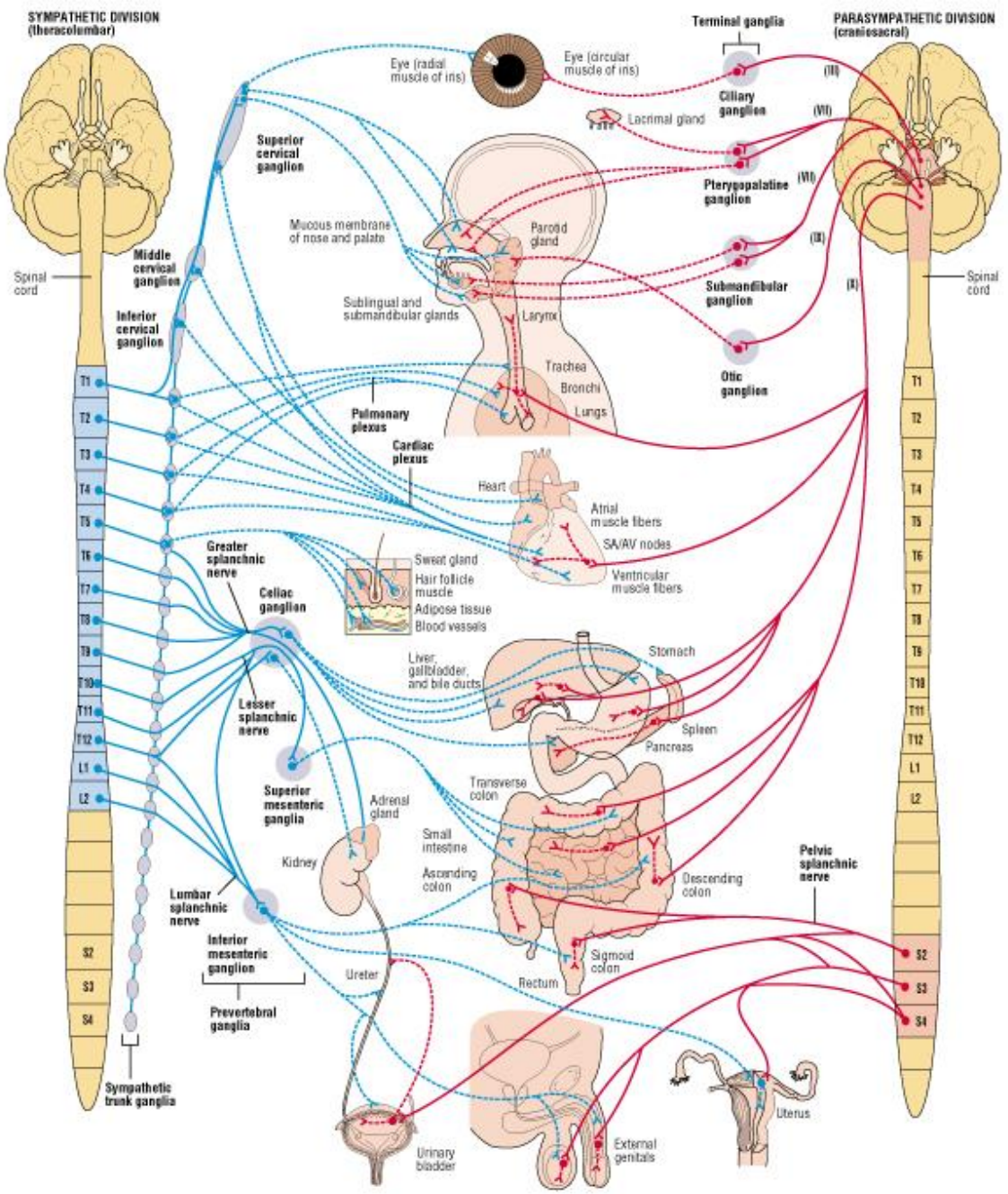
Autonomic Nervous System

Autonomic Nervous System

Ref: **Textbook of Medical Physiology,** Guyton, 14th Ed.:763-773, 13th ed.: 773-784. 12th ed: 729-738, and 11th ed. P748-760.

Fig.17.02



2 divisions of ANS

General functions

importance ↘

Control and Adaptation of body systems to internal and/or external changes

Example of adaptation to external stimuli

Fight and Flight Reaction → Sympathetic.

in both situations we need the activity of muscles.

↓

All body systems are working to increase the delivery of O_2 towards these muscles.

(1) -Increase heart rate and force of contraction. → more delivery of O_2 → muscles.

-Widely dilated pupils. "mydriasis" (to see all details of that dangerous object).

-Pallor (pale of fear) as blood is directed to the skeletal muscle. (discoloration of skin)

we have vascularization in skin → in this case we reduce / redistribute blood → more blood towards muscles → less blood for unnessecary tissues like skin.

↓

Vasoconstriction for vessels supplying skin + vasodilation for ones supplying muscles.

-Goose pimples. = when the hair stands on the skin. → at the base of hair follicles we have smooth muscles (pilocrctor muscles) by activating them it cause the hair to stand up.

-Cold sweat. many sweat glands are activated → (Cold) because of low distribution of blood towards the skin → so we are not heating that sweat.

-Dry mouth. Because we have decreased the activity of GIT, one of it's glands is the salivary gland → decrease in salivation.

* The decrease of secretion happens bcs of vasoconstriction → less fluids available for secrete

What division is involved in the control during fight or flight reaction???

The sympathetic division

ANS characteristics

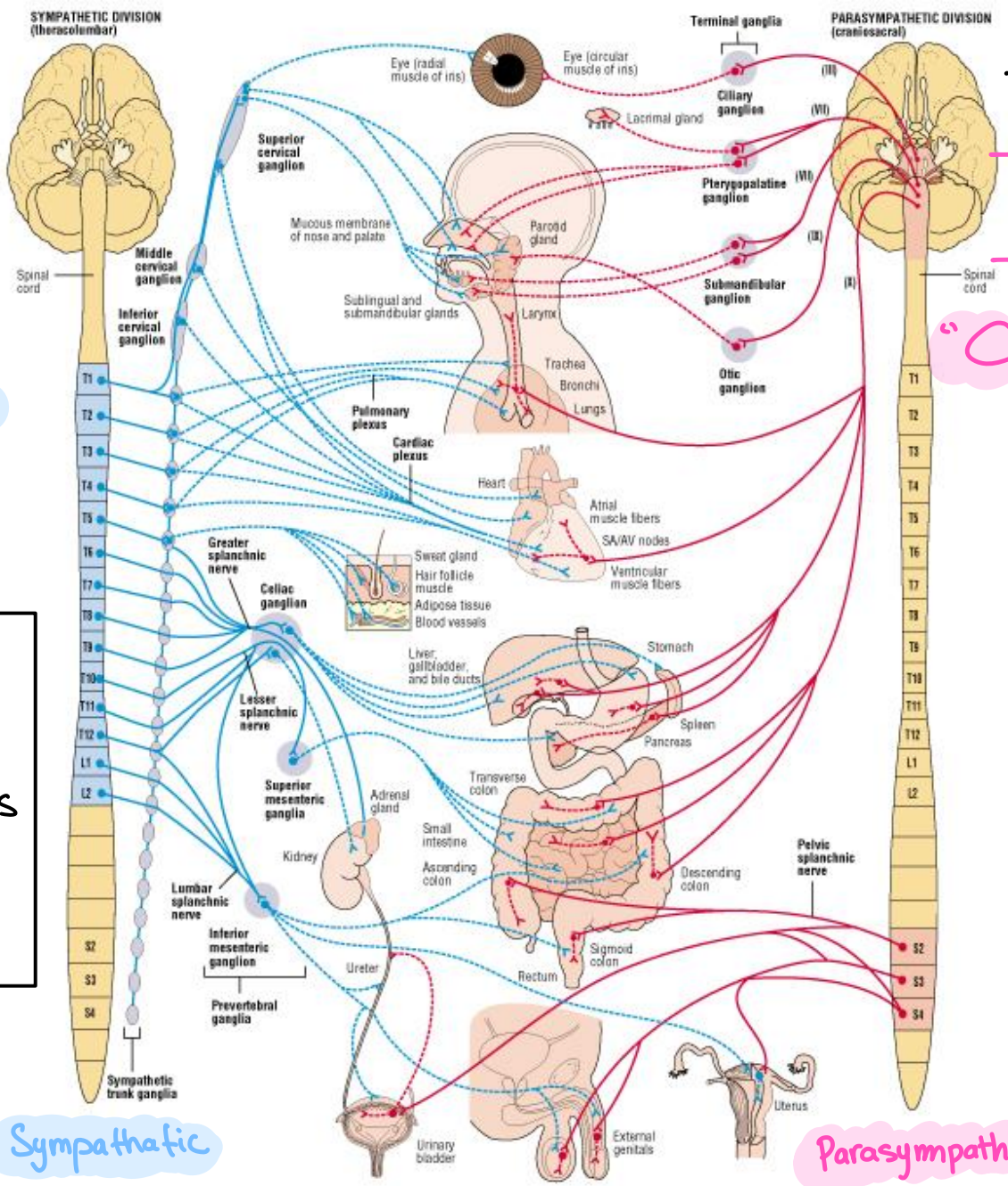
1. Anatomical characteristics and
2. Synaptic organization of ANS

Fig.17.02

Origin :-

→ Spinal Cord ($T_1 \rightarrow L_2$)

"thoracolumbar"



Origin :-

→ Base of the Brain

→ Sacral region.

