AUTONOMIC NERVOUS SYSTEM

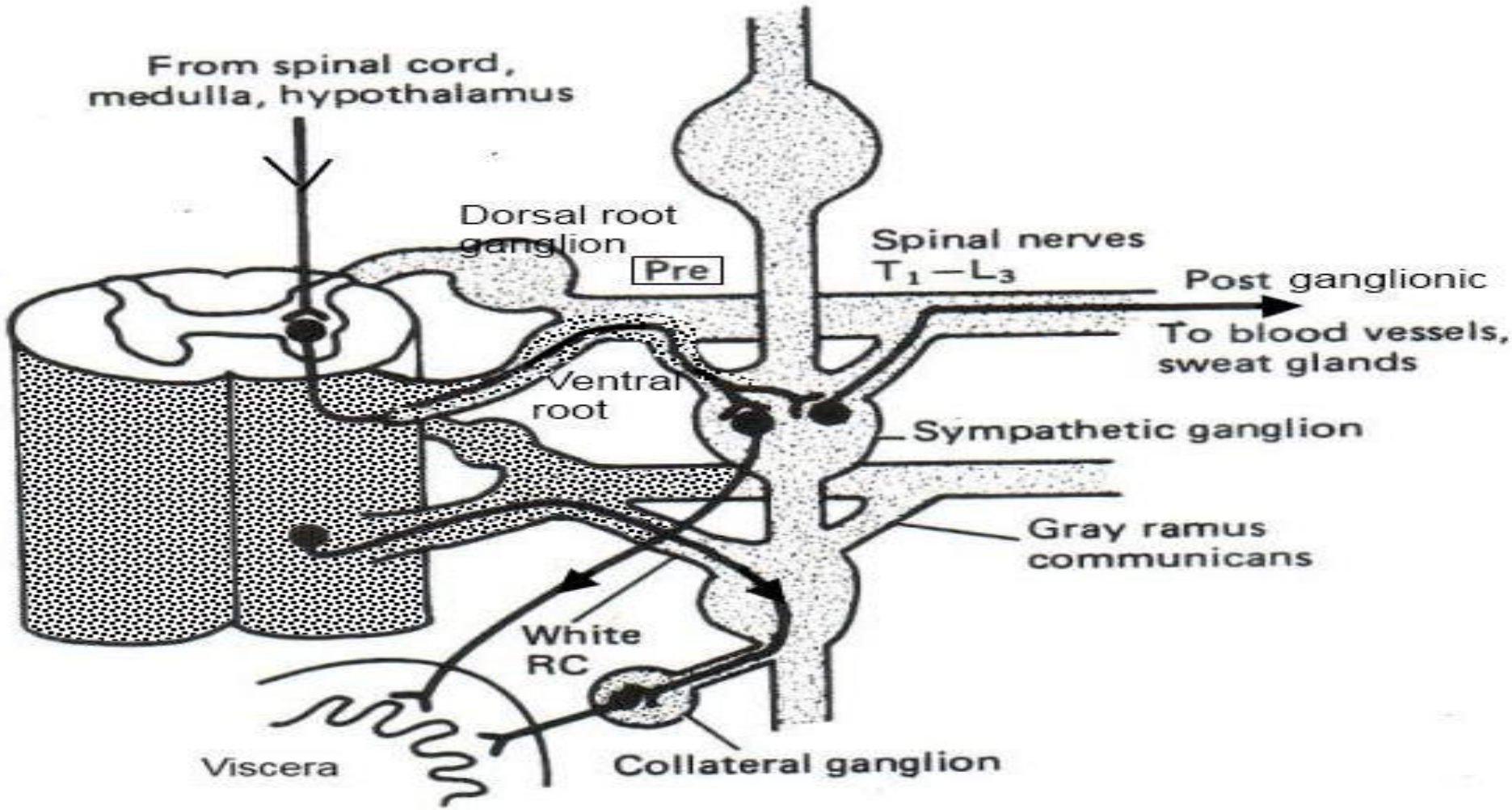
The portion of the nervous system that controls all the vegetative or visceral functions including cardio-vascular, respiratory, gastrointestinal secretions and motility, reproductive, renal, endocrine, metabolic functions, and sweating and body temperature is called as **autonomic nervous system (ANS).**

- ANS activity is under involuntary control. However, some activities such as micturition and defecation are partly voluntary.
- The ANS is activated by centres located in the spinal cord, brainstem and hypothalamus.
- It is also operated by means of visceral reflexes that functions subconsciously.

