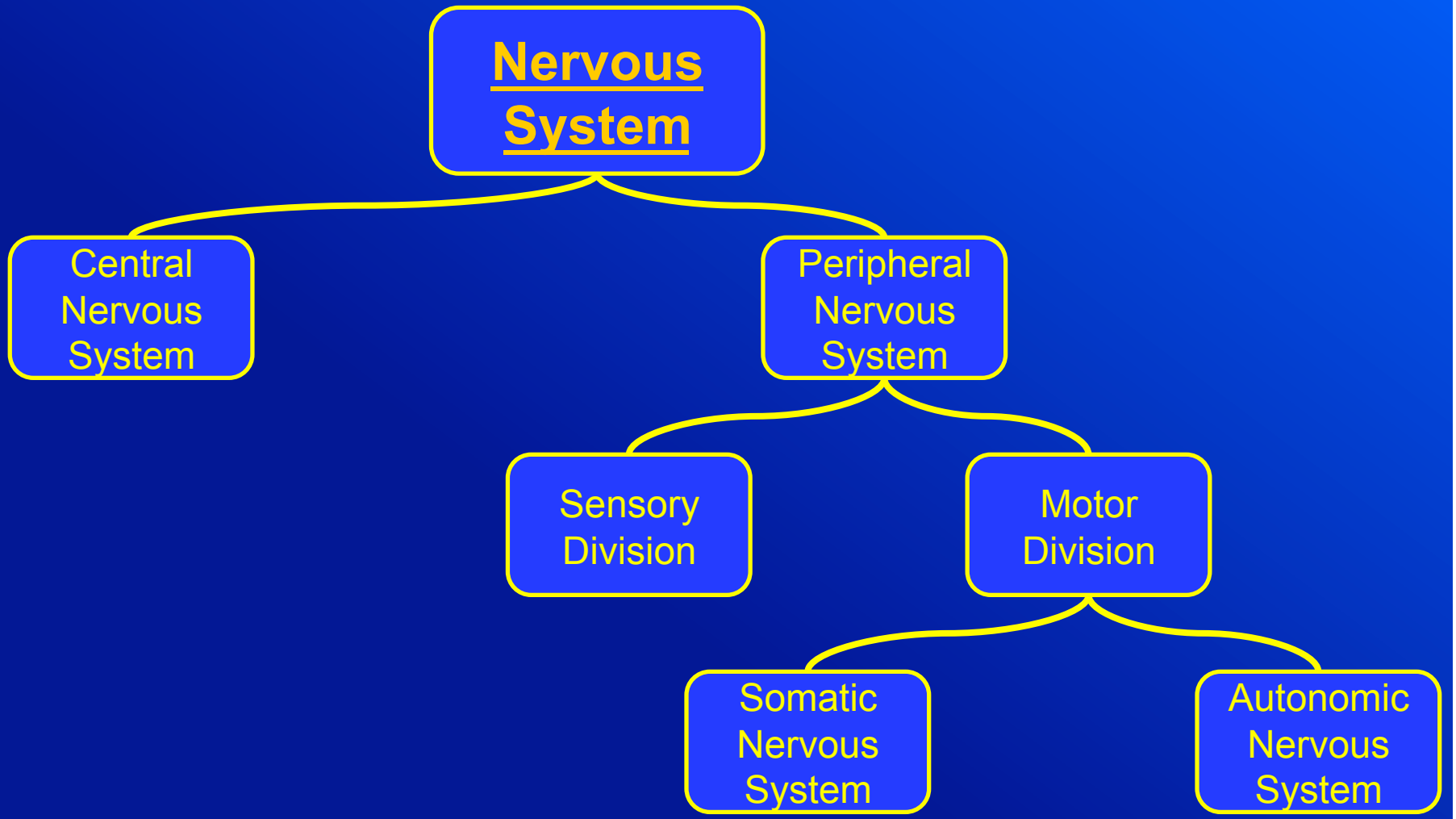
Chapter 16

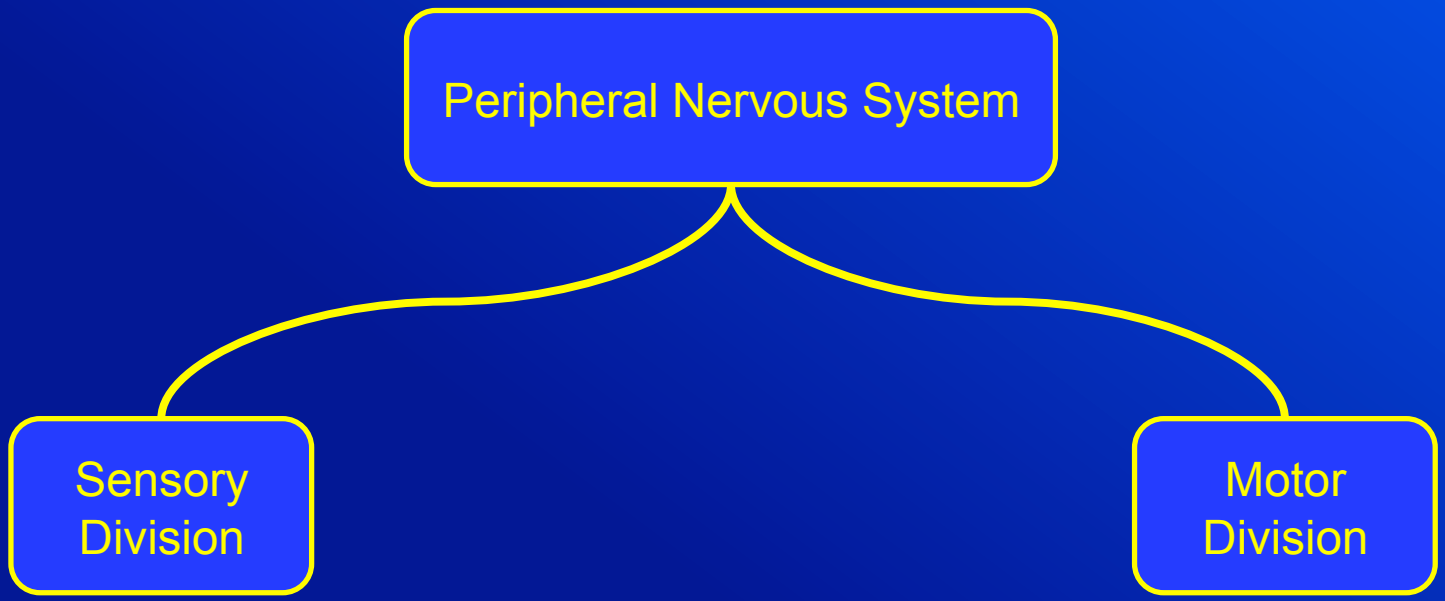
Autonomic nervous system

Quick Review



Focus on PNS

Carries action potentials to and away from the CNS



Carries action potentials toward the CNS for processing

Carries action potentials away from the CNS toward the effector

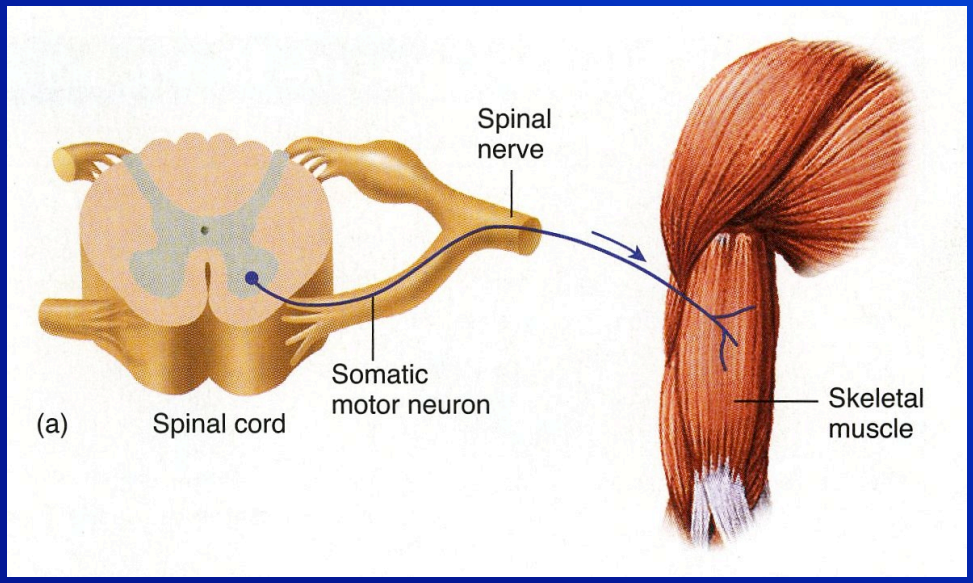
Focus on Motor Division

Motor Division

Somatic Nervous System

Autonomic Nervous System

- **One** neuron cell body in the anterior gray horn of the SC with its axon extending to the effector (Monosynaptic)
- Carries AP for conscious control
- Effector = skeletal muscle
- Always excitatory

