# Physiology of the Autonomic Nervous system (ANS)

Dr. Taha Sadig Ahmed

Physiology Department , College of Medicine , King Saud University

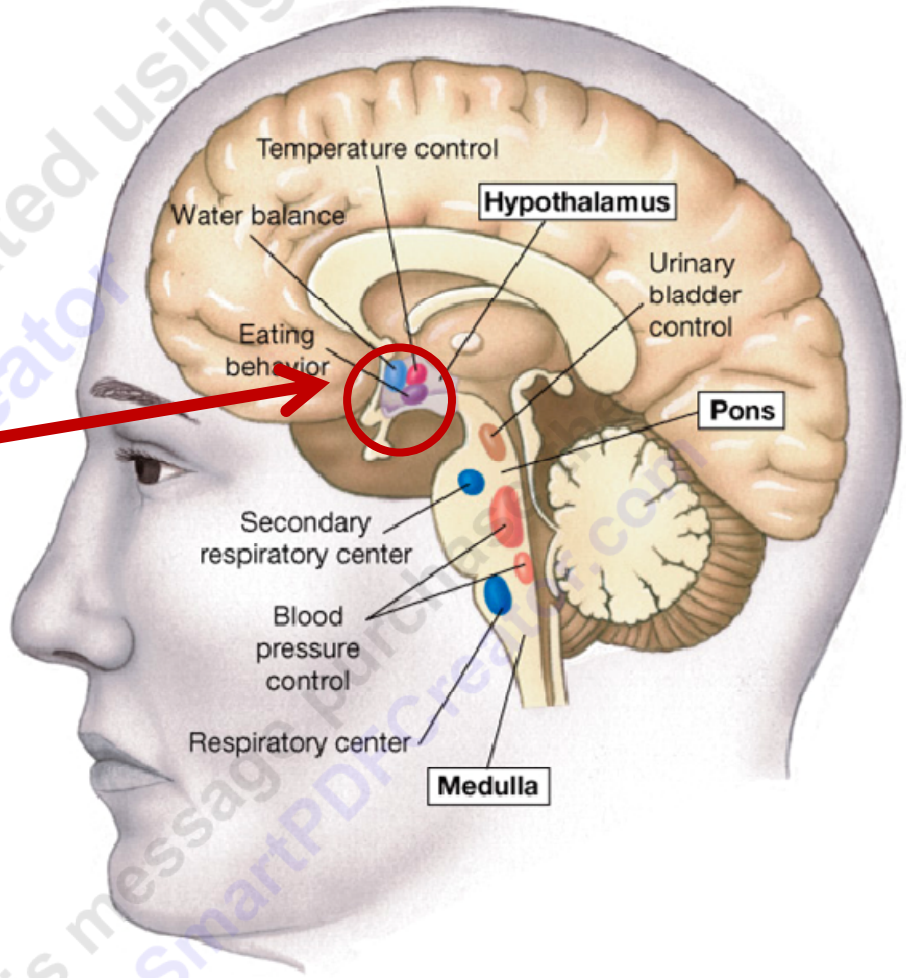
## • L1 Objectives

- At the end of this lecture the student should be able to :
- (1) describe the general arrangement of the sympathetic and parasympathetic systems .
- (2) explain the consequences of activation of either of these systems on body functions .

## • Reference

- Ganong Review of Medical physiology, 23rd edition. Barret et al ( eds) . Mc Graw Hill , Boston 2010 .
- Page 261-272 .

- ANS has two subdivisions:
- Sympathetic and Parasympathetic
- Higher (CNS) controller of ANS is the Hypothalamus :
- Posterior hypothalamus controls Sympathetic NS
- Anterior hypothalamus controls Parasympathetic NS
- These hypothalamic centers exert their effects via the motor centers of he brainstem & spinal cord .

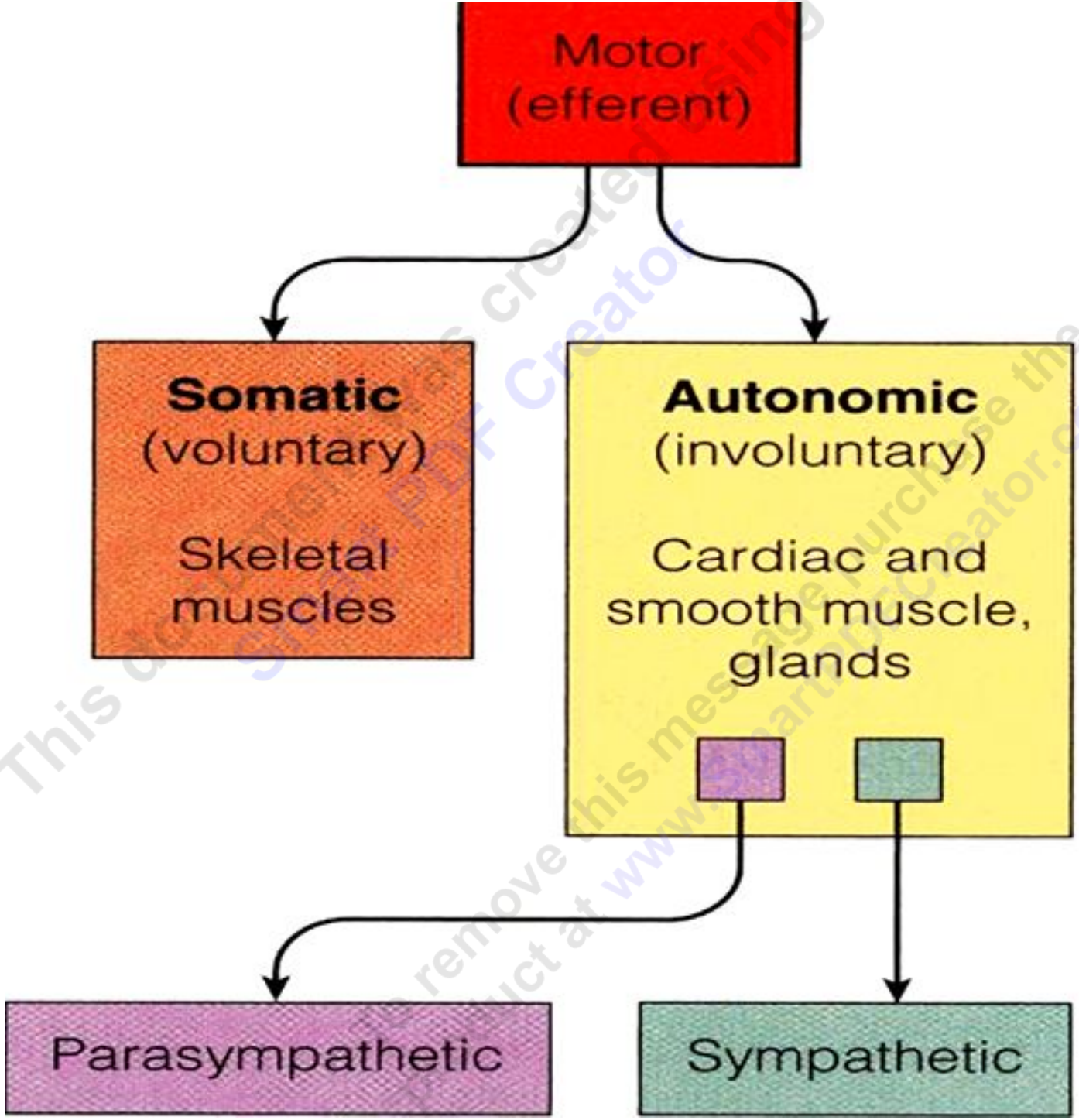



- Moreover , the hypothalamic centers are influenced by impulses from the Cerebral Cortex and Limbic System .

