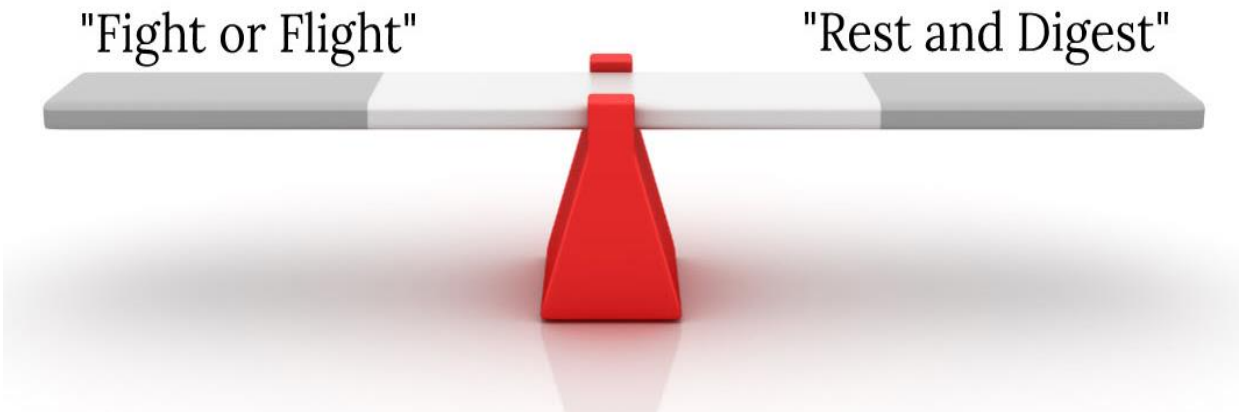
PHYSIOLOGY OF SYMPATHETIC AND PARASYMPATHETIC NERVOUS SYSTEM



Prof. Sultan Ayoub Meo
MBBS, Ph.D, M Med Ed (Dundee), FRCP (London), FRCP (Dublin), FRCP (Glasgow), FRCP (Edinburgh)
Professor and Consultant, Department of Physiology, College of Medicine, King Saud University, Riyadh, KSA

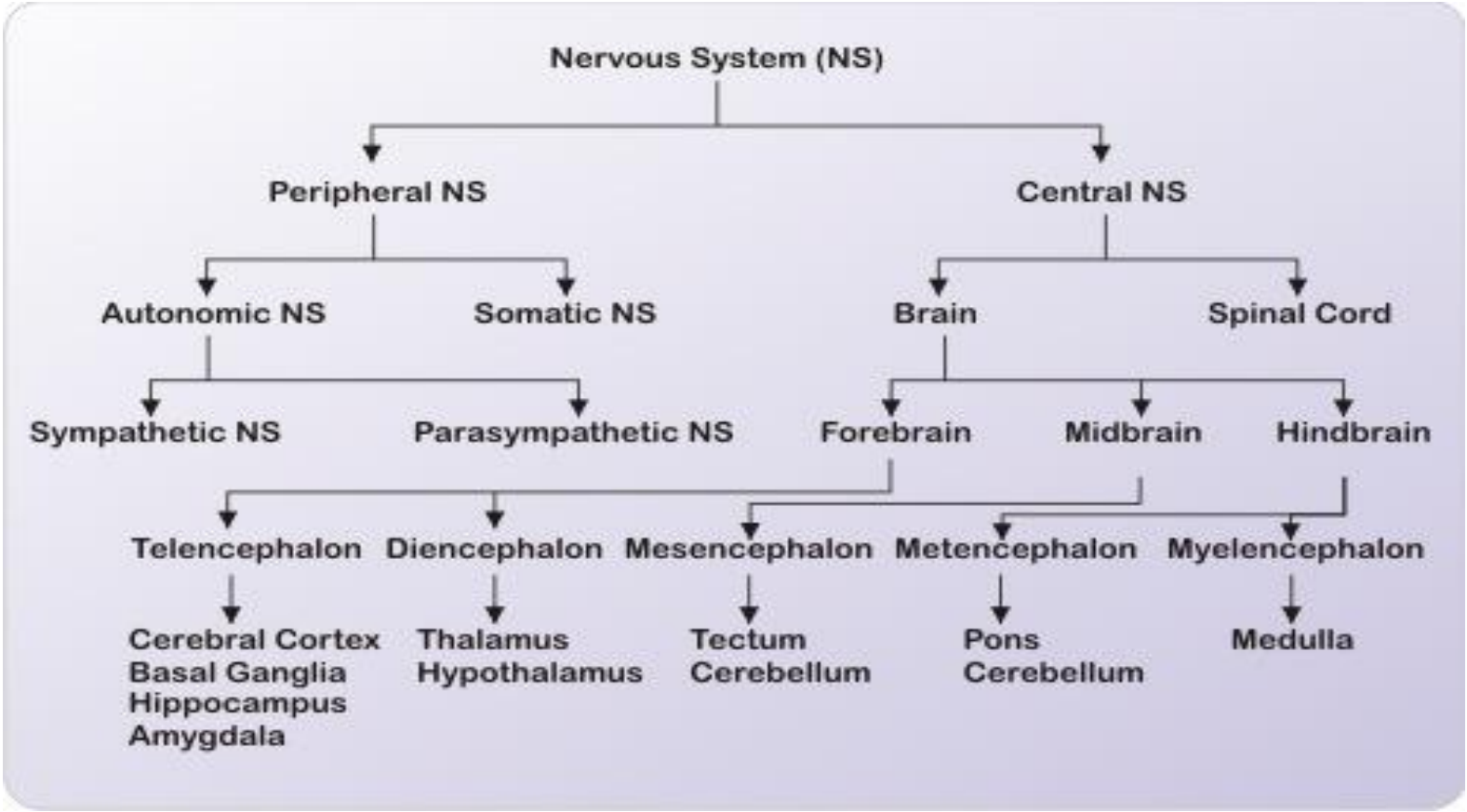
AUTONOMIC NERVOUS SYSTEM

Lecture Objectives:

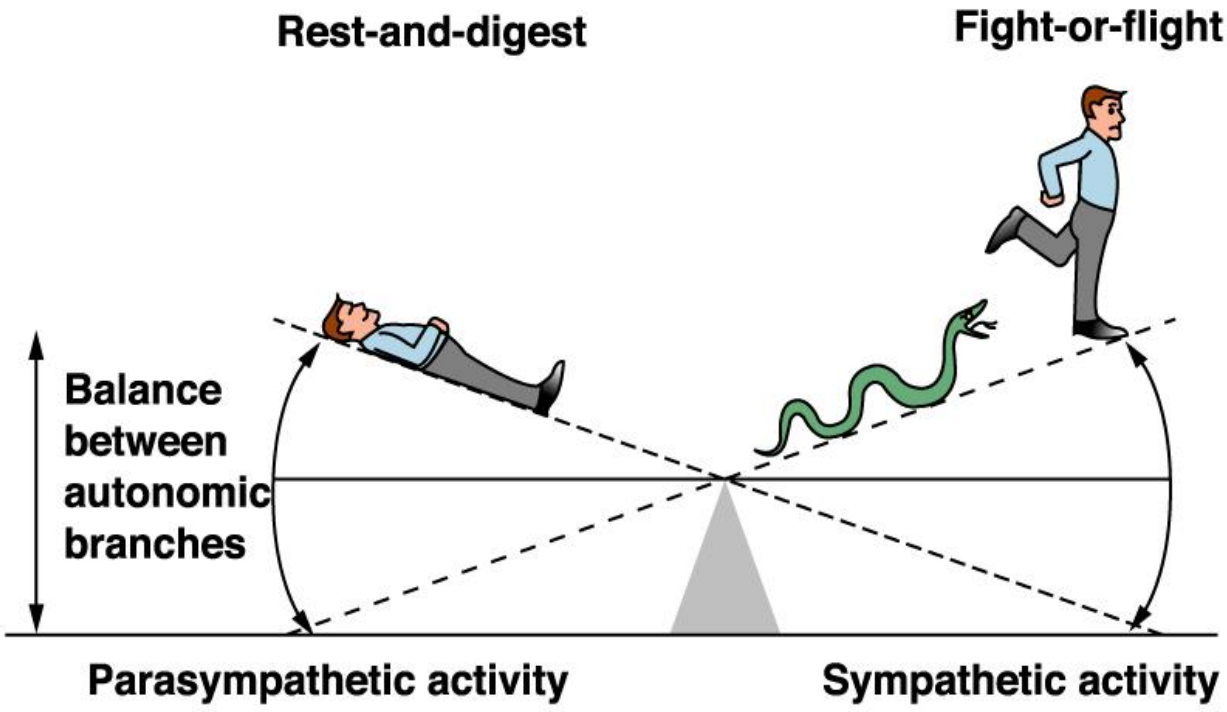
The somatic and autonomic nervous system
Sympathetic and parasympathetic nerves
Pre and post ganglionic neurons
Functions of sympathetic and parasympathetic nerves in head & neck, chest, abdomen and pelvis
Neurotransmitters release at pre and post ganglionic sympathetic / parasympathetic nerves endings
Various responses due to stimulation of the sympathetic / parasympathetic nervous system