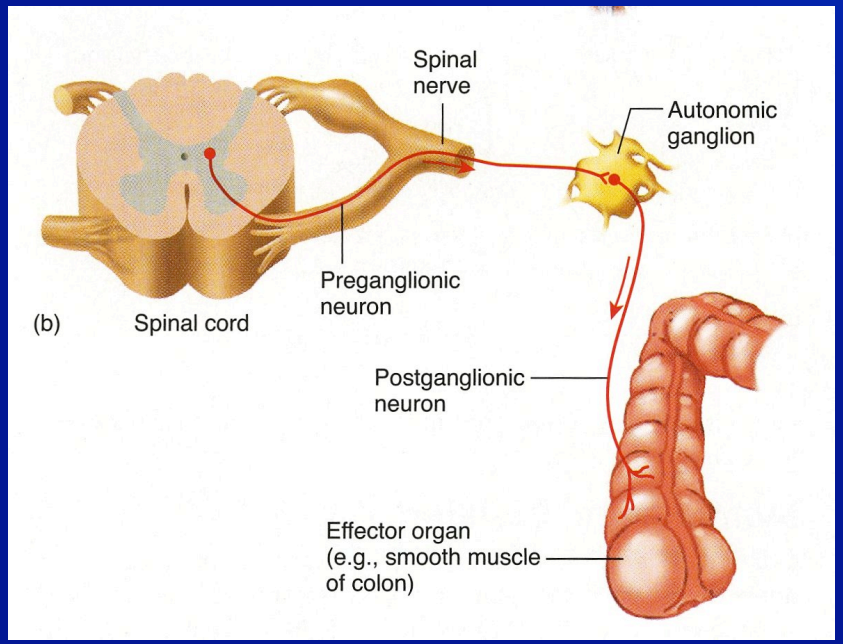


Focus on Motor Division

Motor Division

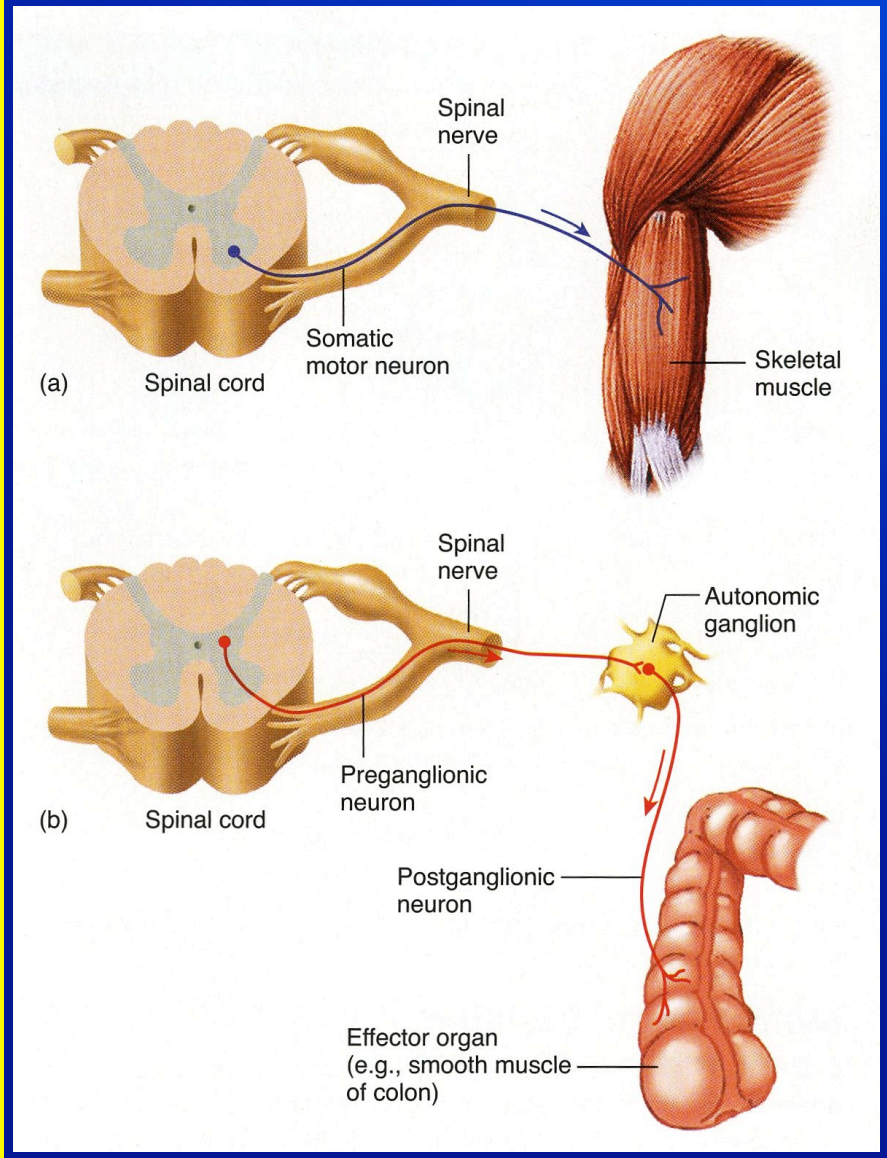
Somatic Nervous System

Autonomic Nervous System



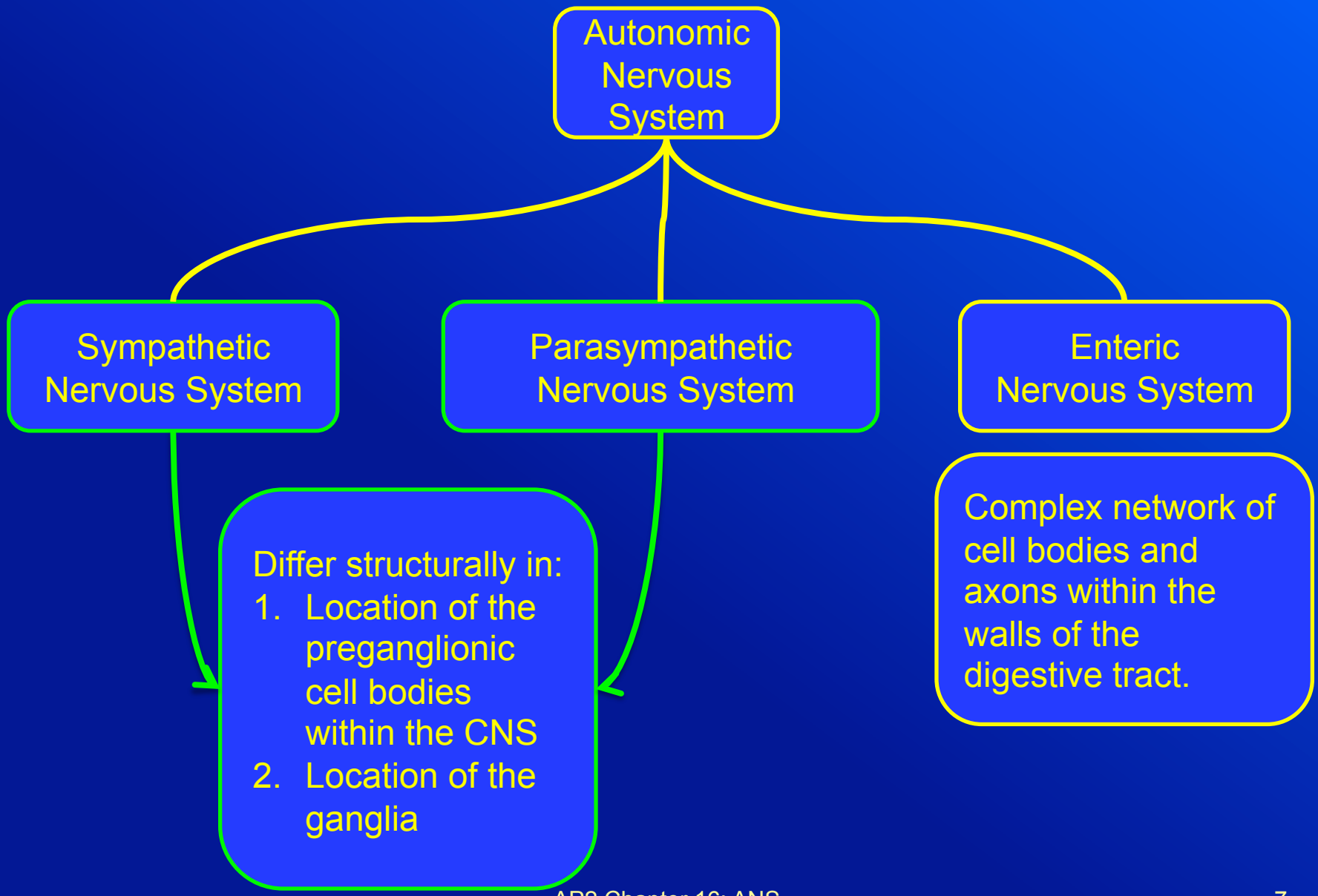
- Autonomic motor neurons come in **pairs**!
  - 1st cell body in the CNS axon extends to the ganglion.
  - 2nd cell body in ganglion axon extends to the effector.
- Carries AP for unconscious control
- Effectors:
  - Smooth muscle
  - Cardiac muscle
  - Glandular tissue
- May be excitatory or inhibitory AP's

Somatic vs. Autonomic Division



- Somatic Division
  - **One** neuron cell body in the anterior gray horn of the SC with its axon extending to the effector (Monosynaptic)
  - Carries AP for conscious control
  - Effector = skeletal muscle
  - Always excitatory
- Autonomic division
  - Autonomic motor neurons come in **pairs**!
    - 1st cell body in the CNS axon extends to the ganglion.
    - 2nd cell body in ganglion axon extends to the effector.
  - Carries AP for unconscious control
  - Effectors:
    - Smooth muscle
    - Cardiac muscle
    - Glandular tissue
  - May be excitatory or inhibitory AP's

Focus on the Autonomic Nervous System



II. Anatomy of the ANS

A. Sympathetic Division
B. Parasympathetic Division
C. Enteric Nervous System
D. Distribution of Autonomic Nerve Fibers

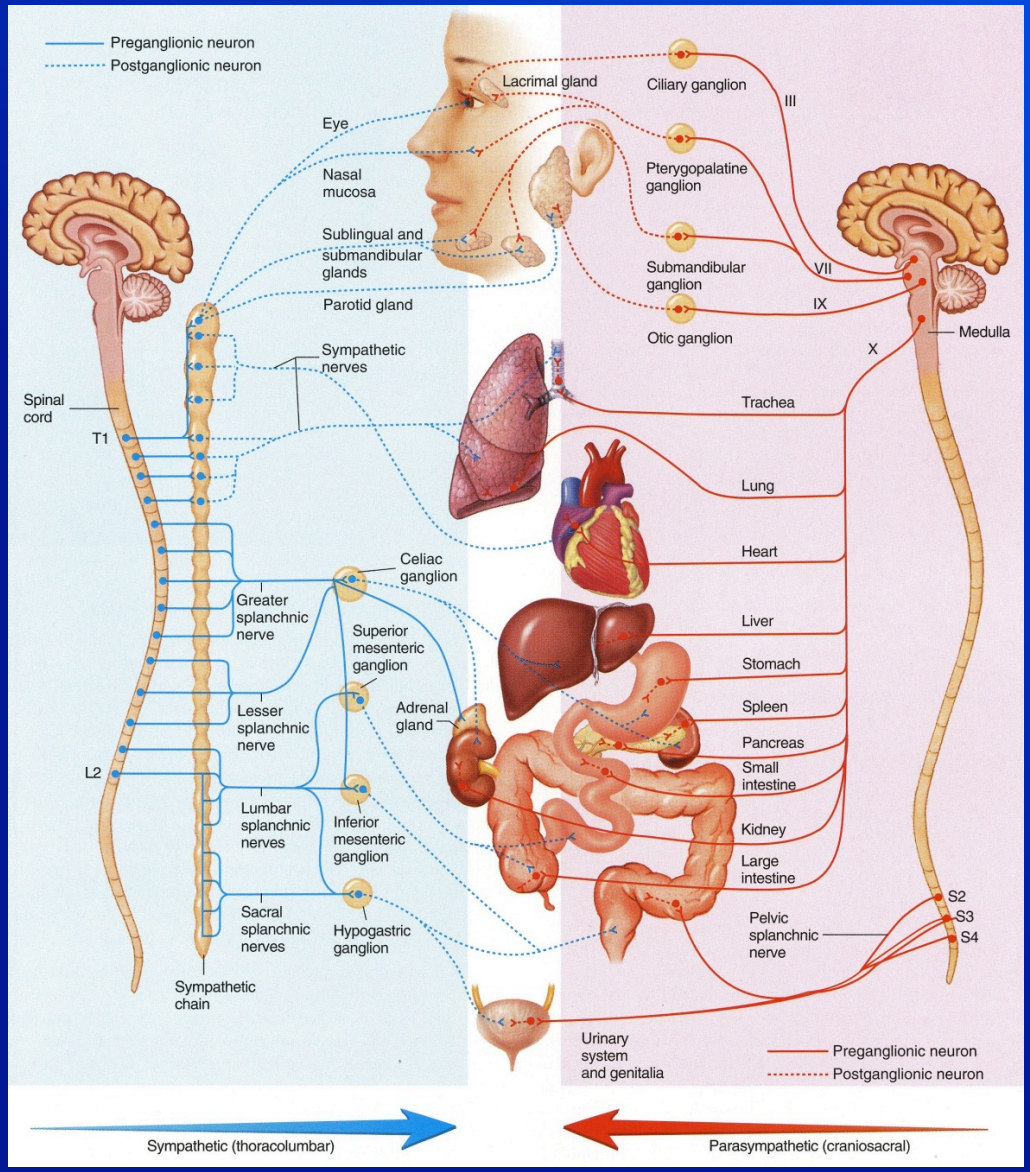
II. Anatomy of the ANS

- There are 3 divisions to the ANS
  1. Sympathetic Nervous System
  2. Parasympathetic Nervous System
     - SNS & PNS differ structurally in location of:
       - Preganglionic neuron cell bodies w/in CNS
       - Autonomic Ganglia
  3. Enteric Nervous System
     - Considered part of the ANS b/c of the FX the SNS & PNS have on ENS fxn
     - It is a complex ntwk of neuron cell bodies & axons w/in the wall of the GI-tract that influence it fxn