# Q :What are the main differences between the Somatic ( Voluntary ) Nervous System and Autonomic( Involuntary ) Nervous System ?

- Somatic NS :

- Controls skeletal muscles , which are voluntary ; & considered a somatic structures
- There is one lower motor neuron that directly innervates the skeletal muscle.
- The cell-body ( soma ) of this motoneuron is located inside the CNS , either →
- (a) in the brain → in case of cranial nerves , or
- (b) in the spinal cord → in case of spinal nerves .
- The axon of the somatic motor neuron is myelinated, therefore fast-conducting .


Motor
(efferent)
Somatic
(voluntary)
Skeletal
muscles
Autonomic
(involuntary)
Cardiac and
smooth muscle,
glands
Parasympathetic
Sympathetic

# • Autonmic Nervous System ( ANS ) :

- Controls smooth and cardiac muscles , both of which are involuntary . They are parts of the visceral organs
- There are 2 lower motor neurons arranged in series :

(1) Preganglionic neuron : , whose cell-body is situated inside the CNS ) , arising from →

(a) spinal cord ( thoracolumbar segments ) →in case of sympathetic sytem ,

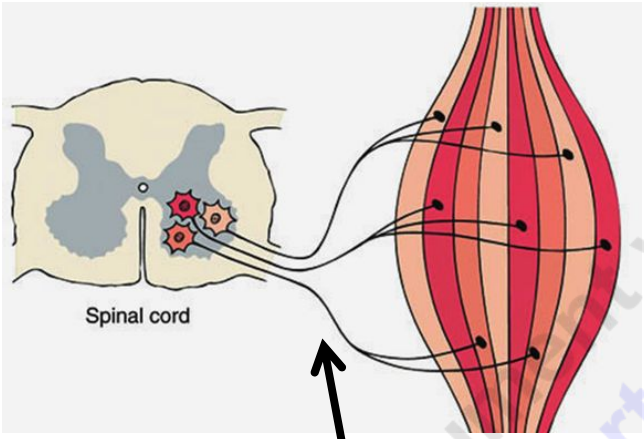
(b) brain ( cranial nerve autonomic nuclei ) + spinal cord ( sacral segments ) → in case of parasympathetic system .

**The preganglionic fiber synapses within a ganglion with a 2nd →**

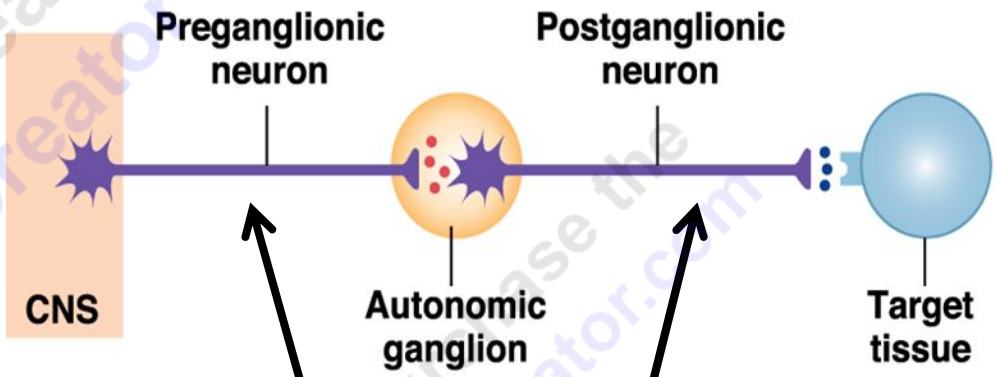
(2) Postganglionic nerve : whose cell-body is situated outside the CNS , in a ganglion .

✓ Axons of preganglionic nerves are myelinated , but those of postganglionic nerves are myelinated .

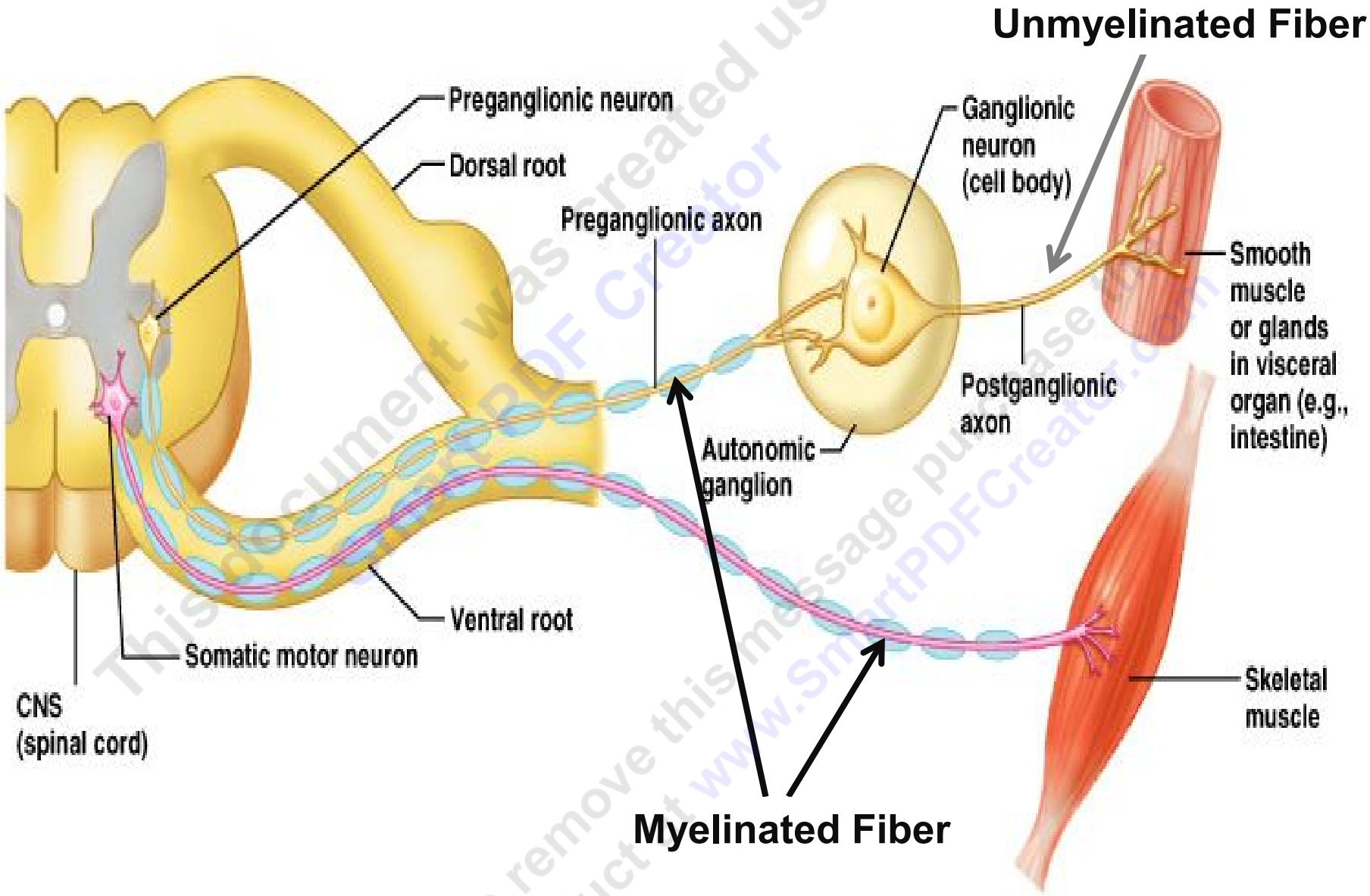
✓ That is why postganglionic nerves are slower-conducting than preganglionic nerves .




