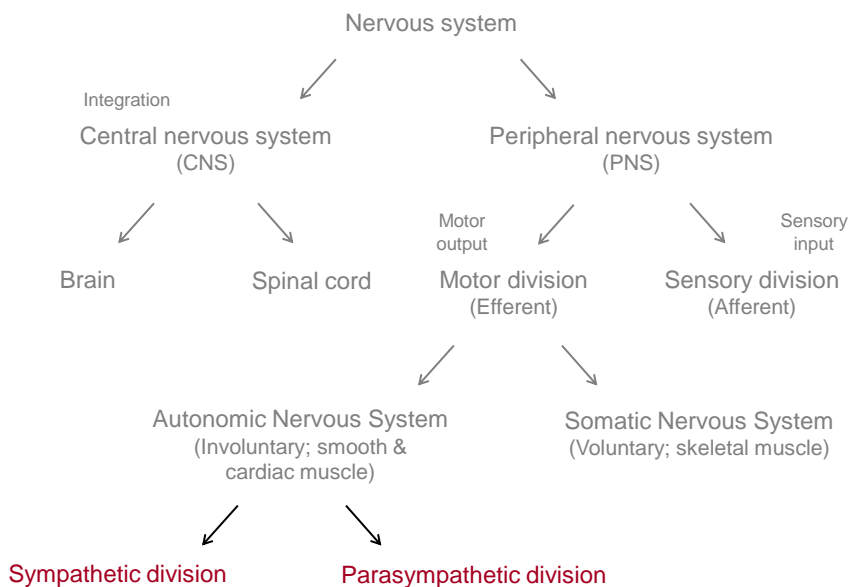


Autonomic Nervous System

Organization of Nervous System:



Autonomic Nervous System

Divisions of Autonomic Nervous System (ANS):

1) **Sympathetic Division:** ("fight or flight")

- Readies body for stressful situations
 - Heightens mental alertness
 - ↑ metabolic rate
 - Activates energy reserves
 - Dampens non-essentials (e.g., digestion)
- ↑ heart rate / blood pressure
- ↑ respiratory rate / bronchiole dilation
- Activates sweat glands



2) **Parasympathetic Division:** ("rest and digest")

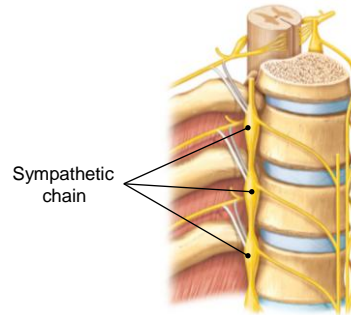
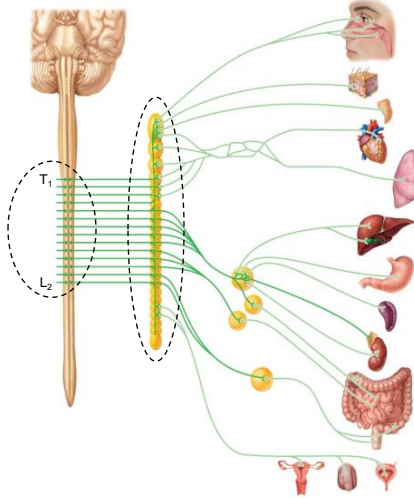
- Conserves energy at rest
 - ↓ metabolic rate
 - ↓ heart rate / blood pressure
 - ↑ digestive gland secretions
- ↑ digestive motility / blood flow
- Stimulates defecation / urination



Sympathetic division also called the thoracolumbar division

Sympathetic Division Anatomy:

- Sympathetic pathways have short preganglionic fibers and long postganglionic fibers
- Preganglionic fibers originate in spinal cord between cord segments T1 – L2
- Autonomic ganglia located close to spinal cord (arranged as **sympathetic chain**)
 - 23 ganglia / chain (3 cervical, 11 thoracic, 4 lumbar, 4 sacral, 1 coccygeal)

