Autonomic Nervous System (ANS)

- The ANS consists of motor neurons that:
  - Innervate smooth and cardiac muscle, glands, and viscera as their effectors
  - Make adjustments to ensure optimal support for body activities
  - Operate via subconscious control (involuntary nervous system or general visceral motor system)
ANS in the Nervous System

CNS

PNS

Sensory division
Motor division

Sympathetic division
Parasympathetic division

Autonomic nervous system
Somatic nervous system

Figure 14.1
The ANS differs from the SNS in the following three areas:

- Effectors
- Efferent pathways
- Target organ responses
**Effectors**

- The effectors of the SNS (somatic nervous system) are skeletal muscles.
- The effectors of the ANS are cardiac muscle, smooth muscle, and glands.
Efferent Pathways & Ganglia

- **Somatic Nervous System:**
  - Motor neuron cell bodies are in the CNS and axons extend in spinal or cranial nerves all the way to the skeletal muscles they activate.
  - Somatic motor fibers are typically thicker, heavily myelinated fibers that conduct impulses rapidly.

- **Autonomic Nervous System:**
  - Use 2-neuron chain to its effectors; cell body of 1st neuron (preganglionic neuron) resides in the brain or spinal cord. The axon of the 1st neuron (preganglionic axon) synapses w/ the 2nd motor neuron (ganglionic neuron) in an autonomic ganglion outside of the CNS.
  - The axon of the ganglionic neuron (postsynaptic axon) extends to the effector organ.
Comparison of Somatic and Autonomic Systems

<table>
<thead>
<tr>
<th>Somatic nervous system</th>
<th>Peripheral nervous system</th>
<th>Effector organs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preganglionic axons</td>
<td>Postganglionic axons</td>
<td>Acetylcholine</td>
</tr>
<tr>
<td>Skeletal muscle</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Autonomic nervous system | | |
|--------------------------| | |
| Sympathetic division     | | |
| Acetylcholine             | Norepinephrine            | Ganglion        |
| Gland, smooth muscle     | Blood vessel              |                 |
| Adrenal medulla          |                           |                 |

| Parasympathetic division | | |
| Acetylcholine            | Ganglion                   |                 |
| Cardiac muscle           |                           |                 |

Key:
- Green = Preganglionic axons (sympathetic)
- Blue = Postganglionic axons (sympathetic)
- Blue = Myelination
- Purple = Preganglionic axons (parasympathetic)
- Purple = Postganglionic axons (parasympathetic)

Preganglionic axons are lightly myelinated, thin fibers
Postganglionic axons are even thinner and unmyelinated fibers
Thus, conduction thru the autonomic efferent chain is slower than conduction thru the somatic motor system
Neurotransmitter Effects

- All somatic motor neurons release Acetylcholine (ACh) at synapses with skeletal muscle, which always has an excitatory effect.

- In the ANS:
  - Preganglionic fibers release ACh.
  - Postganglionic fibers release norepinephrine (NE) or ACh and the effect is either stimulatory or inhibitory.
  - ANS effect on the target organ is dependent upon the neurotransmitter released and the receptor type of the effector.
Divisions of the ANS

- ANS divisions: sympathetic and parasympathetic
- Serve the same visceral organs but cause opposite effects
- Help maintain homeostasis
- Sympathetic division mobilizes the body during activity
- Parasympathetic division conserves body energy
Role of the Parasympathetic Division

- Concerned with keeping body energy use as low as possible

- Its activity is illustrated in a person who relaxes after a meal
  - Blood pressure, heart rate, and respiratory rates are low
  - Gastrointestinal tract activity is high
  - The skin is warm and the pupils are constricted
Al Bundy’s Parasympathetic Division…

- Working just fine!
Role of the Sympathetic Division

- The sympathetic division is the “fight-or-flight” system
- Promotes adjustments during exercise – blood flow to organs is reduced, flow to muscles is increased
- Its activity is illustrated by a person who is threatened
  - Heart rate increases, and breathing is rapid and deep
  - Glucose is released from the liver to the blood
  - The skin is cold and sweaty, and the pupils dilate
And the person looks something like this
Anatomy of ANS

- Sympathetic and parasympathetic are distinguished by:
  - Origin sites: PS are craniosacral; S are in the thoracolumbar region
  - Relative lengths of their fibers: PS has long preganglionic and short postganglionic fibers; S has the opposite
  - Location of their ganglia: PS ganglia are located in the visceral effector organs; S ganglia lie close to the spinal cord
## Anatomy of ANS