**Somatic NS** : one efferent (motor) fiber that directly innervates the muscle

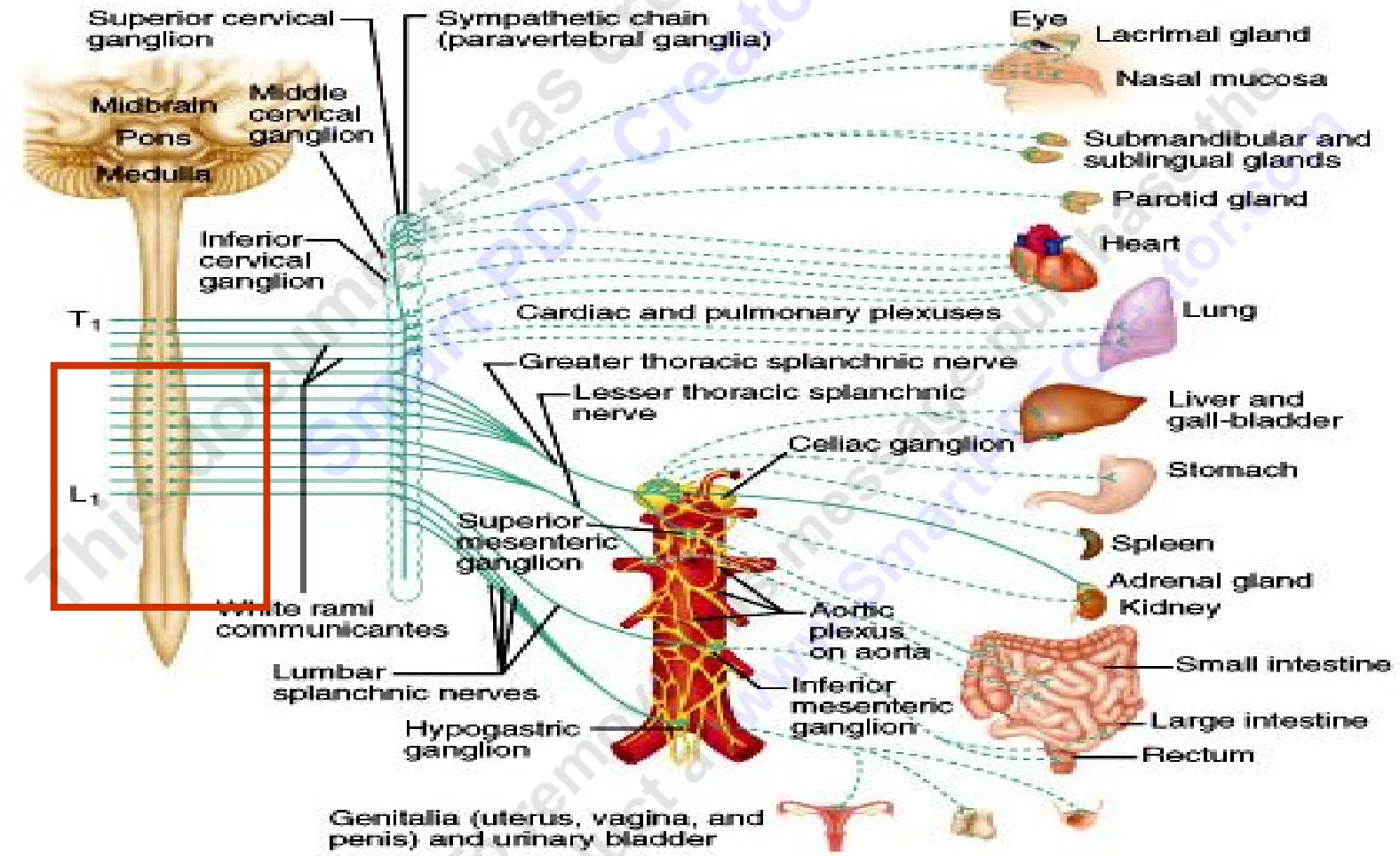



**ANS** : Two efferent (motor) neurons in series : preganglionic & postganglionic to innervate the target cell ,


Unmyelinated Fiber
Preganglionic neuron
Dorsal root
Preganglionic axon
Ganglionic neuron (cell body)
Smooth muscle or glands in visceral organ (e.g., intestine)
Postganglionic axon
Autonomic ganglion
Ventral root
Somatic motor neuron
CNS (spinal cord)
Skeletal muscle
Myelinated Fiber