Somatic motor nerves	Autonomic nerves
a) Innervate skeletal muscles	Innervate cardiac, smooth muscles, glands
b) Has one neuron system - nerve cell bodies located in CNS and its axons innervate skeletal muscles	Has two neuron system – pre and postganglionic neurons; preganglionic neuron in CNS and postganglionic neuron in ganglia
c) Many axons myelinated	Post ganglionic axons unmyelinated
d) Always stimulate muscle cells	Stimulate or inhibit smooth muscles or gland
e) Controls movement of the animal	Controls internal environment of the body (homeostasis); mobilizes body resources during stress

Sympathetic Division (SNS)

- The myelinated preganglionic efferent fibres of this system have their cell bodies within the intermediolateral cell column of the first thoracic to the third or fourth lumbar spinal cord. Hence, the sympathetic system is also known as **thoracolumbar division.**
- The preganglionic fibres leave the spinal cord as part of the ventral roots of the respective spinal nerves.
- Outside the vertebral canal, these preganglionic fibres leave the nerve trunk and pass through a white ramus to enter the paravertebral sympathetic ganglionic chain, (sympathetic trunk) where they synapse with postganglionic fibres.
- The postganglionic fibres that leave the sympathetic trunk are relatively longer fibres.
- The postganglionic axons (unmyelinated) extend to the visceral organs or re-enter the spinal nerve through gray ramus to supply skeletal muscle blood vessels, sweat glands and piloerector muscles of hair.


From spinal cord,
medulla, hypothalamus
Dorsal root
ganglion
Pre
Spinal nerves
$T_1 - L_3$
Post ganglionic
To blood vessels,
sweat glands
Ventral
root
Sympathetic ganglion
Gray ramus
communicans
White
RC
Viscera
Collateral ganglion

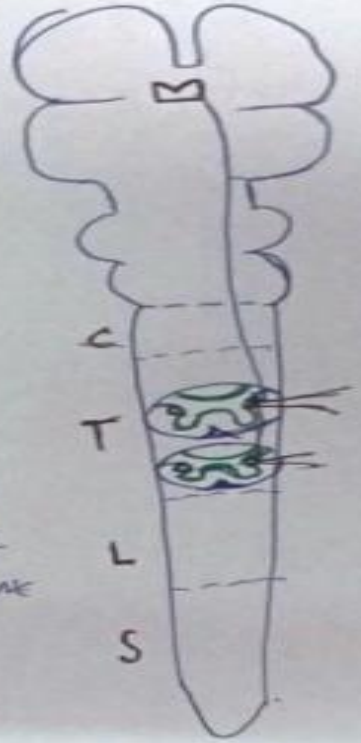
All the preganglionic Sympathetic, Parasympathetic and somatic motor fibres are cholinergic in nature.