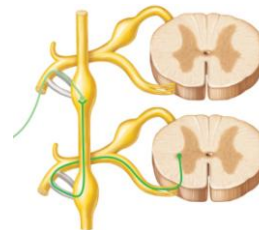
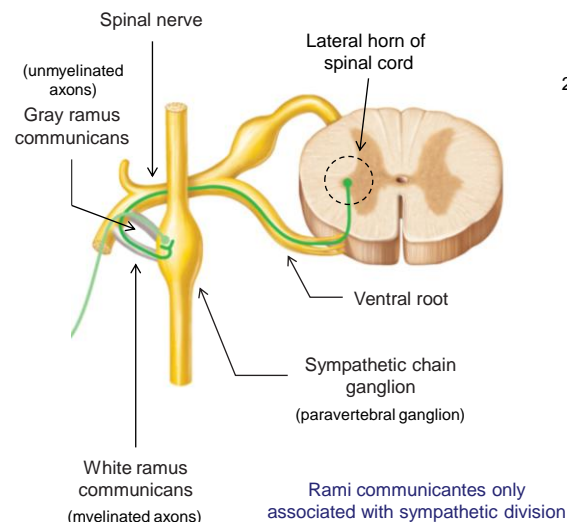


Marieb & Hoehn – Figure 14.5 / 14.6

Sympathetic Division Anatomy:

Pathways in sympathetic chain:

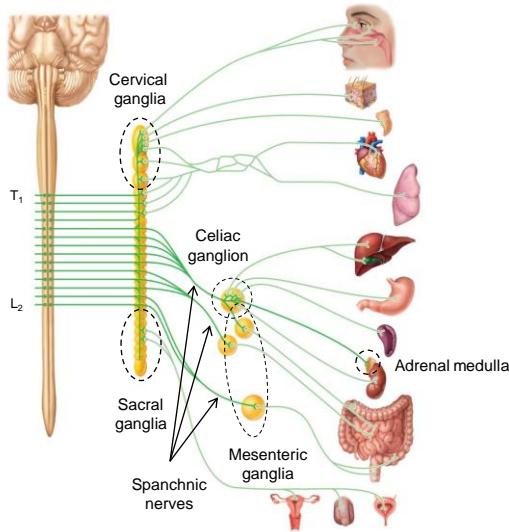
- 1) Terminate directly in sympathetic chain
 - Postganglionic axons exit out **gray ramus communicans**
- 2) Ascend / descend several segments before terminating



- May ascend / descend to ganglia located outside T1 – L2
- **Cervical ganglia:** (fed via T₁ – T₆)
Serve head / thorax
- **Sacral ganglia:** (fed via T₁₀ – L₂)
Serve genitalia / urinary bladder

Marieb & Hoehn – Figure 14.5

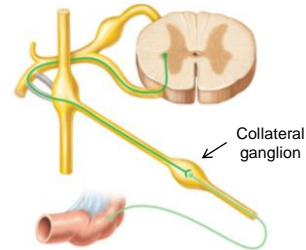
Sympathetic Division Anatomy:



Marieb & Hoehn – Figure 14.5 / 14.6

Pathways in sympathetic chain:

- 3) Exit sympathetic chain before terminating in collateral (prevertebral) ganglia



- Form **splanchnic nerves** (fed via T₅ – L₂)

Celiac ganglion:

Serves upper abdominal cavity

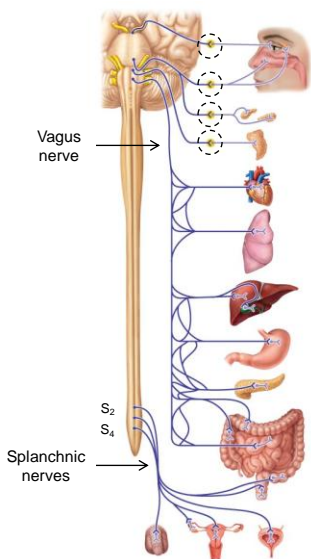
- Pass-through point for splanchnic nerve feeding adrenal medulla