"Craniosacral"

Similarities :-

→ from the origin until the effector we have 2 neurons forming the axe of that division.

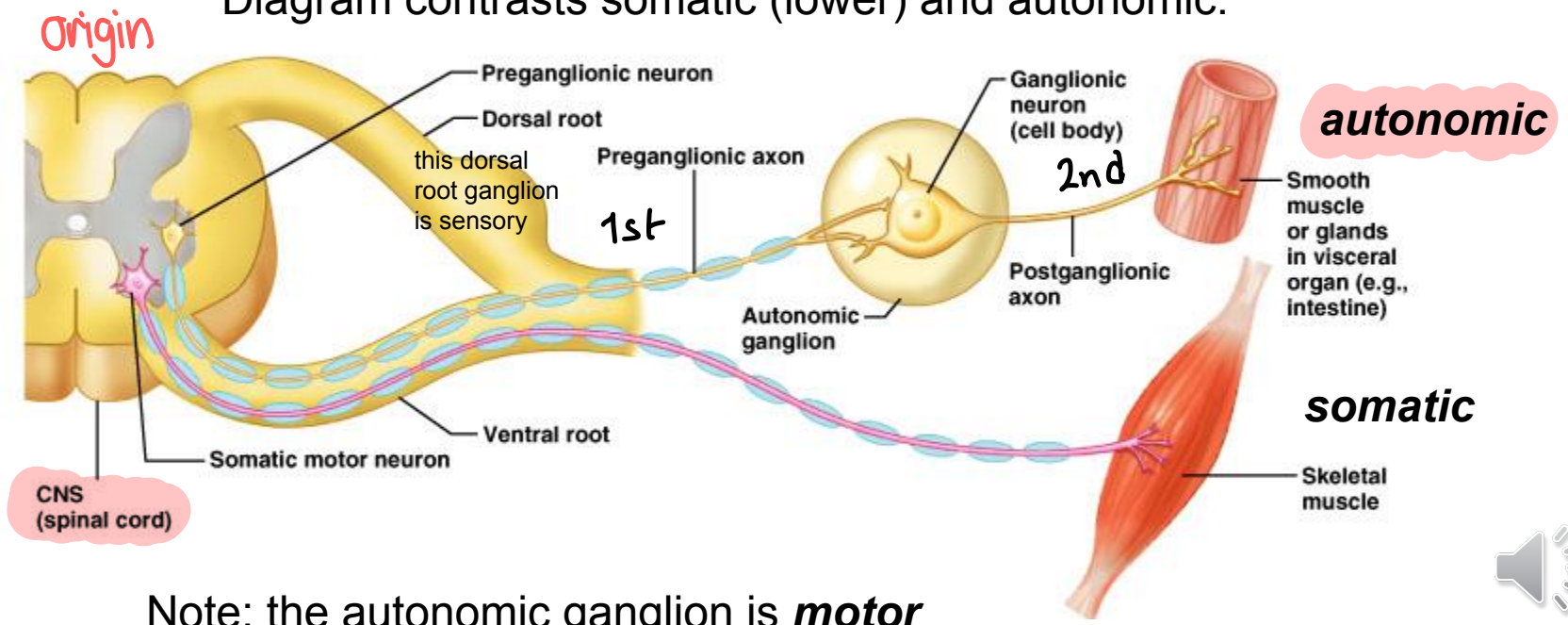
Sympathatic

Parasympathetic.

- Axon of 1st (*preganglionic*) neuron leaves CNS to synapse with the 2nd (*ganglionic*) neuron
- Axon of 2nd (*ganglionic*) neuron extends to the organ it serves

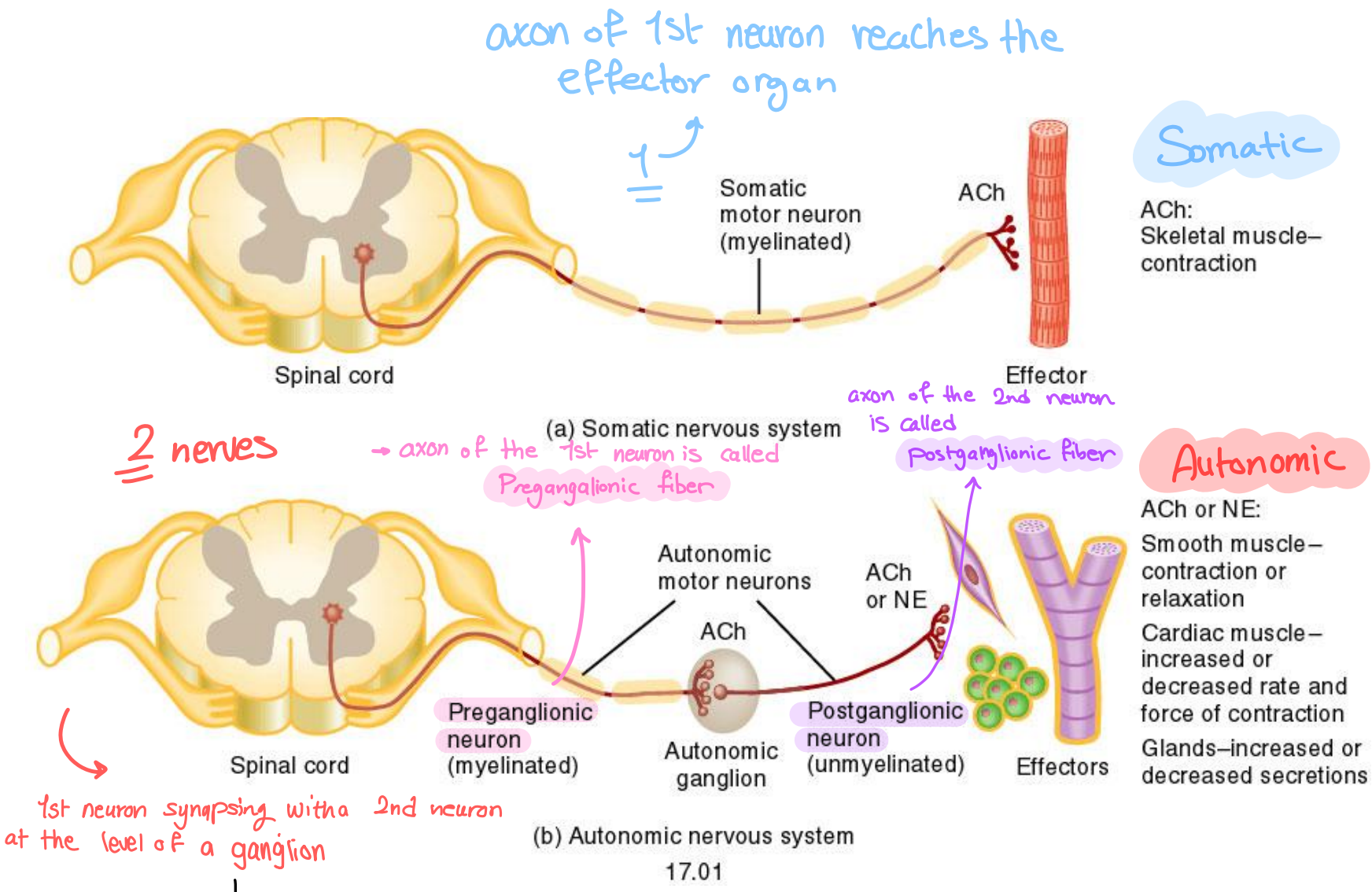
→in somatic we have only one neuron forming the axe from the origin until the effector.