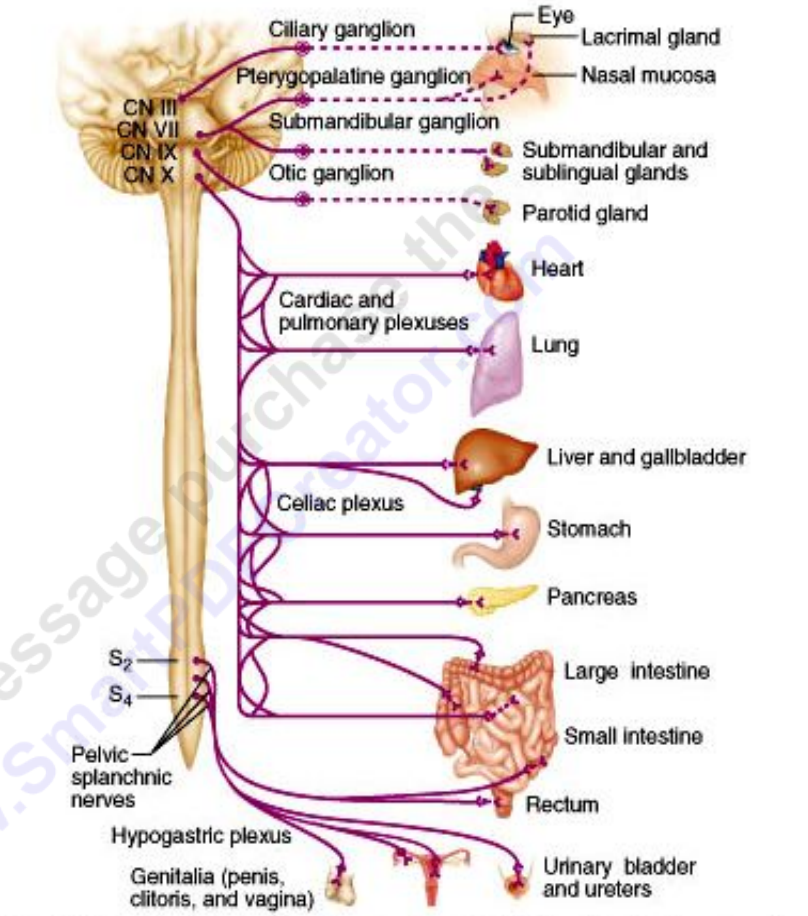
# Sympathetic - Origin

- **Thoracolumbar : lateral horns of the spinal segments T1-L2.**



# Parasympathetic - Origin

- ❑ Craniosacral Cell bodies of the motor nuclei of the cranial nerves III, VII, IX and X in the brain stem
- ❑ Second, third and fourth [S2-S4] sacral segments of the spinal cord
- Nerve fibers emerge from brain &
- sacrum cranio-sacral outflow



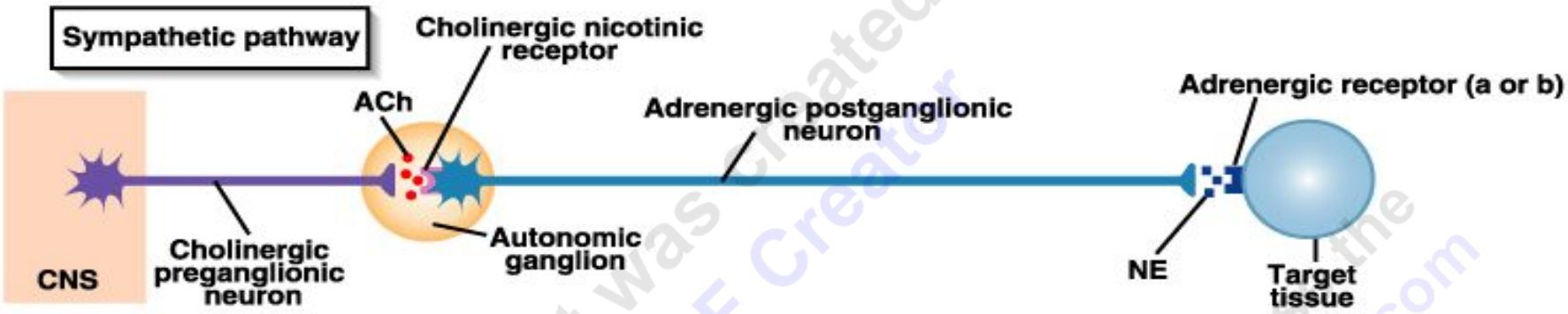
# Parasympathetic System

- The cranial nerves III, VII and IX affect the pupil and salivary gland secretion

- Vagus nerve (X) carries fibers to the heart, lungs, stomach, upper intestine and ureter

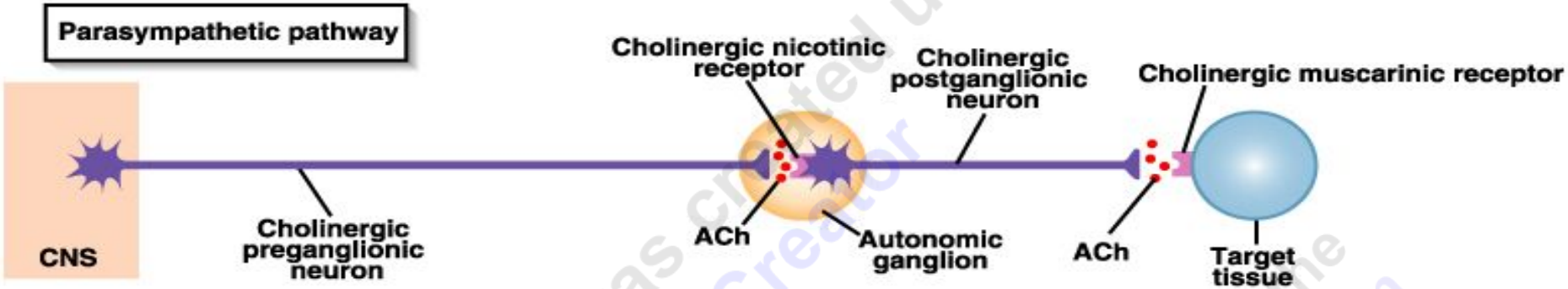
- The sacral fibres form pelvic plexuses which innervate the distal colon, rectum, bladder and reproductive organs.

