The Autonomic Nervous System

**FIGURE QUESTIONS**
1. Name the regions of the CNS where the two branches originate.
The Autonomic Division

Controlled by the limbic system and the medulla oblongata, which is in turn controlled by the hypothalamus.
CNS

PNS

EFFERENT

Somatic

- voluntary

ANS

Cardiac & smooth muscles

- involuntary

AFFECTENT

Somatic

Cardiac & smooth muscles

Visceral

Skeletal muscle, tendons

Glands

joints

Glands
Somatic vs. Autonomic

What happens if innervation is absent?
Somatic vs. Autonomic

- Somatic has 1 neuron in the efferent pathway
- Autonomic division has 2
  - Preganglionic neuron has its cell body in the gray matter of brain or spinal cord
  - Postganglionic neuron has its cell body in an autonomic ganglion
why have 2 neurons in the efferent pathway?
| Comparison of Somatic Motor and Autonomic Divisions |
|---------------------------------|---------------------------------|---------------------------------|
| **Number of neurons in efferent path** | **SOMATIC MOTOR**<br>1 | **AUTONOMIC**<br>2 |
| **Neurotransmitter/receptor at neuron-target synapse** | **ACh/nicotinic** | **ACh/muscarinic or NE/α- or β-adrenergic** |
| **Target tissue** | **Skeletal muscle** | **Smooth and cardiac muscle; some endocrine and exocrine glands; some adipose tissue** |
| **Neurotransmitter released from** | **Axon terminals** | **Varicosities and axon terminals** |
| **Effects on target tissue** | **Excitatory only: muscle contracts** | **Excitatory or inhibitory** |
| **Peripheral components found outside the CNS** | **Axons only** | **Preganglionic axons, ganglia, postganglionic neurons** |
| **Summary of function** | **Posture and movement** | **Visceral function, including movement in internal organs and secretion; control of metabolism** |
Divisions of the Autonomic Nervous System

Parasympathetic Division
- pupil constricted
- heart rate slow
- stomach stimulated
- contracted

Sympathetic Division
- inhibited
- salivation inhibited
- accelerated
- airways expanded
- inhibited
- adrenal gland stimulated
- bladder relaxed
Sympathetic (Thoracolumbar) Division

• Preganglionic neurons originate in the thoracic and lumbar regions; paravertebral ganglia

• ‘Flight or Fight' system
• Preganglionic neurons originate in the brain (midbrain, medulla oblongata and pons) and sacral region of the spinal cord and send axons to ganglia located at or near effector organs.

• “Rest and Digest” system
Homeostasis is a dynamic balance between the autonomic branches.

for the most part...

Rest-and-digest: Parasympathetic activity dominates.

Fight-or-flight: Sympathetic activity dominates.
Functions of the Autonomic NS

What Determines the Meaning of a Message?
Oh yes, here we go again…
Neurotransmitters of the ANS

Cholinergic: Acetylcholine

Adrenergic: Epinephrine and Norepinephrine
Cholinergic Neurons of the ANS

- ACh is the neurotransmitter of all preganglionic fibers of both divisions (as well as for somatic motor neurons).
- ACh is also the NT for parasympathetic postganglionic neurons.
<table>
<thead>
<tr>
<th>Sympathetic</th>
<th>Parasympathetic</th>
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Cholinergic Stimulation Responses

• Cholinergic effects of somatic motor neurons and of preganglionic neurons are always excitatory.

• Cholinergic effect of postganglionic parasympathetic neurons may be stimulatory or inhibitory

How is that possible?
Cholinergic Receptors

- Nicotinic subtype
  - $N_m$ found in neuromuscular junctions
  - $N_n$ found elsewhere
- Muscarinic subtypes
  - $M_1$: CNS, gastric parietal cells, ANS ganglia
  - $M_2$: myocardium
  - $M_3$: smooth muscle
  - $M_4, M_5$: CNS
(a) The **neuromuscular junction** consists of axon terminals, motor end plates on the muscle membrane, and Schwann cell sheaths.

(b) The **motor end plate** is a region of muscle membrane that contains high concentrations of ACh receptors.

- Schwann cell sheath
- Axon terminal
- Mitochondrion
- Motor end plate
- Somatic motor neuron branches at its distal end
- Skeletal muscle fiber
- Motor end plate
(c) The neuromuscular junction

- Synaptic vesicle (ACh)
- Presynaptic membrane
- Synaptic cleft
- Nicotinic ACh receptors
- Postsynaptic membrane
- Postsynaptic membrane is modified into a motor end plate.

(d) An action potential arrives at the axon terminal, causing voltage-gated Ca\(^{2+}\) channels to open. Calcium entry causes synaptic vesicles to fuse with the presynaptic membrane and release ACh into the synaptic cleft.