UNDERSTANDING OF AUTONOMIC NERVOUS SYSTEM

THE NERVOUS SYSTEM

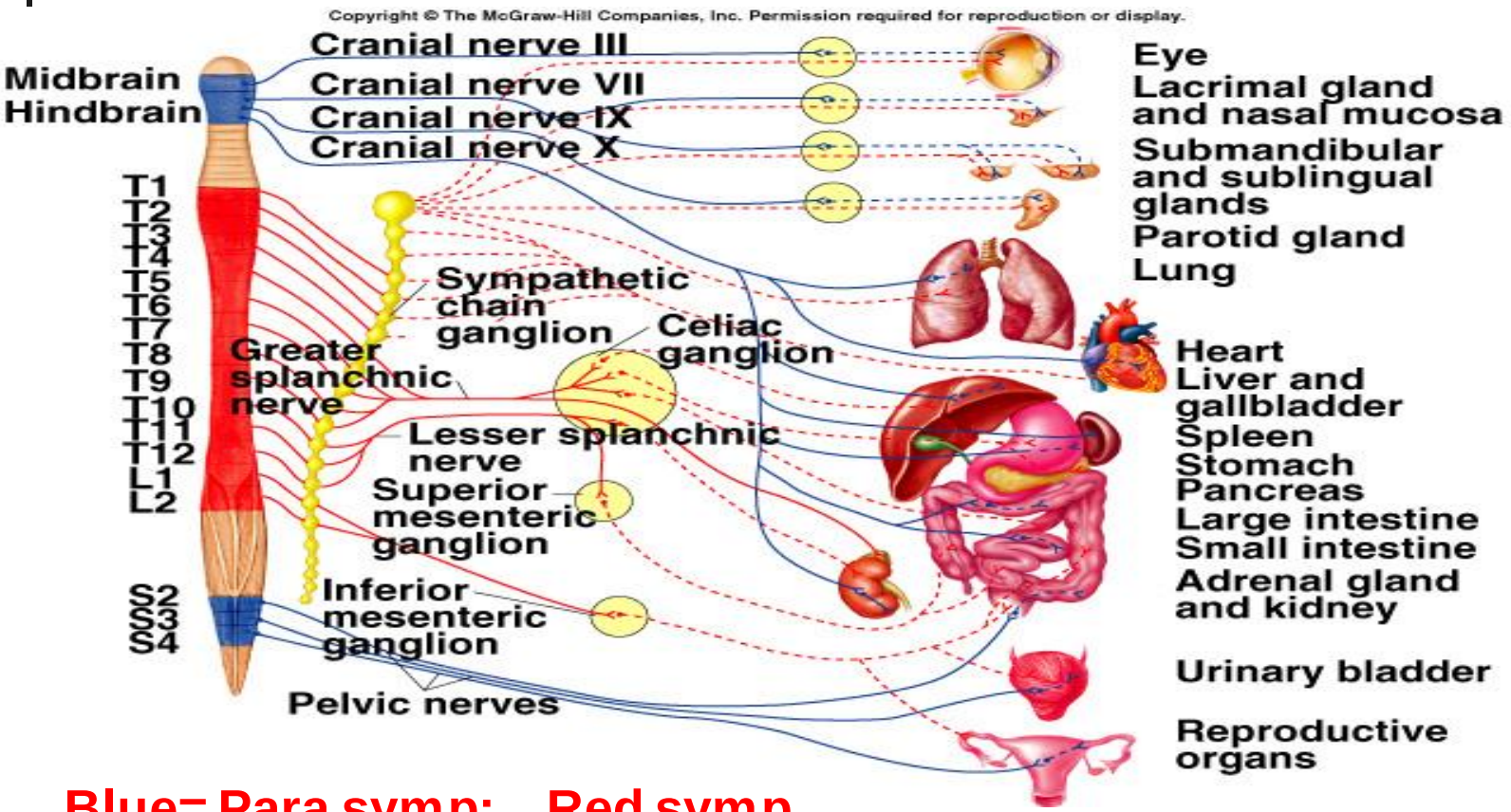


THE AUTONOMIC NERVOUS SYSTEM



THE AUTONOMIC NERVOUS SYSTEM

DISTRIBUTION OF THE SYMPATHETIC AND PARASYMPATHTIC NERVOUS SYSTEM



Blue= Para symp; Red symp

Parasympathetic: Craniosacral: Originate from cranial nerves (3rd, 7th, 9th, 10th), and sacral spinal nerves S2,3,4

Sympathetic: Thoracolumbar: Originate in the thoracic & lumbar regions of the spinal cord (T1-T12; L1-L2,3)

