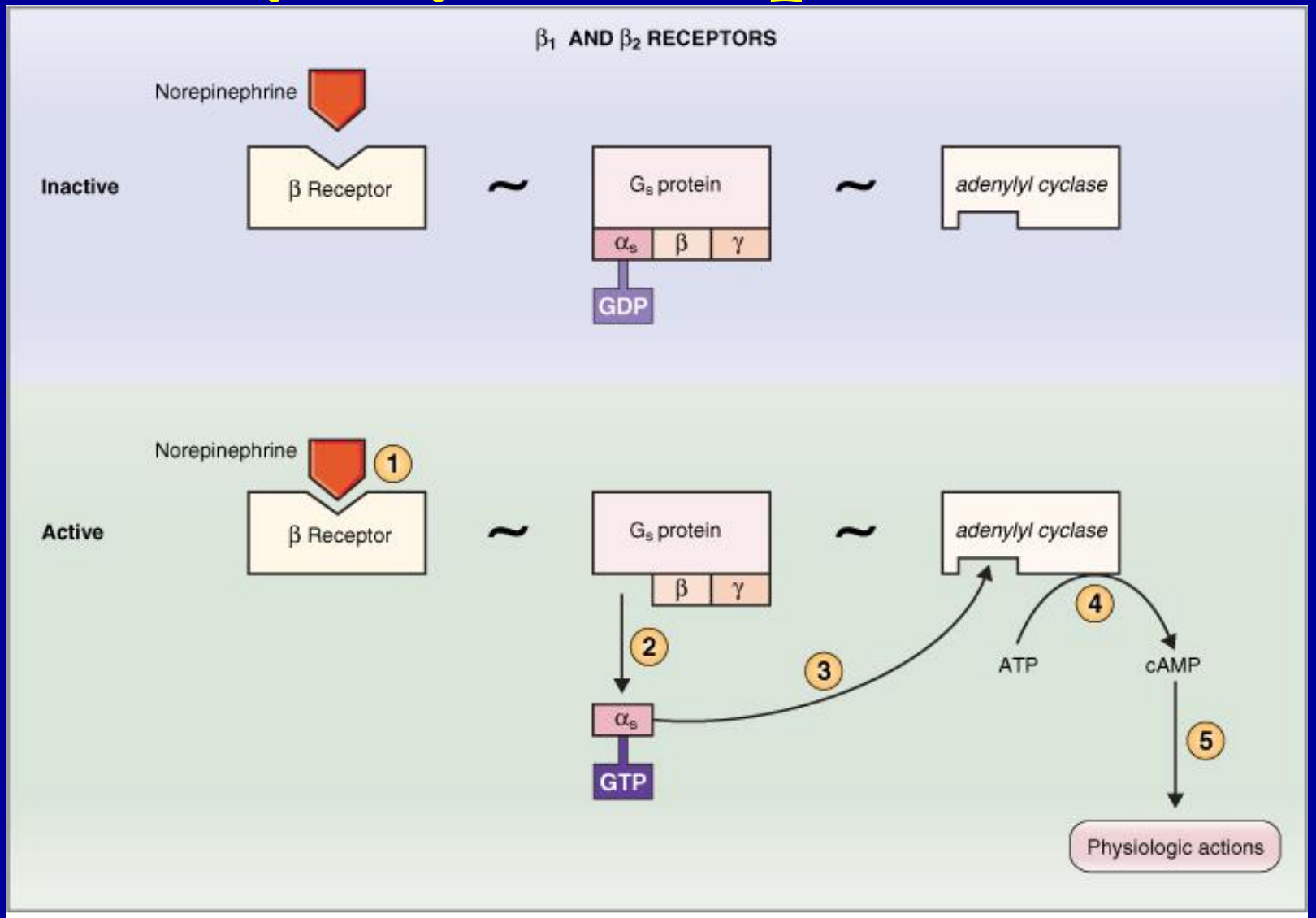
β_2 receptors:
found in vascular smooth muscle wall of bladder, and wall of GI.

- Activation of β_2 ⟶ relaxation.
- β_2 more sensitive to Epinephrine than Nor-epinephrine.

α1 receptor



β1, β2 receptors



Cholinorecepters

- **Nicotinic Receptor (N):**

  - an ion channel for Na+ and K+

  - in all postganglionic neurons, motor end plate at skeletal muscle and chromaffin cells

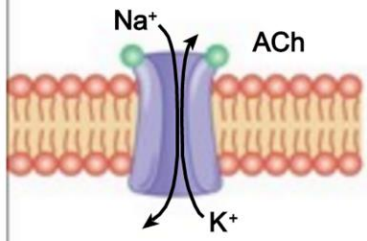
- **Muscurinic Receptor (M):**

  - Works either like α_1 adrenoreceptor via DAC, PKC and IP3 or via G protein which has α subunit that binds K+ channel and open it.