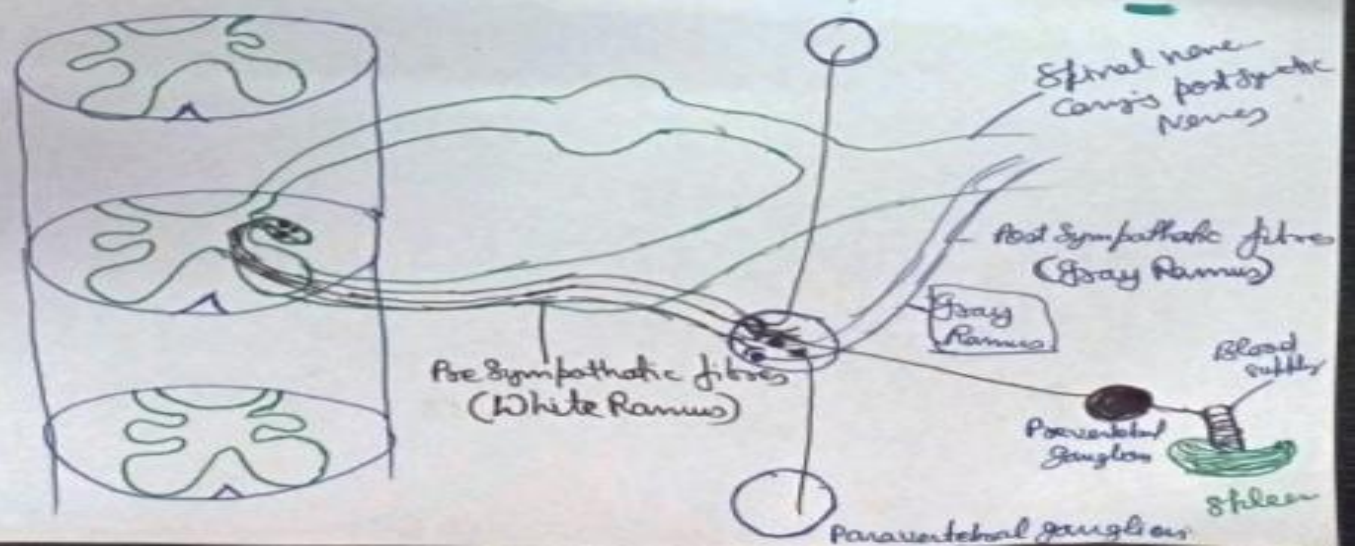
Heart supply -

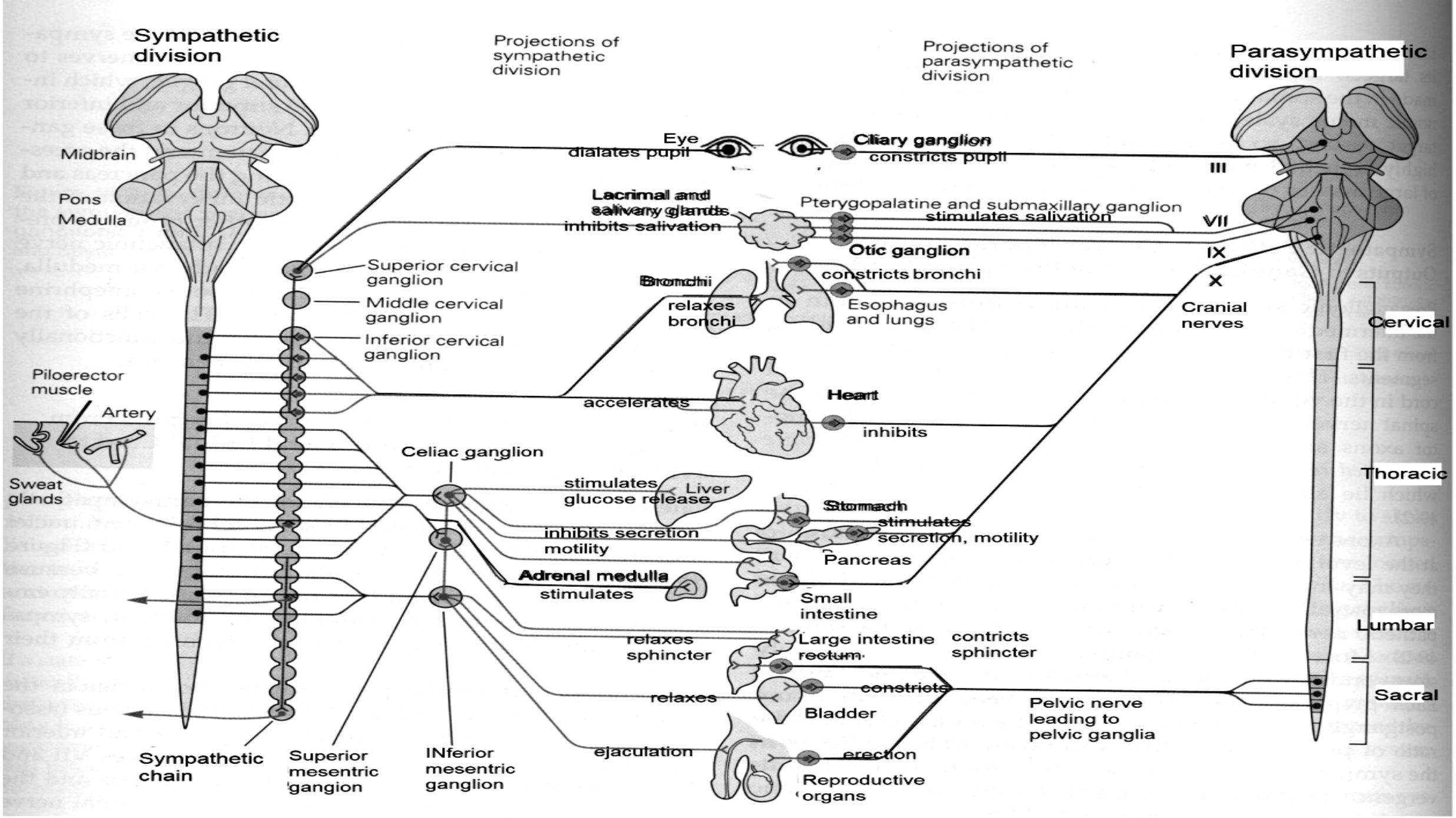
T_1, T_2, T_3, T_4 & T_5 nerves upward in cervical ganglia and then nerves act as cardiac nerve.