<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 the spinal cord</td>
</tr>
<tr>
<td>Parasympathetic</td>
<td>Brain and sacral spinal cord</td>
<td>Long preganglionic and short postganglionic</td>
<td>In the visceral effector organs</td>
</tr>
</tbody>
</table>
Parasympathetic Division Outflow

- Anatomically simpler than the sympathetic division
- Preganglionic fibers arise from opposite ends of the CNS
- Preganglionic axons extend from the CNS nearly all the way to the organs to be innervated
- There the axons synapse w/ ganglionic neurons located in terminal ganglia that lie close to (or w/i) the target organs
- Very short postganglionic axons issue from the terminal ganglia and synapse w/ effector cells in their immediate area
# Parasympathetic Division Outflow

<table>
<thead>
<tr>
<th>Cranial Outflow: Preganglionic fibers run <em>in</em> the following cranial nerves:</th>
<th>Cranial Nerve</th>
<th>Ganglion</th>
<th>Effector Organ(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occulomotor (III)</td>
<td>Ciliary</td>
<td>Eye</td>
<td></td>
</tr>
<tr>
<td>Facial (VII)</td>
<td>Pterygopalatin 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>Located within the walls of target organs</td>
<td>Heart, lungs, and most visceral organs</td>
<td></td>
</tr>
<tr>
<td>Sacral Outflow</td>
<td>$S_2$-$S_4$</td>
<td>Located within the walls of the target organs</td>
<td>Large intestine, urinary bladder, ureters, and reproductive organs</td>
</tr>
</tbody>
</table>
Parasympathetic Division Outflow

- **Occulomotor:**
  - Parasympathetic fibers of the oculomotor nerves innervate smooth muscles in the eye that cause the pupils to constrict & the lenses to “round” in order to focus on near objects.
  - Cell bodies of the ganglionic neurons are in the ciliary ganglia w/i the orbits

- **Facial:**
  - Stimulate large glands in the head
  - E.g. nasal glands, lacrimal glands, submandibular & sublingual salivary glands

- **Glossopharyngeal:**
  - Activate the parotid salivary gland
  - The distal ends synapse, and travel with, branches of the trigeminal nerves to reach the face
Parasympathetic Division Outflow

- Vagus:
  - The 2 vagus nerves account for 90% of all preganglionic parasympathetic fibers in the body
  - Serve every organ in the thoracic & abdominal cavities
  - As the vagus nerves pass into the thorax, they send branches to the cardiac plexuses supplying fibers to the heart slowing heart rate
  - Pulmonary plexus: lungs & bronchi
  - Esophageal plexus: supply the esophagus
  - When the main fibers reach the esophagus, they intermingle then “ride” the esophagus down to the abdominal cavity and innervate the liver, gall bladder, stomach, small intestine, kidneys, pancreas, and proximal half of the large intestine
Parasympathetic Division Outflow

- Sacral Outflow:
  - S2-S4 (location)
  - Serve the distal half of the large intestine, urinary bladder, ureters, and reproductive organs
  - Ventral roots lead to ventral rami then branch to form the pelvic splanchnic nerves
Sympathetic (Thoracolumbar) Outflow

- More complex than the Parasympathetic division
- Innervates more organs
- Innervates visceral and superficial regions
- Arises from spinal cord segments $T_1$ through $L_2$
- Sympathetic neurons produce the lateral horns in the gray matter of the spinal cord
- Preganglionic fibers pass through the white rami communicantes and synapse in the chain (paravertebral) ganglia
- Fibers from $T_5$-$L_2$ form splanchnic nerves and synapse with collateral ganglia
- Postganglionic fibers innervate the numerous organs of the body
Sympathetic Trunks and Pathways

- The paravertebral ganglia form part of the sympathetic trunk or chain
- Typically there are 23 ganglia – 3 cervical, 11 thoracic, 4 lumbar, 4 sacral, and 1 coccygeal
Sympathetic Trunks and Pathways