Cholinorecepters

Nicotinic ACh receptors

Postsynaptic membrane of
- All autonomic ganglia
- All neuromuscular junctions
- Some CNS pathways



Ligand-gated channels (ion channels are part of receptor)

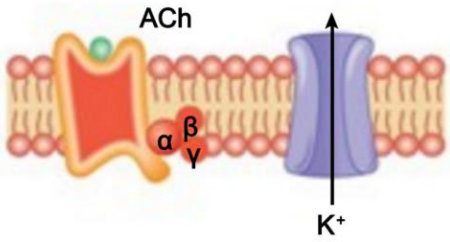
Depolarization

↓

Excitation

Muscarinic ACh receptors

- Produces parasympathetic nerve effects in the heart, smooth muscles, and glands
- G-protein-coupled receptors (receptors influence ion channels by means of G-proteins)

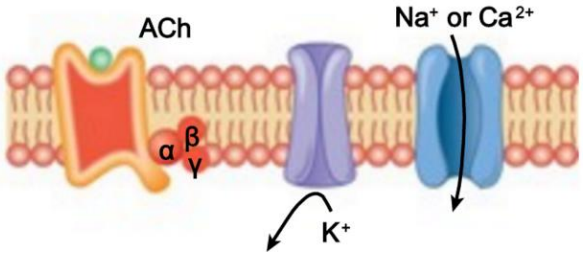


Hyperpolarization

↓ (K^+ channels opened)

Inhibition

Produces slower heart rate



Depolarization

↓ (K^+ channels closed)

Excitation

Causes smooth muscles of the digestive tract to contract

Autonomic Receptors (in summary)

- The type of receptor and its mechanism of action determine the physiologic response: e.g. β_1 receptor in SA node and in ventricular muscle:

➢ SA node: activation of SA node by the agonist (Norepinephrine) → ↑ heart rate

➢ ventricular muscles → ↑ contractility

Prototypes of Agonists and Antagonists to Autonomic Receptors

Receptor	Agonists	Antagonists
Adrenoreceptors		
α_1	Norepinephrine	Phenoxybenzamine
	Phenylephrine	Prazosin
α_2	Clonidine	Yohimbine
β_1	Norepinephrine	Propranolol
	Isoproterenol	Metoprolol
β_2	Epinephrine	Propranolol
	Isoproterenol	Butoxamine
	Albuterol	
Cholinoreceptors		
Nicotinic	ACh	Curare
	Nicotine Carbachol	Hexamethonium (blocks ganglionic receptor but not neuromuscular junction)
Muscarinic	ACh	Atropine
	Muscarine	
	Carbachol	

Sympathetic and Parasympathetic Tone

- The role of them is to keep the stimulated organs in normal stage.
- Examples:

1. sympathetic always keeps the blood vessel constricted ½ of its normal diameter.
2. removal of vagus nerve → atony → loss of peristalsis (contraction of small intestine) → constipation.

Effect of loss of sympathetic and parasympathetic tone after denervation

- Loss of sympathetic tone in blood vessel causes severe vasodilatation but after sometime, intrinsic tone increases by chemical adaptation.

Function of Adrenal Gland

- Stimulation of sympathetic nerves causes large quantities of Epinephrine and Nor-epinephrine to be secreted in blood from adrenal gland.
- The effect of Epinephrine & Nor-epinephrine lasts 5-10 times more than the ones which secreted from sympathetic.

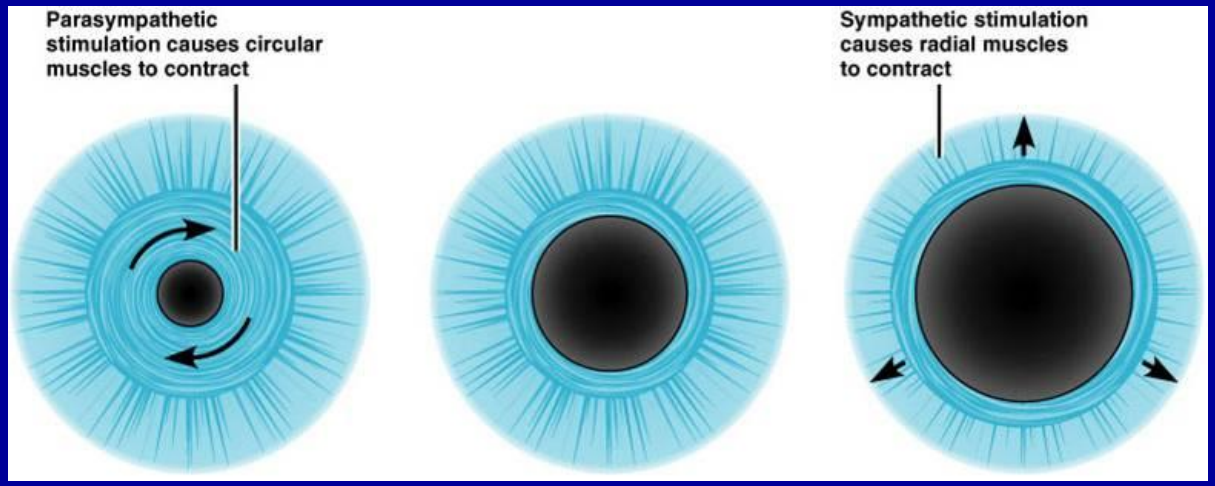
Examples of The Effects of Sympathetic and Parasympathetic