Diagram contrasts somatic (lower) and autonomic:



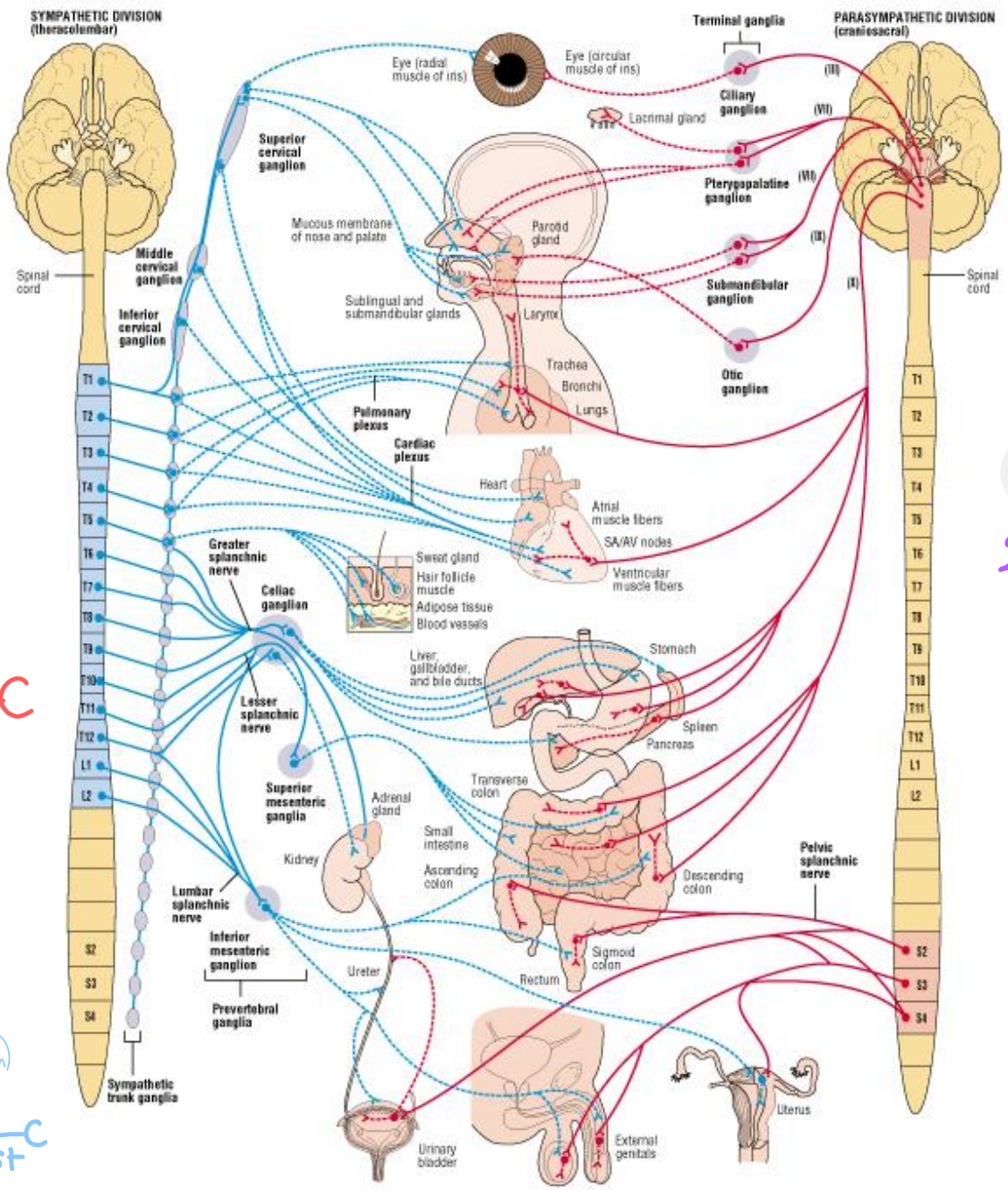
Note: the autonomic ganglion is ***motor***

Fig.17.01



↳ a ganglia : is a cluster of cell body of neurons which represents the 2nd neuron.

Fig.17.02



• differences :-

→ Sympathatic.

Preganglionic fibers

short

Postganglionic fibers

Long

→ Parasympathetic

Preganglionic Fibers

Long

Postganglionic fibers

Short (located at the effector organ)

• Similarities :-

2 neurons forming the arc

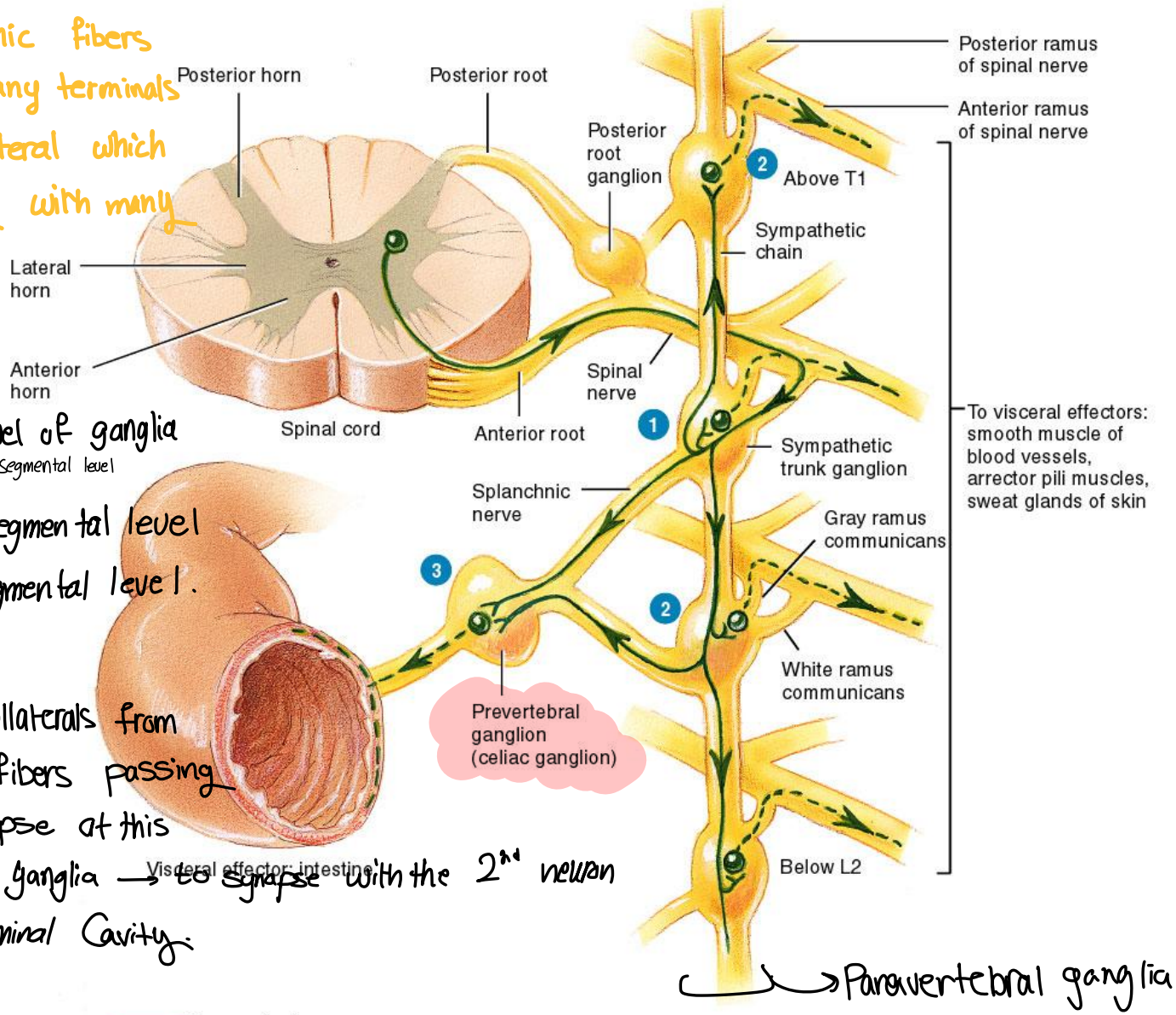
Synaptic organization of ANS

Convergence and Divergence in Sympathetic division

• Divergence ⇝ in Sympathetic

Fig. 17.05

→ pregagnlionic fibers are having many terminals and many collateral which are synapsing with many neurons



→ at the level of ganglia
at the Segmental level
→ upper segmental level
→ lower segmental level.

Some also collaterals from Preganglionic fibers passing without synapse at this paravertebral ganglia → to synapse with the 2nd neuron in the abdominal Cavity.

→ Paravertebral ganglia.

→ the group of ganglia found inside abdominal cavity ⇒ Pre vertebral Ganglia.

17.05

Convergence

→ neuron located at the same segmental level → it can recieve terminals or preganglionic fibers synapsing with that neuron coming from upper / lower / same segmental level of the sympathetic division to synapse with that neuron.

Collateral from many neurons synapsing with one neuron ⇒ Convergence.

* parasympathetic → we don't have that high divergence and convergence *

A difference between sympathetic + para in the synaptic organization.