- A preganglionic fiber follows one of three pathways upon entering the paravertebral ganglia
  - 1) Synapse with the ganglionic neuron within the same chain ganglion
  - 2) Ascend or descend the sympathetic chain to synapse in another chain ganglion
  - 3) Pass through the chain ganglion and emerge without synapsing.
    - These help form the splanchnic nerves that synapse in collateral (prevertebral) ganglia located anterior to the vertebral column (fig. 14.6a)
Sympathetic Trunks and Pathways

Figure 14.6

[Diagram showing the sympathetic trunks and pathways, including spinal cord, sympathetic trunk ganglion, Dorsal root, Ventral root, Sympathetic trunk (chain) ganglion, Lateral horn (visceral motor zone), Dorsal root ganglion, Sympathetic trunk, Ventral ramus of spinal nerve, Gray ramus communicans, White ramus communicans, Ventrer root, Dorsal ramus of spinal nerve, Blood vessels, Skin (arrector pilorum muscles and sweat glands), Collateral (presynaptic) ganglion such as the celiac, Target organ (in abdomen)].
Pathways with Synapses in Chain Ganglia

- **White rami communicantes** carry preganglionic axons to the sympathetic chains and are found only in the T1-L2 cord segments.

- Postganglionic axons enter the ventral or dorsal rami of the adjoining spinal nerves via the **gray rami communicantes** (found only from the cervical to sacral regions).

- From the GRC, axons travel to their effectors.

- **White, gray rami** reflect their appearance (myelinated or unmyelinated).
Pathways to the Head

- Preganglionic sympathetic fibers emerge from T_1-T_4 and synapse in the superior cervical ganglion

- These fibers:
  - Serve the skin and blood vessels of the head
  - Stimulate dilator muscles of the iris
  - Stimulate the tarsus muslce of the eye (below)
  - Inhibit nasal and salivary glands (dry mouth)
Pathways to the Thorax

- Preganglionic fibers emerge from T₁-T₆ and synapse in the cervical chain ganglia.
- Postganglionic fibers emerge from the middle and inferior cervical ganglia and enter nerves C₄-C₈.
- These fibers innervate the heart via the cardiac plexus, as well as innervating the thyroid.
- But most service the skin.
Pathways with Synapses in Collateral Ganglia

- Splanchnic nerves innervate the viscera
- Preganglionic fibers from T5 down synapse in collateral ganglia and form splanchnic nerves including:
  - Greater/lesser thoracic splanchnic nerves
  - Sacral splanchnic nerves
    - These form the abdominal aortic plexus which cling to the abdominal aorta
- Most important ganglia from top to bottom are:
  - Celiac
  - Superior/inferior mesenteric
  - Inferior hypogastric
    - (Named for the arteries to which they are most associated)
    - Travel to their organs by means of the arteries servicing the organs
Pathways with Synapses in Collateral Ganglia
Pathways to the Abdomen

- Sympathetic nerves innervating the abdomen have preganglionic fibers from T_5-L_2
- They travel through the thoracic splanchnic nerves and synapse at the celiac and superior mesenteric ganglia
- Postganglionic fibers serve the stomach, intestines, liver, spleen, and kidneys (but not the distal half of the large intestine)
Pathways to the Pelvis

- Preganglionic fibers originate from T_{10}-L_{2}

- Most travel via the lumbar and sacral splanchnic nerves to the inferior mesenteric and hypogastric ganglia

- Postganglionic fibers serve the distal half of the large intestine, the urinary bladder, and the reproductive organs (where they have inhibitory effects)
Pathways with Synapses in the Adrenal Medulla

- Fibers of the thoracic splanchnic nerve pass directly to the hormone-producing medullary cells of the adrenal gland

- Upon stimulation, medullary cells secrete norepinephrine and epinephrine (adrenaline) into the blood (definitely a stimulatory effect!)
# Segmental Sympathetic Supplies

## Table 14.2

<table>
<thead>
<tr>
<th>SPINAL CORD SEGMENT</th>
<th>ORGANS SERVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_1$–$T_5$</td>
<td>Head and neck, heart</td>
</tr>
<tr>
<td>$T_2$–$T_4$</td>
<td>Bronchi and lungs</td>
</tr>
<tr>
<td>$T_2$–$T_5$</td>
<td>Upper limb</td>
</tr>
<tr>
<td>$T_5$–$T_6$</td>
<td>Esophagus</td>
</tr>
<tr>
<td>$T_6$–$T_{10}$</td>
<td>Stomach, spleen, pancreas</td>
</tr>
<tr>
<td>$T_7$–$T_9$</td>
<td>Liver</td>
</tr>
<tr>
<td>$T_9$–$T_{10}$</td>
<td>Small intestine</td>
</tr>
<tr>
<td>$T_{10}$–$L_1$</td>
<td>Kidney, reproductive organs (uterus, testis, ovary, etc.)</td>
</tr>
<tr>
<td>$T_{10}$–$L_2$</td>
<td>Lower limb</td>
</tr>
<tr>
<td>$T_{11}$–$L_2$</td>
<td>Large intestine, ureter, urinary bladder</td>
</tr>
</tbody>
</table>
Visceral Reflexes