# *Sympathetic (Thoracolumbar) System*



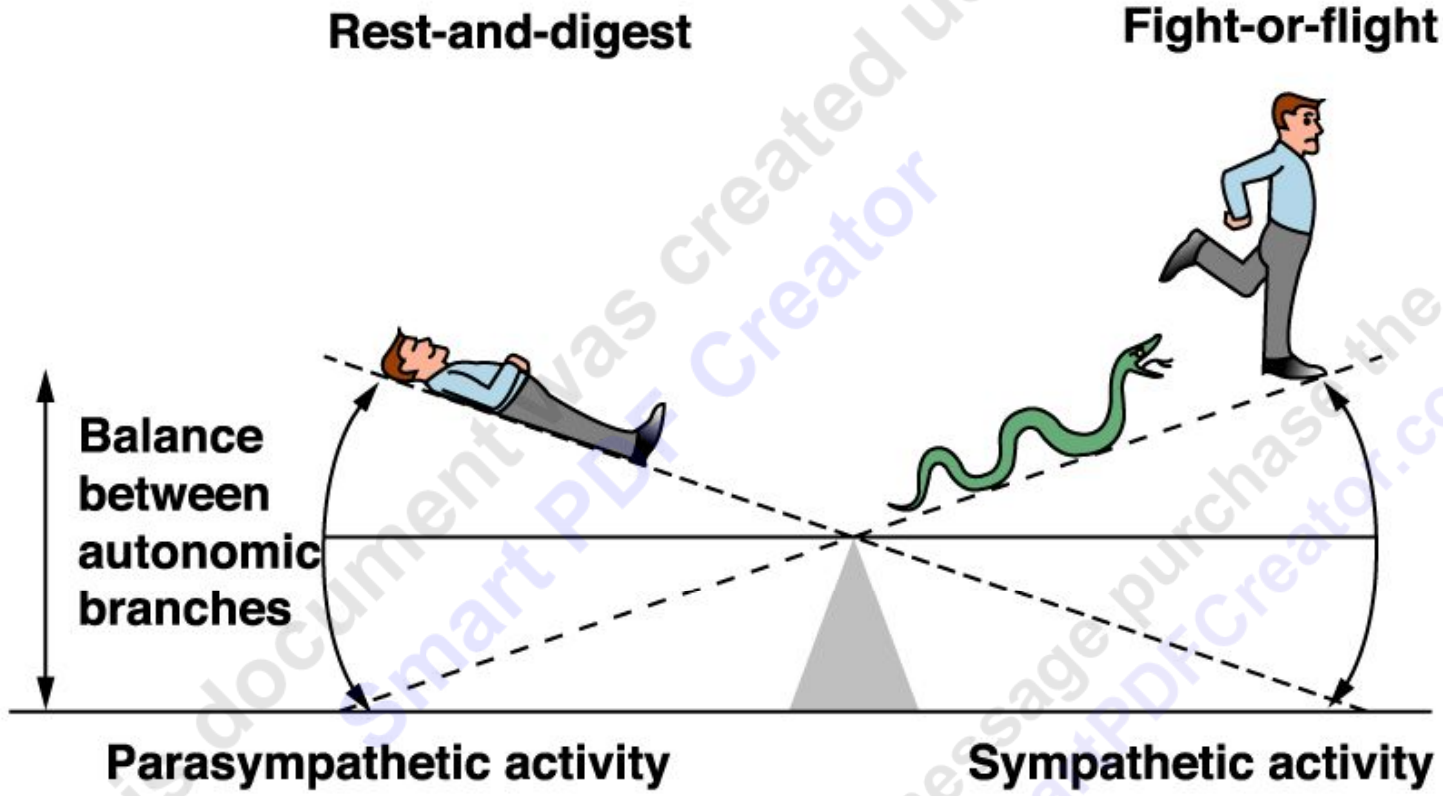

1. Preganglionic nerves in exit the CNS from the thoracic and lumbar segments of the spinal cord →therefore , the sympathetic system is also called : " Thoraco-lumbar Outflow "
2. Preganglionic fibers are myelinated
3. The postganglionic neuron cell-bodies are located in paravertebral sympathetic ganglia , distant from their target tissues .
4. Postganglionic fibers are unmyelinated & longer than preganglionic fibers .
5. There is much divergence . The ratio (pre/post) being = 1:10 ;
6. This considerable divergence results in generalized and widespread effects on body functions when this system is activated .

# *Parasympathetic (Craniosacral ) system*




1. Preganglionic nerves exit the CNS from the cranium and sacral segments of the spinal cord .Therefore , the paraympathetic system is also called " Craniosacral Outflow "
2. Preganglionic fibers are myelinated
3. The postganglionic neuron cell-bodies are located in parasympathetic ganglia , close to their target tissues or embedded in their walls
4. Postganglionic fibers are unmyelinated & shorter than preganglionic fibers .
5. There is little divergence , the ratio of pre- to postgaglionic fibers is 1:3
6. This little divergence results in more specific ,discrete and localized effects in the body when this system is activated .

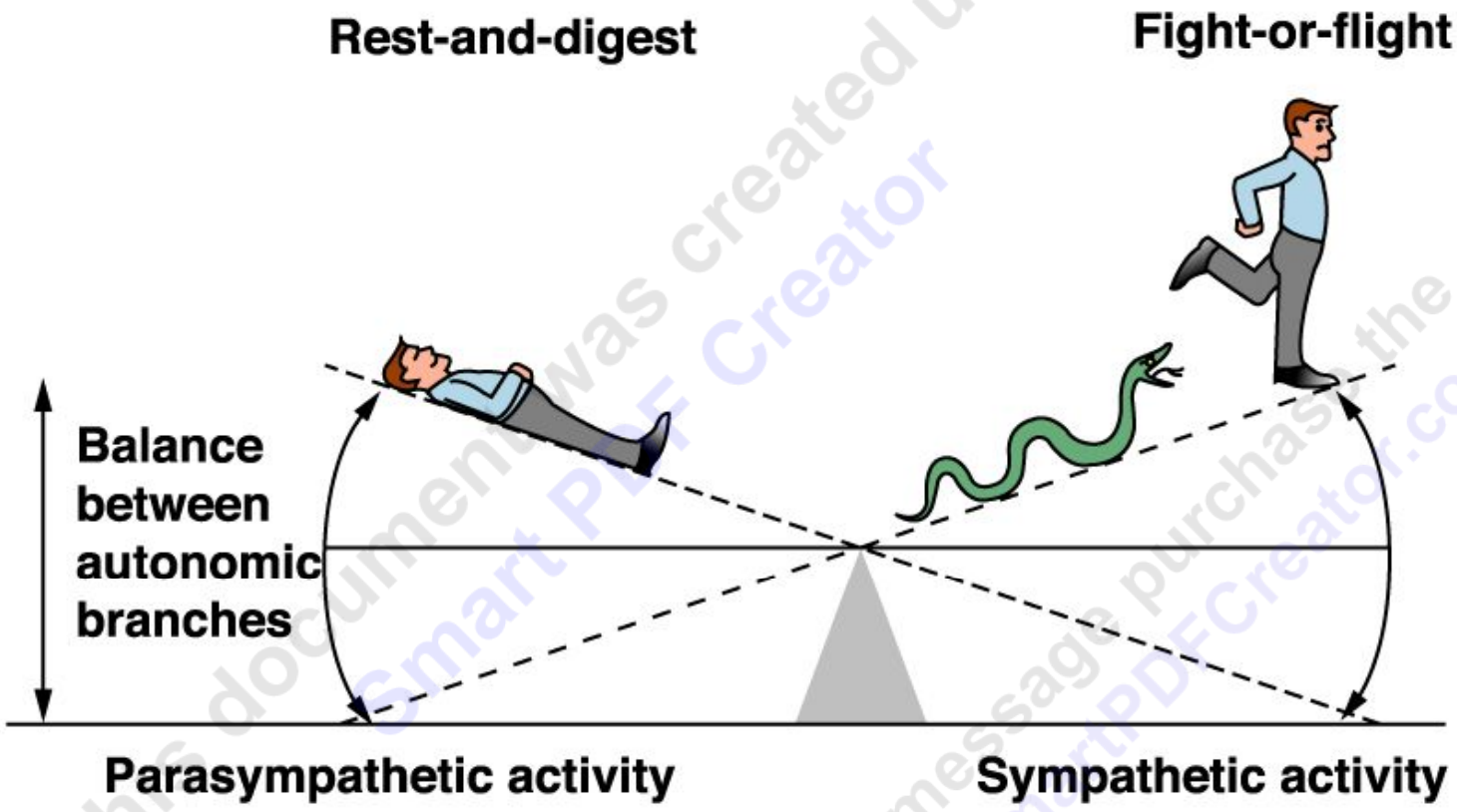
# General Effect of Sympathetic Activation ( Stimulation )