DISTRIBUTION OF THE SYMPATHETIC AND PARASYMPATHTIC NERVOUS SYSTEM

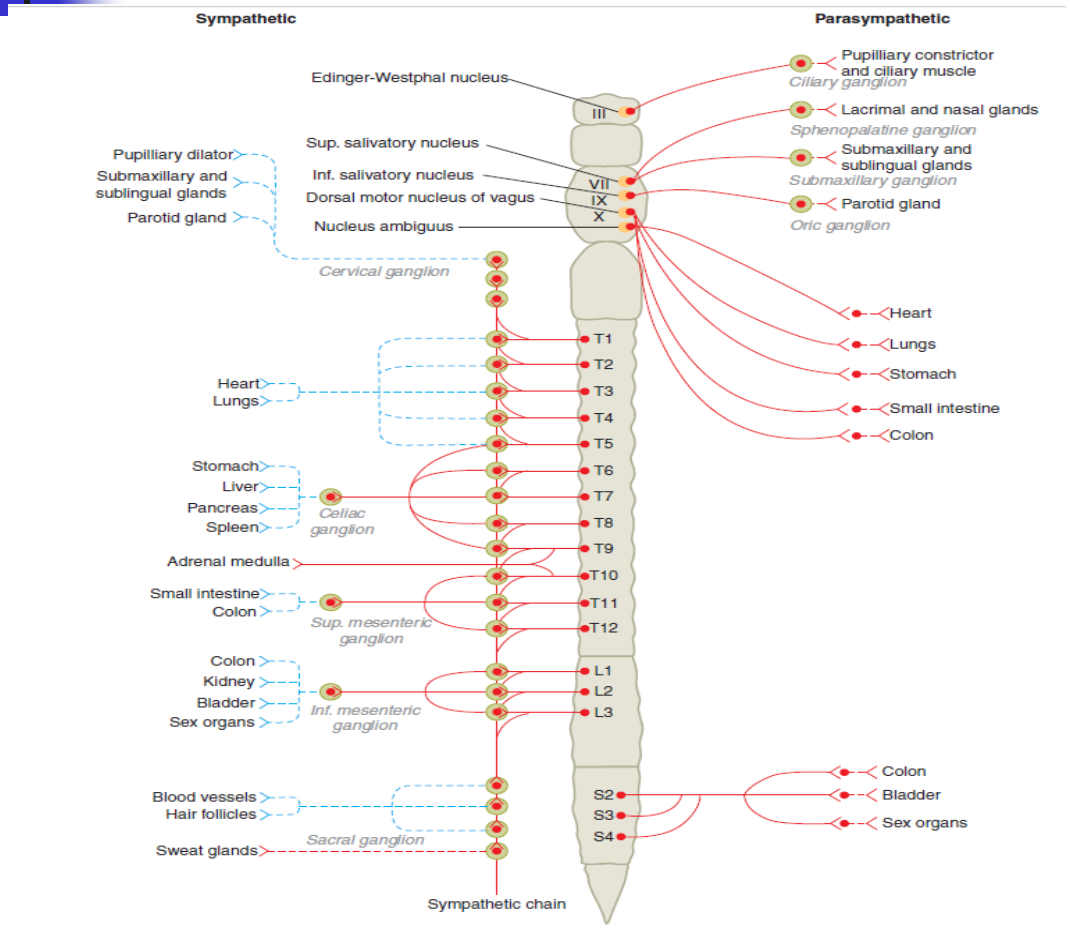
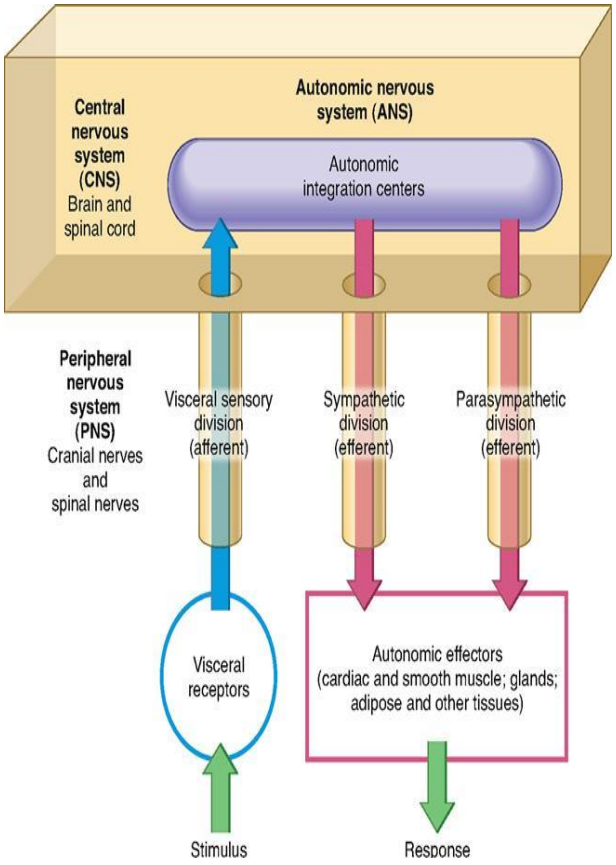
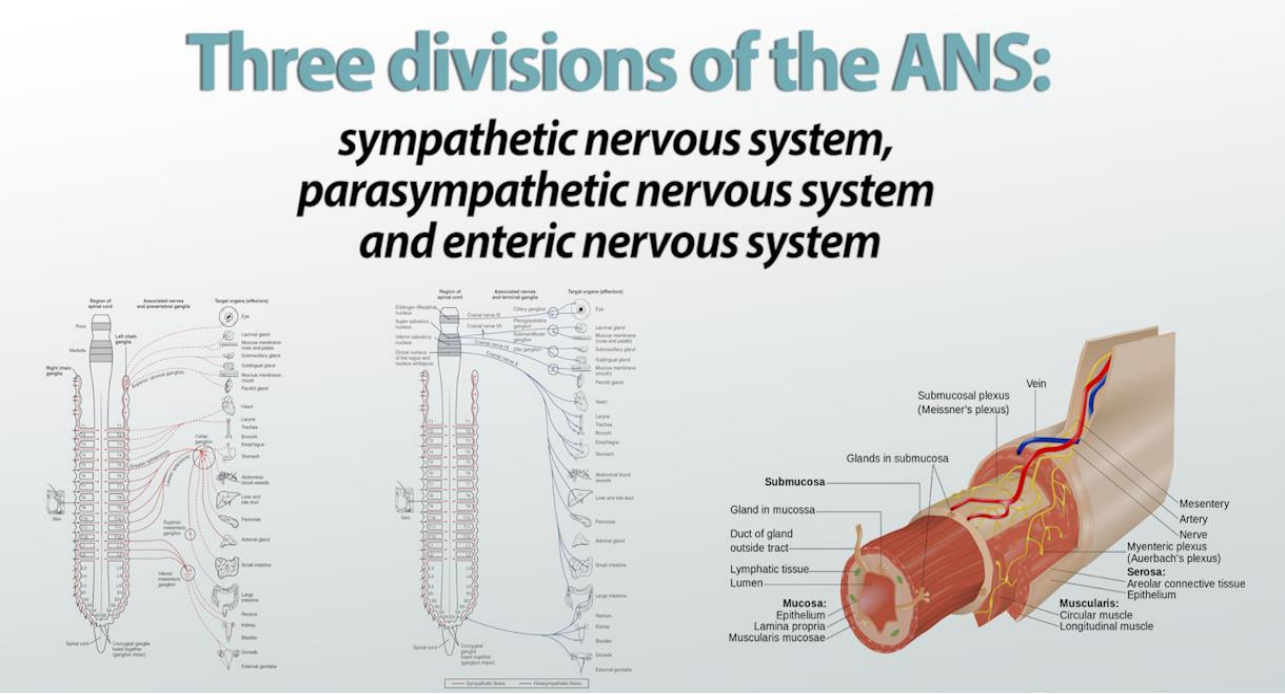


FIGURE 13–3 Organization of sympathetic (left) and parasympathetic (right) nervous systems. Cholinergic nerves are shown in and noradrenergic nerves are shown in blue. Preganglionic nerves are solid lines; postganglionic nerves are dashed lines. (Courtesy of P. Banyas Michigan State University.)



(Ganong's, 2012 24th Edi, pp 255-266

DISTRIBUTION OF THE SYMPATHETIC AND PARASYMPATHTIC NERVOUS SYSTEM



Myenteric plexus is located between longitudinal and circular layers of muscle; it is involved in control of digestive tract motility.

Submucosal plexus is located between the circular muscle and the luminal mucosa; it senses the environment of the lumen and regulates gastrointestinal blood fl ow and epithelial cell function.

(Ganong's, 2012, 24th Edi, pp 255-266

THE AUTONOMIC NERVOUS SYSTEM

Somatic nervous system: Controls organs under voluntary control (mainly skeletal muscles)

Autonomic Nervous System (ANS): Not under voluntary control.

It regulates individual organ, visceral functions and homeostasis, known as the visceral or automatic system. Effectors includes cardiac, smooth muscles and glands.

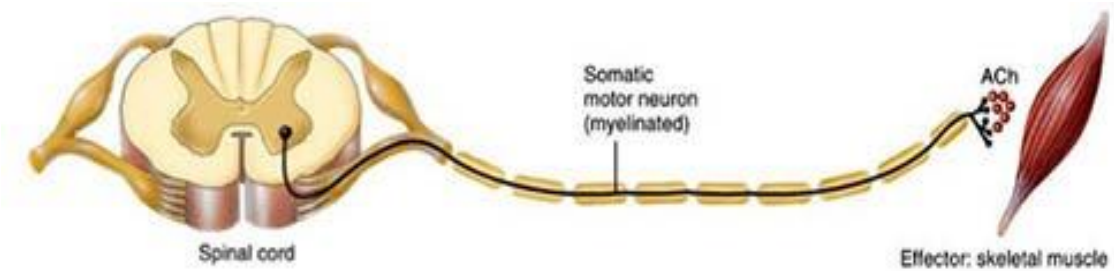
Helps to adapt the changes in environment. Adjusts or modifies functions in response to stress such as blood pressure, sweating body temperature, sweating etc. It fully response in 3-5 seconds.

(Guyton and Hall, 2016 13th Edi, pp 773-785)

COMPARISON OF AUTONOMIC AND SOMATIC SYSTEMS

Somatic system

- One motor neuron extends from the CNS to skeletal muscle
- Axons are well myelinated
- Conduct impulses rapidly



(a) Somatic nervous system

Cause of demyelination

- Inflammatory processes
- Viral demyelination
- Metabolic derangements
- Hypoxic–ischemic demyelination
- Focal compression.
- Multiple sclerosis
- Acute encephalomyelitis