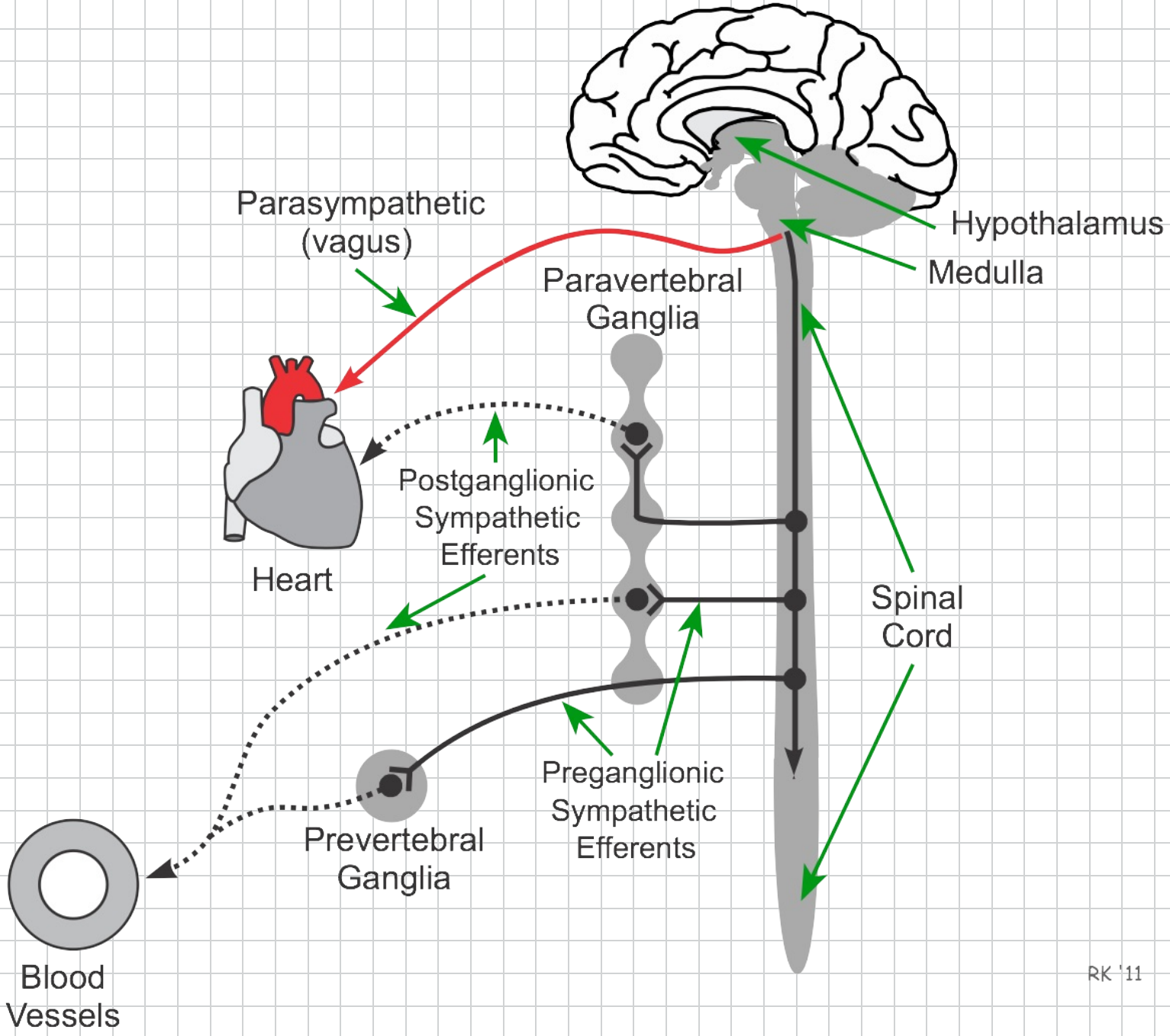

Parasympathetic
(vagus)
Hypothalamus
Medulla
Paravertebral
Ganglia
Heart
Postganglionic
Sympathetic
Efferents
Spinal
Cord
Preganglionic
Sympathetic
Efferents
Prevertebral
Ganglia
Blood
Vessels
RK '11

Fig.17.02

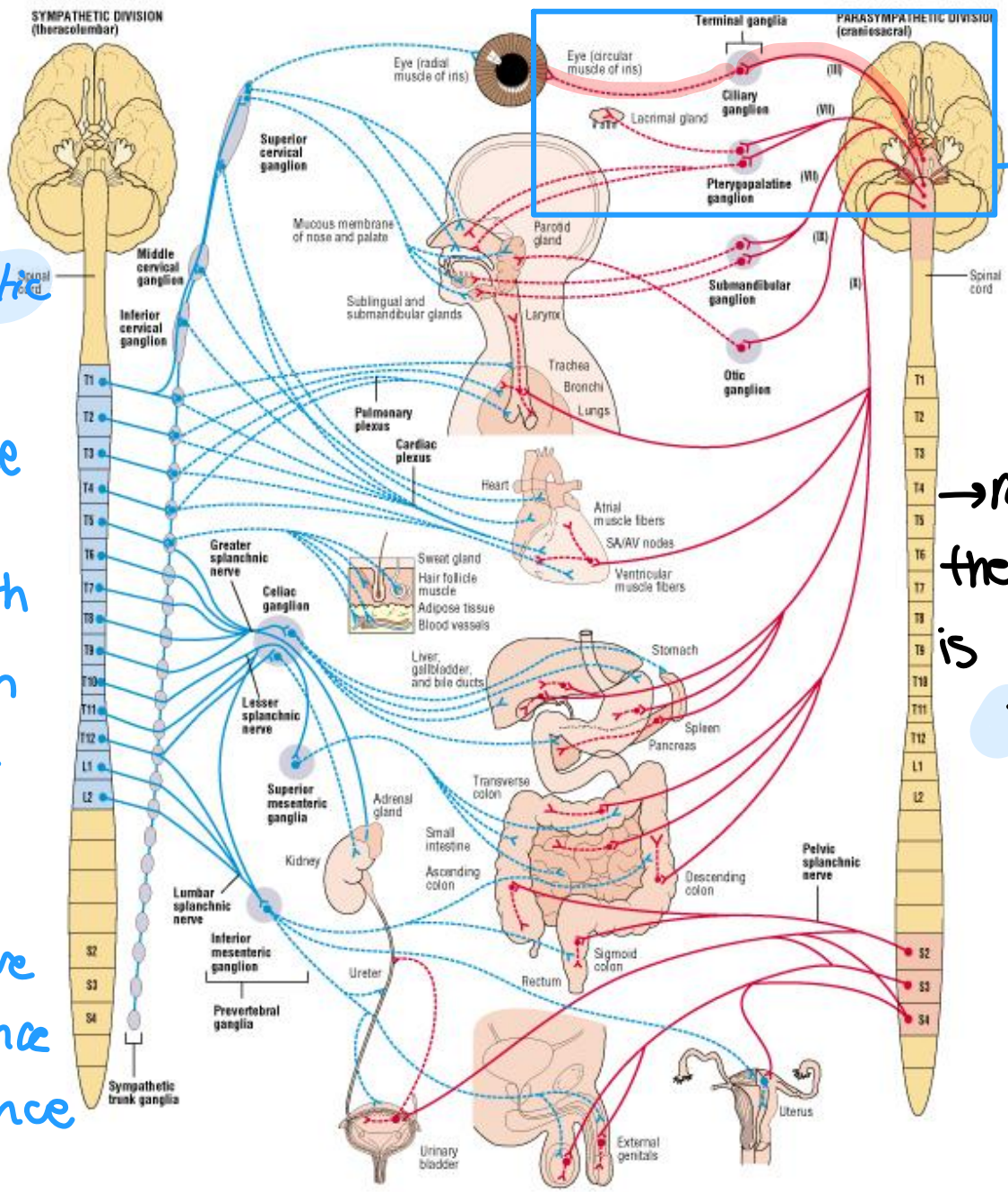
Divergence + Convergence In Parasympathetic

↓

the axon of the 1st neuron is synapsing with the 2nd neuron located at the organ it self

↓

we don't have that divergence and convergence



neuron is located at the organ.

→ ratio between the pre + post is almost 1:1

Synaptic organization of ANS

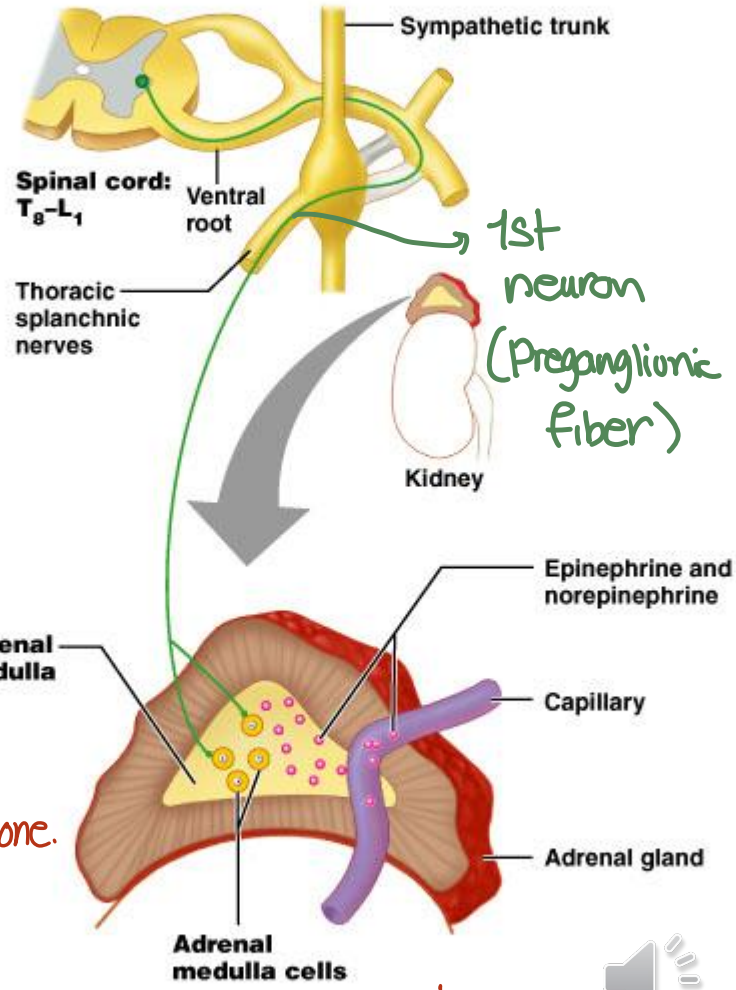
What is the importance for having more Convergence and Divergence in the Sympathetic division?

