Thought Question’s

1. What are 2 ways to assess whether or not a particular spinal nerve has been damaged?

2. If you cut a dorsal root, what would the result be?
The Nervous System

PERIPHERAL NERVE DISEASES
NERVE REGENERATION
ANS
RECEPTORS AND PHARMACOLOGY
Peripheral Nerve Regeneration

- Possible if cell body has not been damaged
- Axon underlying myelin sheath can regenerate
The axon becomes fragmented at the injury site.
Macrophages clean out the dead axon distal to the injury.
Axon sprouts, or filaments, grow through a regeneration tube formed by Schwann cells.
The axon regenerates and a new myelin sheath forms.
Neuritis

- Inflammation of a nerve
  - Sciatica
  - Bell’s Palsy
Shingles

- Herpes Zoster virus
- Dorsal root ganglia
- Consistent with dermatome
- Vaccine
Multiple Sclerosis

- Loss of myelin in CNS → scleroses
  - Visual disturbances
  - Muscle weakness
- Autoimmune disorder
- Remissions
- Progressive
Central nervous system (CNS)

Peripheral nervous system (PNS)

Sensory (afferent) division

Motor (efferent) division

Somatic nervous system

Autonomic nervous system (ANS)

Sympathetic division

Parasympathetic division

Figure 14.1
Autonomic Nervous System (ANS)

- Involuntary
- Visceral reflex system
- Sensory (afferent) neurons
- Motor (efferent) neurons
  - Innervate smooth and cardiac muscle and glands
  - Operate via subconscious control
<table>
<thead>
<tr>
<th>Cell bodies in central nervous system</th>
<th>Peripheral nervous system</th>
<th>Neurotransmitter at effector</th>
<th>Effector organs</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SOMATIC NERVOUS SYSTEM</strong></td>
<td>Single neuron from CNS to effector organs</td>
<td>ACh</td>
<td>Skeletal muscle</td>
<td>+ Stimulatory</td>
</tr>
<tr>
<td></td>
<td>Heavily myelinated axon</td>
<td>ACh</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>AUTONOMIC NERVOUS SYSTEM</strong></td>
<td>Two-neuron chain from CNS to effector organs</td>
<td>NE</td>
<td></td>
<td>+ - Stimulatory or inhibitory, depending on neurotransmitter and receptors on effector organs</td>
</tr>
<tr>
<td></td>
<td>Lightly myelinated preganglionic axons</td>
<td>Unmyelinated postganglionic axon</td>
<td>Adrenal medulla, Blood vessel</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ACh</td>
<td>Epinephrine and norepinephrine</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>PARASYMPATHETIC</strong></td>
<td>Lightly myelinated preganglionic axon</td>
<td>ACh</td>
<td>Smooth muscle (e.g., in gut), glands, cardiac muscle</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ganglion</td>
<td>Unmyelinated postganglionic axon</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[\text{Acetylcholine (ACh) \quad Norepinephrine (NE)}\]
**Stimulus**

1. Sensory receptor in viscera
2. Visceral sensory neuron
3. Integration center
   - May be preganglionic neuron (as shown)
   - May be a dorsal horn interneuron
   - May be within walls of gastrointestinal tract
4. Efferent pathway (two-neuron chain)
   - Preganglionic neuron
   - Ganglionic neuron
5. Visceral effector

**Response**

- Dorsal root ganglion
- Spinal cord
- Autonomic ganglion

*Figure 14.7*
Structure of the ANS

- **Afferent (sensory) pathway**
  - Visceral interoceptors (visceroceptors)
    - Osmolarity
    - Pressure
    - Temperature
    - Blood gases
    - Chemical composition of plasma and body fluids
Structure of the ANS

- Afferent (sensory) pathway
  - Sensory neuron from organ to CNS
    - Cell body in dorsal root ganglion
    - Synapse with association neurons
Dorsal root (sensory)

Dorsal root ganglion

Somatic sensory neuron

Visceral sensory neuron

Visceral motor neuron

Somatic motor neuron

Spinal nerve

Ventral root (motor)

Ventral horn (motor neurons)

Dorsal horn (interneurons)