II. Anatomy of the ANS

1.SNS/ Thoracolumbar Division

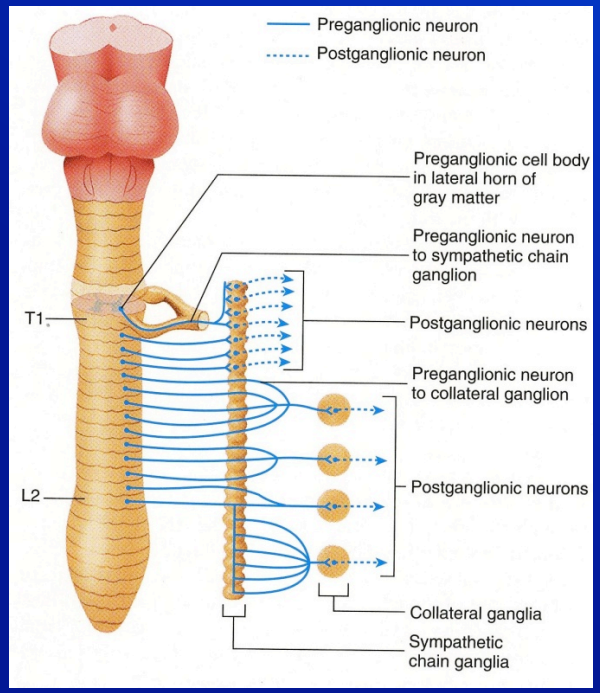
2. PNS/Craniosacral Division



II. Anatomy of the ANS

1.SNS

Thoracolumbar Division



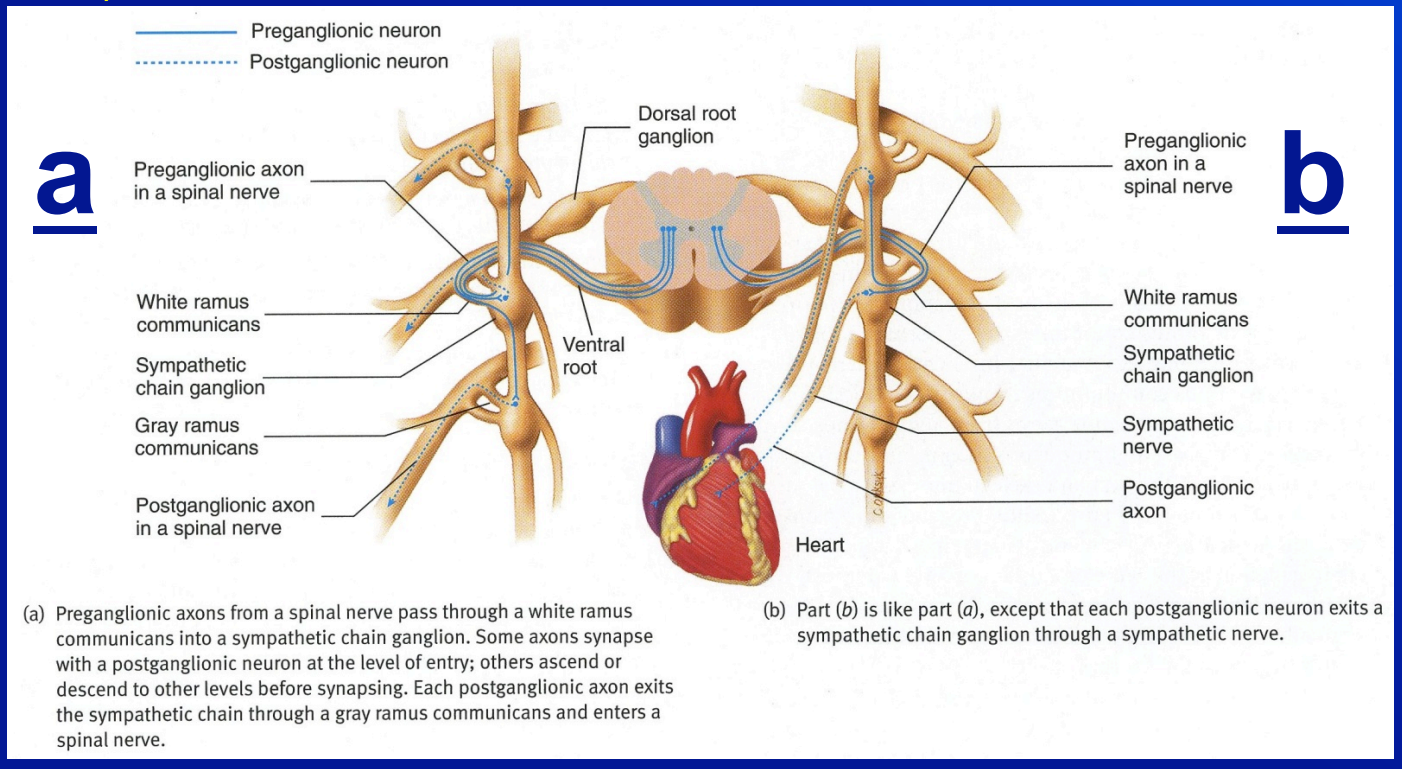
- Chain Ganglia:
  - lie in a linked chain along the length of the spinal cord
- Collateral Ganglia:
  - Unpaired ganglia in the abdominopelvic cavity anterior to spinal cord

- Location PreG cell body
  - Gray matter btwn T1 & L2
  - Axons w/in ventral roots of T1-L2 spinal nerves
- Exit from CNS
  - a) Spinal Nerves
  - b) Sympathetic Nerves
  - c) Splanchnic Nerves
  - d) Innervation of the adrenal medulla
- Ganglia
  - Chain ganglia along side SpCd for spinal and sympathetic nerves
  - Collateral ganglia for Splanchnic nerves
- # of PostG neurons for every PreG neuron
  - ↑ # of PostG for every PreG much divergence
- Relative lengths of PreG's and PostG's
  - Short PreG Neuron
  - Long PostG Neuron

II. Anatomy of the ANS

1.SNS /Thoracolumbar Division

- Exit from CNS
  - a) Spinal Nerves
    - PostG's are non-myelinated thus Gray
    - PostG's go thru all spinal nerves & project to the skin & Skeletal Muscle
  - b) Sympathetic Nerves
    - Post G axons supply organs in the thoracic cavity
  - c) Splanchnic Nerves
  - d) Innervation of the adrenal medulla



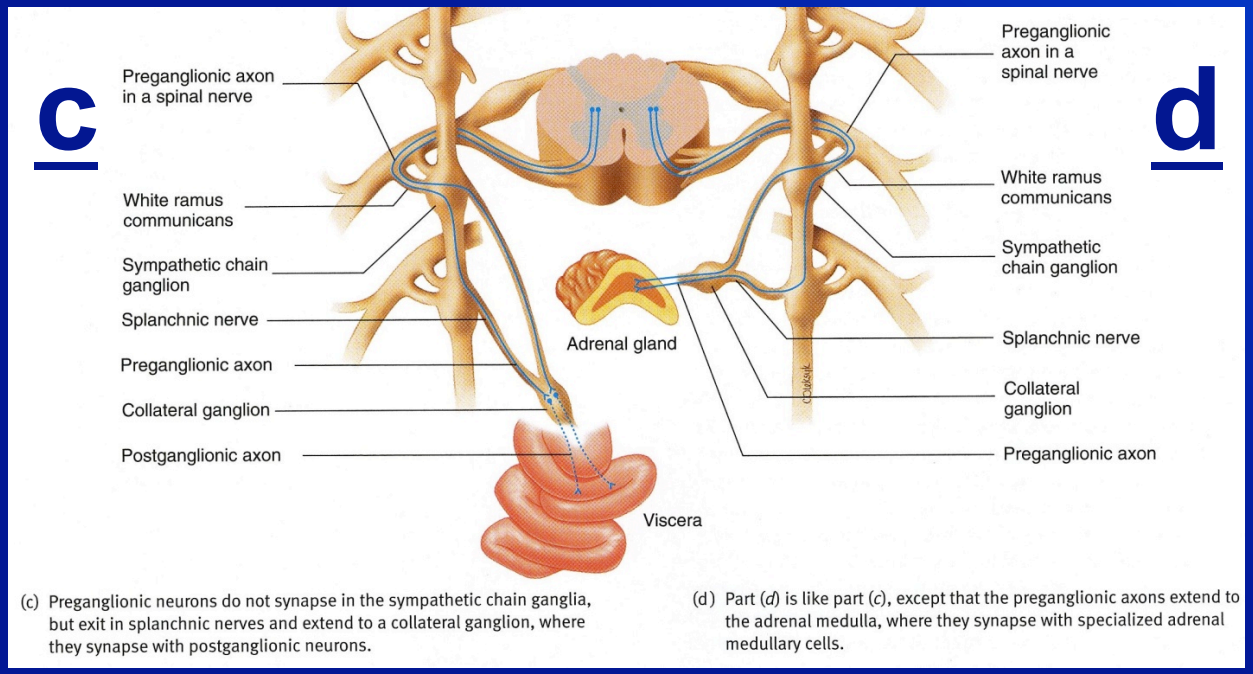
(a) Preganglionic axons from a spinal nerve pass through a white ramus communicans into a sympathetic chain ganglion. Some axons synapse with a postganglionic neuron at the level of entry; others ascend or descend to other levels before synapsing. Each postganglionic axon exits the sympathetic chain through a gray ramus communicans and enters a spinal nerve.

(b) Part (*b*) is like part (*a*), except that each postganglionic neuron exits a sympathetic chain ganglion through a sympathetic nerve.

II. Anatomy of the ANS

1.SNS /Thoracolumbar Division

- Exit from CNS
  - a) Spinal Nerves
  - b) Sympathetic Nerves
  - c) Splanchnic Nerves
    - PostG extend to targets in the abdominopelvic cavity
  - d) Innervation of the adrenal medulla
    - PreG's only extend thru the ganglion directly to their target ➔ cells in the adrenal medulla



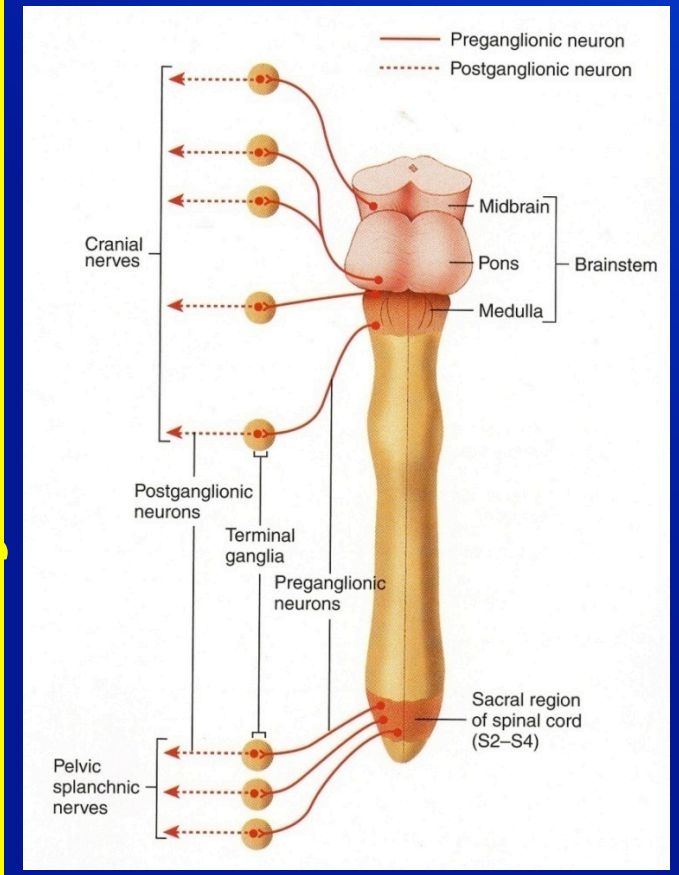
(c) Preganglionic neurons do not synapse in the sympathetic chain ganglia, but exit in splanchnic nerves and extend to a collateral ganglion, where they synapse with postganglionic neurons.