→ by stimulating the **sympathetic** system, because of that synaptic organization the reaction that you are getting is more **diffuse** reaction. [at fight or flight we are getting All the reactions. High sweating, increased heart rate, dry mouth. ...]

→ but in **Parasympathetic** → we have no convergence or divergence → the reaction for parasympathetic stimulation is more **Localized**. [eating → activates stomach only, but no decrease in ♡ rate]

Adrenal gland is exception

- Synapse in gland
- Can cause body-wide release of epinephrine



↝ we can have some collaterals passing

Para vertebral ganglia ↝ pre vertebral ganglia

↝ suprarenal glands ↝ Adrenal Medulla

↳ where we have endocrine cells, that releases

- epinephrine as a hormone.

↳ synapsing with endocrine cells from suprarenal glands.

Physiological characteristics of ANS

- High speed of onset: there's no delay in getting response.
- Automatic nature: you can't control it, it is involuntary act
- Tonic activity: to get the control by sympathetic or parasympathetic stimulation.
  - ↳ Certain level of activity

for example:

→ neurons of the sympathetic divisions are generating 100 AP per min.
↳ tonic level of activity

we can get that tonic increased by generating more APs per time unit
OR decreasing the tonic activity by generating less APs per time unit.

Effects of sympathetic stimulation

-**Blood pressure** (blood vessels supplying skeletal muscle are major players). In addition to that the effect on heart also contributes in regulation of blood pressure.

- **Body temperature** by the sympathetic effects on cutaneous blood vessels and sweat glands.

↓ Vasodilation ↓ increasing Activity.

• vessels + sweat glands → widely distributed tissues in our body → for the Activity of widely distributed tissues → we need a division that can have **diffuse** effect = **Sympathetic**

→ Widely distributed tissues are Innervated only by sympathetic NS [Ex. Blood vessels / Glands]

Effects of sympathetic stimulation

- **Cardiovascular system**: effects on vessels will result in redistribution of blood by enhancing blood flow to skeletal muscle and reducing blood flow to skin and mesentery.
- **Effects on heart**: increasing cardiac output (volume of blood pumped per minute). → to deliver more oxygenated blood to muscles.
- **Respiratory system**: causes relaxation of bronchial muscle which result in bronchodilation. to get more Air flow towards the lung + more exchange of gases by the lung.
- **Digestive system**: inhibition of motility and secretion.
- **Metabolic effects**:

* Mobilization of glucose.
* Increased lipolysis.
* Increased metabolic rate. → to mobilize nutrients for the activity of muscles to provide these muscles during fight - flight by these nutrients (Shut down any unnessacry tissue)

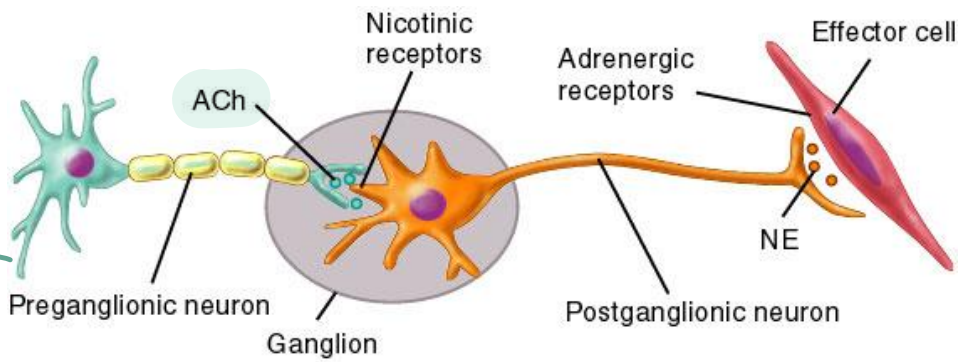
Effects of parasympathetic stimulation

- **Gastrointestinal system**: increases motility and secretory activity.
- **Glands:** increases secretory activity (but remember sweat glands are under sympathetic control).
- **Heart**: decrease rate of contraction (bradycardia).
- **Pupil**: control pupil diameter by papillary light reflex (myosis) (regulates the amount of light falling on retina).
- Accommodation of the **lens** for near vision → by changing convexity of the lense by contraction of some smooth muscles there.
- Voiding the **urinary bladder** (micturation).

MOLECULAR BASIS OF PHYSIOLOGICAL ACTIONS OF THE ANS

- neurotransmitters
- types of receptors

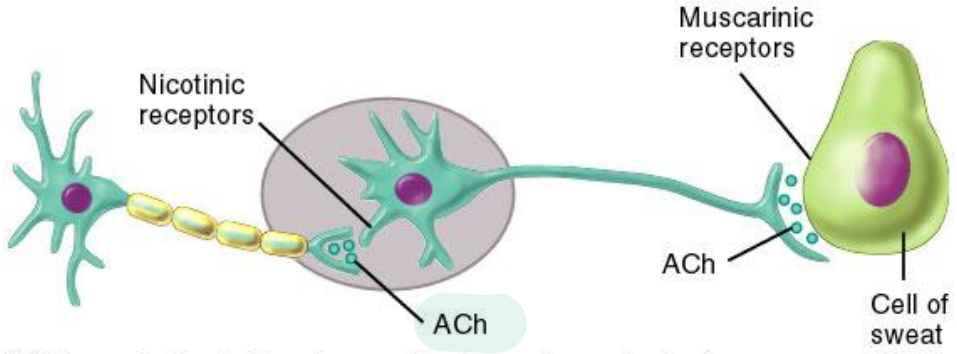
Fig. 17.06



(a) Sympathetic division–innervation to most effector tissues

1

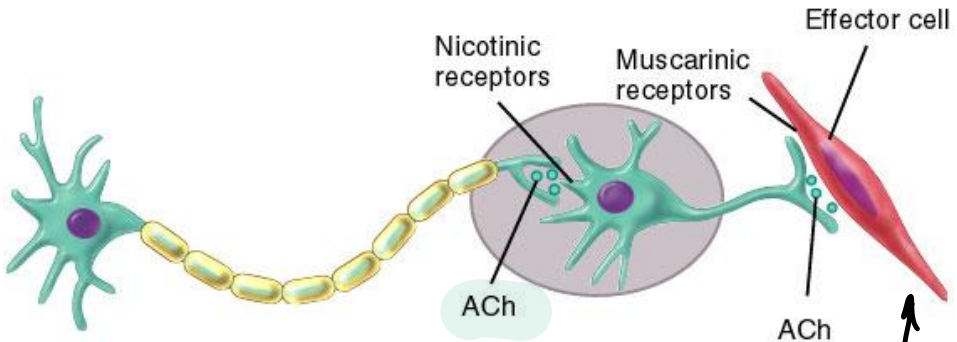
- the Preganglionic fibers are releasing ACh as neurotransmitters in both divisions (sympathetic + Para.)



(b) Sympathetic division–innervation to most sweat glands

2

- Postganglionic
  - → Parasympathetic → Acetylcholine
  - → Sympathetic → norepinephrine
    - ↓
    - exception