Effects of Sympathetic and Parasympathetic stimulation on specific organs

The Eyes:

- Sympathetic stimulation contracts the meridional fibers of the iris to dilate the pupil.
- Parasympathetic stimulation contracts the circular muscle of the iris to constrict the pupil.
- Focusing of the lens is controlled by parasympathetic through contraction of ciliary muscle.

Pupil Dilation and Constriction



Effects of Sympathetic and Parasympathetic stimulation on specific organs

- **The Glands:**

  - Controlled by parasympathetic → ↑ their secretions.

  - Sympathetic causes vasoconstriction of the blood vessels to the glands which causes reduction in their secretion.

  - Sweat glands secretion:
  increased by sympathetic stimulation.

Effects of Sympathetic and Parasympathetic stimulation on specific organs (continued)

- The Gastrointestinal tract (GI)

  - Enteric nervous system
  - Parasympathetic nervous system increases the activity of GI tract (increases peristaltic contraction, and sphincter relaxation).
  - Sympathetic decreases the activity of GI.

Effects of Sympathetic and Parasympathetic stimulation on specific organs

- **The Heart:**
  - Sympathetic stimulation → ↑ activity of the heart.
  - Parasympathetic stimulation doing the opposite.
- **Systemic Blood Vessels:**
  - Constricted by stimulation of sympathetic.
  - <u>No effect of the parasympathetic except in certain areas, such as blushing of the face.</u>

Effects of Sympathetic and Parasympathetic stimulation on specific organs

- **Arterial Pressure:**
  - Sympathetic stimulation → ↑ the cardiac output and ↑ resistance to the blood flow and blood pressure.

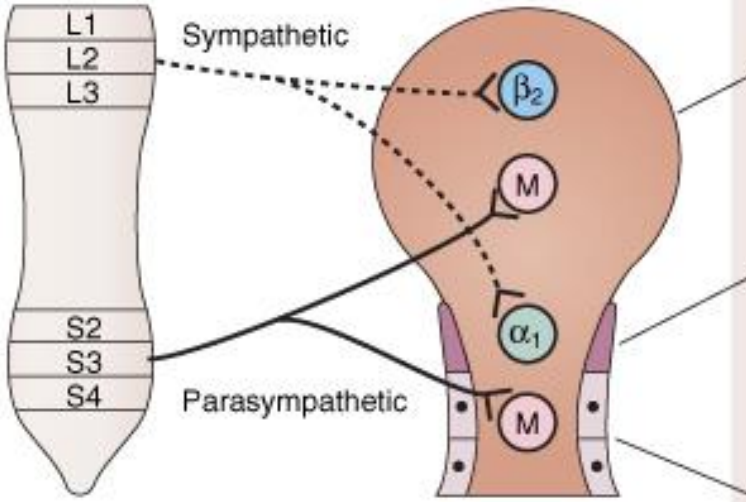
  -Parasympathetic → ↓ cardiac output and has no effect on blood vessels.

Autonomic Reflexes

Most of the visceral functions of the body are regulated by autonomic reflexes.

- **Cardiovascular:**
  - baroreceptor reflex:
  It is a stretch reflex in the main arteries such as carotid artery to detect the blood pressure.
- **Gastrointestinal:**
  The receptors in the nose and mouth send a signal to parasympathetic to notify the glands of mouth & stomach to secrete the digestive juices.
- **Urinary Bladder:**
  - Initiate the micturition (urination) by parasympathetic innervations.
- **Sexual reflexes: erection by parasympathetic, ejaculation by sympathetic.**

Urinary Bladder



Muscle	Filling of Bladder		Emptying of Bladder	
	State	Control Mechanism	State	Control Mechanism
Detrusor muscle	Relaxed	Sympathetic (β_2)	Contracted	Parasympathetic (M)
Internal sphincter	Contracted	Sympathetic (α_1)	Relaxed	Parasympathetic (M)
External sphincter	Contracted	Voluntary	Relaxed	Voluntary

Autonomic Reflexes

- Sympathetic activation could occur in isolated portions such as:
  - heart regulation.
  - many sympathetic reflexes that regulate G.I. functions.

- The parasympathetic usually causes specific localized responses:

  - The effect of parasympathetic usually specifies to certain organ , but sometimes there is a common effect of parasympathetic activity by affecting the functions of some organs together such as rectal emptying and bladder emptying, salivary secretion and gastric secretion.

The End