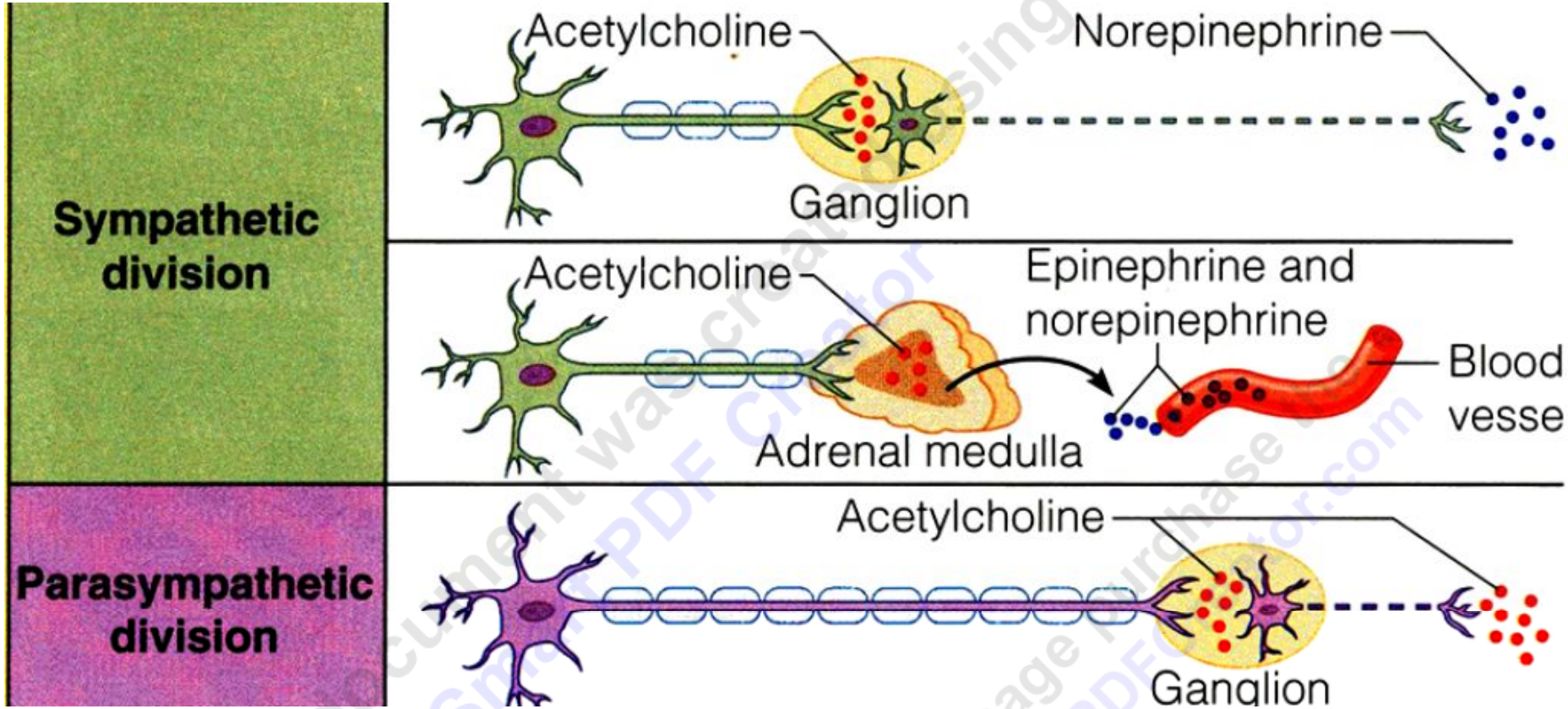

- Sympathetic system is active during stress and physical activity , such as physical exercise ( as in sport ) ; and during increased mental & emotional activity such as in fear, anger , worry , anxiety, severe pain → preparing the body for fight or flight
- And promoting mechanisms which increase energy production & accelerate metabolism

# Sympathetic


## *General Effect of Parasympathetic Stimulation*




- Parasympathetic system activities is related to the relaxed state and rest
- Conservation of body energy ,and
- vegetative functions ( nutritive , body-building , restorative anabolic functions & tissue repair ) , & is more active during feeding , digestion & rest & sleep .