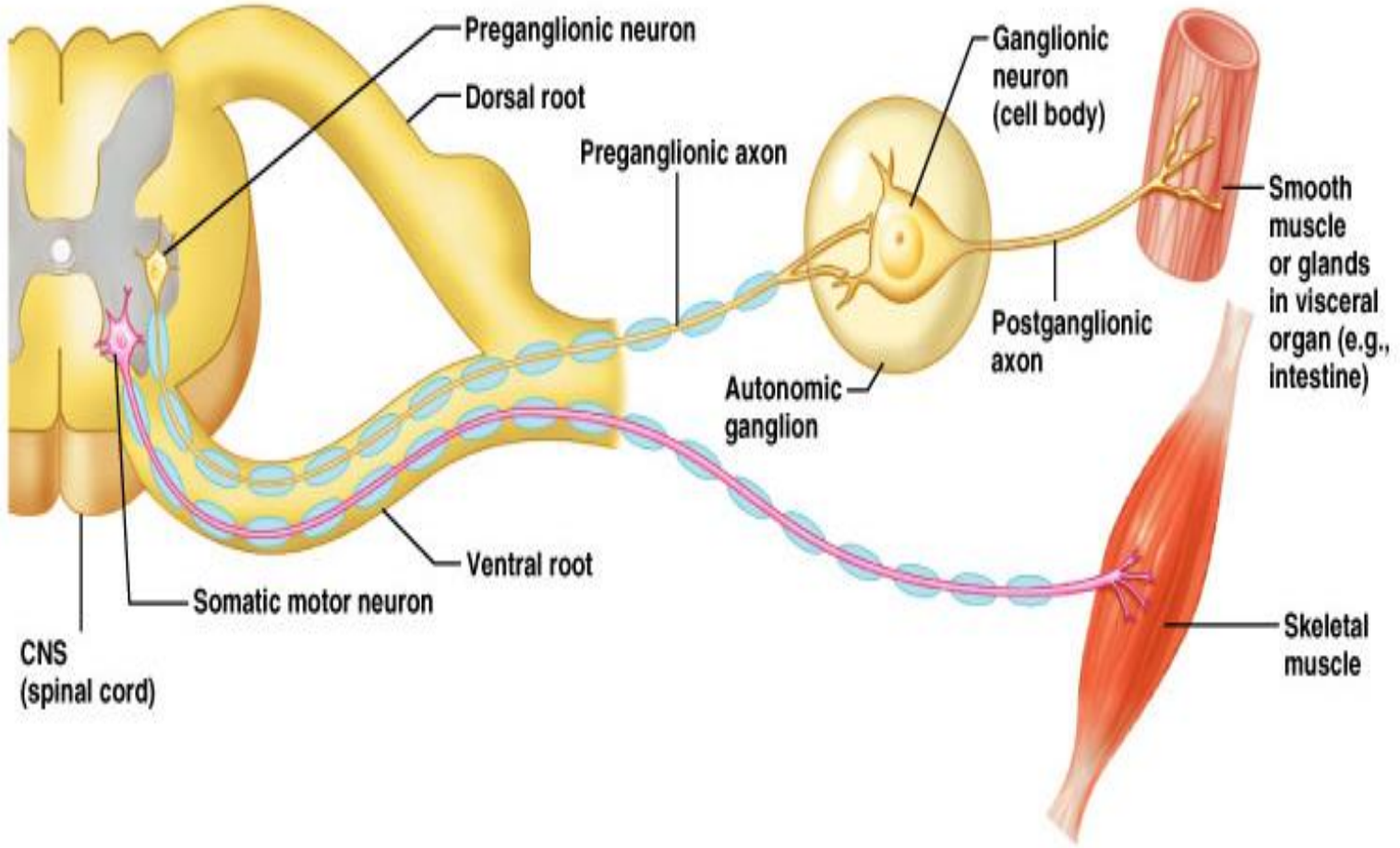
(Guyton and Hall, 2016 13th Edi, pp 773-785)
Medicine, Kumar and Clark,

COMPARISON OF AUTONOMIC AND SOMATIC MOTOR SYSTEMS

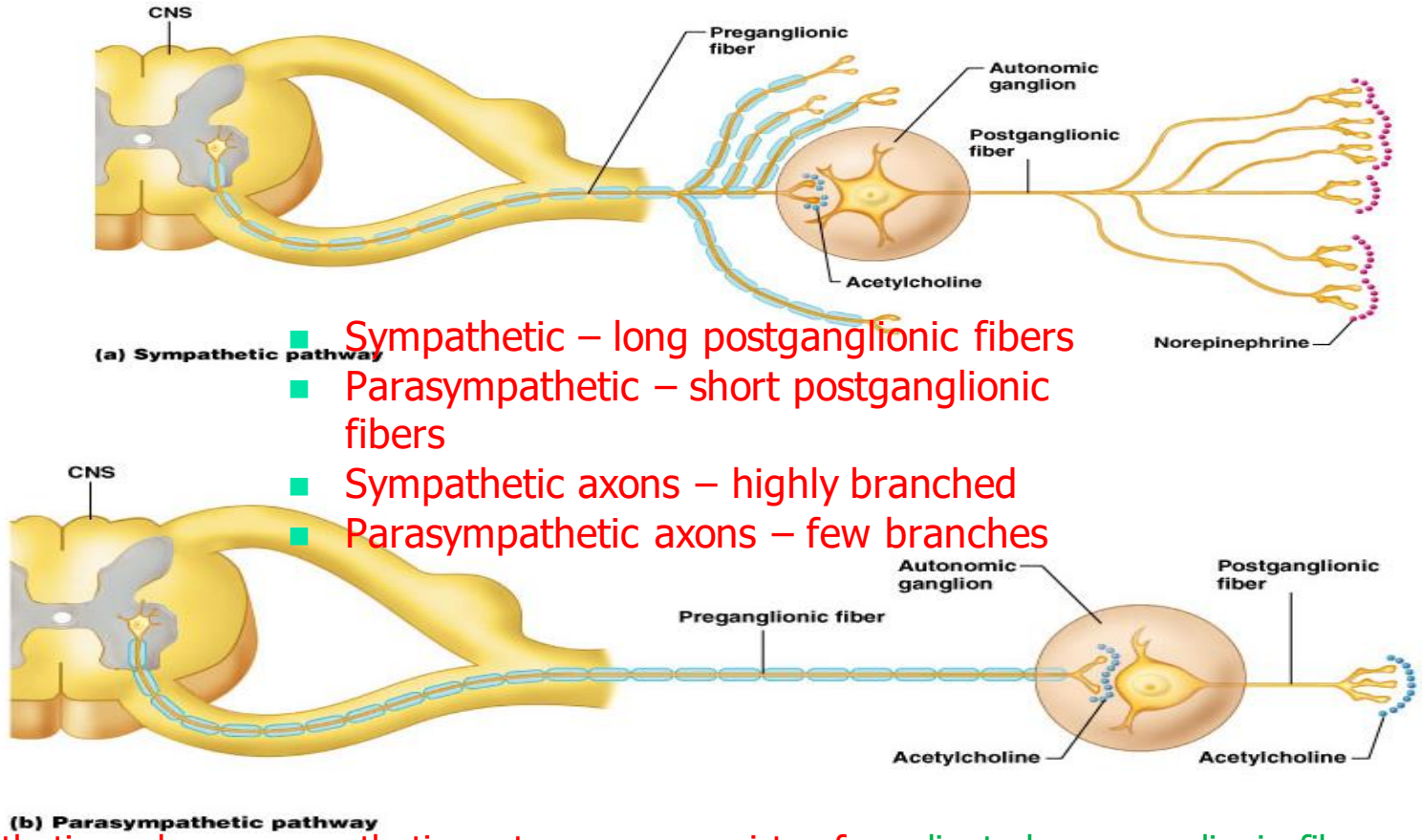
Autonomic nervous system

- Chain of two motor neurons
  - Preganglionic neuron
  - Postganglionic neuron
- Conduction is slower due to thin or un-myelinated axons

COMPARISON OF AUTONOMIC AND SOMATIC MOTOR SYSTEMS



DIFFERENCES IN SYMPATHETIC AND PARASYMPATHETIC DIVISIONS



- Sympathetic – long postganglionic fibers
- Parasympathetic – short postganglionic fibers
- Sympathetic axons – highly branched
- Parasympathetic axons – few branches

Sympathetic and parasympathetic systems are consists of myelinated pre-ganglionic fibers which make synaptic connections with un-myelinated postganglionic fibers and then innervate the effector organ. These synapses usually occur in clusters called ganglia.

DIFFERENCES IN SYMPATHETIC AND PARASYMPATHETIC DIVISIONS

Preganglionic neuron:

- Cell body in brain or spinal cord
- Axon is myelinated type fiber that extends to autonomic ganglion

Postganglionic neuron:

- Cell body lies outside the CNS in an autonomic ganglion
- Axon is unmyelinated type fiber that terminates in a visceral effector

THE AUTONOMIC NERVOUS SYSTEM

The ANS is predominantly an efferent system transmitting impulses from the Central Nervous System (CNS) to peripheral organ systems.