~~Medulla of~~

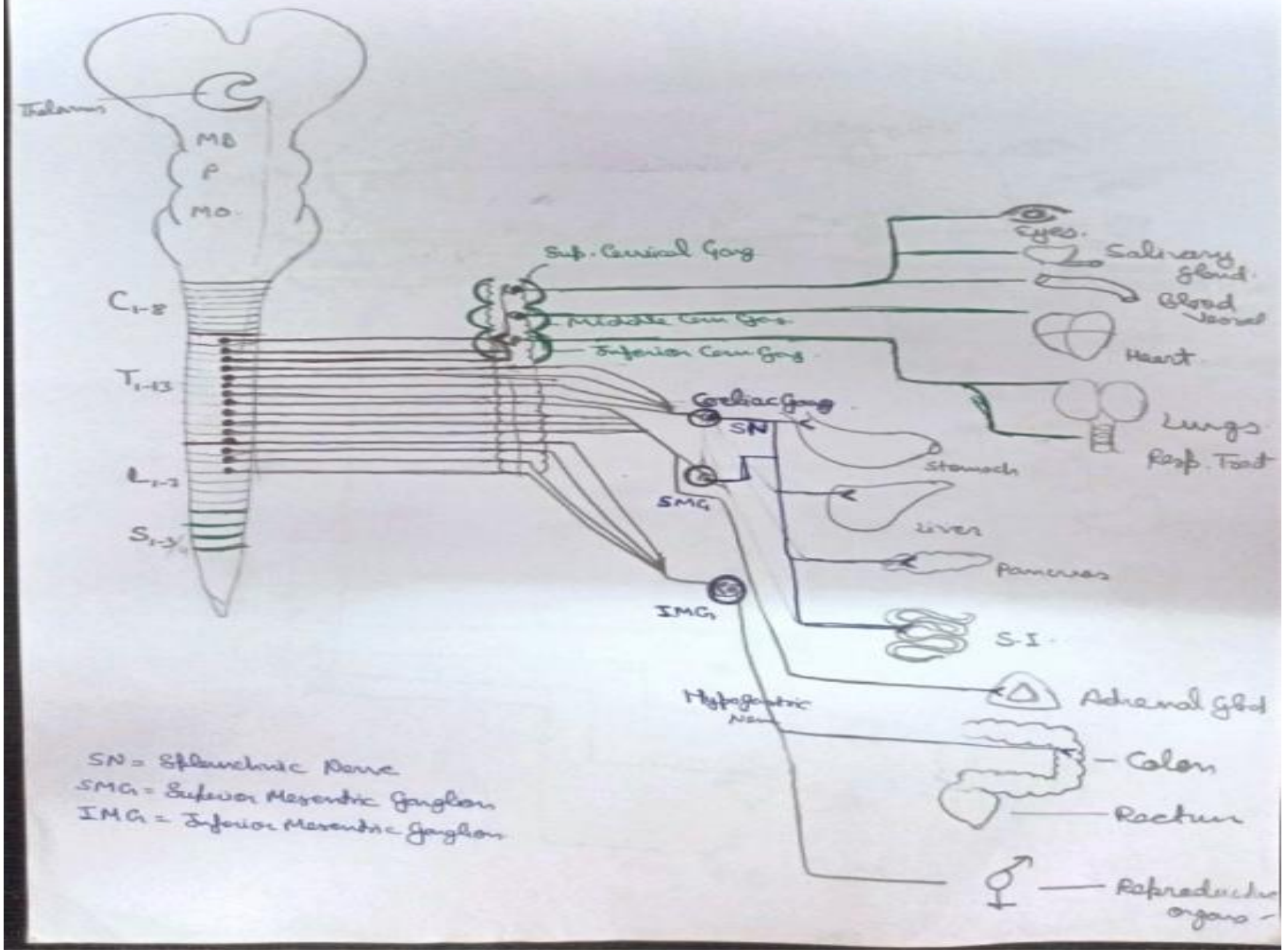
Adrenal Medulla is like a bunch of Post Sympathetic ganglion, there don't have post ganglionic fibres do secret EPINE in general circulation.