- Synaptic vesicle (ACh)
- Voltage-gated Ca\(^{2+}\) channel
- Acetylcholine (ACh)
- Acetyl + choline
- AChE

(e) The nicotinic cholinergic receptor binds two ACh molecules, opening a nonspecific monovalent cation channel. The open channel allows Na\(^+\) and K\(^+\) to pass. Net Na\(^+\) influx depolarizes the muscle fiber.

- Na\(^+\)
- K\(^+\)

- Closed channel
- Open channel

Acetylcholine (ACh) is metabolized by acetylcholinesterase (AChE).
ACh Nicotinic Receptor
ACh Muscarinic Receptors

**M<sub>2</sub>**
- Ligand: ACh
- G protein: α<sub>γ</sub>β<sub>γ</sub>
- Ion channel: K<sup>+</sup>
- Effect: Hyperpolarization leads to inhibition, producing a slower heart rate

**M<sub>3</sub>**
- Ligand: ACh
- G protein: α<sub>γ</sub>β<sub>γ</sub>
- Ion channel: K<sup>+</sup> and Na<sup>+</sup> or Ca<sup>2+</sup>
- Effect: Depolarization leads to excitation, causing smooth muscles of the digestive tract to contract

**Key Points**
- M<sub>2</sub> receptors lead to inhibition.
- M<sub>3</sub> receptors lead to excitation.
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Adrenergic Stimulation Responses

- Most postganglionic sympathetic nerve fibers release norepinephrine
- Effects vary

*How is that possible?*
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<td>( \text{NE and E} ) bind to Adrenergic Receptors</td>
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# Adrenergic Receptors

<table>
<thead>
<tr>
<th>Receptor</th>
<th>Found in</th>
<th>Sensitivity</th>
<th>Effect on Second Messenger</th>
</tr>
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<tbody>
<tr>
<td>$\alpha_1$</td>
<td>Most sympathetic target tissues</td>
<td>NE &gt; E*</td>
<td>Activates phospholipase C</td>
</tr>
<tr>
<td>$\alpha_2$</td>
<td>Gastrointestinal tract and pancreas</td>
<td>NE &gt; E</td>
<td>Decreases cAMP</td>
</tr>
<tr>
<td>$\beta_1$</td>
<td>Heart muscle, kidney</td>
<td>NE = E</td>
<td>Increases cAMP</td>
</tr>
<tr>
<td>$\beta_2$</td>
<td>Certain blood vessels and smooth muscle of some organs</td>
<td>E &gt; NE</td>
<td>Increases cAMP</td>
</tr>
<tr>
<td>$\beta_3$</td>
<td>Adipose tissue</td>
<td>NE &gt; E</td>
<td>Increases cAMP</td>
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*NE = norepinephrine, E = epinephrine.
Sympathetic pathways use acetylcholine and norepinephrine.

Parasympathetic pathways use acetylcholine.
**Autonomic Pathways**

- **Somatic Motor Pathway**
- **Parasympathetic Pathway**
- **Sympathetic Pathways**
- **Adrenal Sympathetic Pathway**

**Key**
- **ACh** = acetylcholine
- **E** = epinephrine
- **NE** = norepinephrine

**Autonomic Effectors:**
- Smooth and cardiac muscles
- Some endocrine and exocrine glands
- Some adipose tissue

**Diagram Details:**
- CNS (Central Nervous System)
- Ganglion
- Nicotinic receptor
- Muscarinic receptor
- Skeletal muscle
- Blood vessel
- Adrenal cortex
- Adrenal medulla

**Note:**
- The diagram illustrates the pathways and neurotransmitters involved in autonomic control, including the effects on various tissues and organs.
One More Thing…. The Adrenal Sympathetic Pathway

- “Postganglionic neuron” replaced by epinephrine-releasing chromaffin cells
- Epinephrine is a neurohormone, released into the blood
THE ADRENAL MEDULLA SECRETES EPINEPHRINE INTO THE BLOOD.

Adrenal cortex is a true endocrine gland.

Adrenal medulla is a modified sympathetic ganglion.

The chromaffin cell is a modified postganglionic sympathetic neuron.

Epinephrine is a neurohormone that enters the blood.

Blood vessel

To target tissues

Spinal cord

Preganglionic sympathetic neuron

ACh

Adrenal medulla

To target tissues
How the Divisions Work Together
Antagonistic

Homeostasis is a dynamic balance between the autonomic branches.

Parasympathetic
Rest-and-digest: Parasympathetic activity dominates.

Sympathetic
Fight-or-flight: Sympathetic activity dominates.
Complementary

• Sympathetic and parasympathetic on salivary gland function
Cooperative

- Urination
- Erection / ejaculation