Interneurons receiving input from somatic sensory neurons

Interneurons receiving input from visceral sensory neurons

Visceral motor (autonomic) neurons

Somatic motor neurons
Structure of the ANS

- Efferent (motor) pathway
  - Two motor neurons between CNS and effector
    - Preganglionic neuron
      - Cell body in CNS
    - Postganglionic neuron
      - Cell body in autonomic ganglion (outside CNS)
Skeletal muscle

Cell bodies in central nervous system

Peripheral nervous system

Effect

**Acetylcholine (ACh)**

**Norepinephrine (NE)**

<table>
<thead>
<tr>
<th>Neurotransmitter at effector</th>
<th>Effector organs</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACh</td>
<td>Skeletal muscle</td>
<td>+ Stimulatory</td>
</tr>
<tr>
<td>NE</td>
<td>Smooth muscle (e.g., in gut), glands, cardiac muscle</td>
<td>+ _ Stimulatory or inhibitory, depending on neurotransmitter and receptors on effector organs</td>
</tr>
</tbody>
</table>

**Figure 14.2**
Central nervous system (CNS) 

Peripheral nervous system (PNS) 

Motor (efferent) division 

Sensory (afferent) division 

Somatic nervous system 

Autonomic nervous system (ANS) 

Sympathetic division 

Parasympathetic division 

Figure 14.1
Divisions at a Glance

- Sympathetic
  - “Fight or Flight”
  - Epinephrine and acetylcholine
  - Thoracolumbar

- Parasympathetic
  - “Rest and Digest”
  - Acetylcholine
  - Craniosacral

Dual Innervation
Dual Innervation

Parasympathetic

- Eye
- Salivary glands
- Heart
- Lungs
- Stomach
- Pancreas
- Liver and gall-bladder
- Bladder
- Genitals

Sympathetic

- Eye
- Skin
- Salivary glands
- Lungs
- Heart
- Stomach
- Pancreas
- Liver and gall-bladder
- Adrenal gland
- Bladder
- Genitals

Brain stem
Cranial Sympathetic ganglia
Cervical
Thoracic
Lumbar
Sacral

T₁
L₁

Figure 14.3: Dual Innervation
## Parasympathetic Division Outflow

<table>
<thead>
<tr>
<th>Cranial Outflow</th>
<th>Nerve</th>
<th>Ganglia (Terminal Ganglia)</th>
<th>Effector Organ(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oculomotor (III)</td>
<td>Ciliary</td>
<td>Eye</td>
<td></td>
</tr>
<tr>
<td>Facial (VII)</td>
<td>Pterygopalatine Submandibular</td>
<td>Salivary, nasal, and lacrimal glands</td>
<td></td>
</tr>
<tr>
<td>Glossopharyngeal (IX)</td>
<td>Otic</td>
<td>Parotid salivary glands</td>
<td></td>
</tr>
<tr>
<td>Vagus (X)</td>
<td>Within the walls of target organs</td>
<td>Heart, lungs, and most visceral organs</td>
<td></td>
</tr>
</tbody>
</table>

| Sacral Outflow | S$_2$-S$_4$ | Within the walls of target organs | Large intestine, urinary bladder, ureters, and reproductive organs |
Parasympathetic Division

= Craniosacral

Figure 14.4
Central nervous system (CNS)

Peripheral nervous system (PNS)

Sensory (afferent) division

Motor (efferent) division

Somatic nervous system

Autonomic nervous system (ANS)

Sympathetic division

Parasympathetic division

Figure 14.1
The Sympathetic Division

- Preganglionic neurons in $T_1 - L_2$
  - Thoracolumbar division
- FYI: Lateral horns
The Sympathetic Division

Preganglionic fibers leave through ventral root

ventral rami → white rami communicantes

sympathetic trunk (paravertebral) ganglia
Figure 14.5b (1 of 3)

- **Blood vessels**
- **Skin (arrector pili muscles and sweat glands)**
- **Dorsal root ganglion**
- **Dorsal root**
- **Dorsal ramus of spinal nerve**
- **Ventral ramus of spinal nerve**
- **Gray ramus communicans**
- **White ramus communicans**
- **Lateral horn (visceral motor zone)**
- **Ventral root**
- **Sympathetic trunk ganglion**
- **Sympathetic trunk**