❑**Aacetylcholine (Ach) is secreted by →**

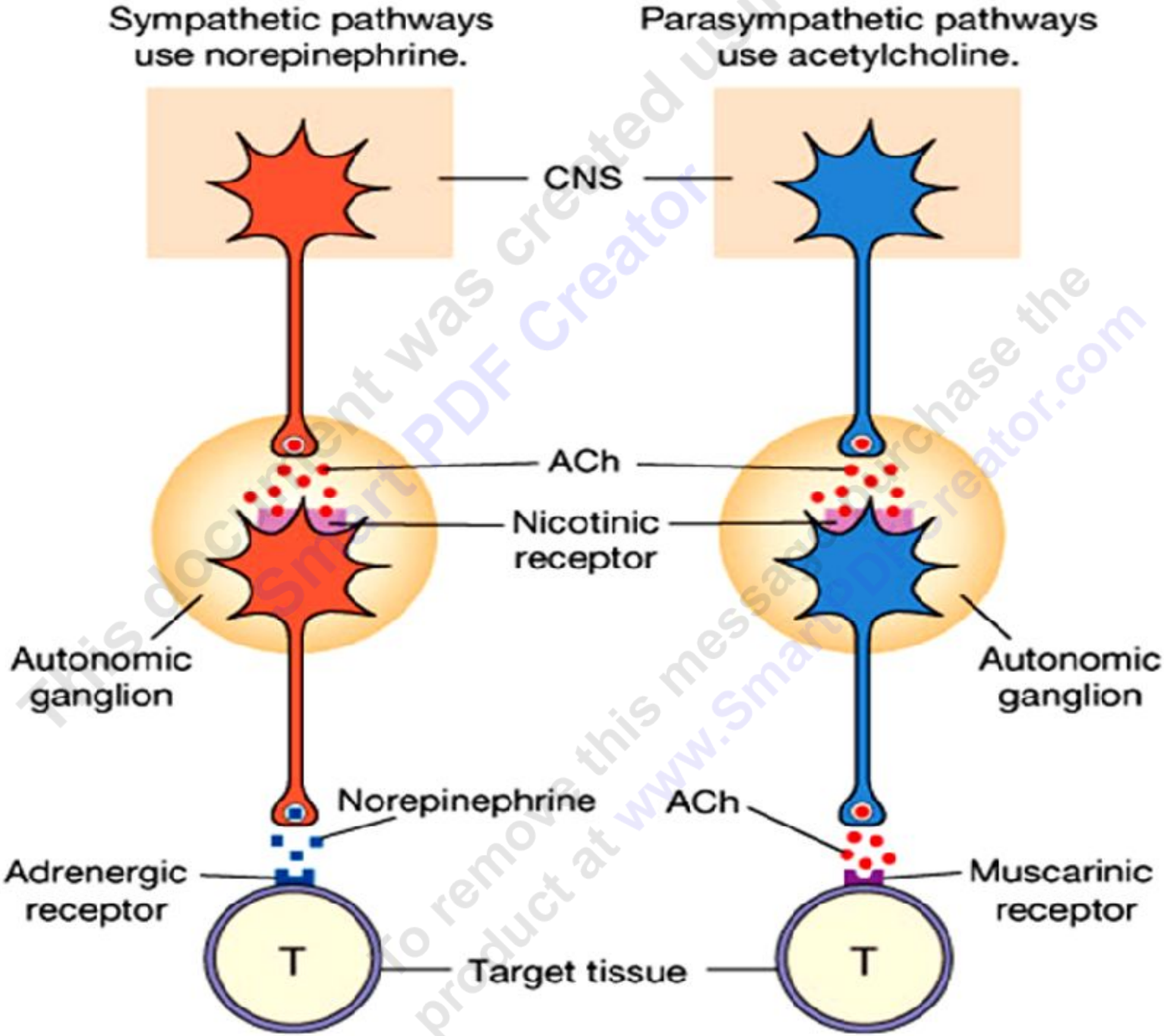
**(1) all preganglionic nerves,**

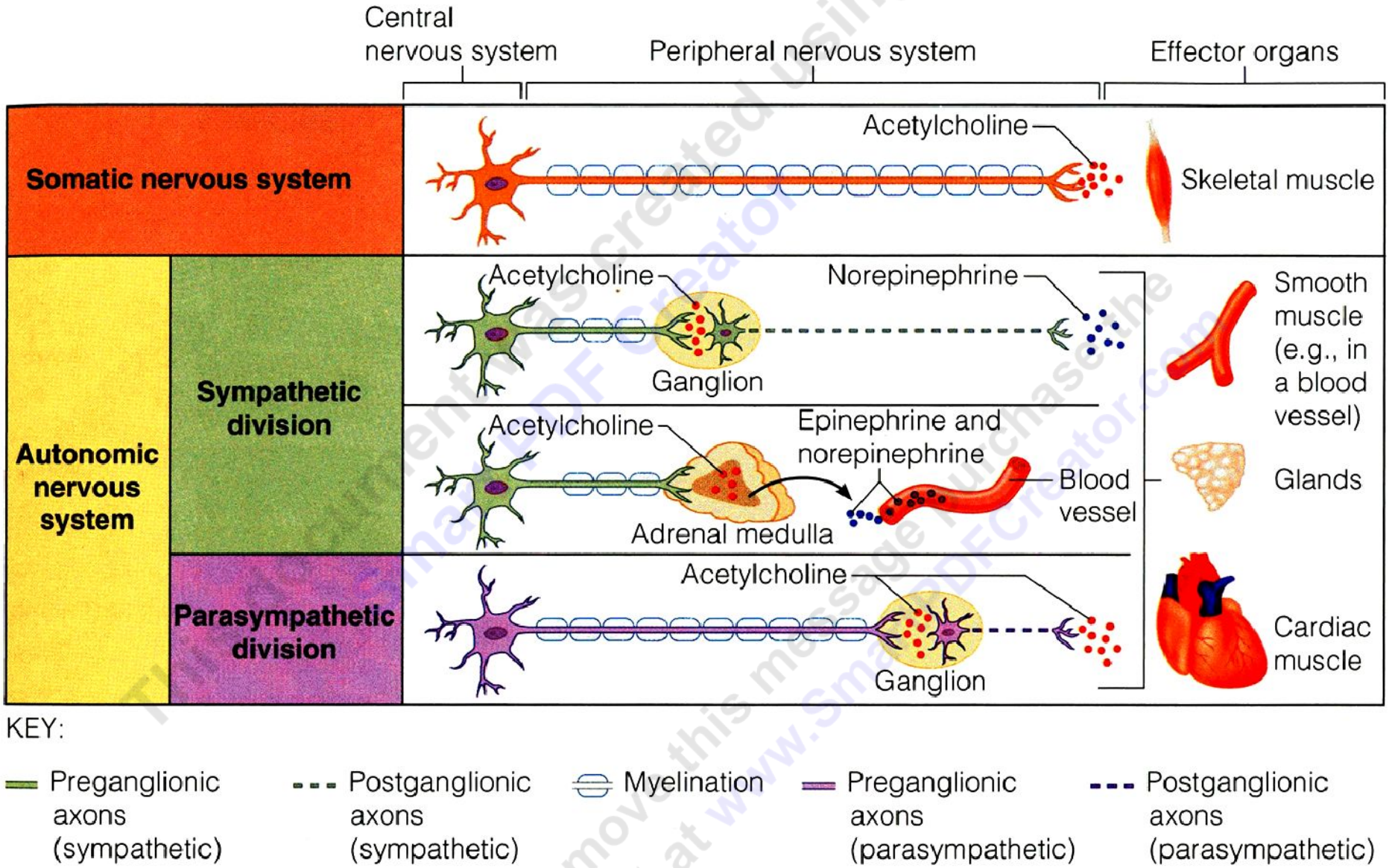
**(2) all postganglionic parasympathetic nerves , &**

**(3) postganglionic sympathetic nerves that innervate sweat glands & blood vessels in skeletal muscle .**

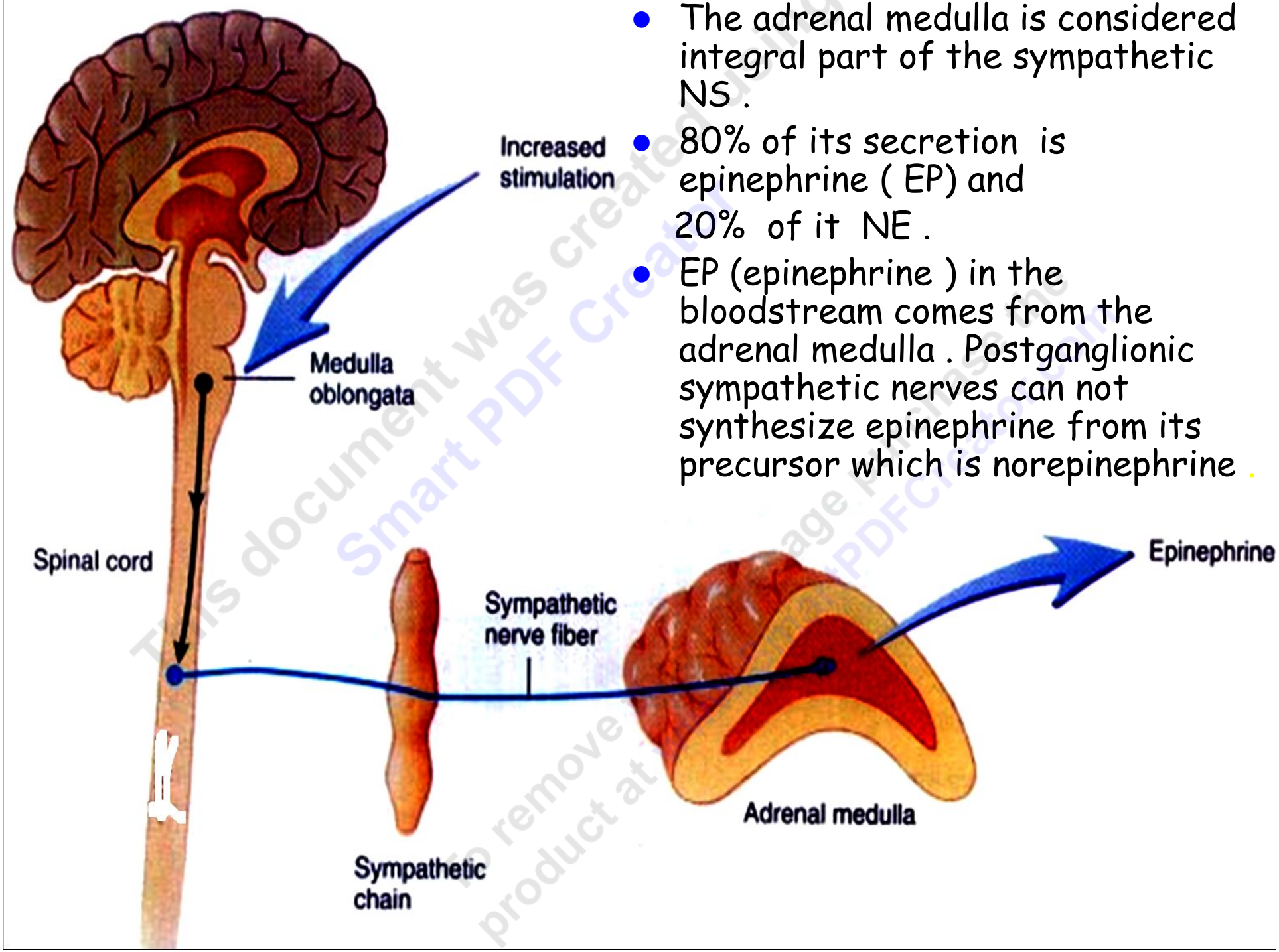
✓**The rest of postganglionic sympathetic nerves secrete norepinephrine ( NE ) .**