Its effects include:

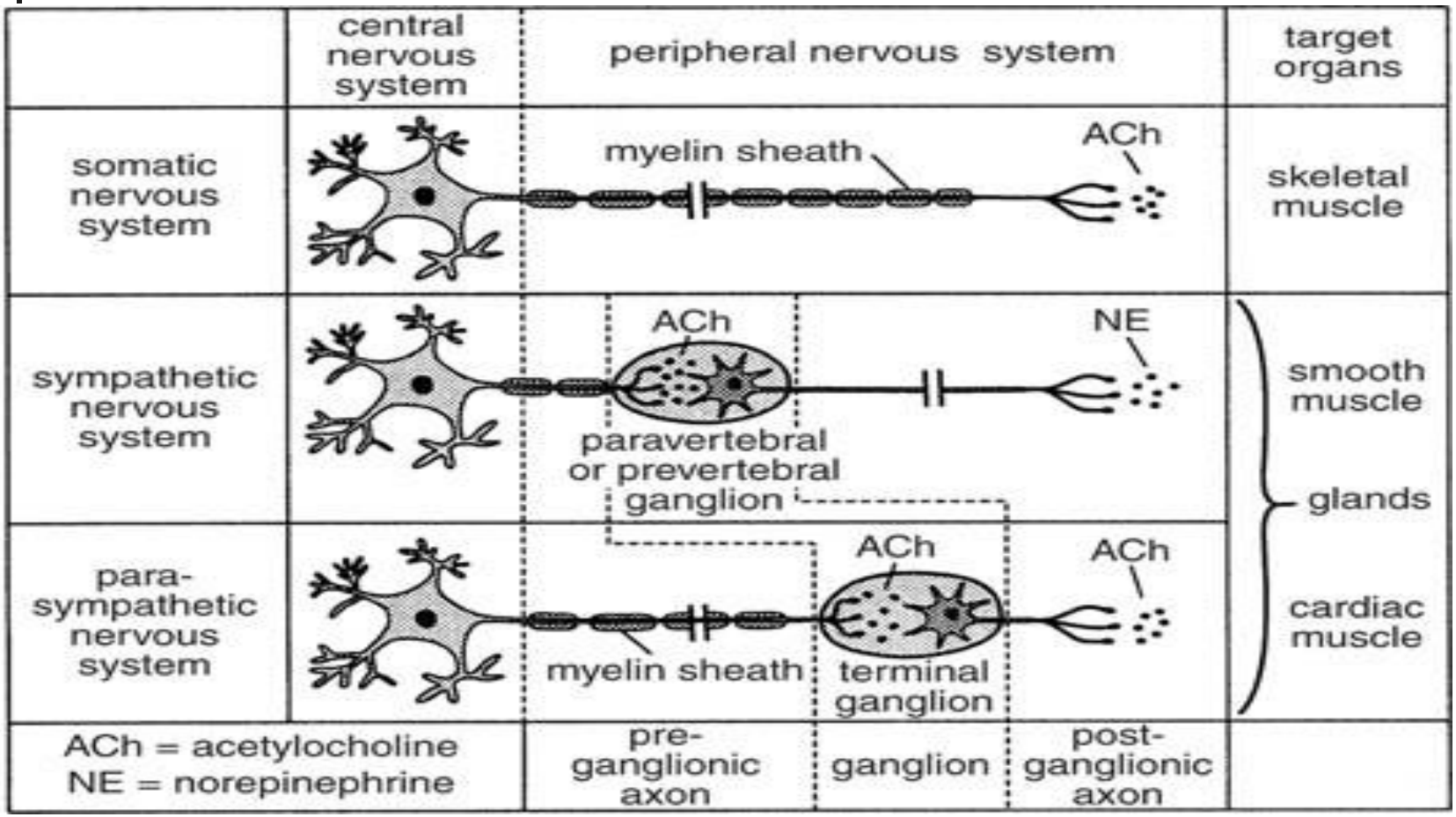
- Control of heart rate and force of contraction
- Constriction and dilatation of blood vessels
- Contraction and relaxation of smooth muscle
- Visual accommodation
- Secretions from exocrine and endocrine glands.

THE AUTONOMIC NERVOUS SYSTEM

ANS activated by centers located in the spinal cord, brain stem, hypothalamus and also cerebral cortex especially the limbic cortex can transmit signals to the lower centers, influence autonomic control.

ANS operates by *visceral reflexes. Subconscious sensory signals from a visceral organ enter* the autonomic ganglia, brain stem or hypothalamus and then return *subconscious reflex responses directly back to the visceral organ to control its* activities.

DIFFERENCES IN SYMPATHETIC AND PARASYMPATHETIC DIVISIONS

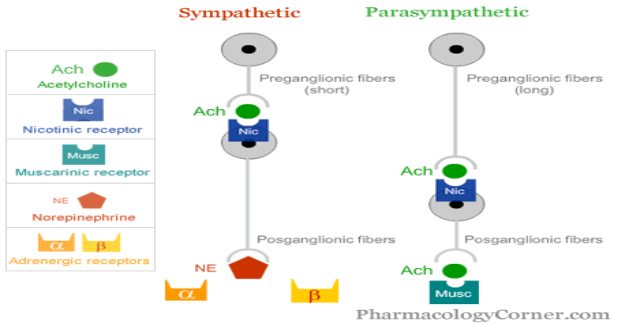


NEUROTRANSMITTERS OF AUTONOMIC NERVOUS SYSTEM

- Neurotransmitter released by pre-ganglionic axons
  - Acetylcholine for both branches (cholinergic)
- Neurotransmitter released by postganglionic axons
  - Sympathetic – most release norepinephrine (adrenergic)
  - Parasympathetic – release acetylcholine

Feature	Sympathetic	Parasympathetic
Origin of pre-ganglionic fibers	Thoracolumbar nerves	Craniosacral nerves
Location of ganglia	Far from visceral effector organs; in sympathetic chain or collateral ganglia	Near or within viscera effector organs
Neurotransmitter	In ganglia, acetylcholine; in effector organs, norepinephrine	In ganglia, acetylcholine; in effector organs, acetylcholine

Fibers



THE AUTONOMIC NERVOUS SYSTEM

Subdivision	Nerves Employed	Location of Ganglia	Chemical Messenger	General Function
Sympathetic	Thoracolumbar	Alongside vertebral column	Norepinephrine	Fight or flight
Parasympathetic	Craniosacral	On or near an effector organ	Acetylcholine	Conservation of body energy