To effector
Spinal cord
Dorsal root
Ventral root
Rib
Sympathetic trunk ganglion
Sympathetic trunk
Ventral ramus of spinal nerve
Gray ramus communicans
White ramus communicans
Thoracic splanchnic nerves
(a) Location of the sympathetic trunk
Sympathetic Trunk Ganglia

- Form longitudinal pathways adjacent to vertebral column
- Each spinal nerve (except in cervical region) has an associated ganglion

“It was the classic fight or flight response. Next time, try flight.”
Figure 14.6

Sympathetic Division = Thoracolumbar

- Superior cervical ganglion
- Middle cervical ganglion
- Inferior cervical ganglion
- Sympathetic trunk (chain) ganglia
- Pons
- White rami communicantes
- Superior mesenteric ganglion
- Inferior mesenteric ganglion
- Lumbar splanchnic nerves
- Sacral splanchnic nerves
- Cardiac and pulmonary plexuses
- Greater splanchnic nerve
- Lesser splanchnic nerve
- Celiac ganglion
- Sympathetic trunk

Organs and structures:
- Eye
- Lacrimal gland
- Nasal mucosa
- Pons
- Blood vessels; skin (arrector pili muscles and sweat glands)
- Salivary glands
- Heart
- Lung
- Liver and gallbladder
- Stomach
- Spleen
- Adrenal medulla
- Kidney
- Small intestine
- Large intestine
- Rectum
- Genitalia (uterus, vagina, and penis) and urinary bladder
- Genitalia

Preganglionic:
- 

Postganglionic:
- 

Figure 14.6
The Sympathetic Division

- Sympathetic trunks and pathways
  - Upon entering a sympathetic trunk ganglion a preganglionic fiber may do one of the following:
    1. Synapse with a ganglionic neuron within the same ganglion
Figure 14.5b (1 of 3)

(b) Three pathways of sympathetic innervation

1. Synapse at the same level

Skin (arrector pili muscles and sweat glands)

Blood vessels

To effector

Dorsal root
Dorsal root ganglion
Dorsal ramus of spinal nerve
Ventral ramus of spinal nerve
Gray ramus communicans
White ramus communicans
Lateral horn (visceral motor zone)

Ventral root
Sympathetic trunk ganglion
Sympathetic trunk

Synapse at the same level

Figure 14.5b (1 of 3)
Sympathetic trunks and pathways

- Upon entering a sympathetic trunk ganglion a preganglionic fiber may do one of the following:
  2. Ascend or descend the sympathetic trunk to synapse in another trunk ganglion
(b) Three pathways of sympathetic innervation

2 Synapse at a higher or lower level

Skin (arrector pili muscles and sweat glands)

Blood vessels

To effector
Sympathetic Trunks and Pathways

• Sympathetic trunks and pathways
  ○ Upon entering a sympathetic trunk ganglion a preganglionic fiber may do one of the following:
    3. Pass through the trunk ganglion and emerge without synapsing
(b) Three pathways of sympathetic innervation

1. Splanchnic nerve
2. Collateral ganglion (such as the celiac)
3. Target organ in abdomen (e.g., intestine)

3. Synapse in a distant collateral ganglion anterior to the vertebral column
Thoracic splanchnic nerves
(a) Location of the sympathetic trunk
## Differences Between the Divisions

<table>
<thead>
<tr>
<th>Division</th>
<th>Origin of Fibers</th>
<th>Length of Fibers</th>
<th>Location of Ganglia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sympathetic</td>
<td>Thoracolumbar region of the spinal cord</td>
<td>Short preganglionic and long postganglionic</td>
<td>Close to spinal cord</td>
</tr>
<tr>
<td>Parasympathetic</td>
<td>Brain and sacral spinal cord (craniosacral)</td>
<td>Long preganglionic and short postganglionic</td>
<td>In visceral effector organs</td>
</tr>
</tbody>
</table>
Neurotransmitters in the ANS