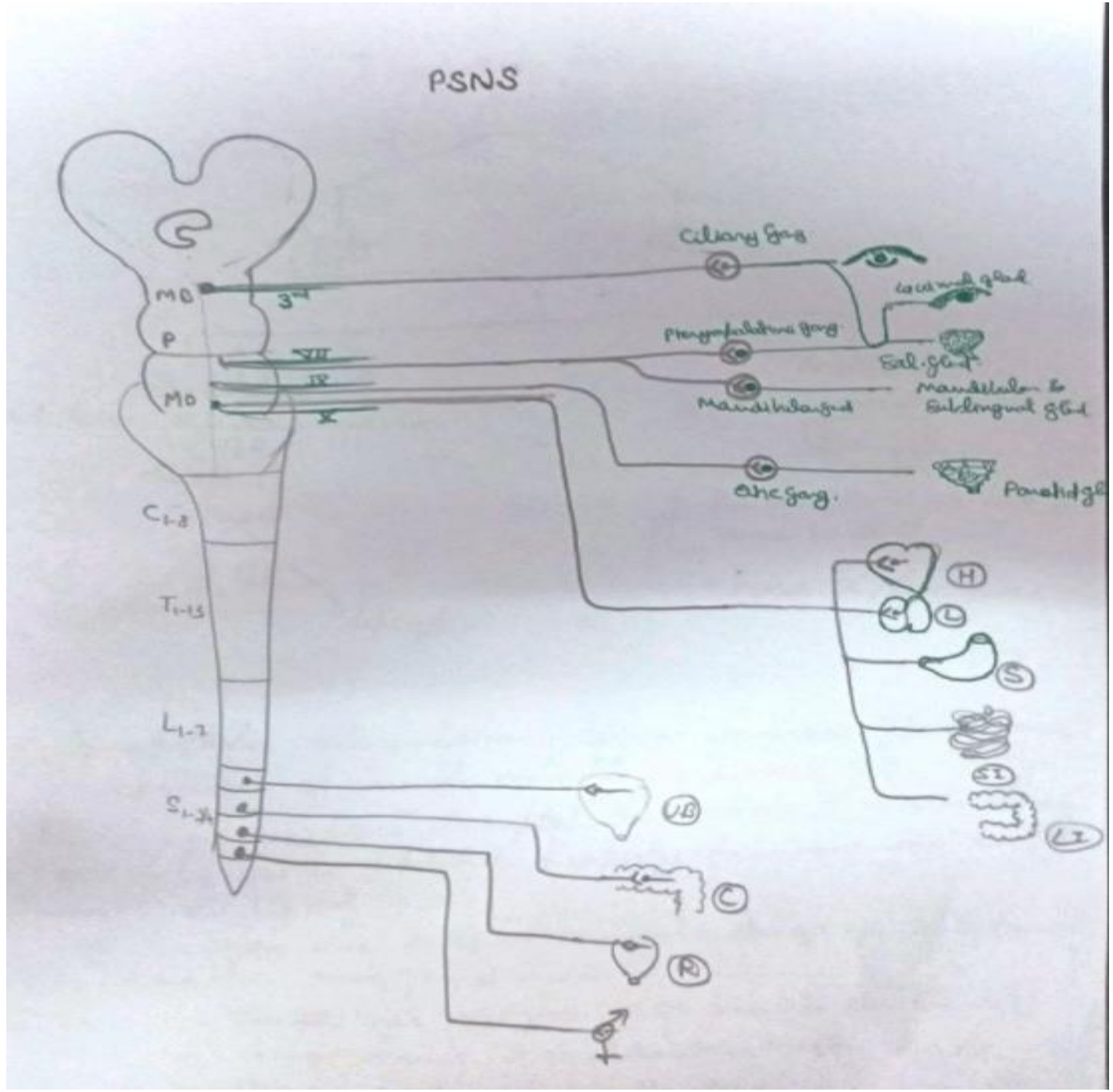





Sympathetic division
Projections of sympathetic division
Projections of parasympathetic division
Parasympathetic division
Midbrain
Pons
Medulla
Eye
dialates pupil
Ciliary ganglion
constricts pupil
III
Lacrimal and salivary glands
inhibits salivation
Pterygopalatine and submaxillary ganglion
stimulates salivation
VII
Otic ganglion
IX
X
Superior cervical ganglion
Middle cervical ganglion
Inferior cervical ganglion
Bronchi
relaxes bronchi
constricts bronchi
Esophagus and lungs
Cranial nerves
Cervical
Piloerector muscle
Artery
Sweat glands
accelerates
Heart
inhibits
Celiac ganglion
stimulates glucose release
Liver
inhibits secretion motility
Stomach
stimulates secretion, motility
Pancreas
Adrenal medulla
stimulates
Small intestine
Thoracic
relaxes sphincter
Large intestine
rectum
contricts sphincter
Lumbar
relaxes
Bladder
constricts
Sacral
Pelvic nerve leading to pelvic ganglia
ejaculation
erection
Reproductive organs
Sympathetic chain
Superior mesentric ganglion
INferior mesentric ganglion

SNS


Thalamus
MB
P
MO
C1-8
T1-13
L1-3
S1-5
Sup. Cervical Ganglion
Middle Cervical Ganglion
Inferior Cervical Ganglion
Eyes
Salivary gland
Blood vessel
Heart
Lungs
Resp. Tract
Coeliac Ganglion
SN
Stomach
SMG
Liver
Pancreas
IMG
S.I
Adrenal gland
Hypogastric Nerve
Colon
Rectum
Reproductive organs
SN = Splanchnic Nerve
SMG = Superior Mesentric Ganglion
IMG = Inferior Mesentric Ganglion


PSNS
MO
P
MO
3rd
VII
IX
X
Ciliary gang
Pterygopalatine gang
Mandibular gang
Otic gang
Lacrimal gland
Sal. gland
Mandibular & Sublingual gland
Parotid gl
C1-8
T1-13
L1-2
S1-3
H
L
S
I
LI
UB
C
R

- Few preganglionic fibres pass through the paravertebral ganglia (without synapsing), and they synapse with post ganglionic neurons in the distal prevertebral ganglia.

- The paravertebral ganglia extend from upper cervical to coccygeal level. It is a paired structure possessing a ganglion for each spinal segment. In the cervical region, the segmental ganglia are fused into three large ganglia known as the **cranial, middle and caudal cervical ganglia.**

-

Usually the caudal cervical ganglion is fused with the upper two or three thoracic ganglia and forms the **stellate ganglion.**

The head portion (eye, salivary glands and blood vessels) receives the postganglionic fibres from the **cranial cervical ganglion** of the sympathetic trunk.

- The postganglionic fibres from the **middle cervical ganglion** of sympathetic trunk supply the heart.

The lungs and upper respiratory tract receive the postganglionic fibres from the stellate ganglion.

- Postganglionic fibres that arise from one of the three prevertebral (collateral) sympathetic ganglia - the celiac, superior mesentric and inferior mesentric, innervate the abdominal visceral organs.

- All the abdominal visceral organs (stomach, small intestine, liver, gall bladder and pancreas) receive their postganglionic fibres through the **splanchnic nerve** which arise from the celiac and superior or cranial mesenteric ganglia.

- The postganglionic fibre to the pelvic organs - (large intestine, rectum and genitalia) is mediated through the **hypogastric nerve** which arises from the **inferior or caudal mesentric ganglion**.