(d) Part (*d*) is like part (*c*), except that the preganglionic axons extend to the adrenal medulla, where they synapse with specialized adrenal medullary cells.

II. Anatomy of the ANS

2. PNS

Craniosacral Division



- Terminal Ganglia
  - Ends on the target

- Location PreG cell body
  - Brain stem & lateral parts of SpCd S2-S4
- Exit from CNS
  a) Cranial Nerves
  b) Pelvic Splanchnic Nerves
- Ganglia
  - Terminal Ganglia near or on the Target Organ
- # of PostG neurons for every PreG neuron
  - ⬇ # of PostG for every PreG little to no divergence
- Relative lengths of PreG's and PostG's
  - Long PreG Neuron
  - Short PostG Neuron

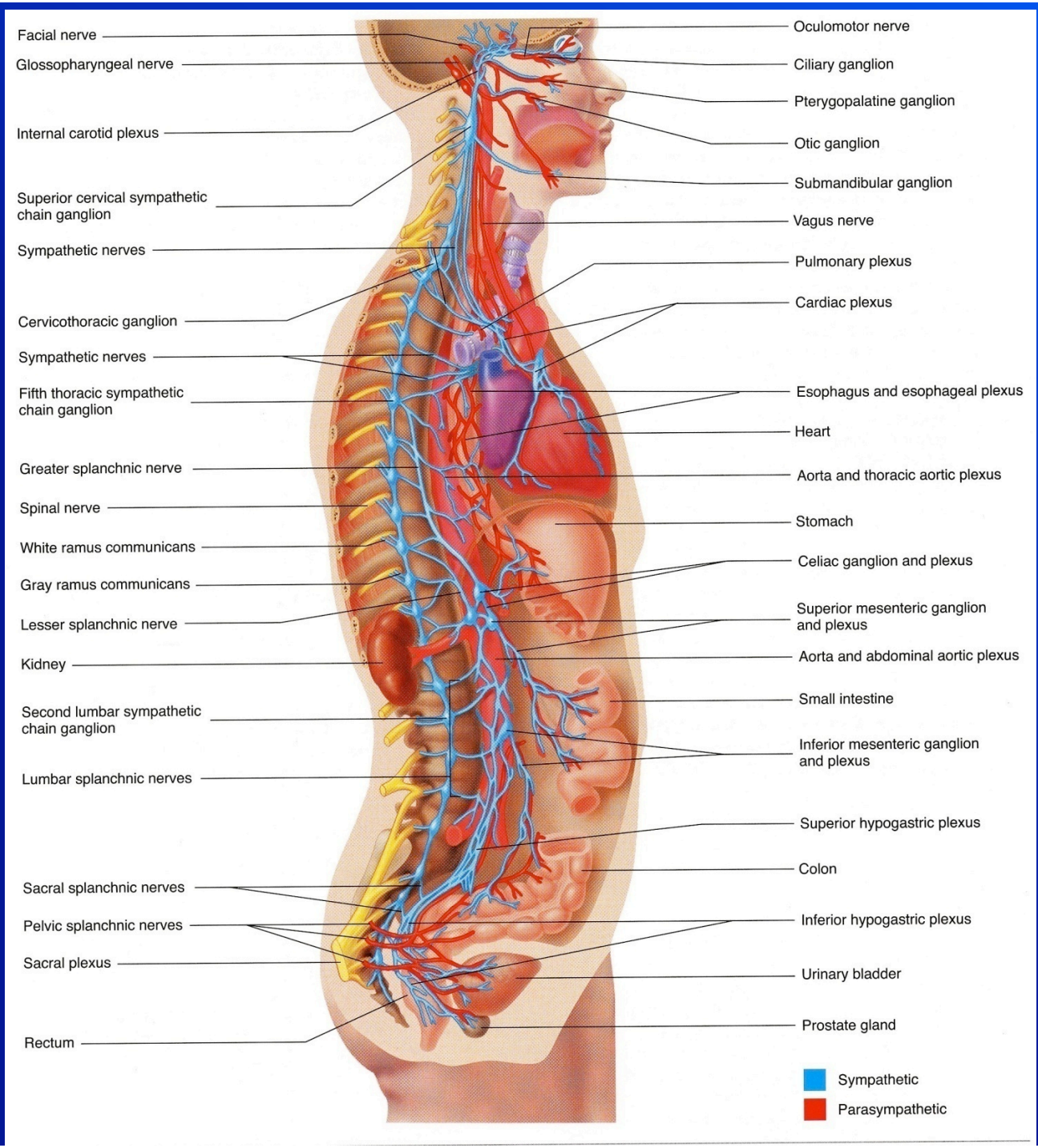
II. Anatomy of the ANS

- Enteric Nervous System
  - Nerve plexuses w/in the wall of the digestive tract
  - ENS contributed from 3 sources
    1. Sensory neurons connecting digestive tract to the CNS
    2. ANS motor neurons connecting CNS to the digestive tract
    3. Enteric neurons which are confined to the enteric plexuses

II. Anatomy of the ANS

Distribution of autonomic nerve fibers

Sympathetic Division



II. Anatomy of the ANS

Distribution of autonomic nerve fibers

Sympathetic Division

- Sympathetic axons pass from sympathetic chain ganglia thru 3 paths: spinal, sympathetic, or splanchnic nerves to get to their target
  - Sympathetic & Splanchnic pathways may join with autonomic nerve plexus
    - These are complex interconnected neural ntwks formed by neurons from the SNS & PNS (sensory neurons can also contribute to the formation of these nerves
- There are 4 major means by wh/sympathetic axons reach organs:

II. Anatomy of the ANS

Distribution of autonomic nerve fibers

Sympathetic Division

- 4 ways sympathetic axons reach organs:
  1. Spinal Nerves
  2. Head & neck nerve plexuses
  3. Thoracic Nerve Plexuses
  4. Abdominopelvic Nerve Plexus

II. Anatomy of the ANS

Distribution of autonomic nerve fibers

Sympathetic Division

- 4 ways sympathetic axons reach organs:
  1. **Spinal Nerves**
     - PostG's innervate same struc's as spinal nerves they follow
       - Sweat glands of the skin
       - Smooth muscle of bld vessels in skin & skeleton
       - Smooth muscle of arrector pili muscles in skin
  2. Head & neck nerve plexuses
  3. Thoracic Nerve Plexuses
  4. Abdominopelvic Nerve Plexus

II. Anatomy of the ANS

Distribution of autonomic nerve fibers

Sympathetic Division

- 4 ways sympathetic axons reach organs:
  1. Spinal Nerves
  2. **Head & neck nerve plexuses**
     - PostG extend up to the head & down to neck
       - Sweat glands of the skin
       - Smooth muscle of bld vessels in skin & skeleton
       - Smooth muscle of arrector pili muscles in skin
       - Skin of the face
       - Iris
       - Ciliary muscles of the eye
  3. Thoracic Nerve Plexuses
  4. Abdominopelvic Nerve Plexus

II. Anatomy of the ANS

Distribution of autonomic nerve fibers

Sympathetic Division

- 4 ways sympathetic axons reach organs:
  1. Spinal Nerves
  2. Head & neck nerve plexuses
  3. **Thoracic Nerve Plexuses**
     - Axons supply organs of the thorax PostG axons
       - Cardiac Plexus ➔ supplying the heart
       - Pulmonary Plexus ➔ supplying the lungs
       - Thoracic Plexus
  4. Abdominopelvic Nerve Plexus

II. Anatomy of the ANS

Distribution of autonomic nerve fibers

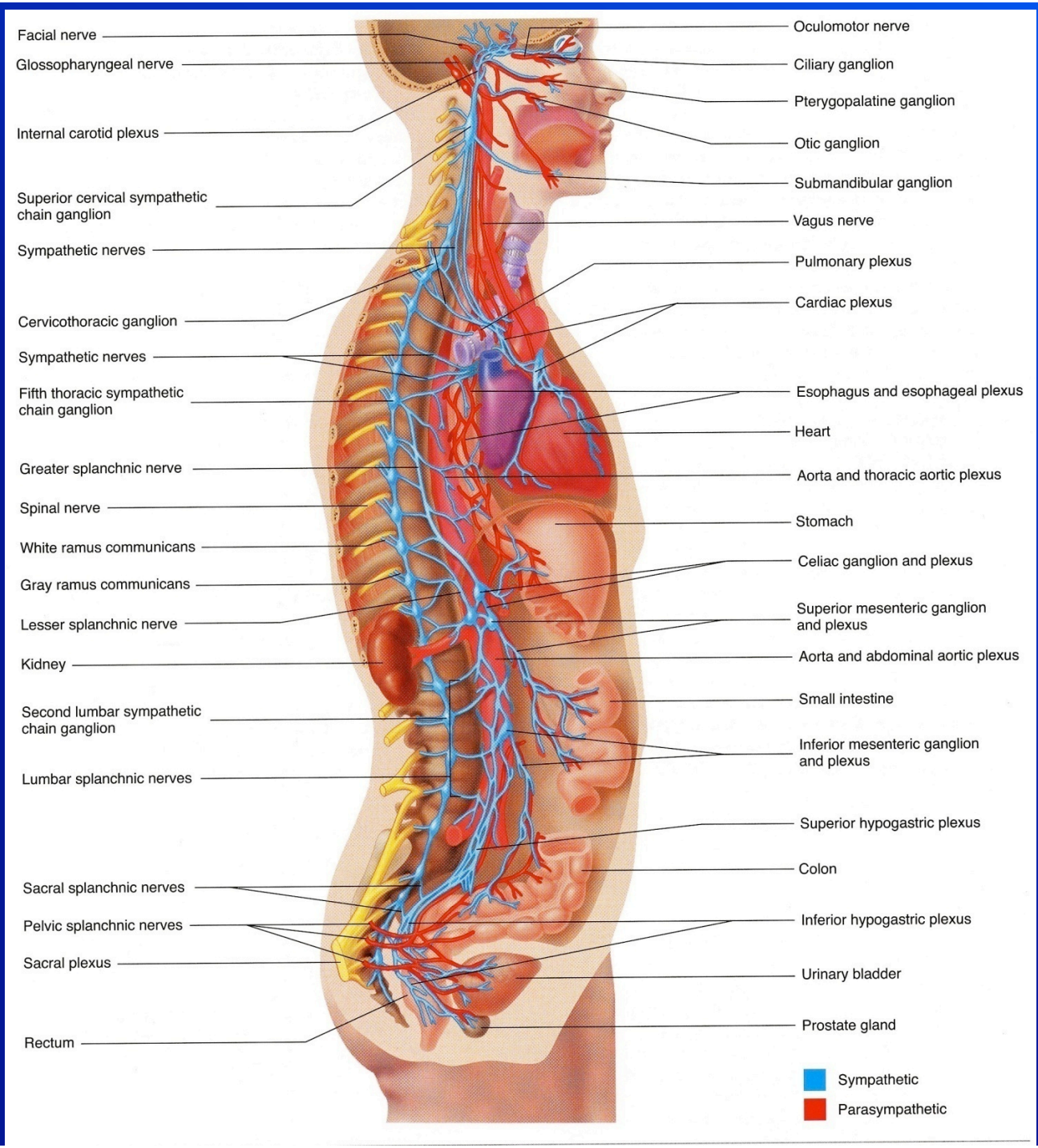
Sympathetic Division

- 4 ways sympathetic axons reach organs:
  1. Spinal Nerves
  2. Head & neck nerve plexuses
  3. Thoracic Nerve Plexuses
  4. **Abdominopelvic Nerve Plexus**
     - Axons supply AP-organs PostG from collateral ganglia innervate smooth muscle & glands in AP-cavity
       - Celiac Plexus: supplies diaphragm, stomach, liver, gallbladder, adrenal glands, kidneys, testis, & ovaries
       - Superior Mesenteric Plexus: supplies pancreas, sm. Intestine, ascending & transverse colon.
       - Inferior Mesenteric Plexus: supplies transverse colon to the rectum
       - Superior & inferior Hypogastric Plexus: supply the descending colon to the rectum, urinary bladder, & reproductive organs