Mesenteric ganglia:

Serve lower abdominal cavity

Parasympathetic division also called the craniosacral division

Parasympathetic Division Anatomy:



Marieb & Hoehn – Figure 14.4

- Sympathetic pathways have long preganglionic fibers and short postganglionic fibers

- **Terminal ganglia** located near effector tissue

- Preganglionic fibers originate in brain stem and S₂ – S₄:

- **Oculomotor Nerve (III)**

- **Ciliary ganglia:** Pupillary sphincters / ciliary muscles

- **Facial Nerve (VII)**

- **Pterygopalatine ganglia:** Nasal / lacrimal glands

- **Submandibular ganglia:** Salivary glands

- **Glossopharyngeal Nerve (IX)**

- **Otic ganglia:** Salivary gland

- **Vagus Nerve (X)**

- **Intramural ganglia:** Visceral organs

- **Sacral Segments (S₂ – S₄):**

- **Intramural ganglia:** Large intestine / bladder / genitalia

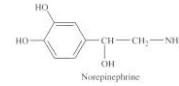
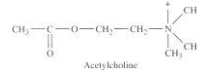
90% of PNS fibers

Autonomic Nervous System

ANS Physiology:

Fiber Types:

- **Cholinergic Fibers:** Synthesize / secrete acetylcholine (NT)
 - All preganglionic fibers (sympathetic and parasympathetic divisions)
 - Postganglionic fibers of **parasympathetic division**
- **Adrenergic Fibers:** Synthesize / secrete norepinephrine (NT)
 - Postganglionic fibers of **sympathetic division** (sans sweat glands / piloerector muscles)



Synthesis of Neurotransmitters:

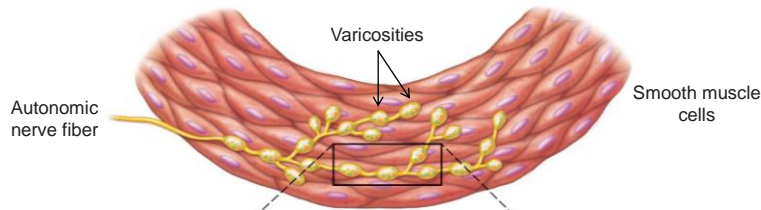
- NTs synthesized / stored in varicosities of nerve fibers

Autonomic Nervous System

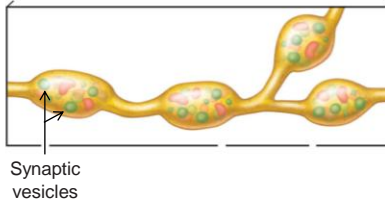
ANS Physiology:

Neuroeffector Junction of ANS:

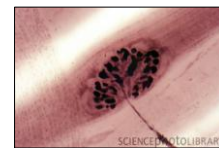
- Postganglionic neuron forms diffuse, branching networks at synapse
 - NTs released from varicosities ("beads")
- Innervation by multiple ANS fibers may occur
- Postsynaptic receptors spread across target



Precision strike
vs.
Saturation bombing



Remember:



Neuromuscular junction

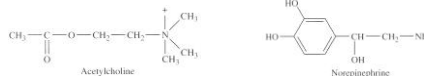
Marieb & Hoehn – Figure 9.27

Autonomic Nervous System

ANS Physiology:

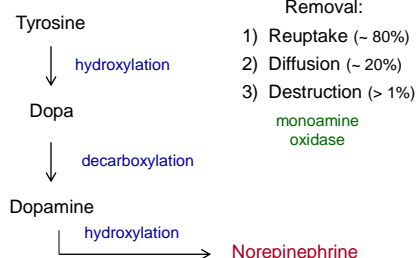
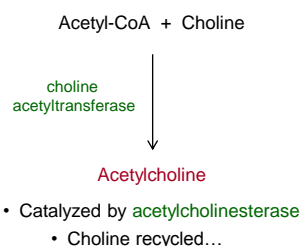
Fiber Types:

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 - All preganglionic fibers (sympathetic and parasympathetic divisions)
 - Postganglionic fibers of parasympathetic division
- Adrenergic Fibers: Synthesize / secrete norepinephrine (NT)
 - Postganglionic fibers of sympathetic division (sans sweat glands / piloerector muscles)



Synthesis of Neurotransmitters:

- NTs synthesized / stored in varicosities of nerve fibers



Autonomic Nervous System

Nature of receptor dictates effects of NTs

ANS Physiology:

Receptor Types:

- A) Adrenoreceptors (bind E / NE): G protein-linked receptor systems
- Located on target tissues of sympathetic nervous system

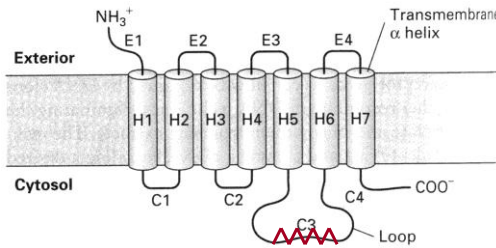
ANS Physiology:

G – protein Receptor Systems:

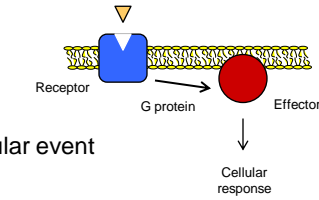
- Receptors interact with G-proteins to trigger cellular event

A. Receptors:

- 7 trans-membrane segments (each segment = similar α -helix sequences)



- Interact with various G-proteins depending on sequence of 3rd intracellular loop



Wolfe – Figure 4.3

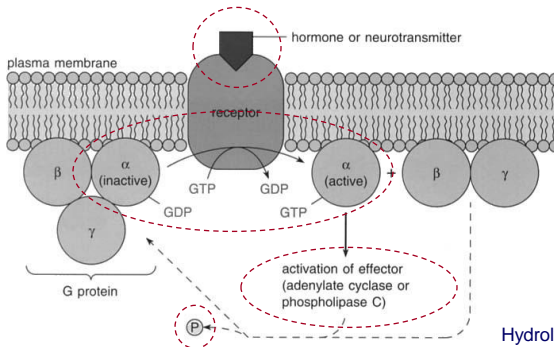
ANS Physiology:

G – protein Receptor Systems:

- Receptors interact with G-proteins to trigger cellular event

B. G proteins:

- Composed of three unique sub-units (α , β , δ)
- No intrinsic enzymatic activity; activates enzymes



G protein Activation:

- 1) Ligand binds to receptor
- 2) Receptor / G protein interact
 - GDP (α -subunit) replaced by GTP; dissociation occurs
- 3) α -subunit activates effector

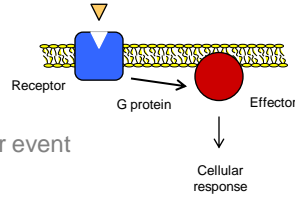
Hydrolysis of GTP to GDP causes α -subunit to dissociate from effector and rejoin other subunits

Autonomic Nervous System

ANS Physiology:

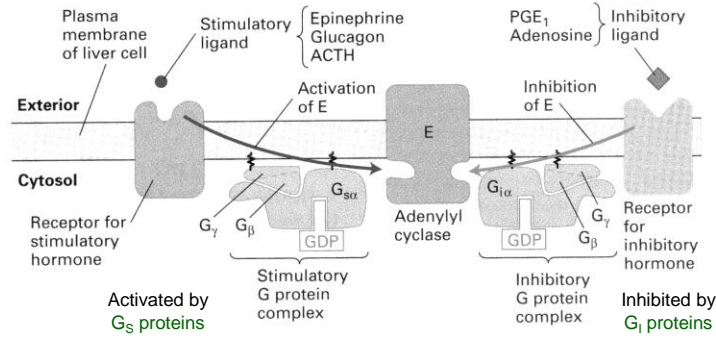
G – protein Receptor Systems:

- Receptors interact with G-proteins to trigger cellular event



C. Effectors:

A) Adenylate cyclase (2nd messenger – cAMP)



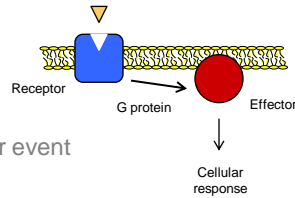
Lodish – Figure 20.20

Autonomic Nervous System

ANS Physiology:

G – protein Receptor Systems:

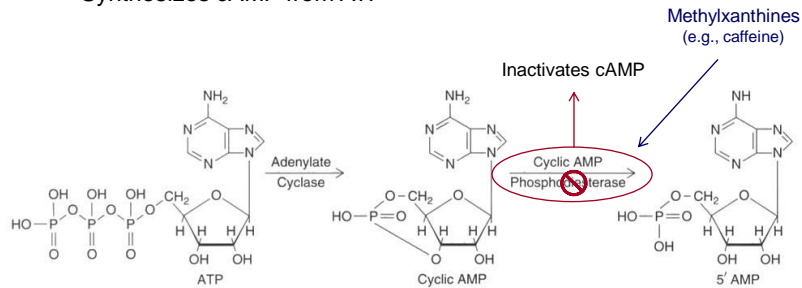
- Receptors interact with G-proteins to trigger cellular event

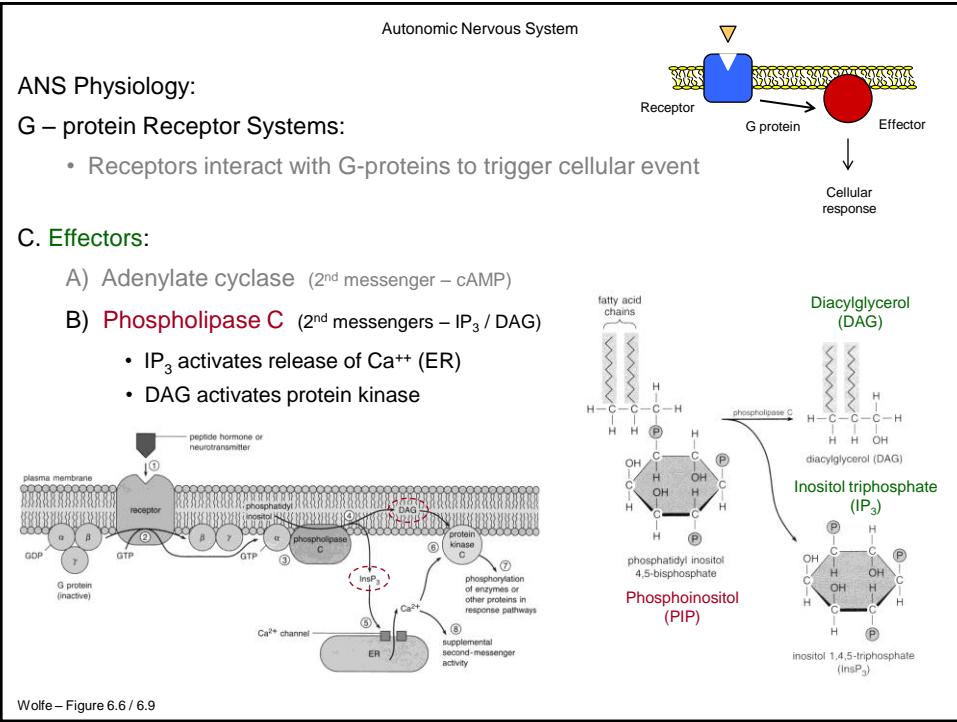


C. Effectors:

A) Adenylate cyclase (2nd messenger – cAMP)

- Synthesizes cAMP from ATP





Autonomic Nervous System

Nature of receptor dictates effects of NTs

ANS Physiology:
Receptor Types:

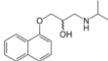
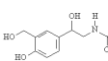
G protein-linked receptor systems

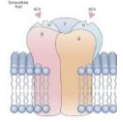
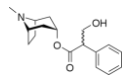
A) **Adrenoreceptors** (bind E / NE):

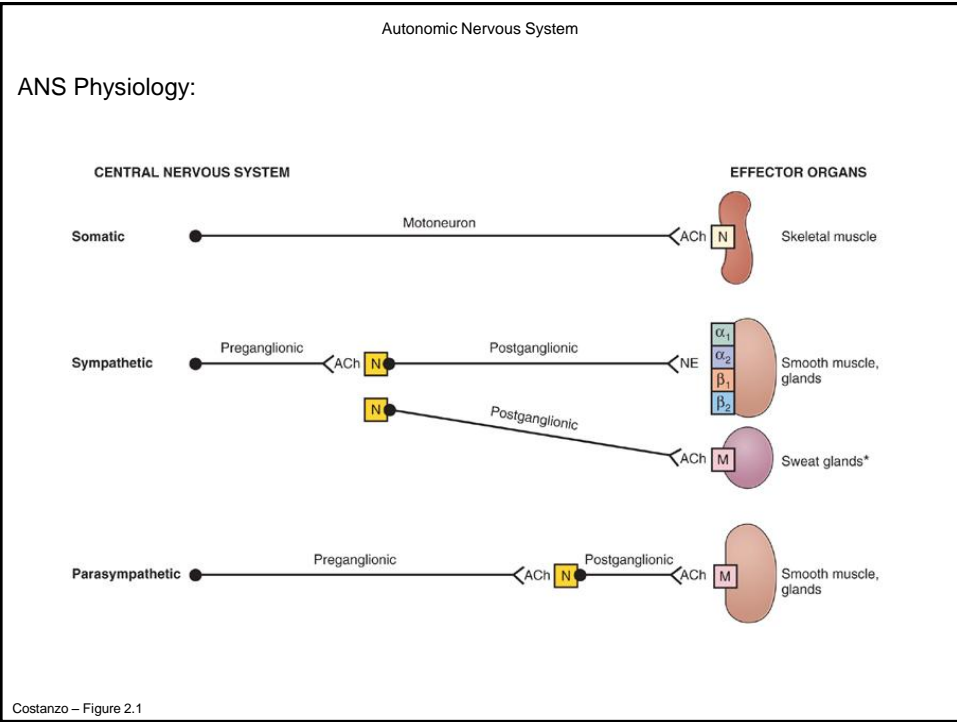
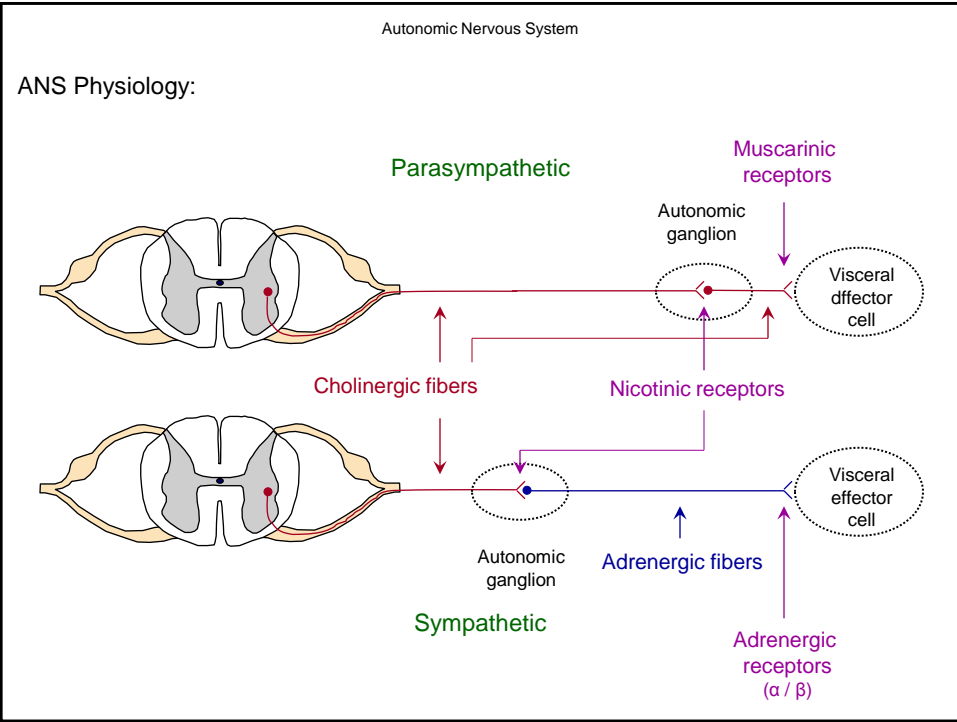
- Located on target tissues of sympathetic NS
- Divided into two types: α and β receptors