- The adrenal medulla receives preganglionic fibres directly from the **celiac ganglia** and these fibres synapse with modified postganglionic neuronal fibres, which are the secreting cells of the adrenal medulla. These cells secrete their transmitter substances directly into the blood.

Parasympathetic Division (PSNS):

The cell bodies are located within the brain stem and the sacral segments of spinal cord, the efferent nerves pass out of the CNS along the fibres of the cranial nerves (III, VII, IX and X) and also with the sacral spinal nerves. Hence, this division of the ANS is also called as **craniosacral division.**

The preganglionic fibres of this division are characterised by longer fibres.

The parasympathetic ganglia are located on the walls of the effector organs

The postganglionic fibres are relatively shorter in length.

The preganglionic fibres in the **third cranial nerve (oculomotor) project to the ciliary ganglion** of the eye, the postganglionic fibres supply pupillary constrictor muscles; it is involved in reflex for reducing the amount of light entering the eye and for accommodation to near vision.

The lacrimal and nasal glands and their smooth muscles receive their postganglionic fibres through **the spheno-palatine ganglion**, that in turn receives one set of preganglionic fibres from the **cranial nerve VII.**

The facial (VII) nerve supplies a second set of preganglionic fibres to mandibular and sublingual glands through mandibular ganglion.

The parotid receives the preganglionic fibres from the IX cranial nerve (glossopharyngeal) which terminates in **otic ganglion.**

The X cranial nerve (vagus) projects its fibres to lungs, heart, lungs, stomach, small and large intestine.

The sacral parasympathetic preganglionic neurons have their cell bodies within the intermediate gray matter of the sacral spinal cord.

Their fibres are projected out of the spinal cord in the ventral roots of the first 4 sacral nerves and it supplies parasympathetic innervation to **urinary bladder, colon, rectum and the sex organs.**

FUNTIONS OF AUTONOMIC NERVOUS DIVISION

In most tissues SNS and PSNS generally functions antagonistically.

Both systems are tonically active but the tonic activity differs with types of tissue – **SNS is more dominant on peripheral blood vessels (tonic vasoconstriction) and on sweat glands.**

PSNS is more dominant in heart, eye, GI tract and bladder.

SNS activation produces widespread activity and PSNS activation is more discrete and tissue specific.

Neurotransmitters of ANS:

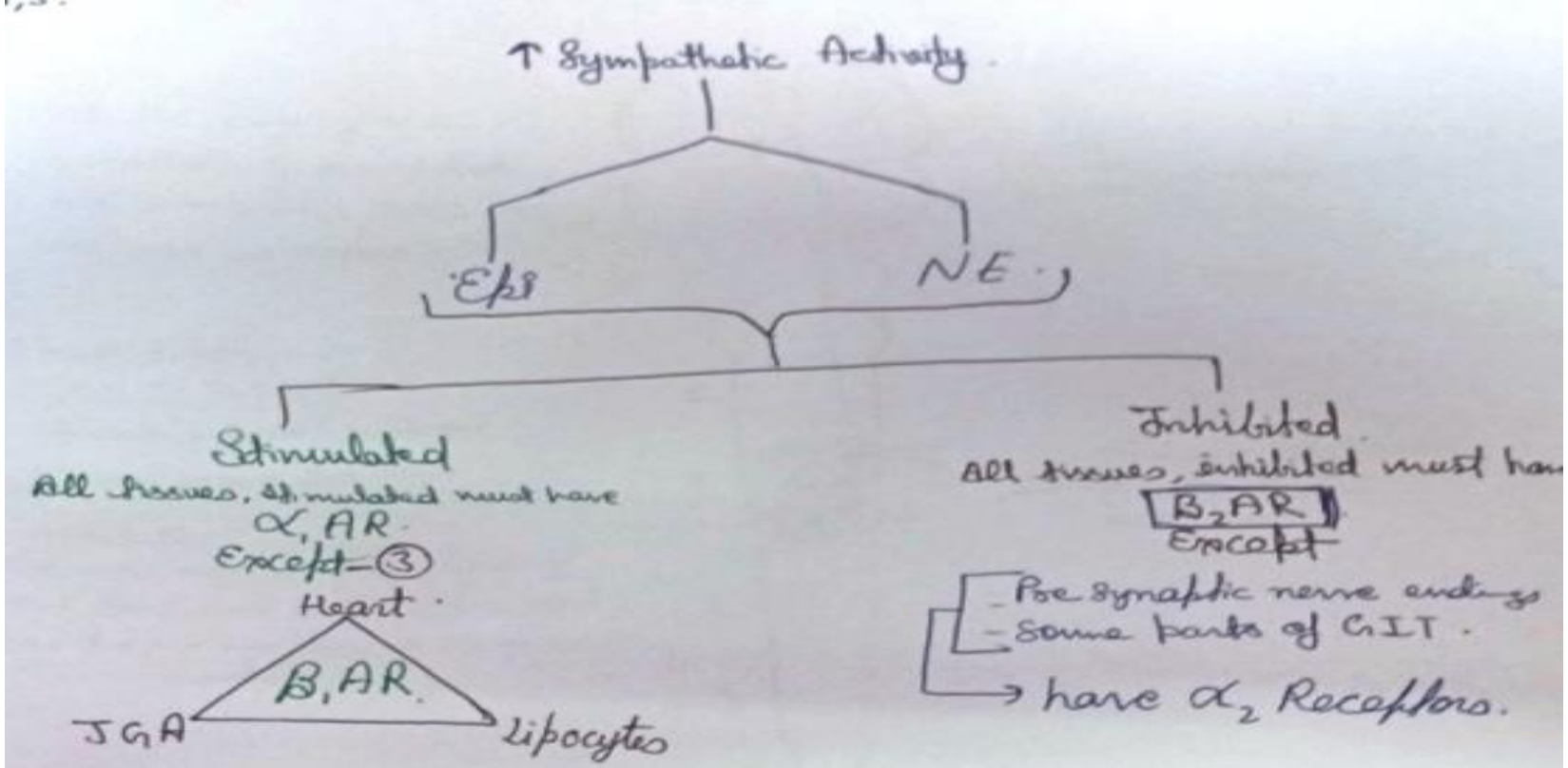
- Acetylcholine and norepinephrine are the two major neurotransmitters released by the cholinergic and the adrenergic nerves of ANS respectively.