✓**Adrenal medulla secretes epinephrine ( EP)) ( 80%) and norepinephrine (NE) ( 20%) .**


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


Central nervous system
Peripheral nervous system
Effector organs
Somatic nervous system
Acetylcholine
Skeletal muscle
Autonomic nervous system
Sympathetic division
Acetylcholine
Norepinephrine
Ganglion
Smooth muscle (e.g., in a blood vessel)
Acetylcholine
Epinephrine and norepinephrine
Blood vessel
Glands
Adrenal medulla
Parasympathetic division
Acetylcholine
Ganglion
Cardiac muscle
KEY:
Preganglionic axons (sympathetic)
Postganglionic axons (sympathetic)
Myelination
Preganglionic axons (parasympathetic)
Postganglionic axons (parasympathetic)

- The adrenal medulla is considered integral part of the sympathetic NS .
- 80% of its secretion is epinephrine ( EP) and 20% of it NE .
- EP (epinephrine ) in the bloodstream comes from the adrenal medulla . Postganglionic sympathetic nerves can not synthesize epinephrine from its precursor which is norepinephrine .



# Effect of sympathetic & parasympathetic stimulation

| Organ | sympathetic | parasympathetic |
|---|---|---|
| Pupil | Dilatation of pupil | Constriction of pupil |
| Heart | Increased heart rate<br><br>Increased force of contraction | Decreased heart rate<br><br>No effect |
| Systemic blood vessels | constriction | Little or no effect |
| Blood Pressure | Raised | Little or no effec |
| Lung (Bronchioles) | Dilation | Constriction |

| Organ | sympathetic | parasympathetic |
| --- | --- | --- |
| <u>Glands :</u><br>Nasal, Lacrimal, Salivary ,<br>Gastric , Intestinal, Pancreatic<br>---------- ----------<br>Sweat Glands | Slight ( small volume ) secretion<br>---------- ----------<br>Increased secretion | Copious ( large volume) secretion<br>---------- ----------<br>No effect |
| Digestive system muscles | Promotes retention ( relaxation of wall muscles & contraction of sphincters ) | Promotes emptying ( contraction of wall muscles & relaxation of sphincters ) |
| Urinary bladder | Promote retention ( relaxation of wall & constriction of sphincter) | Promotes emptying ( contraction of wall& relaxation of sphincter) |
| Blood sugar | raised | No effect |

| | | |
|---|---|---|
| Gastrointestinal Tract (GIT) secretions | Decreased | Increased |
| GIT motility ( contraction of muscles in walls , Peristalsis )<br><br>Sphincters | Decreased<br><br>Constricn<br><br>Therefore , sympathetic system to GIT promotes retention | Increased<br><br>Relaxation<br><br>Therefore , parasympathetic system to GIT promotes digestion & excretion |

| | | |
|---|---|---|
| Blood vessels to skeletal muscles | Dilatation (cholinergic) | None |
| Genital System | Ejaculation | Erection |
| Adrenal medulla | Secretion of epinephrine & norepinephrine | No effect |
| Metabolism | Increased | No effect |
| Blood: Coagulation | Increased | No effect |

# Autonomic Neurotransmitter

- All preanglionic fibres (sympathetic and parasympathetic ) secrete acetylcholine at the ganglia .
- All postganglionic parasympathetic fibers secrete acetylcholine at target organs .
- Most postganglionic sympathetic fibers secrete norepinephrine
- However → Postganglionic sympathetic fibers to sweat gland & blood vessels of skeletal muscles release acetylcholine
- All epinephrine in the bloodstream comes from the adrenal medulla . Postganglionic sympathetic nerves can not synthesize epinephrine from its precursor which is norepinephrine .

# Adrenergic Receptors are either Alpha or Beta

- Alpha (α) adrenergic receptors are found in :
  - Iris
  - Blood vessels
  - GIT
- Beta (β) adrenergic receptors can be beta one (β1) or beta 2 (β1) → found in :
  - Heart (β1)
  - Bronchioles (β1)
  - Skeletal muscle (β2)
  - GIT (β2)
- Norepinephrine mainly excite α (and β to a lesser extent)
- Epinephrine excites both α & β equally

# Effects of Adrenergic Receptor Stimulation

| Alpha (α) receptors | Beta (β) receptors |
|---|---|
| (1) Vasoconstriction<br>( → raised BP)<br>(2) Pupillary dilatation<br>( Mydriasis) | (1) Increased HR ($\beta_1$)<br>(2) Increased myocardial contractility ($\beta_1$)<br>2 and 3 above lead to increased cardiac output andconsequently lead to increased BP<br>(3)Vasodilatation ($\beta_2$)<br>(4) Bronchiolar relaxation ($\beta_2$)<br>(5) Intestinal wall relaxation ($\beta_2$)<br>(6) Bladder wall relaxation ($\beta_2$) |

| Alpha (α) receptors | Beta (β) receptors |
| --- | --- |
| -Vasoconstriction<br>-Iris dilatation<br>-Intestinal sphincter contraction<br>-Bladder sphincter contraction | -Vasodilatation ($\beta_2$)<br>-Increased myocardial strength of contraction ($\beta_1$)<br>-Intestinal relaxation($\beta_2$)<br>-Bladder wall relaxation ($\beta_2$) |

# Adrenergic receptors blockers

- α blockers:
  - Prazosin (α 1)
  - Yohimbine (α 2)
- β blockers:
  - Propranolol (β1 & β2)
  - Atenolol (β 1)

# Cholinergic Receptors

- Are divided into
- (1) Nicotinic → found in all ganglia ( i.e., the synapses between pre- & postganglionic of both sympathetic & parasympathetic divisions of the ANS
- (2) Muscarinic → found on all effector cells innervated ( & stimulated ) by →
- (1) postganglionic parasympathetic fibers , &
- (2) postganglionic cholinergic sympathetic nerves

- Drugs blocing cholinergic receptors:
  Hexamethonium (block both types)
  Atropine (block muscarinic receptors)

- END