- **Cholinergic fibers release the neurotransmitter ACh**
  - All ANS preganglionic axons
  - All parasympathetic postganglionic axons

- **Adrenergic fibers release the neurotransmitter NE**
  - Most sympathetic postganglionic axons
  - Exceptions: sympathetic postganglionic fibers secrete ACh at sweat glands and some blood vessels in skeletal muscles
Figure 14.2

**AUTONOMIC NERVOUS SYSTEM**

**PARASYMPATHETIC**

- Lightly myelinated preganglionic axons
- Ganglion
- Unmyelinated postganglionic axon
- Acetylcholine (ACh)

**SYMPATHETIC**

- Lightly myelinated preganglionic axons
- Adrenal medulla
- Blood vessel
- Norepinephrine (NE)

- Ganglion
- Epinephrine and norepinephrine

- Smooth muscle (e.g., in gut), glands, cardiac muscle

Stimulatory or inhibitory, depending on neurotransmitter and receptors on effector organs

- Acetylcholine (ACh) • Norepinephrine (NE)
Adrenal Medulla

“Sympathomimetic”
Receptors for Neurotransmitters

- Cholinergic receptors for ACh
- Adrenergic receptors for NE
Cholinergic Receptors

- Two types of receptors bind ACh
  1. Nicotinic
  2. Muscarinic
- Named after drugs that bind to them and mimic ACh effects
Cholinergic Receptors

• Nicotinic receptors
  ○ Blocked with curare
  ○ Effect of ACh at nicotinic receptors
    ▪ Always stimulatory
Cholinergic Receptors

- **Muscarinic**
  - Blocked by atropine
  - Effect of ACh at muscarinic receptors
    - Can be either inhibitory or excitatory
    - Depends on the receptor type of the target organ

*Correction, PNS 8: 2d.*

*acetylcholine is not always stimulatory. It IS always stimulatory at nicotinic receptors.*
<table>
<thead>
<tr>
<th>NEUROTRANSMITTER</th>
<th>RECEPTOR TYPE</th>
<th>MAJOR LOCATIONS*</th>
<th>EFFECT OF BINDING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetylcholine</td>
<td>Cholinergic</td>
<td>All ganglionic neurons; adrenal medullary cells (also neuromuscular junctions of skeletal muscle)</td>
<td>Excitation</td>
</tr>
<tr>
<td>Nicotinic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Muscarinic</td>
<td></td>
<td>All parasympathetic target organs</td>
<td>Excitation in most cases; inhibition of cardiac muscle</td>
</tr>
<tr>
<td>Limited sympathetic targets:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Eccrine sweat glands</td>
<td></td>
<td>Activation</td>
<td></td>
</tr>
<tr>
<td>- Blood vessels in skeletal muscles</td>
<td></td>
<td>Vasodilation (may not occur in humans)</td>
<td></td>
</tr>
</tbody>
</table>
Adrenergic Receptors

- Two types
  - Alpha (α) (subtypes α₁, α₂)
  - Beta (β) (subtypes β₁, β₂, β₃)
- Effects of NE depend on which subclass of receptor predominates on the target organ
<table>
<thead>
<tr>
<th>NEUROTRANSMITTER</th>
<th>RECEPTOR TYPE</th>
<th>MAJOR LOCATIONS*</th>
<th>EFFECT OF BINDING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Norepinephrine (and epinephrine released</td>
<td>Adrenergic</td>
<td></td>
<td>Increases heart rate and strength; stimulates renin release by kidneys \</td>
</tr>
<tr>
<td>by adrenal medulla)</td>
<td>β₁</td>
<td>Heart predominantly, but also kidneys and adipose tissue</td>
<td></td>
</tr>
<tr>
<td></td>
<td>β₂</td>
<td>Lungs and most other sympathetic target organs; abundant on blood vessels serving the heart, liver and skeletal muscle</td>
<td>Effects mostly inhibitory; dilates blood vessels and bronchioles; relaxes smooth muscle walls of digestive and urinary visceral organs; relaxes uterus</td>
</tr>
<tr>
<td></td>
<td>β₃</td>
<td>Adipose tissue</td>
<td>Stimulates lipolysis by fat cells</td>
</tr>
<tr>
<td></td>
<td>α₁</td>
<td>Most importantly blood vessels serving the skin, mucosae, abdominal viscera, kidneys, and salivary glands; also, virtually all sympathetic target organs except heart</td>
<td>Constricts blood vessels and visceral organ sphincters; dilates pupils of the eyes</td>
</tr>
<tr>
<td></td>
<td>α₂</td>
<td>Membrane of adrenergic axon terminals; pancreas; blood platelets</td>
<td>Inhibits NE release from adrenergic terminals; inhibits insulin secretion by pancreas; promotes blood clotting</td>
</tr>
</tbody>
</table>