- **Serotonin, substance P, VIP, nitric oxide, somatostatin and NPY** are also released from both SNS and PSNS divisions.

- These transmitters may be coreleased with Ach or NE, have slower onset of response for a longer duration.

Autonomic neurotransmitters

Sympathetic system		Parasympathetic	
Transmitter	Location	Transmitter	Location
Adrenergic		Cholinergic	
NE	Sympathetic postganglionic nerves	Acetylcholine	Parasympathetic ganglia, parasympathetic postganglionic nerves
Epinephrine (EPI)	Adrenal medulla		
Dopamine (DA)	SNS postganglionic fibres in renal, mesenteric, coronary blood vessels		
Cholinergic	Sympathetic ganglia, sympathetic postganglionic fibres to sweat glands and skeletal muscle blood vessels		



- Sympathetic stimulation causes tremors Hc of poor functioning of muscle spindle. reduce
- Adrenergic receptors are disrupted due to the activity of muscle spindle CNS, may not be updated properly from sensitive had of muscle shidle.
  eg. Tremors due to sympathomimetic drugs e.g. Salbutamol & Terbutaline and Thyrotoxicosis.
- the muscle ~~shoulder~~ has receptors over muscle shidle, when adrenergic surge occurs, it stimulates the muscle spindle, when muscle shidles are overstimulated by Epi, muscle shindles are desynchronised & the