	α_1 receptors		α_2 receptors
Effect:	(+) Excitatory (+)	Effect:	(-) Inhibitory (-)
Location:	Vascular smooth muscle - skin (constricts blood vessels) Gastrointestinal tract / bladder (constricts sphincters) Iris of eye (dilates pupil of eye)	Location:	Membrane of adrenergic axon terminals (inhibits NE release) Gastrointestinal tract (inhibits GI function) Pancreas (inhibits insulin secretion)
Mechanism of Action:	G protein coupled to phospholipase C	Mechanism of Action:	G _i protein coupled to adenylate cyclase

Phenylephrine
(α_1 agonist)

Autonomic Nervous System		Nature of receptor dictates effects of NTs	
ANS Physiology:			
Receptor Types:			
A) Adrenoreceptors (bind E / NE):		G protein-linked receptor systems	
<ul style="list-style-type: none"> • Located on target tissues of sympathetic NS • Divided into two types: α and β receptors 			
β_1 receptors		β_2 receptors	
Effect:	(+) Excitatory (+)	Effect:	(-) Inhibitory (-)
Location:	Predominately in the heart (increases contraction rate / strength) Kidney (triggers renin (hormone) release)	Location:	Vascular smooth muscle - skeletal muscle (dilates vessels) muscle Lungs (dilates bronchioles) Gastrointestinal tract (relaxes GI tract)
	Propranolol (β -blocker)		Albuterol (β_2 agonist)
Mechanism of Action:	G_s protein coupled to adenylate cyclase	Mechanism of Action:	G_s protein coupled to adenylate cyclase

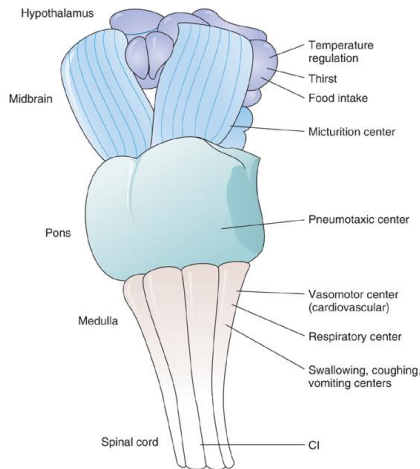
Autonomic Nervous System		Nature of receptor dictates effects of NTs	
ANS Physiology:			
Receptor Types:			
A) Adrenoreceptors (bind E / NE):		Activated by nicotines	
B) Cholinergic receptors (bind ACh):		Activated by toxins from toadstools	
<ul style="list-style-type: none"> • Located on postganglionic neurons / target tissues of parasympathetic NS • Divided into two types: nicotinic & muscarinic 			
Nicotinic		Muscarinic	
Effect:	(+) Excitatory (+)	Effect:	(+) Excitatory (+) & (-) Inhibitory (-)
Location:	Motor end plate – skeletal muscle (contracts skeletal muscle) All postganglionic neurons (activate postganglionic neurons) Chromaffin cells – adrenal medulla (triggers release of E / NE)	Location:	Parasympathetic organs – sans heart (excites organ activity) Heart (inhibits heart rate) Sweat glands – sympathetic NS (activates sweat glands)
		G protein coupled to K^+ channel...	
Mechanism of Action:	Ligand-gated ion channel	Mechanism of Action:	G protein coupled to phosphorylase C (Majority of locations)
			atropine (muscarinic antagonist)