II. Anatomy of the ANS

Distribution of autonomic nerve fibers

Parasympathetic Division



II. Anatomy of the ANS

Distribution of autonomic nerve fibers

Parasympathetic Division

- Exit from cranial & pelvic splanchnic nerves
- Branches supply organs directly or join nerve plexuses to be distributed to organs
- 4 major means by wh/parasympathetic axons reach their organs:

II. Anatomy of the ANS

Distribution of autonomic nerve fibers

Parasympathetic Division

- 4 ways parasympathetic axons reach organs:
  1. Cranial nerves supplying the head & neck
  2. Vegus nerve & thoracic nerve plexus
  3. Abdominal Nerve Plexus
  4. Pelvic splanchnic nerves & pelvic nerve plexuses

II. Anatomy of the ANS

Distribution of autonomic nerve fibers

Parasympathetic Division

- 4 ways parasympathetic axons reach organs:
  1. Cranial nerves supplying the head & neck
     - 3 pairs of cranial nerves end at terminal ganglia where PostG axons supply near by struc's: ex's/
       - Oculomotor nerve thru ciliary ganglion→ ciliary muscles & iris
       - Pterygopalatine ganglion→ lacrimal gland, mucosal glands of nasal cavity & palate
  2. Vegus nerve & thoracic nerve plexus
  3. Abdominal Nerve Plexus
  4. Pelvic splanchnic nerves & pelvic nerve plexuses

II. Anatomy of the ANS

Distribution of autonomic nerve fibers

Parasympathetic Division

- 4 ways parasympathetic axons reach organs:
  1. Cranial nerves supplying the head & neck
  2. Vegus nerve & thoracic nerve plexus
     - The vegus nerve parasympathetic distribution goes to the thorax & abdomen
     - PreG's go thru vegus nerve to thorax to contribute to:
       - Cardiac Plexus→ heart
       - Pulmonary Plexus → Lungs
       - Vegus continues down esophagus & braches to form esophageal plexus
  3. Abdominal Nerve Plexus
  4. Pelvic splanchnic nerves & pelvic nerve plexuses

II. Anatomy of the ANS

Distribution of autonomic nerve fibers

Parasympathetic Division

- 4 ways parasympathetic axons reach organs:
  1. Cranial nerves supplying the head & neck
  2. Vegus nerve & thoracic nerve plexus
  3. Abdominal Nerve Plexus
     - Terminal ganglia in stomach wall contribute to celiac & superior plexus
     - PreG supply terminal ganglia in walls of:
       - Gallbladder, biliary ducts, pancreas, Sm. Intestine, ascending colon, & transverse colon
  4. Pelvic splanchnic nerves & pelvic nerve plexuses

II. Anatomy of the ANS

Distribution of autonomic nerve fibers

Parasympathetic Division

- 4 ways parasympathetic axons reach organs:
  1. Cranial nerves supplying the head & neck
  2. Vegus nerve & thoracic nerve plexus
  3. Abdominal Nerve Plexus
  4. Pelvic splanchnic nerves & pelvic nerve plexuses
     - PreG's of S2-S4 region pass to ventral rami of spinal nerves & enter pelvic splanchnic nerves which supply
       - Terminal ganglia in transverse colon to rectum
       - Contribute to hypogastric plexus
         - Supplies: lower colon, rectum, urinary bladder, organs of the reproductive system in the pelvis

II. Anatomy of the ANS

Distribution of autonomic nerve fibers

Sensory neurons in autonomic nerve plexuses

- Not strictly part of the ANS but axons run along ANS axons w/in the ANS & plexuses
- These are also part of the reflex arches regulating organ activity
- They transmit pain & pressure sensations from organs to the CNS
- Cells Bodies
  - Found in dorsal root ganglia
  - Found in some sensory ganglia of certain cranial nerves

III. Physiology of the ANS

A. Neurons and their NTs
   1. Cholinergic Neurons
   2. Adrenergic Neurons

B. Receptors
   1. Cholinergic receptors
   2. Adrenergic Receptors

#1

Neuron- a cell inside of the nervous system that reacts to neurotransmitters and transmits electrical signals

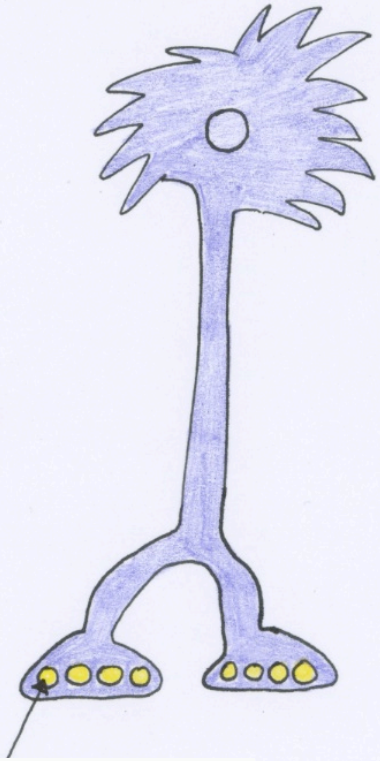
Neurotransmitter- chemical signals released by a neuron that causes a cell carrying the correct "target" receptor to respond

Receptor- transmembrane protein that will react to the matching ligand.

Neurons of the Autonomic Nervous System

2 Major types

Cholinergic Neuron- neurons that release *acetylcholine* as their neurotransmitter



Acetylcholine

Adrenergic Neuron- neurons that release *norepinephrine* as their neurotransmitter