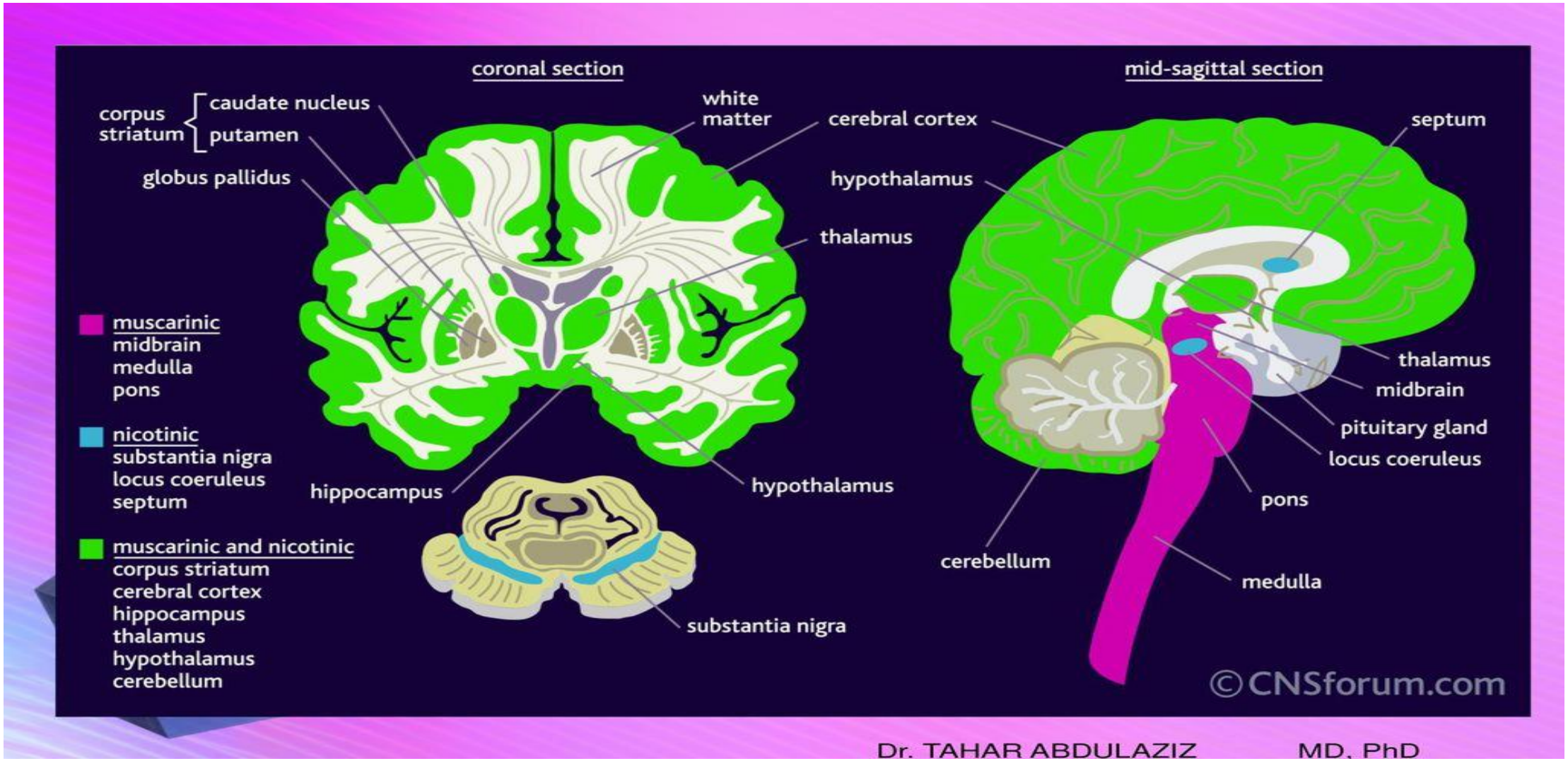
Receptors

- The receptors are located on postsynaptic membranes where they produce the main sympathetic / parasympathetic effects and on presynaptic membranes to produce negative effects.
- Adrenergic receptors
- **NE acts on all α receptors and β1 receptors but not on β2 receptors.**
- **EPI acts on all α- and β- receptors**.
- DA acts on dopaminergic, α and β receptors.
- Both sympathetic and parasympathetic preganglionic fibres release acetylcholine as the neurotransmitter substance.
- All the parasympathetic postganglionic fibres and sympathetic postganglionic fibres to blood vessels of skeletal muscles and sweat glands in some species are also **cholinergic in nature.**
- **Cholinergic receptors are two types – *muscarinic* and *nicotinic***

Receptors

Adrenergic receptors	Location	Function	Sub types	Location	Function
α	Postganglionic sympathetic synapses	Generally excitatory except in gut (**relaxation**)	α1	Smooth muscles of blood vessels, genital, urinary, GI tract, liver, heart	Sympathetic effects
			α2	On presynaptic membrane	Inhibits transmitter release
β	Postganglionic sympathetic synapses	Generally inhibitory except heart (**stimulation)**	β1	Heart, kidney,	Sympathetic effects
			β2	smooth muscles of blood vessels, bronchial, gut, genital, urinary, skeletal muscles, liver	glycogenolysis
			β3	Adipocytes	lipolysis
Dopaminergic	Sympathetic ganglia, also in kidney	Sympathetic effects			

Nicotinic receptors	Muscarinic receptors
Bind nicotine (Plant alkaloid of Solanaecae family)	Bind muscarine (Plant alkaloid present in certain types of mushrooms)
Blocked by curare (tubocurarine)	Blocked by atropine
Act through ionic channels (ionotropic effect)	Act through 2nd messenger systems through G proteins (metabotropic effect)
Response is brief and fast	Response is slow and prolonged
Located at neuromuscular junctions (skeletal muscles), autonomic ganglia (both SNS, PSNS), and to a small extent in the CNS	Postganglionic synapses of PSNS and postganglionic cholinergic synapses of SNS Found on myocardial muscle, certain smooth muscle, and in discrete CNS regions
Mediate excitation in target cells	Mediate inhibition or excitation in target cells
Postsynaptic	Both pre- and postsynaptic subtype


coronal section
mid-sagittal section
corpus striatum
caudate nucleus
putamen
globus pallidus
white matter
cerebral cortex
hypothalamus
thalamus
septum
thalamus
midbrain
pituitary gland
locus coeruleus
pons
medulla
cerebellum
hippocampus
hypothalamus
substantia nigra
muscarinic
midbrain
medulla
pons
nicotinic
substantia nigra
locus coeruleus
septum
muscarinic and nicotinic
corpus striatum
cerebral cortex
hippocampus
thalamus
hypothalamus
cerebellum
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cholinergic toxic syndrome

1- Muscarinic effects: S*LUDGE/BBB mnemonic*

S = Salivation	L = Lacrimation	U = Urination
D = Defecation	G = GI symptoms	E = Emesis
B = Bronchorrhea	B = Bronchospasm	B = Bradycardia

2- Nicotinic effects at neuromuscular junctions and autonomic ganglia: weakness, fasciculations, and paralysis.

3- CNS effects may lead to seizures and CNS depression.

- **Gastro intestinal autonomic reflexes** – smell of appetizing food initiates secretion from salivary and gastric glands and pancreas;
- Fullness of rectum initiates defecation reflex.
- Emptying of urinary bladder, sexual reflexes, sweating, blood glucose concentration and many other visceral functions are regulated by autonomic reflexes.