- Visceral sensory neurons send information concerning chemical changes, stretch, and irritation

- Visceral reflex arcs have the same elements as somatic reflex arcs

- EXCEPT, a visceral reflex arc has 2 neurons in its motor component
Visceral Reflexes

Figure 14.7
Referred Pain

- Visceral pain afferents travel along the same pathways as somatic pain fibers
- Pain stimuli arising in the viscera are perceived as somatic in origin
  - E.g. heart attack produces sensation of pain in the superior thoracic wall and the medial aspect of the left arm
  - The same spinal segments (T1-5) innervate both the heart and the somatic regions, the brain perceives pain from the more common somatic regions.
- Heart burn too
- Gall stones too
Referred Pain

Figure 14.8
Neurotransmitters and Receptors

- Acetylcholine (ACh) and norepinephrine (NE) are the two major neurotransmitters of the ANS
- ACh is released by:
  - 1) All preganglionic axons
  - 2) All parasympathetic postganglionic axons
- Cholinergic fibers – ACh-releasing fibers
- Adrenergic fibers – sympathetic postganglionic axons that release NE
- Neurotransmitter effects can be excitatory or inhibitory depending upon the receptor type
Cholinergic Receptors

- The two types of receptors that bind ACh are nicotinic and muscarinic.
- These are named after drugs that bind to them and mimic ACh effects.
Nicotinic Receptors (Nicotine)

- Nicotinic receptors are found on:
  - Motor end plates (somatic targets)
  - All ganglionic neurons of both sympathetic and parasympathetic divisions
  - The hormone-producing cells of the adrenal medulla
- Ach binding opens ion channels resulting in depolarization
- The effect of ACh binding to nicotinic receptors is always stimulatory
Muscarinic Receptors (Mushroom Poison)

- Muscarinic receptors occur on all effector cells stimulated by postganglionic cholinergic fibers.
- The effect of ACh binding:
  - Can be either inhibitory or excitatory.
  - Depends on the receptor type of the target organ.
Adrenergic Receptors

- The two types of adrenergic receptors are alpha and beta
- Each type has two or three subclasses ($\alpha_1$, $\alpha_2$, $\beta_1$, $\beta_2$, $\beta_3$)
- Effects of NE binding to:
  - $\alpha$ receptors is generally stimulatory
  - $\beta$ receptors is generally inhibitory
- A notable exception – NE binding to $\beta$ receptors of the heart is stimulatory
Effects of Drugs

- Atropine – anticholinergic, blocks ACh receptors, prevents salivation during surgery, dilates pupils for eye exam
- Neostigmine – antiacetylcholinesterase, inhibits acetylcholinesterase, prevents breakdown of ACh, and is used to treat myasthenia gravis (impairment of skeletal muscle)
- Tricyclic antidepressants – prolong the activity of NE on postsynaptic membranes
- Over-the-counter drugs for colds, allergies, and nasal congestion – stimulate α-adrenergic receptors
- Beta-blockers – attach mainly to β₁ receptors and reduce heart rate and prevent arrhythmias. Help asthma victims with Albuterol
# Drugs that Influence the ANS