Norepinephrine

Receptors of the Autonomic Nervous System

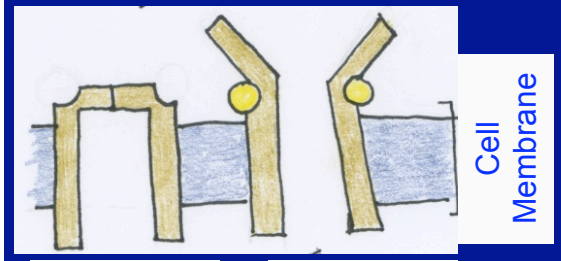
2 Major types

Cholinergic receptors
Respond to Ach

2 subtypes

Ligand-gated receptors

Nicotinic

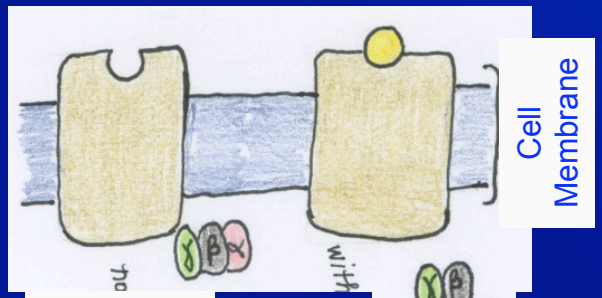


- Ligand

+ Ligand

GPCR's

Muscarinic

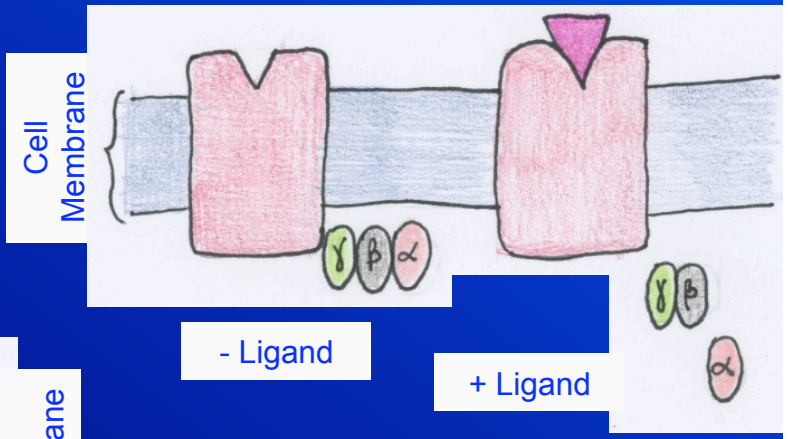


- Ligand

+ Ligand

Adrenergic receptors
Respond to Norepi

GPCR's
α or β types



- Ligand

+ Ligand

Receptors of the Autonomic Nervous System

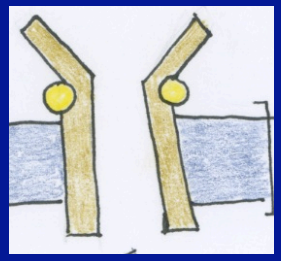
2 Major types

Cholinergic receptors
Respond to Ach

2 subtypes

Ligand-gated receptors

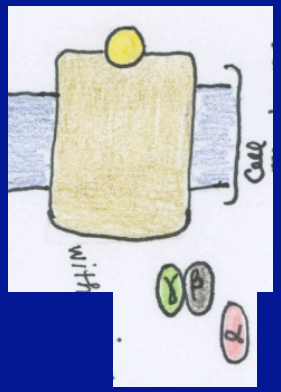
Nicotinic



•Binding = excitatory FX
•Na+ ch's open
•Prod'n of an AP

GPCR's

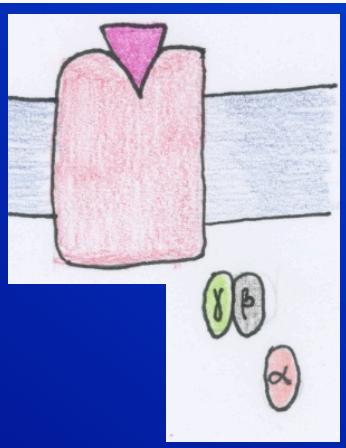
Muscarinic



•Binding may be excitatory or inhibitory
•Target tissue dependent

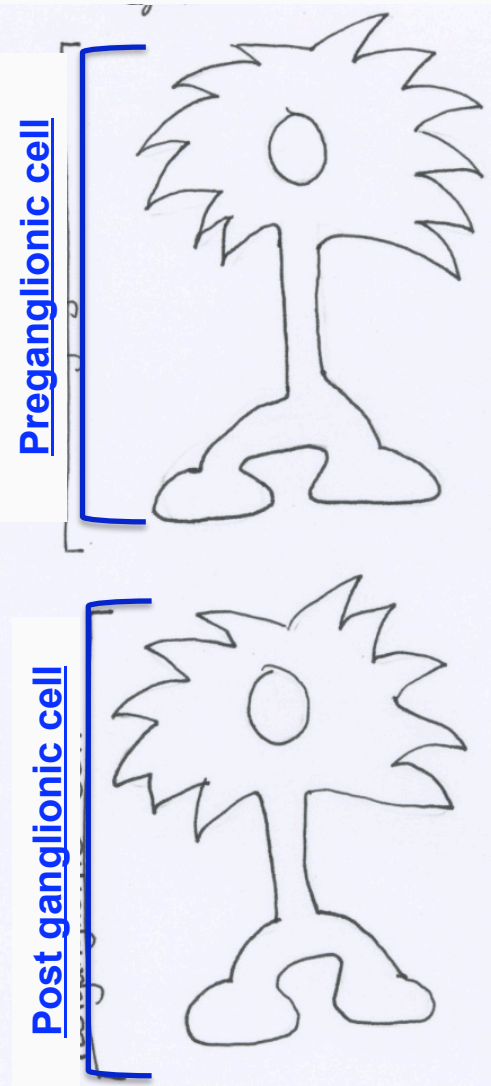
Adrenergic receptors
Respond to Norepi

GPCR's
α or β types

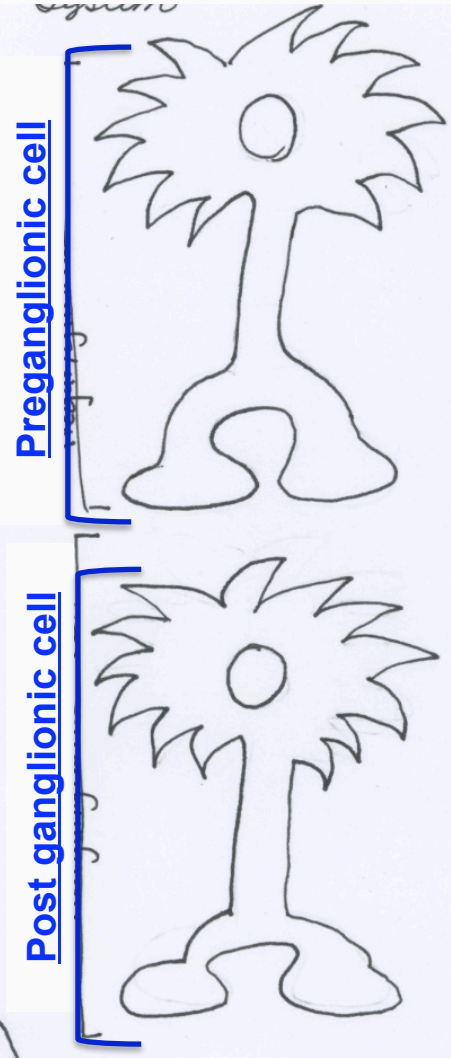


•Binding may be excitatory or inhibitory
•Target tissue dependent
•Activation can result from the ANS or endocrine system

Parasympathetic Nervous System (Rest and Digest)

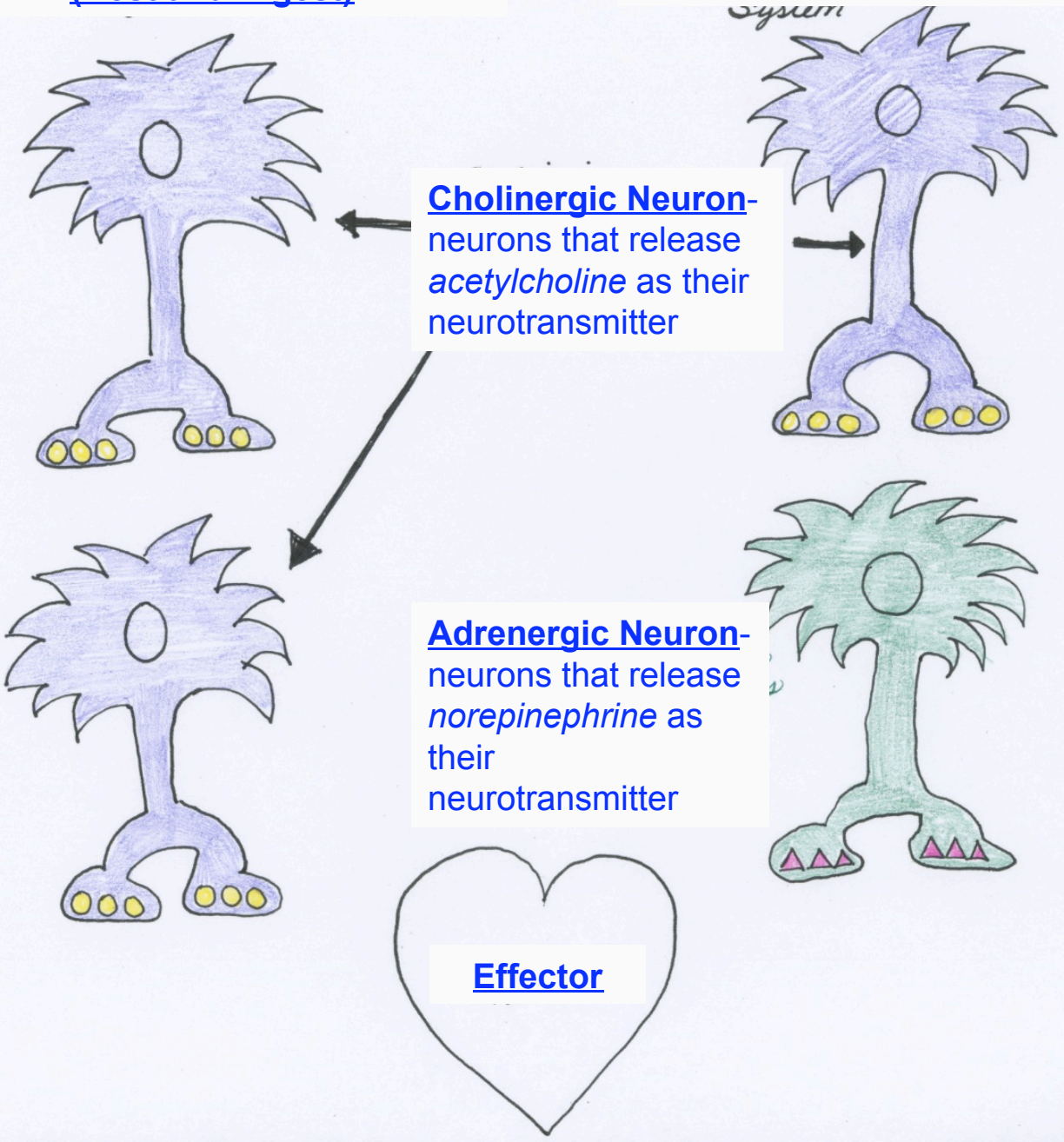


Sympathetic Nervous System (Fight or Flight)



Parasympathetic Nervous System (Rest and Digest)

Sympathetic Nervous System (Fight or Flight)



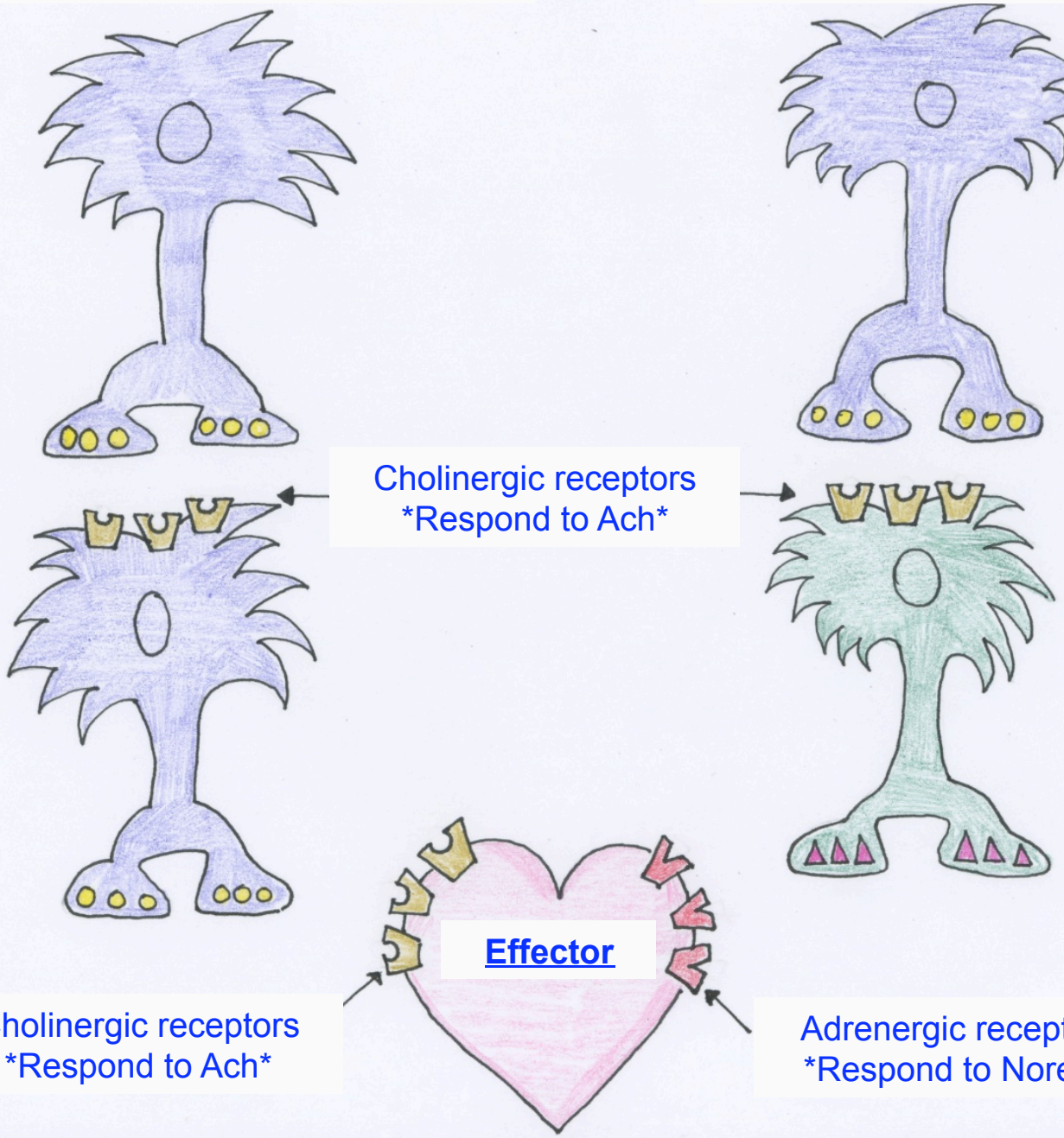
Cholinergic Neuron- neurons that release *acetylcholine* as their neurotransmitter

Adrenergic Neuron- neurons that release *norepinephrine* as their neurotransmitter

Effector

Parasympathetic Nervous System (Rest and Digest)

Sympathetic Nervous System (Fight or Flight)