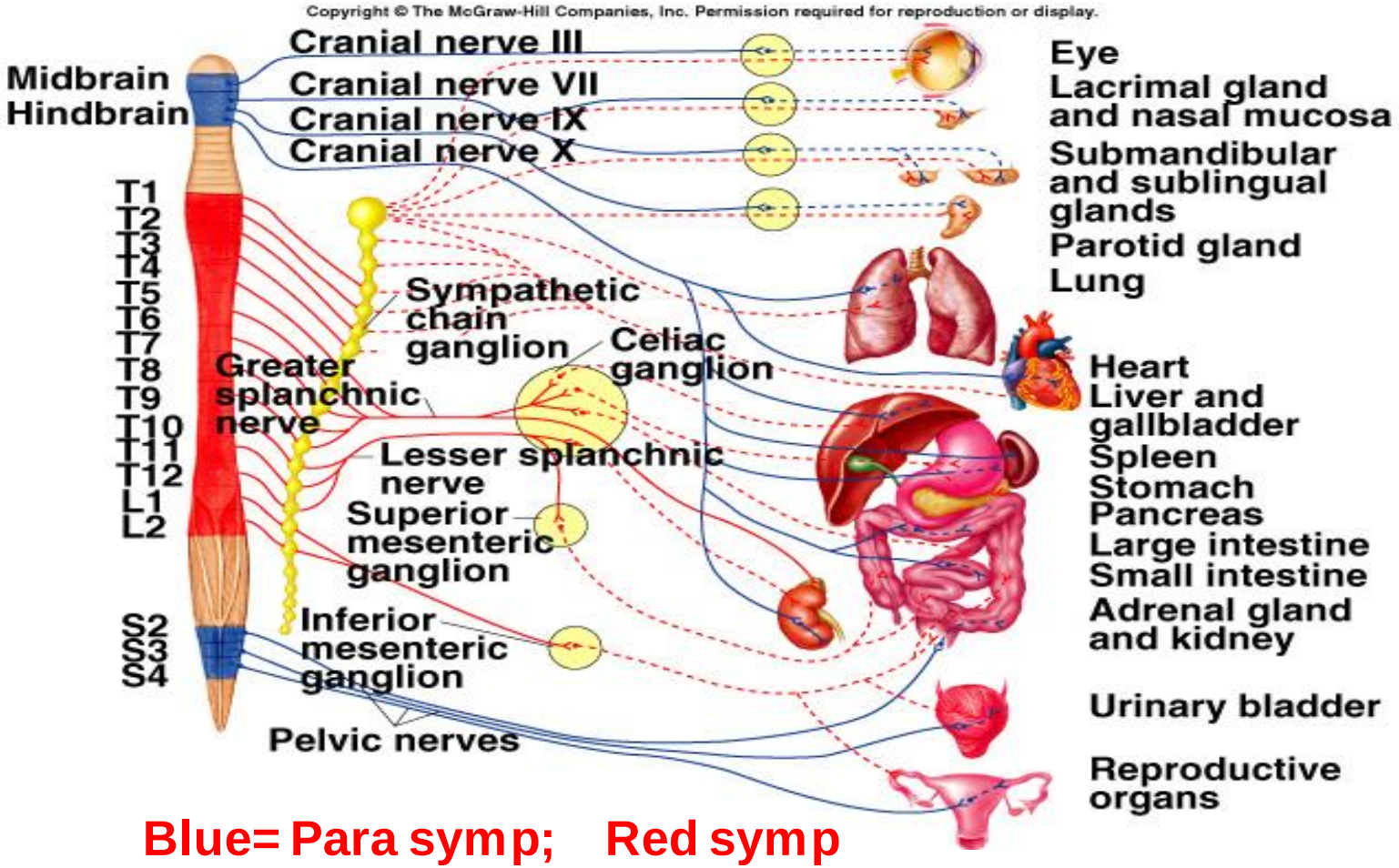
THE AUTONOMIC NERVOUS SYSTEM

Organization of the Autonomic Nervous System

Characteristics	Sympathetic Division	Parasympathetic Division	Somatic Nervous System*
Origin of preganglionic neurons	Spinal cord segments T1–L3 (thoracolumbar)	Nuclei of CN III, VII, IX, and X; spinal cord segments S2–S4 (craniosacral)	—
Location of autonomic ganglia	Paravertebral and prevertebral	In or near effector organs	—
Length of preganglionic axons	Short	Long	—
Length of postganglionic axons	Long	Short	—
Effector organs	Smooth muscle; cardiac muscle; glands	Smooth muscle; cardiac muscle; glands	Skeletal muscle
Neurotransmitter and receptor type in ganglion	ACh/nicotinic receptor	ACh/nicotinic receptor	—
Neurotransmitter in effector organs	Norepinephrine (except sweat glands)	ACh	ACh
Receptor types in effector organs	α_1, α_2, β_1, β_2	Muscarinic	Nicotinic

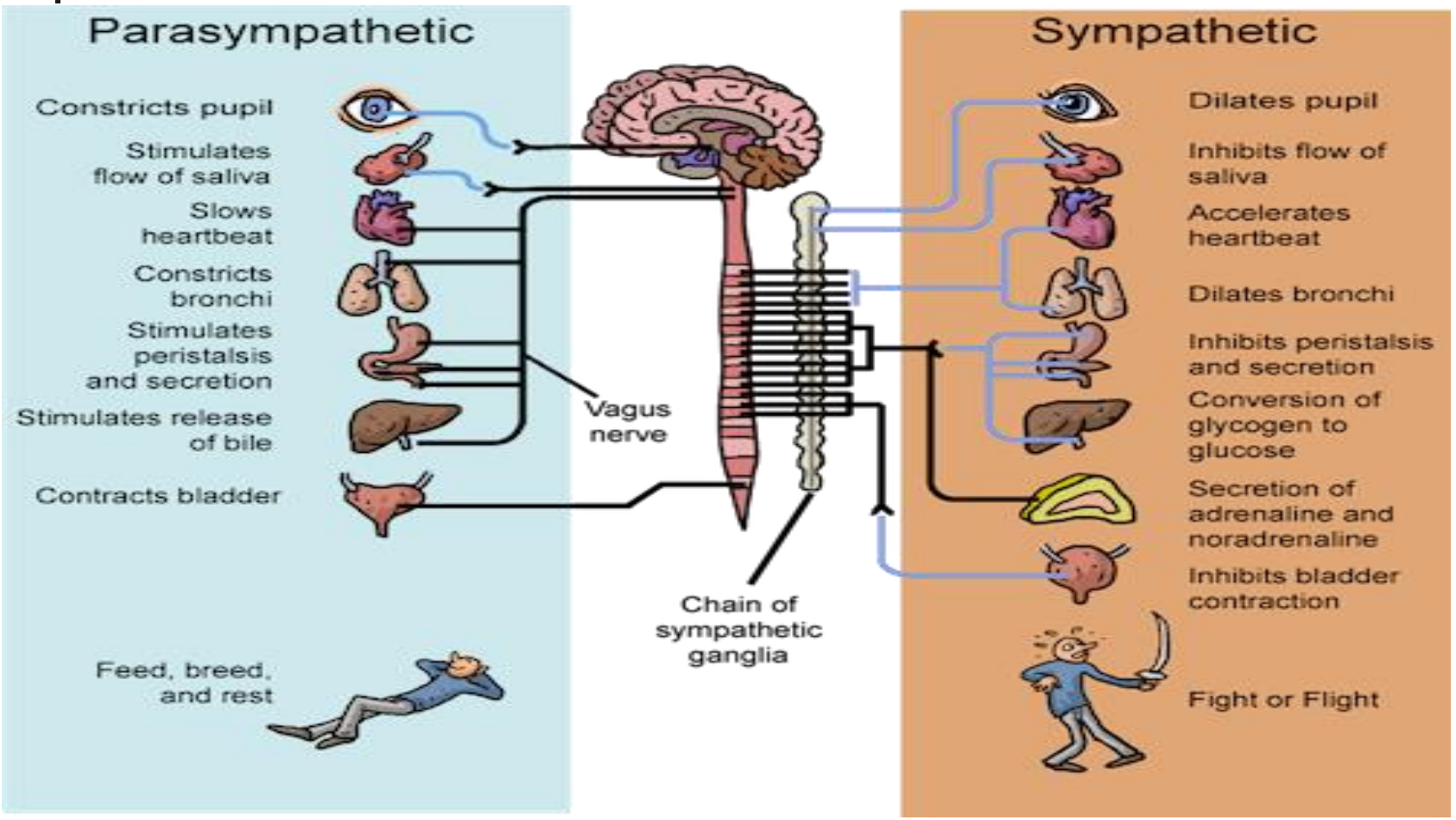
ACh, Acetylcholine; *CN*, cranial nerve.