## Table 14.4

<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</td>
<td>Nicotinic ACh receptors on all</td>
<td>Typically stimulation of sympathetic effects; heart</td>
<td>Nicotine</td>
<td>Used in smoking cessation products</td>
</tr>
<tr>
<td>therapeutic value, but</td>
<td>ganglionic neurons and in CNS</td>
<td>rhythm becomes less regular; blood pressure increases</td>
<td></td>
<td></td>
</tr>
<tr>
<td>important because of presence</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>of nicotine in tobacco)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parasympathomimetic agents</td>
<td>Muscarinic ACh receptors</td>
<td>Mimics effects of ACh, enhances PNS effects</td>
<td>Pilocarpine</td>
<td>Glaucoma (opens aqueous humor drainage pores)</td>
</tr>
<tr>
<td>(muscarinic agents)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acetylcholinesterase inhibitors</td>
<td>None; binds to the enzyme (AChE)</td>
<td>Indirect effect at all ACh receptors; prolongs the effect of ACh</td>
<td>Neostigmine</td>
<td>Myasthenia gravis, (increases availability of ACh)</td>
</tr>
<tr>
<td></td>
<td>that degrades ACh</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sympathomimetic agents</td>
<td>Adrenergic receptors</td>
<td>Enhances sympathetic activity by increasing NE release or binding to</td>
<td>Albuterol (Ventolin)</td>
<td>Asthma (dilates bronchioles by binding to ( \beta_2 ) receptors)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>adrenergic receptors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sympatholytic agents</td>
<td>Adrenergic receptors</td>
<td>Decreases sympathetic activity by blocking adrenergic receptors or</td>
<td>Propranolol</td>
<td>Hypertension (member of a class of drugs called ( \beta ) blockers that decrease heart rate and blood pressure)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>inhibiting NE release</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Interactions of the Autonomic Divisions

- Most visceral organs are innervated by both sympathetic and parasympathetic fibers.
- This results in dynamic antagonisms that precisely control visceral activity.
- Sympathetic fibers increase heart and respiratory rates, and inhibit digestion and elimination.
- Parasympathetic fibers decrease heart and respiratory rates, and allow for digestion and the discarding of wastes.
Sympathetic Tone

- The sympathetic division controls blood pressure and keeps the blood vessels in a continual state of partial constriction

- This sympathetic tone (vasomotor tone):
  - Constricts blood vessels and causes blood pressure to rise as needed by firing the fibers more rapidly
  - Prompts vessels to dilate if blood pressure is to be decreased

- Alpha-blocker drugs interfere with vasomotor fibers and are used to treat hypertension

- Also involved with blood shunting
Parasympathetic Tone

- Parasympathetic tone:
  - Slows the heart
  - Dictates normal activity levels of the digestive and urinary systems
- The sympathetic division can override these effects during times of stress
- Drugs that block parasympathetic responses increase heart rate and block fecal and urinary retention
Cooperative Effects

- ANS cooperation is best seen in control of the external genitalia

- Parasympathetic fibers cause vasodilation and are responsible for erection of the penis and clitoris

- Sympathetic fibers cause ejaculation of semen in males and reflex peristalsis in females
Unique Roles of the Sympathetic Division

- Regulates many functions not subject to parasympathetic influence
- These include the activity of the adrenal medulla, sweat glands, arrector pili muscles, kidneys, and most blood vessels
- The sympathetic division controls:
  - Thermoregulatory responses to heat
  - Release of renin from the kidneys
  - Metabolic effects
Thermoregulatory Responses to Heat

- Applying heat to the skin causes reflex dilation of blood vessels
- Systemic body temperature elevation results in widespread dilation of blood vessels
- This dilation brings warm blood to the surface and activates sweat glands to cool the body
- When temperature falls, blood vessels constrict and blood is retained in deeper vital organs
Release of Renin from the Kidneys

- Sympathetic impulses activate the kidneys to release renin
- Renin is an enzyme that promotes increased blood pressure
Metabolic Effects

- The sympathetic division promotes metabolic effects that are not reversed by the parasympathetic division
  - Increases the metabolic rate of body cells
  - Raises blood glucose levels
  - Mobilizes fat as a food source
Localized Versus Diffuse Effects

- The parasympathetic division exerts short-lived, highly localized control
- The sympathetic division exerts long-lasting, diffuse effects
Effects of Sympathetic Activation

- Sympathetic activation is long-lasting because NE:
  - Is inactivated more slowly than ACh
  - Is an indirectly acting neurotransmitter, using a second-messenger system
  - Epinephrine is released into the blood and remains there until destroyed by the liver
Levels of ANS Control

- The hypothalamus is the main integration center of ANS activity
- Subconscious cerebral input via limbic lobe connections influences hypothalamic function
- Other controls come from the cerebral cortex, the reticular formation, and the spinal cord

Fin
KU GAME DAY!!

- Saturday 3 pm

...And Happy Holidays!!!