Cholinergic receptors
Respond to Ach

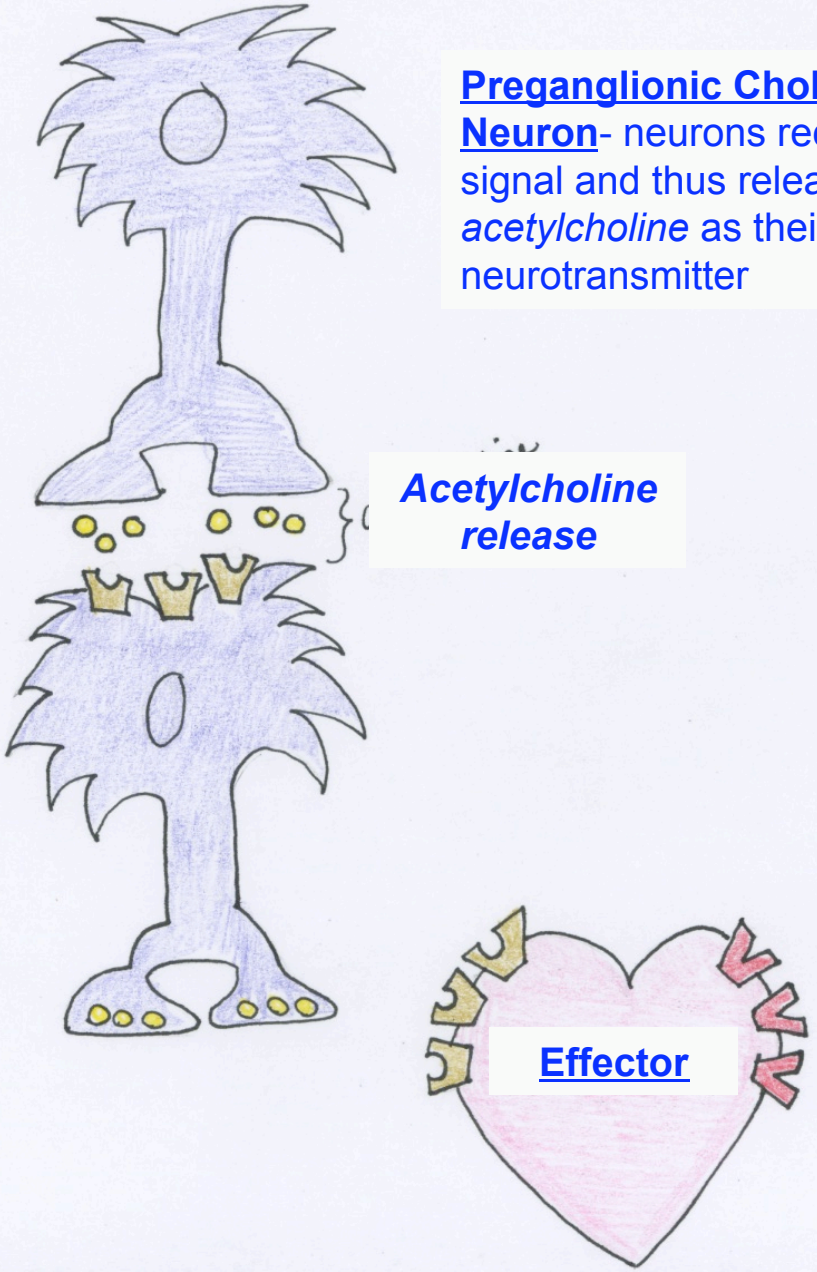
Effector

Cholinergic receptors
Respond to Ach

Adrenergic receptors
Respond to Norepi

Parasympathetic nervous system (Rest and digest)

Parasympathetic Nervous System (Rest and Digest)

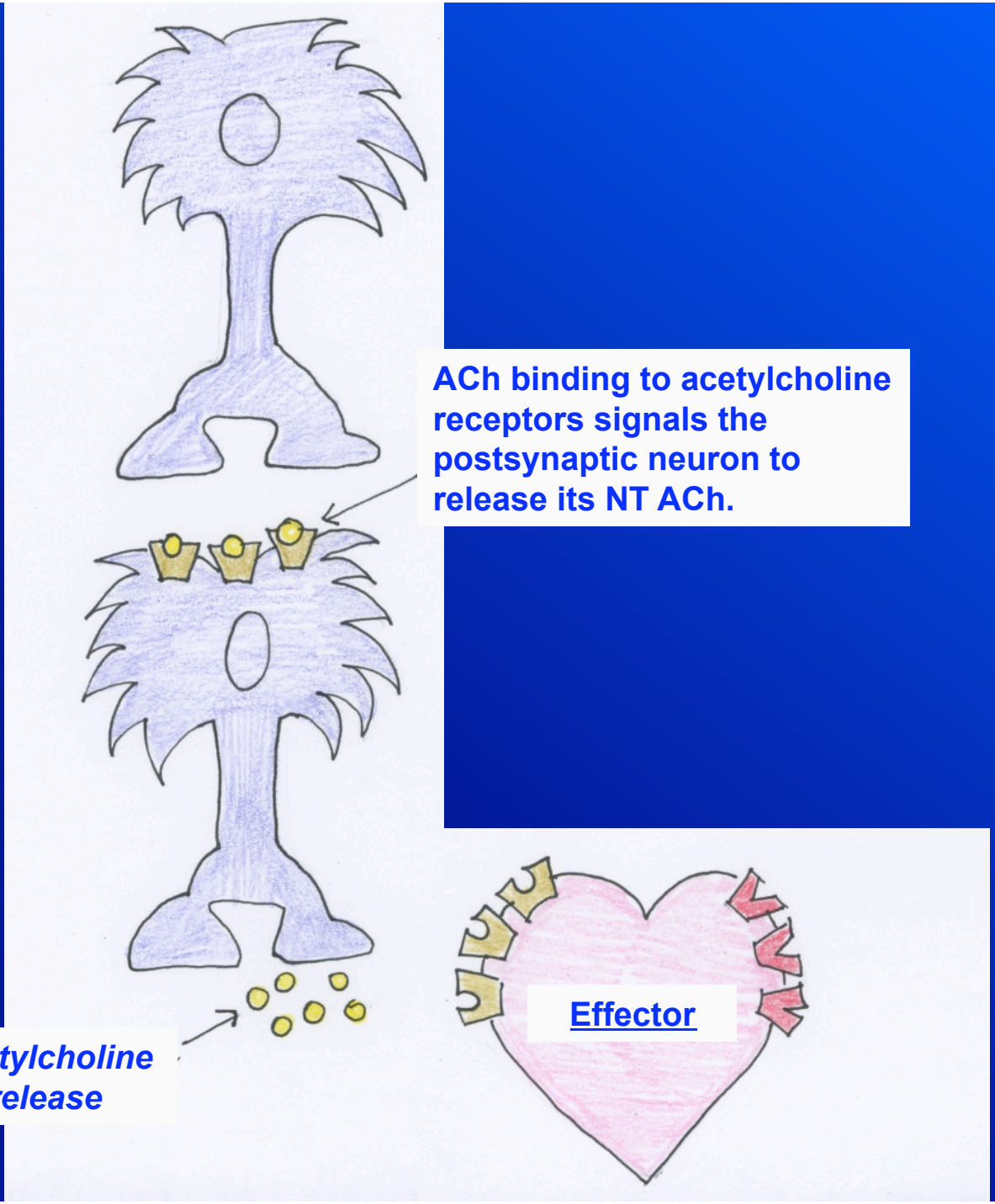


Preganglionic Cholinergic Neuron- neurons receive a signal and thus release *acetylcholine* as their neurotransmitter

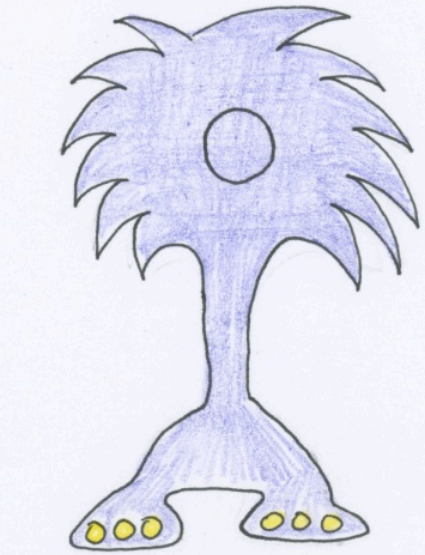
Acetylcholine release

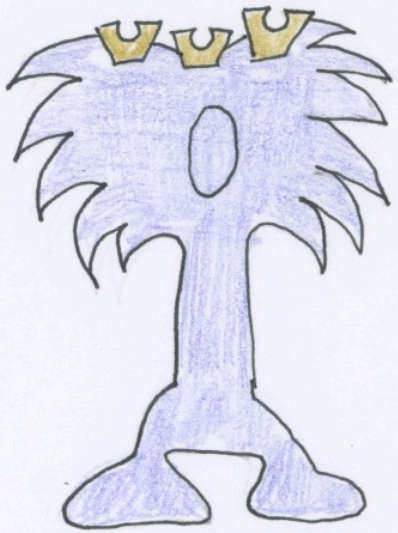
Effector

Parasympathetic nervous system (Rest and digest)

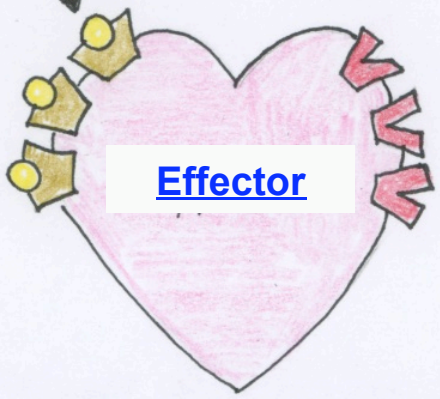


Parasympathetic nervous system (Rest and digest)