DISTRIBUTION OF THE SYMPATHETIC AND PARASYMPATHTIC NERVOUS SYSTEM



Blue= Para symp; Red symp

FUNCTIONS OF THE SYMPATHETIC AND PARASYMPATHTIC NERVOUS SYSTEM



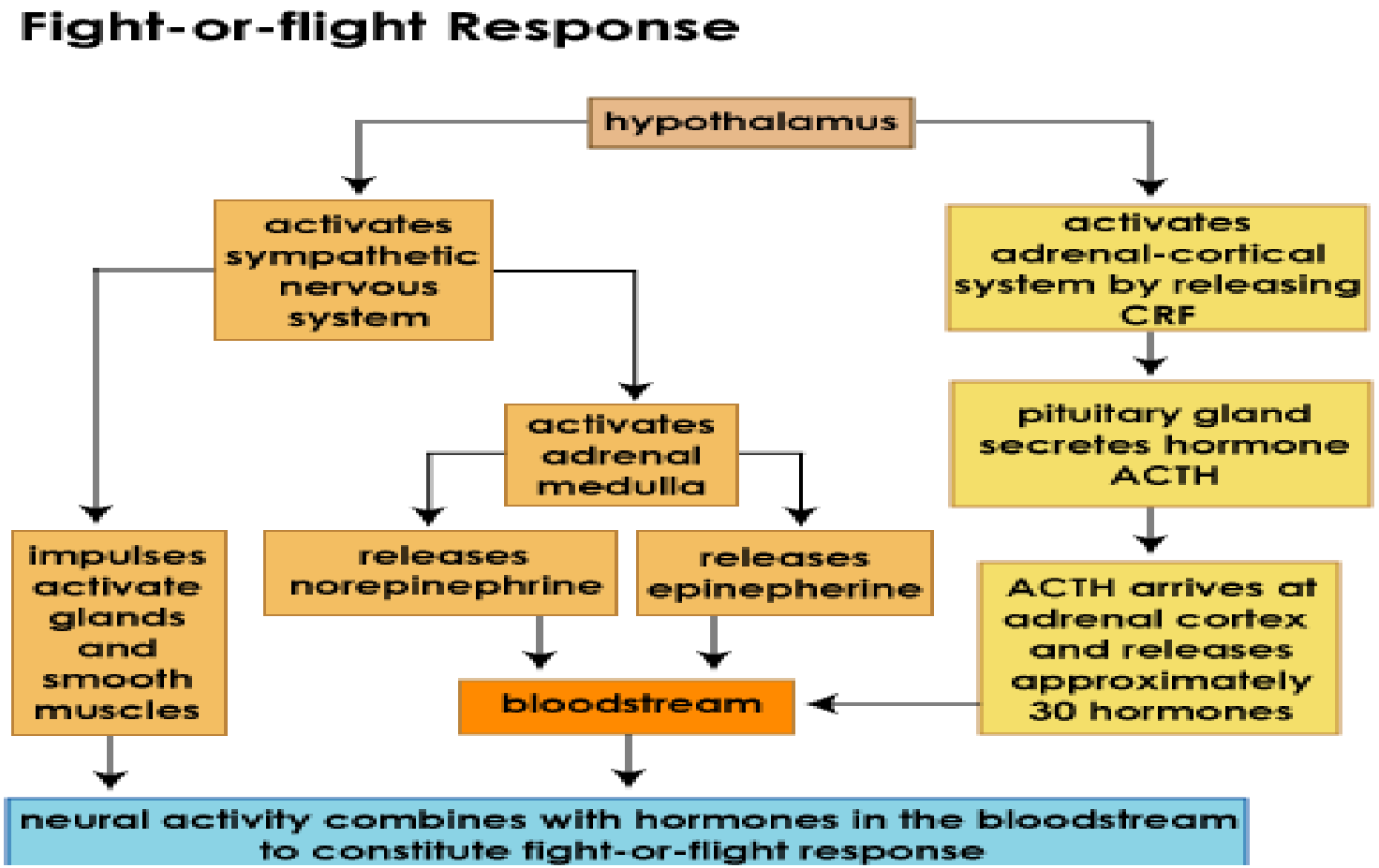
FUNCTIONS OF THE SYMPATHETIC AND PARASYMPATHTIC NERVOUS SYSTEM

Structure	Sympathetic Stimulation	Parasympathetic Stimulation
Iris (eye muscle)	Pupil dilation	Pupil constriction
Salivary Glands	Saliva production reduced	Saliva production increased
Oral/Nasal Mucosa	Mucus production reduced	Mucus production increased
Heart	Heart rate and force increased	Heart rate and force decreased
Lung	Bronchial muscle relaxed	Bronchial muscle contracted
Stomach	Peristalsis reduced	Gastric juice secreted; motility increased
Small Intes	Motility reduced	Digestion increased
Large Intes	Motility reduced	Secretions and motility increased
Liver	Increased conversion of glycogen to glucose	
Kidney	Decreased urine secretion	Increased urine secretion
Bladder	Wall relaxed Sphincter closed	Wall contracted Sphincter relaxed

(Guyton and Hall, 2016 13th Edi, pp 773-785)

THE SYMPATHETIC NERVOUS SYSTEM

THE SYMPATHETIC NERVOUS SYSTEM



THE SYMPATHETIC NERVOUS SYSTEM

FEAR, FIGHT- FLIGHT RESPOSE

- The sympathetic system enables the body to be prepared for fear, flight or fight
- Sympathetic responses include an increase in heart rate, blood pressure and cardiac output
- Diversion of blood flow from the skin and splanchnic vessels to those supplying skeletal muscle
- Increased pupil size, bronchiolar dilation, contraction of sphincters and metabolic changes such as the mobilisation of fat and glycogen.

THE SYMPATHETIC NERVOUS SYSTEM

Frequently referred to as the fear, fight or flight response

It has a stimulatory effect on organs and physiological systems, responsible for rapid sensory activity (pupils in the eye) and movement (skeletal muscle).

It diverts blood flow away from the GIT and skin via vasoconstriction.

Blood flow to skeletal muscles, lungs is not only maintained, but enhanced (by as much as 1200%), in case of skeletal muscles.

THE SYMPATHETIC NERVOUS SYSTEM

Dominance by the sympathetic system is caused by physical or emotional stress "E situations"

Emergency, Embarrassment, Excitement, Exercise

Alarm reaction = flight or fight response:

- ❑ Dilation of pupils
- ❑ Increase heart rate, force of contraction & BP
- ❑ Decrease in blood flow to nonessential organs
- ❑ Increase in blood flow to skeletal & cardiac muscle
- ❑ Airways dilate & respiratory rate increases
- ❑ Blood glucose level increase

(Guyton and Hall, 2016 13th Edi, pp 773-785)

THE PARASYMPATHETIC DIVISION

- The parasympathetic nervous system has "rest and digest" activity.
- Concerned with conservation and restoration of energy, as it causes a reduction in heart rate and blood pressure, and facilitates digestion and absorption of nutrients, and consequently the excretion of waste products
- The chemical transmitter at both pre and postganglionic synapses in the parasympathetic system is Acetylcholine (Ach).

THE PARASYMPATHETIC DIVISION

Enhance "rest-and-digest" activities

Normally dominate over sympathetic impulses

SLUDD type responses: salivation, lacrimation, urination, digestion & defecation

3 "Decreases" decreased HR, diameter of airways and diameter of pupil

- Paradoxical fear when there is no escape route or no way to win causes massive activation of parasympathetic division
loss of control over urination and defecation

THE AUTONOMIC NERVOUS SYSTEM

Acetylcholine activates mainly two types of *receptors*. They are called *muscarinic* and *nicotinic* receptors.

Muscarine activates only muscarinic receptors whereas nicotine activates only nicotinic receptors; acetylcholine activates both of them.

Muscarinic receptors are found on all effector cells that are stimulated by the postganglionic cholinergic neurons of either the parasympathetic nervous system or the sympathetic system.

Nicotinic receptors are found in the autonomic ganglia at the synapses between the pre-ganglionic and post-ganglionic neurons of both the sympathetic and parasympathetic systems.

(Ganong's, 2016 24th Edi, pp 255-266

THE AUTONOMIC NERVOUS SYSTEM

	Sympathetic (adrenergic, with exceptions)	Parasympathetic (muscarinic)
circulatory system		
cardiac output	increases	M2: decreases
SA node: heart rate (chronotropic)	β1, β2: increases	M2: decreases
cardiac muscle: contractility (inotropic)	β1, β2: increases	M2: decreases (atria only)
conduction at AV node	β1: increases	M2: decreases
vascular smooth muscle	M3: contracts; α = contracts; β2 = relaxes	---
platelets	α2: aggregates	---
mast cells - histamine	β2: inhibits	---

(Ganong's, 2016 24th Edi, pp 255-266

THE AUTONOMIC NERVOUS SYSTEM

	Sympathetic (adrenergic)	Parasympathetic (muscarinic)
respiratory system		
smooth muscles of bronchioles	β2: relaxes (major contribution); α1: contracts (minor contribution)	M3: contracts
nervous system		
pupil of eye	α1: relaxes	M3: contracts
ciliary muscle	β2: relaxes	M3: contracts