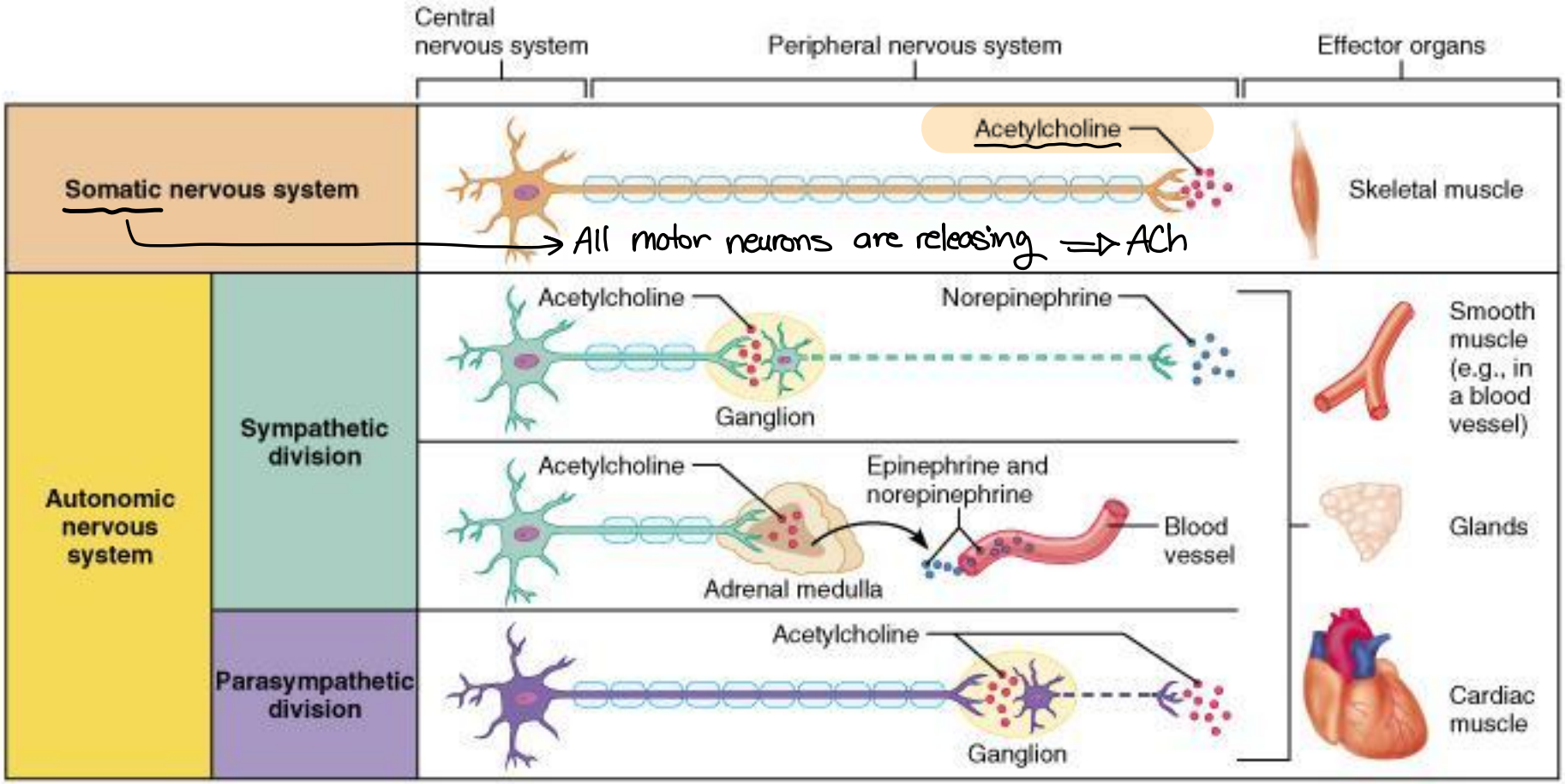


(c) Parasympathetic division

3

↳ effector: Sweat glands / piloerctor muscles = Acetylcholine

difference Between Somatic + Autonomic



Key:

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

– Neurotransmitters

- **At ganglion**: preganglionic neurons of both sympathetic and parasympathetic release **acetylcholine** (Ach).
- **Effector organs:**

  - parasympathetic fibers release **acetylcholine**

  - Sympathetic: **norepinephrine**.
- **An exception** for sympathetic nerves to **sweat glands**, which release **acetylcholine** (Ach).

Don't forget !!
– neurons synapsing with endocrine cells of glands → Are 1st neurons of sympathetic division ≈→ releases ACh

Receptors and Signal transduction mechanisms

- **At ganglia**: sympathetic and parasympathetic have **nicotinic** receptors at the post synaptic membrane
  - ↳ nicotine can stimulate them
  - → Muscarine can activate them.
- **on effector cells: Muscarinic receptors**.

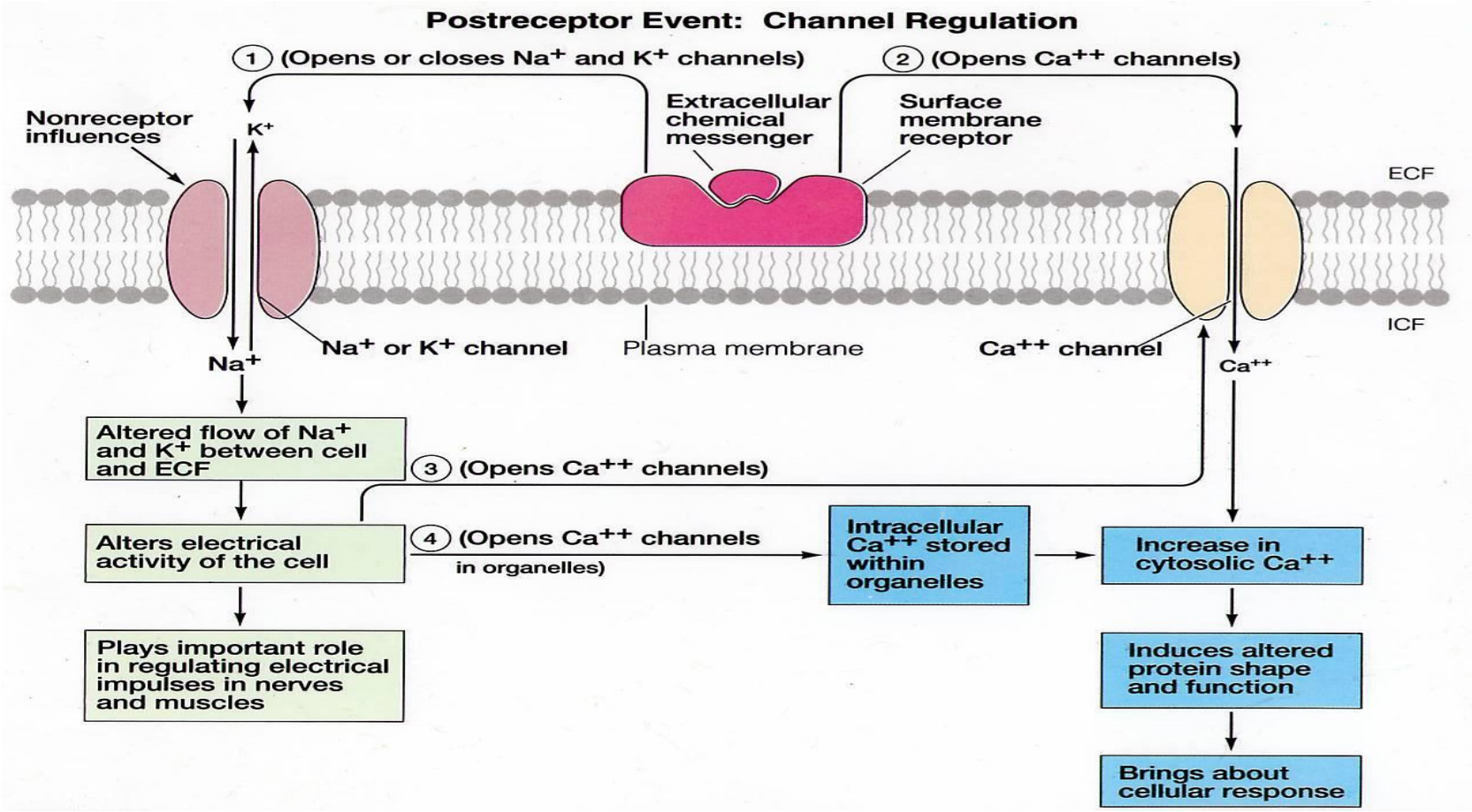
* ACh is also released by terminals of Motor Neurons of the Somatic System ⟶ at the level of skeletal muscles ⟶ type of receptors of Ach are called nicotinic receptors

* At which plant we can find Muscarine ?

Some toxic **Mushroom** is rich with Muscarine ⟶ so if somebody has ingested that mushroom they will develop or activate all muscarinic reseptors in the body.

Signal Transduction Mechanism for Nicotinic receptors:

Activation of Na+ Channels



- At the level of ganglia → nicotinic receptors are linked to chemical gated Na^+ channels

→ Signal Transduction Mechanism :

- once we have activated the receptors
- Activation of chemical gated Na^+ channels
- Depolarizing membrane
- AP at the 2nd neuron.

Receptors and Signal transduction mechanisms

Muscarinic Receptors (M1-M5)

Inhibitory:

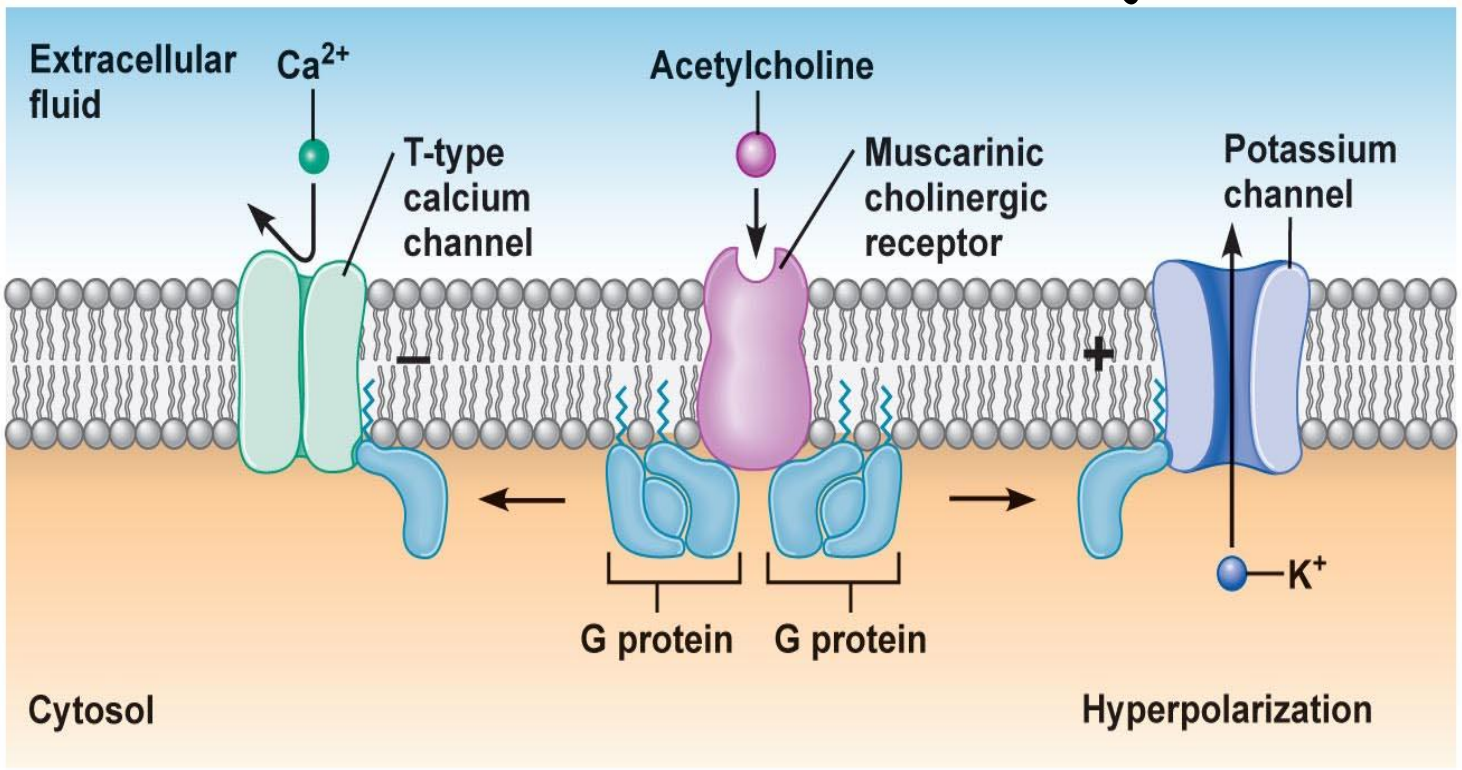
Conductive tissue of Heart

- **M2 in the heart**: G protein → K+ channel → slow the rate of depolarization.

reduce

inactivates

Gi → adenylate Cyclase → reduces cAMP → increasing Activity of K^+ channels + Decreasing # of T-type of Ca^+ and Na^+ channels.



(b) Parasympathetic

Receptors and Signal transduction mechanisms

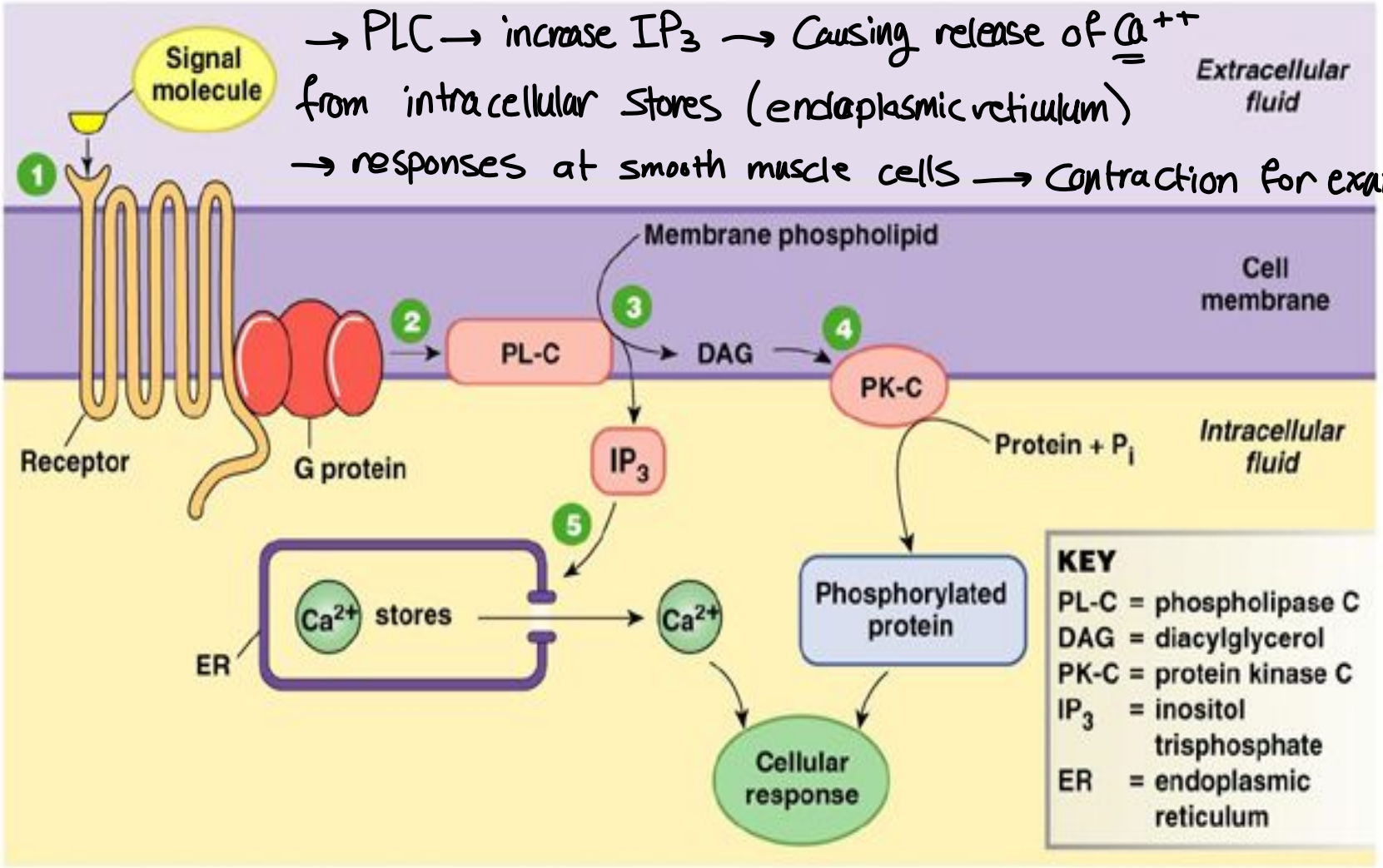
Muscarinic Receptors (M1-M5)

Excitatory Rceptors: (M1, M3, M5)

Found on smooth muscle and glands are coupled Gq protein → phospholipase C.

This enzyme increases production of inositol-1,4,5-trisphosphate (IP3)

→ PLC → increase IP_3 → causing release of Ca^{++} from intracellular stores (endoplasmic reticulum) → responses at smooth muscle cells → contraction for example.



1. Signal molecule activates receptor and associated G protein.
2. G protein activates phospholipase C (PL-C), an amplifier enzyme.
3. PL-C converts membrane phospholipids into diacylglycerol (DAG), which remains in the membrane, and IP_3, which diffuses into the cytoplasm.
4. DAG activates protein kinase C (PK-C), which phosphorylates proteins.
5. IP_3 causes release of Ca^{2+} from organelles, creating a Ca^{2+} signal.

Fig. 6-12

Activation of Muscarinic Receptors

during Muscarine intoxication → Patients who ingested toxic mushroom develop:

- Stimulation of secretory activity: salivation, tearing, sweating, nasal and bronchial secretion.
- Increase gastrointestinal tract motility → vomiting and diarrhea.
- Contraction of urinary bladder → urination.
- Slowing of the heart → Bradycardia.

to reverse effects of Muscarinic intoxication → Drug

Blocking of Muscarinic Receptors by ATROPIN

Signs related to giving high dose of Atropin:-

- Inhibition of glandular secretions ⇨ dry mouth, dry eyes, and dry nasal passages.
- Tachycardia. (increase heart rate).
- Loss of pupillary light reflex ⇨ Mydriasis
- Loss of ability to focus the lens for near vision.

→ you are following the heart rate of patient + pupillary light reflex

once you have any increase in the heart Rate → you can Stop giving Atropin

Receptors and Signal transduction mechanisms

Adrenergic receptors:

These receptors respond to **catecholamines:** (epinephrine (EP) and norepinephrine (NE)).