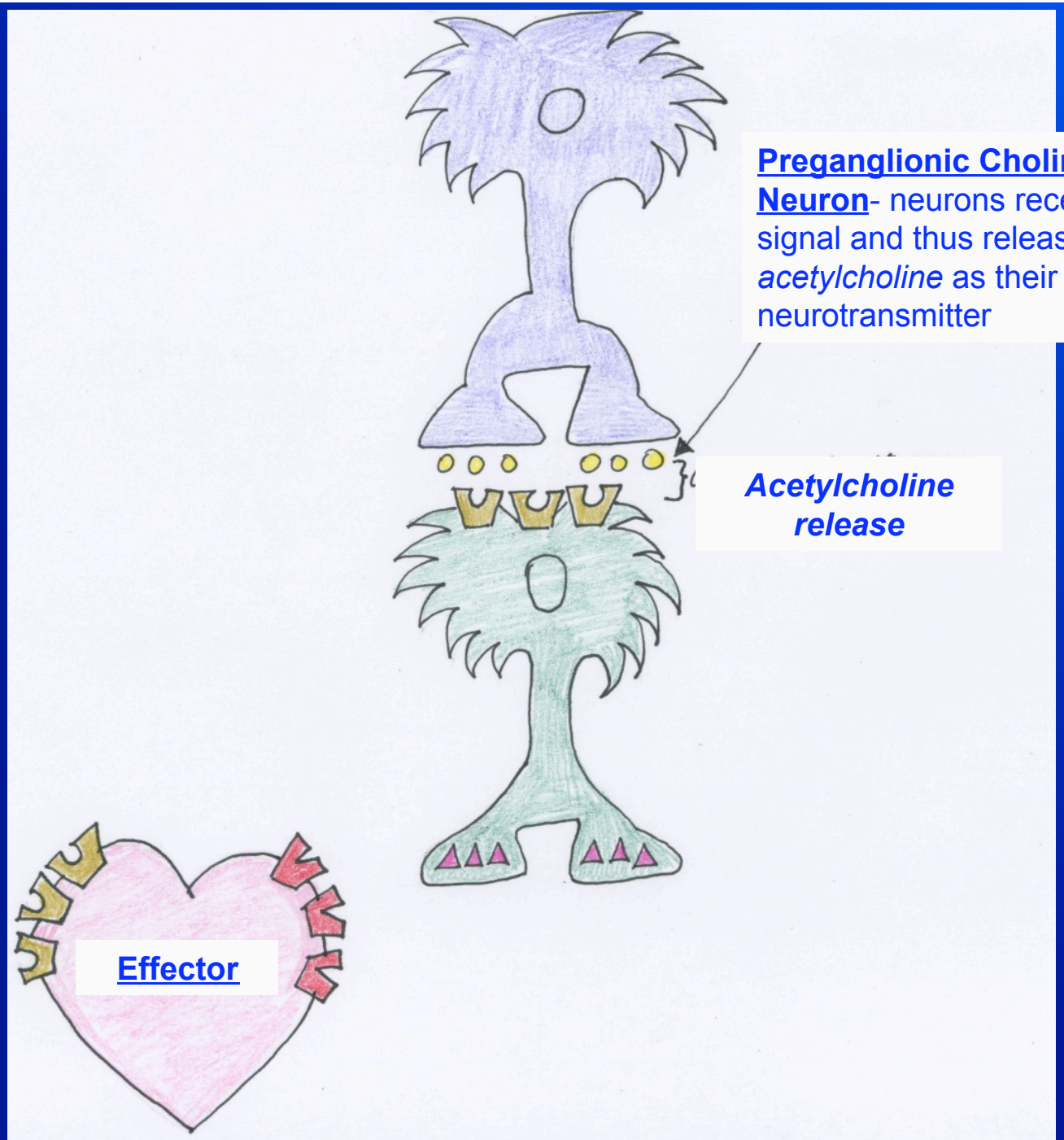


ACh binding to acetylcholine receptors on the effector (The heart). The parasympathetic dividion produces a parasympathetic response (Rest and digest) The heart rate slows down.



Effector

Sympathetic nervous system (Fight or Flight)



Preganglionic Cholinergic Neuron- neurons receive a signal and thus release *acetylcholine* as their neurotransmitter

Acetylcholine release

Effector

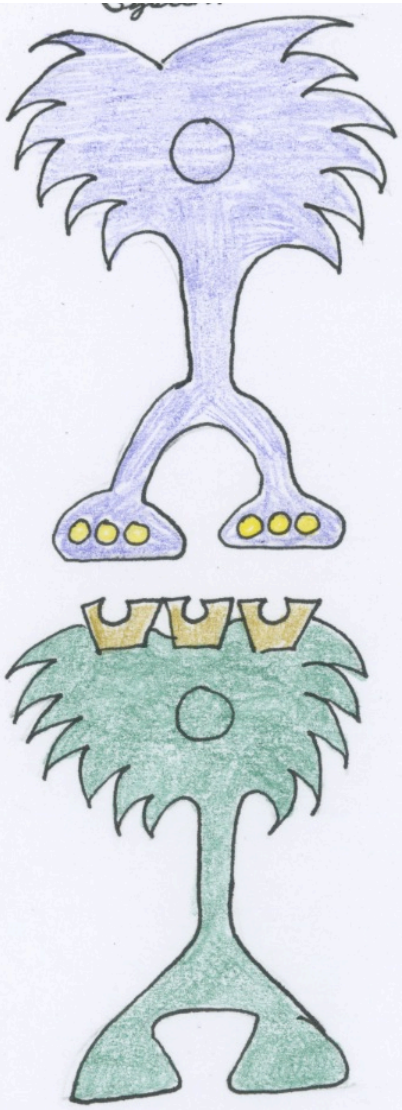
Sympathetic nervous system (Fight or Flight)

ACh binding to acetylcholine receptors signals the postsynaptic neuron to release its NT Norepinephrine

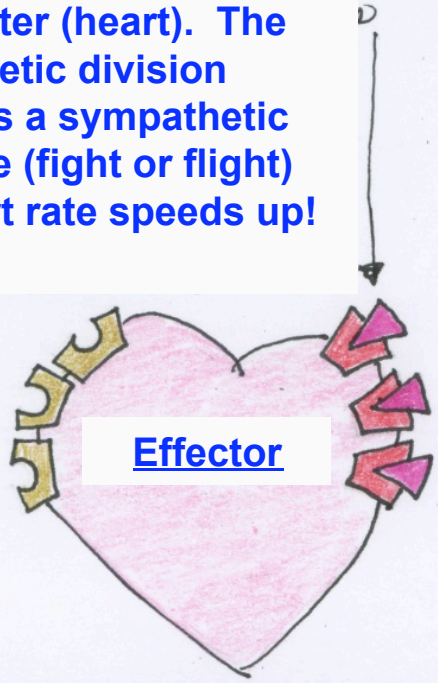
Norepinephrine release

Effector

Sympathetic nervous system (Fight or Flight)



Norepinephrine binds to the adrenergic receptor on the effecter (heart). The sympathetic division produces a sympathetic response (fight or flight) The heart rate speeds up!



Effector

IV. Regulation of the ANS

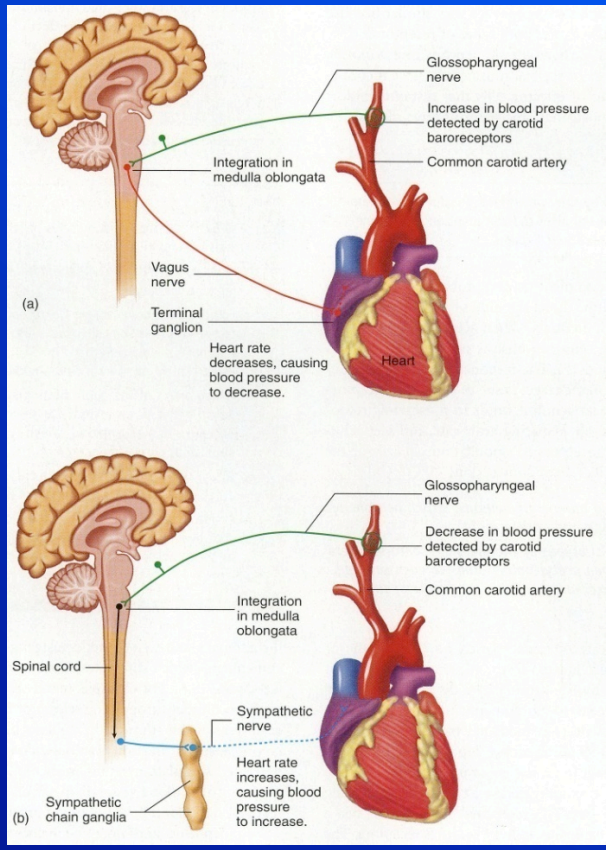
A. Autonomic Reflexes
B. Enteric NS involved with autonomic reflexes & local reflexes that regulate GI-tract activity

IV. Regulation of the ANS

- Much occurs via autonomic reflexes
- Input from the cerebrum, hypothalamus, & other areas of the brain allow conscious thought & actions, emotions, & other CNS activities to influence ANS.
- The regulation provided by the ANS is req'd to maintain homeostasis

IV. Regulation of the ANS
Autonomic Reflexes

- Involves
  - Sensory receptors
  - Sensory neurons
  - Interneurons
  - Motor Neurons
  - Effector Cells
- 2 imp. autonomic reflex centers:
  - Brainstem
  - Spinal Cord
- Overall Control of the ANS: **Hypothalamus**
  - Monitors & controls body temp
  - Cxns w/ cerebrum (fxns in limbic system) thus the hypothalamus uses thoughts & emotions to prod ANS responses.
    - ❖ There is overlap
      - ❖ Posterior Hypothalamus: stimulation→ Sympathetic Response
      - ❖ Anterior Hypothalamus: stimulation→ Parasympathetic Response



IV. Regulation of the ANS

Enteric NS involved w/Autonomic & local reflexes that regulate activity of the GI-tract

Autonomic Reflexes

- Help to control the GI-tract b/c sensory neruons of the enteric plexus supply CNS w/ info about intestinal contents & ANS neurons to the enteric plexus affect the responses of the smooth muscle & glands w/in the GI-tract
- Ex: sensory neurons detect stretch & send info→ CNS wh/ sends signals→to smooth muscle of GI-tract to contract

Local Reflexes

- Neurons of the ENS can also act independently
- A local reflex doesn't involve the CNS but it still produced an involuntary, unconscious, stereotypic response to a stimulus
- Ex: Sensory neurons not connected to CNS detect stretch ➔ action potential thru enteric plexus → motor neurons cause muscle contraction or relaxation

V. Fxnal Generalizations about the ANS

A. Stimulatory vs. Inhibitory FX
B. Duel Innervation
C. Opposite FX
D. Cooperative FX
E. General vs. Localized FX
F. Fxns at rest vs. Activity

V. Fxnal Generalizations about the ANS on effector organs but most have exceptions

A. Stimulatory vs. Inhibitory FX

- Both the SNS & PNS have both FX.
- Ex/ SNS will increase the heart rate but decrease contraction of the stomach

B. Duel Innervation

- Most effectors are innervated by both types of neurons
- Although most are not regulated equally by both (one side is more dominate)
  - Ex: GI-tract PNS is more extensive than SNS
- BUT it isn't universal:
  - Sweat glands & blood vessels are almost exclusively SNS

V. Fxnal Generalizations about the ANS on effector organs but most have exceptions

C. Opposite FX

- In the situation of duel innervation the FX of the SNS are opposite of the PNS
- This means the ANS can increase or decrease the activity of a structure
- But it isn't always clear cut
  - Ex:
  - PNS: salivary glands prod lrg vol of thin watery saliva
  - SNS: Salivary glands prod sm. Vol of viscous saliva

D. Cooperative FX

- 1 division of the ANS can coordinate the activities of diff struc's
  - Ex: PNS can stimulate the pancreas to secrete digestive enz's into sm. intest. & also stimulate contractions of the sm.intest to mix food w/enz's
- Both divisions can also wk. together to coordinate activity of diff struc's
  - Ex: In males: PNS➔ initiates an erection SNS➔ stimulates the release of secretions from glands & helps initiate ejaculation

V. Fxnal Generalizations about the ANS on effector organs but most have exceptions

E. General vs. Localized FX:

- SNS has more general FX than PNS
- SNS:
  - b/c activation often causes secretion of both epi & norepi from adrenal medulla
    - These go throughout the bld stream & stimulate effectors throughout the body
    - Also prod longer FX than postsynaptic stimulation
  - SNS diverges more than PNS
    - SNS PreG synapse w/multiple PostG
    - PNS PreG synapse w/only 2 PostG
    - THUS stmulation of SNS PreG can result in greater stimulation of the effector
    - SNS also often activates many diff kinds of effectors simultaneously but it can isolate

V. Fxnal Generalizations about the ANS on effector organs but most have exceptions

F. Fxns at rest vs. Activity

- SNS
  - Fight or Flight Response
  - Fxns under conditions of physical activity or stress
  - Decreases activity of organs not essential for maintenance of physical activity & shunts bld & nutrients to structures that are active during exercise
- PNS
  - Rest & Digest Response
  - Fxns under resting conditions
  - Regulates digestion by increasing the secretions of glands, promoting the mixing of fd w/ digestive enz's & bile, and moving material thru digestive tract
  - Defecation & urination also controlled
  - Increased activity of the PNS➔ lower: heart rate, BP, constricts air passages, thus decreasing air mvmt