(Ganong's, 2016 24th Edi, pp 255-266

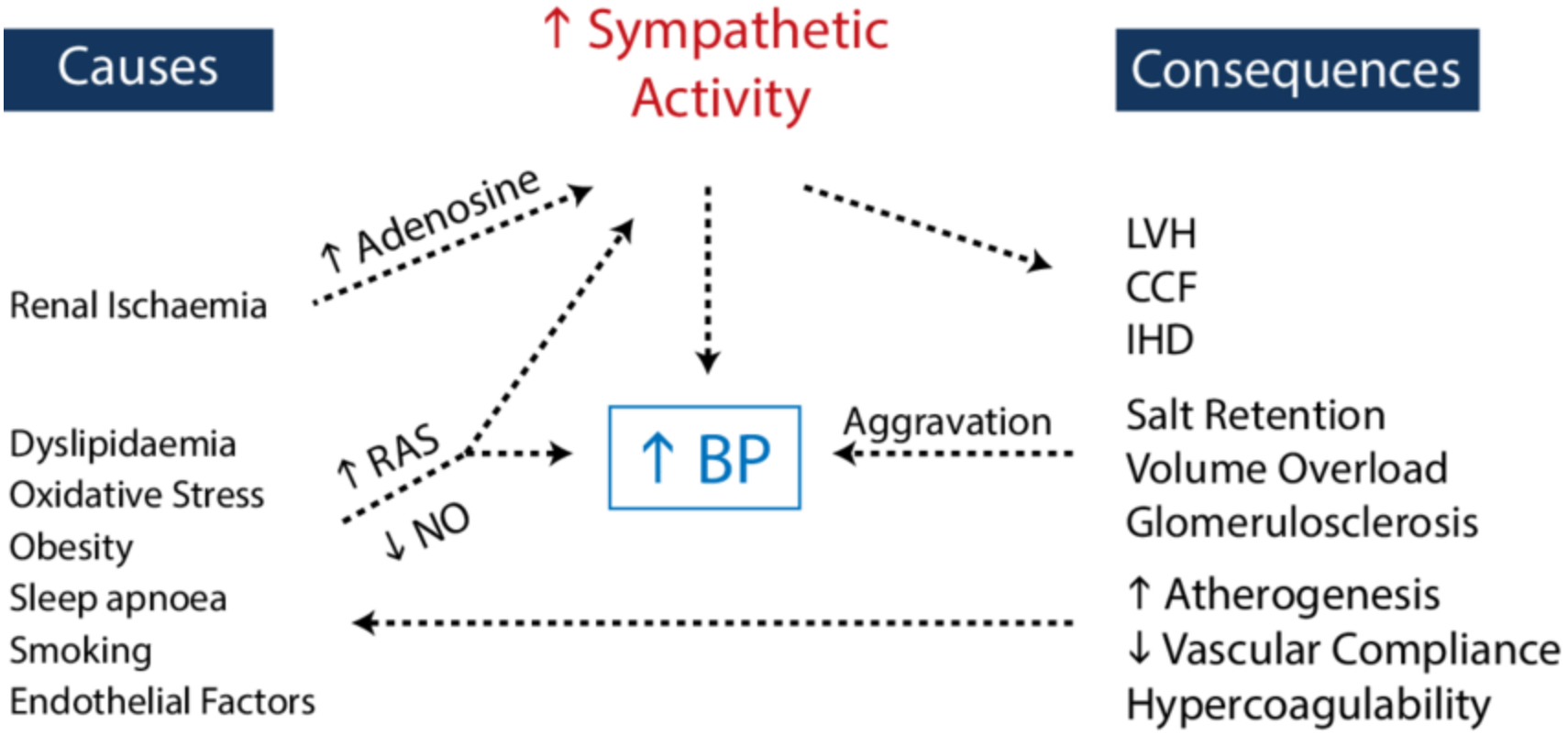
THE AUTONOMIC NERVOUS SYSTEM

	Sympathetic (adrenergic, with exceptions)	Parasympathetic (muscarinic)
digestive system		
salivary glands: secretions	β: stimulates viscous, amylase secretions; α1 = stimulates potassium cation	stimulates watery secretions
lacrimal glands (tears)	decreases	M3: increases
kidney (renin)	secretes	---
parietal cells	---	M1: secretion
liver	α1, β2: glycogenolysis, gluconeogenesis	---
GI tract motility	decreases	M1, M3: increases
smooth muscles of GI tract	α, β2: relaxes	M3: contracts
sphincters of GI tract	α1: contracts	M3: relaxes

THE AUTONOMIC NERVOUS SYSTEM

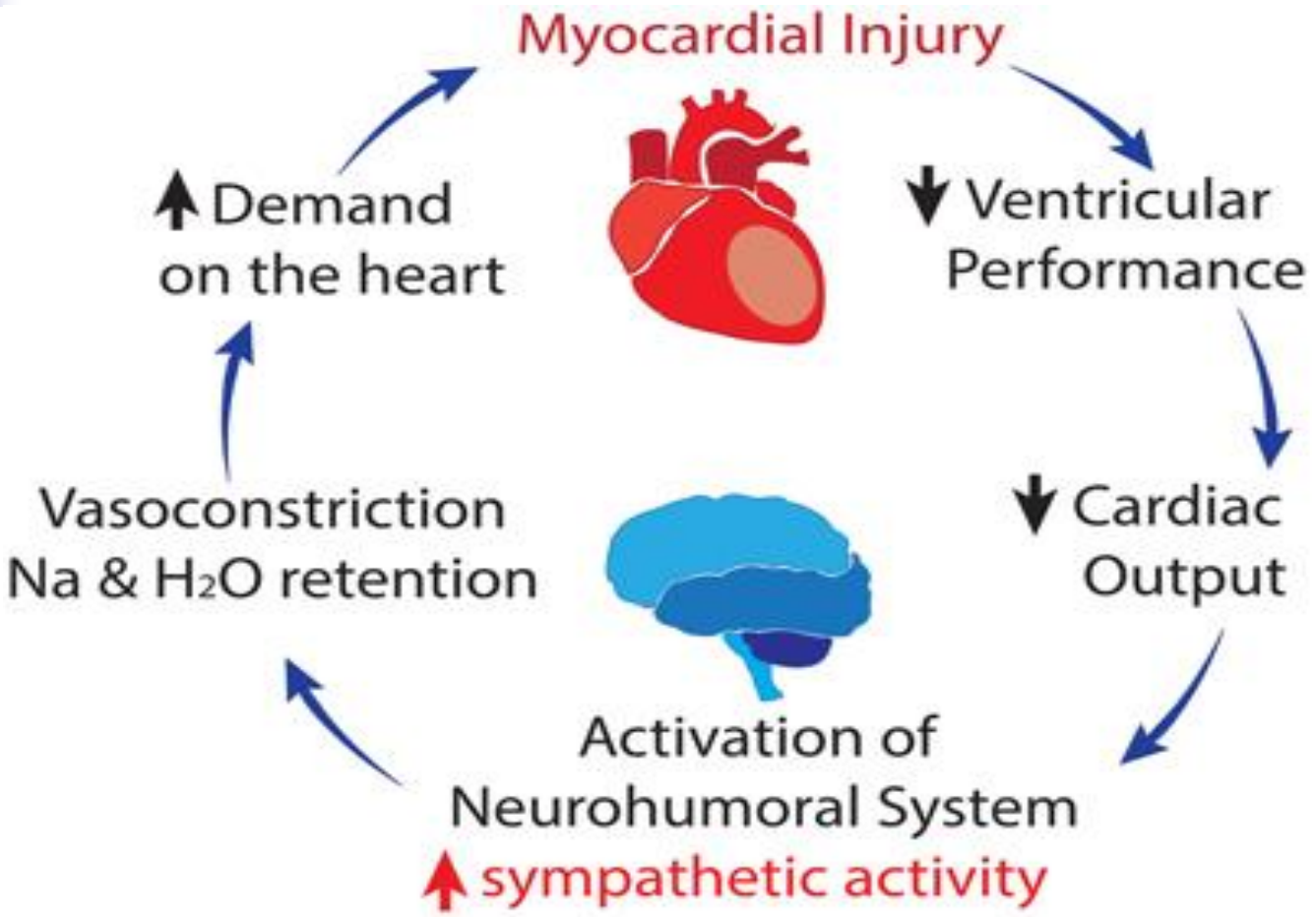
	Sympathetic (adrenergic)	Parasympathetic (muscarinic)
ENDOCRINE		
pancreas (islets)	α2: decreases secretion	---
adrenal medulla	N: secretes epinephrine	---
urinary system		
bladder wall	β2: relaxes	contracts
ureter	α1: contracts	relaxes
sphincter	α1: contracts; β2 relaxes	relaxes
sweat gland secretions	M: stimulates (major contribution); α1: stimulates (minor contribution)	---
arrector pili	α1: stimulates	---

THE AUTONOMIC NERVOUS SYSTEM



GopalaKrishnan et al Alpha-blockers in Renal Disease: Appraisal of Evidence, J Asso of Ind, 2014

THE AUTONOMIC NERVOUS SYSTEM



THE AUTONOMIC NERVOUS SYSTEM

Non – invasive tests

Tests for cardiac vagal function

- Respiratory sinus arrhythmia
- Vasalva ratio(Phase IV/II)
- Bradycardia during phenylephrine challenge
- Absence of tachycardia with atropine

Tests for sympathetic function

I) CARDIAC

- Tachycardia during standing or head-up tilt
- Tachycardia during vasalva strain(PhaseII)

II) PERIPHERAL

- Blood pressure overshoot after vasalva release
- BP increase with cold pressure test
- Diastolic BP rise with isometric handgrip
- Systolic and diastolic BP response to upright position

THANK YOU