ANS Physiology:

Control of Autonomic Functioning:



Costanzo – Figure 2.4

A) Brain stem / Spinal cord

- Vasomotor center (cardiovascular)
- Respiratory center
- Micturition center (urination)
- Swallowing / coughing / vomiting

B) Hypothalamus

- Main integration center
 - Body temperature
 - Water balance
 - Food intake
- Links emotion with ANS

C) Cortical control

- Links emotional past with ANS
- Voluntary cortical ANS control possible

Sympathetic = "fight or flight"

Parasympathetic = "rest and digest"

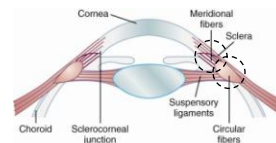
ANS Physiology:

Interactions of Autonomic Divisions:

A) Antagonistic Interactions:

Systems do not 'compete' with each other; coordinated by nervous system

- Pupil:
 - **Parasympathetic** = Constriction (circular fibers)
 - **Sympathetic** = Dilation (meridional fibers)
- Heart (sinoatrial node):
 - **Parasympathetic** = Decrease heart rate
 - **Sympathetic** = Increase heart rate



B) Synergistic Interactions:

- External genitalia
 - **Parasympathetic** = Vasodilation of blood vessels (erection of tissue)
 - **Sympathetic** = Smooth muscle contraction (ejaculation / reflex contraction)

* Tone:

- Basal rate of activity present in a system
- Allows increase / decrease by single system

Blood vessels under **sympathetic tone**

Decrease output = vasodilation of vessel

Increase output = vasoconstriction of vessel

Autonomic Nervous System

ANS Physiology:

Interactions of Autonomic Divisions:

C) Coordinated Function within Organ:

• Bladder:

- Filling = **Relaxed** detrusor muscle; **contracted** internal sphincter
- Emptying = **Contracted** detrusor muscle; **relaxed** internal sphincter

Sympathetic = "fight or flight"
Parasympathetic = "rest and digest"

Sympathetic

Parasympathetic

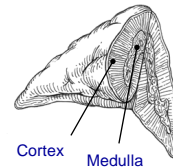
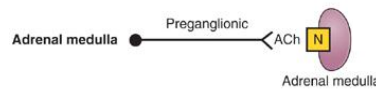
Muscle	Filling of Bladder		Emptying of Bladder	
	State	Control Mechanism	State	Control Mechanism
Detrusor muscle	Relaxed	Sympathetic (β ₂)	Contracted	Parasympathetic (M)
Internal sphincter	Contracted	Sympathetic (α ₁)	Relaxed	Parasympathetic (M)
External sphincter	Contracted	Voluntary	Relaxed	Voluntary

Costanzo – Figure 2.4

Autonomic Nervous System

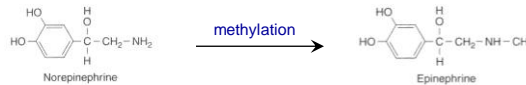
Adrenal Medulla:

• Large sympathetic ganglion



• Postganglionic cells = **Chromaffin cells**

• Releases **catecholamines** (epinephrine (80%) and norepinephrine (20%))



• Catecholamines transported via blood (= hormone)

- Delayed effect (3 – 5 sec.); prolonged effect (2 – 4 min. to clear from system)
 - Stimulation of cardiovascular function / metabolic rate (helps deal with stress)

• Perceived purpose:

- 1) Safety factor (dual mechanism – backs up sympathetic nervous system)
- 2) Stimulate structures not directly innervated (e.g., every cell of body...)