Receptors and Signal transduction mechanisms

• Adrenergic Receptors

Alpha receptors:

- The alpha 1 (α_1): Excitatory: PLC⇨ IP3

↳Smooth muscle cells of vessels + Arterioles → by activation → Vasoconstriction

- Alpha2 receptors: Nerve Adrenergic terminals⇨ reduce NE release

Alpha 2 Heteroreceptors: Nonadrenergic -

Gi⇨ Adenylate cyclase⇨ decrease cAMP

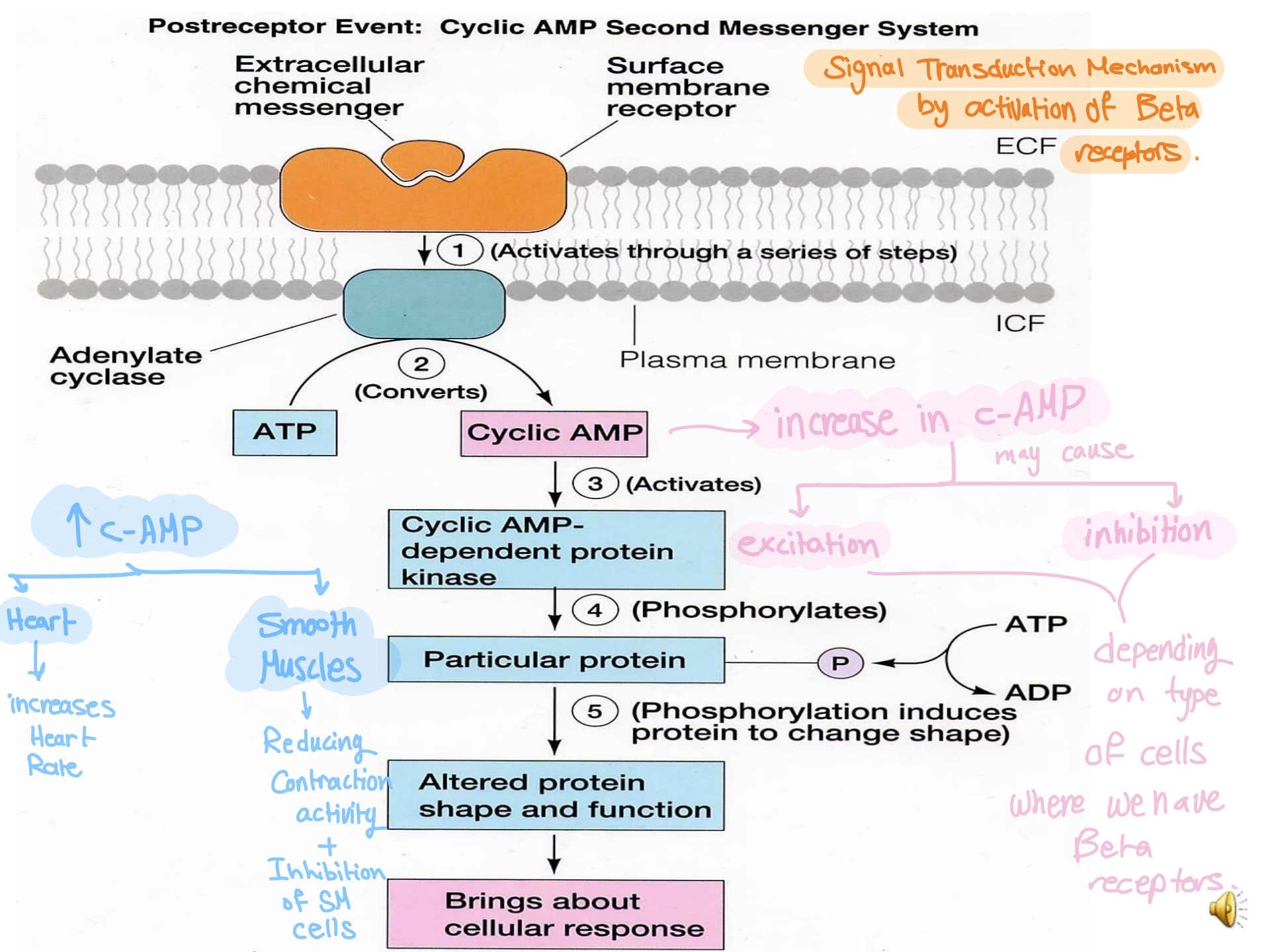
Receptors and Signal transduction mechanisms

Beta receptors:

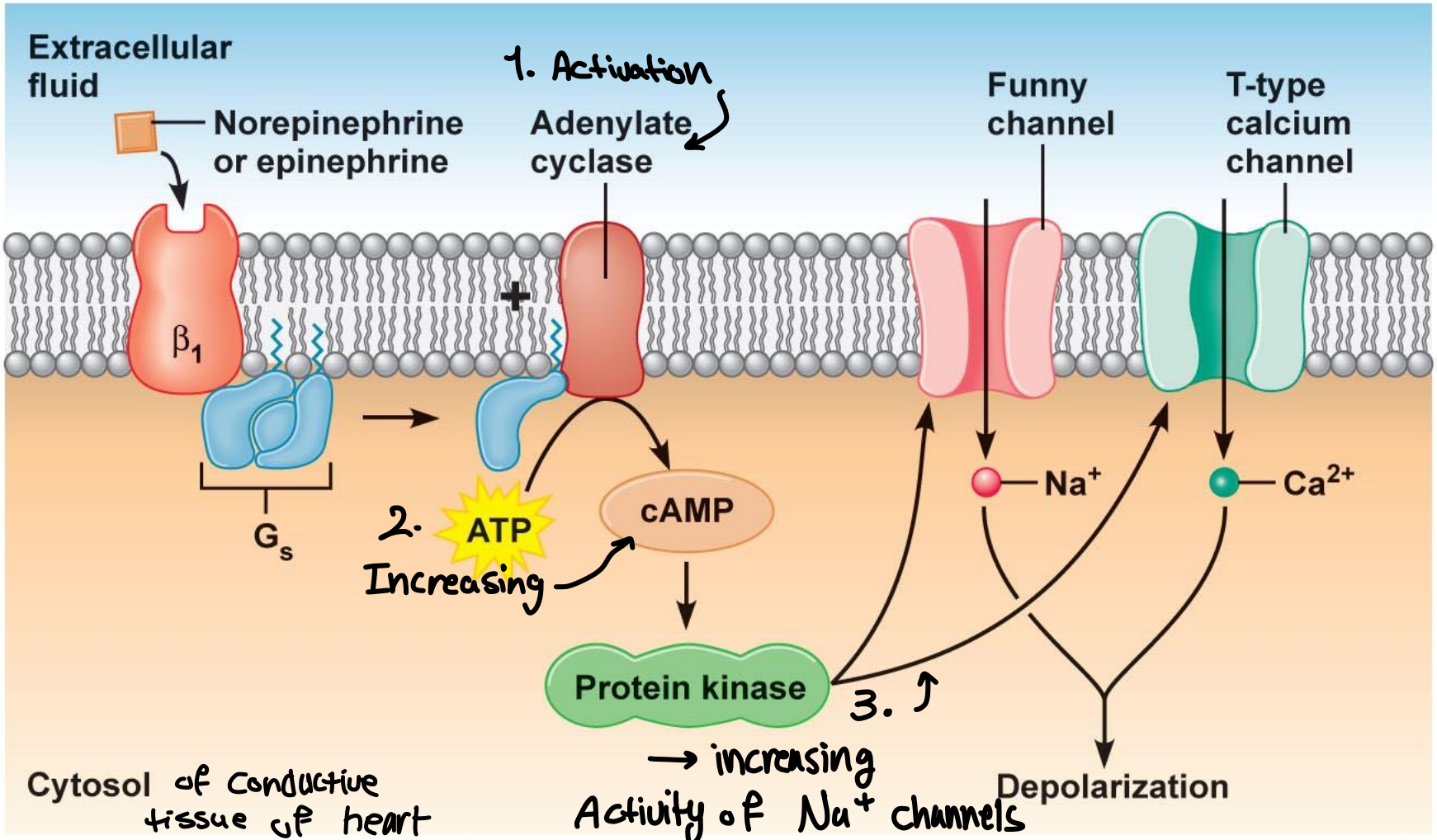
- Beta 1 **(β_1) receptors**: found on heart
  - ↳ excitatory
- Beta 2 **(β_2) receptors**: found on tracheal and bronchial smooth muscle, in the gastrointestinal tract, and on smooth muscles of blood vessels supplying skeletal muscles
  - ↳ Inhibitory

Gs → Adenylate cyclase → increase cAMP

↳ Both B_1/B_2 work by activation of AC
- ↳ Heart → increases Heart rate
- ↳ Smooth Muscles → reduce relaxation of smooth muscles.


Postreceptor Event: Cyclic AMP Second Messenger System
Extracellular chemical messenger
Surface membrane receptor
ECF
ICF
1 (Activates through a series of steps)
Adenylate cyclase
2 (Converts)
Plasma membrane
ATP
Cyclic AMP
3 (Activates)
Cyclic AMP-dependent protein kinase
4 (Phosphorylates)
Particular protein
P
ATP
ADP
5 (Phosphorylation induces protein to change shape)
Altered protein shape and function
Brings about cellular response
Signal Transduction Mechanism by activation of Beta receptors.
increase in c-AMP may cause
excitation
inhibition
depending on type of cells where we have Beta receptors.
↑ c-AMP
Heart
increases Heart Rate
Smooth Muscles
Reducing Contraction activity + Inhibition of SM cells

What happens at the Conductive tissue of the Heart



Summary

Muscarinic receptors: Activated by Ach.

- **Inhibitory: M2, M4**
- **Excitatory: M1, M3, M5**

Adrenergic receptors: activated by Epinephrine and Norepinephrine.

- **Alpha (α) Receptors: α1, α2, α2 hetero-**
- **Beta (β) Receptors: β_1, β_2, … β_3**

- **Beta 2 (β_2) receptors**: found on tracheal


E-mail: malessa@ju.edu.jo
GOOD LUCK