* Note that all of these receptor subtypes are also found in the CNS.
End of Midterm #1 Material
Cardiovascular Pharmacology

- **Heart**
  - $\beta_1$ - Excitatory in heart
    - increases heart rate, conduction velocity, and contraction strength

- **Major blood vessels**
  - $\beta_2$ – Inhibitory
    - Vasodilation
  - $\alpha_1$ – Excitatory
    - Vasoconstriction
Cardiovascular Pharmacology

- **Adrenergic blockers**
  - Used to treat hypertensive disease
  - $\alpha$ blockers - produce vasodilation
  - $\beta_1$ blockers - decrease heart rate and blood pressure
<table>
<thead>
<tr>
<th>DRUG CLASS</th>
<th>RECEPTOR BOUND</th>
<th>EFFECTS</th>
<th>EXAMPLE</th>
<th>CLINICAL USE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nicotinic agents (little therapeutic value, but important because of presence of nicotine in tobacco)</td>
<td>Nicotinic ACh receptors on all ganglionic neurons and in CNS</td>
<td>Typically stimulation of sympathetic effects; blood pressure increases</td>
<td>Nicotine</td>
<td>Used in smoking cessation products</td>
</tr>
<tr>
<td>Parasympathomimetic agents (muscarinic agents)</td>
<td>Muscarinic ACh receptors</td>
<td>Mimic effects of ACh, enhance parasympathetic effects</td>
<td>Pilocarpine</td>
<td>Glaucoma (opens aqueous humor drainage pores)</td>
</tr>
<tr>
<td>Acetylcholinesterase inhibitors</td>
<td>None; bind to the enzyme (AChE) that degrades ACh</td>
<td>Indirect effect at all ACh receptors; prolong the effect of ACh</td>
<td>Neostigmine</td>
<td>Myasthenia gravis, (increases availability of ACh)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sarin</td>
<td>Used as chemical warfare agent (similar to widely used insecticides)</td>
</tr>
<tr>
<td>Sympathomimetic agents</td>
<td>Adrenergic receptors</td>
<td>Enhance sympathetic activity by increasing NE release or binding to adrenergic receptors</td>
<td>Albuterol (Ventolin)</td>
<td>Asthma (dilates bronchioles by binding to β2 receptors)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Phenylephrine</td>
<td>Colds (nasal decongestant, binds to α1 receptors)</td>
</tr>
<tr>
<td>Sympatholytic agents</td>
<td>Adrenergic receptors</td>
<td>Decrease sympathetic activity by blocking adrenergic receptors or inhibiting NE release</td>
<td>Propranolol</td>
<td>Hypertension (member of a class of drugs called beta-blockers that decrease heart rate and blood pressure)</td>
</tr>
</tbody>
</table>
Interactions of the Autonomic Divisions

- Most visceral organs have dual innervation
- Dynamic and precise control of visceral activity
  - Sympathetic division increases heart and respiratory rates, and inhibits digestion and elimination
  - Parasympathetic division decreases heart and respiratory rates, and allows for digestion and the discarding of wastes
Figure 14.3
Questions?

- Activity
  - Complete PNS 18 and 19
Business

- Homework due in lab
  1) PreLab #4
  2) Homework #4 Matching
- Midterm #1 Monday!
  - Study Guide in “Exams” Section
  - Study suggestions
    - Discovery questions PNS 14-15
    - PNS 21 and 22 Worksheets
    - PNS 24 Practice Quiz

Optional MT Review: Tuesday 5-6pm